THE INSTITUTE FOR ADVANCED STUDY

PATRICIA H. LABALME
Associate Director

November 13, 1986

Dr. Russell D. Dupuis
AT&T Bell Laboratories
Room 7C-327
600 Mountain Avenue
Murray Hill, NJ 07974

Dear Dr. Dupuis,

Thank you for your letter of November 4, 1986, and for sending us a copy
of the von Neumann manuscript and his letter to Edward Teller.

We appreciate your consulting us about publication rights, but the
Institute does not own the publication rights to von Neumann's papers.
Therefore, permission to publish this material resides with his heir, Marina
von Neumann Whitman.

With all good wishes, I am

Sincerely yours,

Patricia H. Labalme

Patricia H. Labalme

Princeton, New Jersey 08540   Telephone 609-734-8200   Telex 229734-IAS-UR

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4 November 1986

Dr. Patricia Labalme
Institute for Advanced Study
South Olden Lane
Princeton NJ 08540

Dear Dr. Labalme:

As we discussed on the telephone today, I have obtained from the Library of Congress a copy of the von Neumann manuscript entitled "Notes on the Photon-Disequilibrium-Amplification Scheme" which John von Neumann wrote in September 1953 while he was at the Institute for Advanced Study. I am enclosing a copy of this manuscript as well as a copy of the cover letter von Neumann wrote to Edward Teller when he sent the manuscript to Teller for his comments. As you can see, the letter was typed on letterhead from the Institute for Advanced Study and I think this clearly indicates that the publication rights are currently owned by your Institute.

As I have told you, the Institute of Electrical and Electronics Engineers (IEEE) is a professional society which publishes many technical journals of interest to the electrical engineering profession. One of these, the *IEEE Journal of Quantum Electronics* (JQE) is particularly interested in all aspects of quantum electronics and lasers. This is the journal in which I propose to publish the von Neumann manuscript mentioned above. Of course, the permission granted by your Institute would be acknowledged in a footnote. Also, a preface would be written which would state that von Neumann was at the Institute for Advanced Study when the manuscript was written. The IEEE requires (as do all professional technical journals) that a "Copyright Transfer Form" be signed before any paper can be published by the IEEE journals. This

is considered "normal business practice" by AT&T and all other companies and universities in the US and throughout the world. A complete explanation of this policy is given on the reverse side of the enclosed forms. I have filled these out in advance so that all you need to do is sign where it says "AUTHORIZED SIGNATURE" and fill in the blank labeled "TITLE IF NOT AUTHOR".

I am enclosing a manuscript that I have prepared which will be an introduction to the historical review section of this special issue of JQE. It is my goal to ensure that proper credit is given to von Neumann since it seems that he was the first person to actually consider the possibility of making a laser, as well as the first to propose a semiconductor laser. I thank you for your cooperation in having his manuscript finally reach print and be available to all workers in this field. Please feel free to call me if you have any questions concerning the enclosed release form.

Sincerely,

Russell D. Dupuis, Chair
IEEE Lasers and Electro-Optics Society
Technical Committee on Semiconductor Lasers

Enclosures

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

RICHARD M. LUDWIG
*Assistant University Librarian
for Rare Books & Special Collections*

March 6, 1975

Mr. Carl Kaysen, Director
The Institute for Advanced Study
Princeton
New Jersey   08540

Dear Dr. Kaysen:

This is in response to your letter of February 14th,
and to follow up our telephone conversation prior to that
date about the papers of Professor von Neumann.

Please be assured that this Library is preparing the
von Neumann papers for shipment to the Library of Congress.
In view of the relatively small size of the material at
Princeton, which has been on deposit from the Institute, it
is obviously the right thing that these papers should join
the larger part of the von Neumann papers which Dr. Whitman
is giving to the Library of Congress.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC:js

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

WILLIAM S. DIX
University Librarian

February 21, 1975

Dear Carl:

Thank you for your note, with the attached letters concerning the von Neumann papers. I have had a very nice note from Mrs. Whitman, a copy of which I enclose, but I am sorry that she decided to let her father's papers leave Princeton.

I have not seen you for a long while. Why not stop by some day soon for a lunch with me at Prospect?

Cordially yours,

Bill

Encl.

Dictated by W. S. Dix
Transcribed in his absence.

Mr. Carl Kaysen
The Institute for Advanced Study
Princeton
New Jersey 08540

MARINA V.N. WHITMAN
5440 AYLESBORO AVENUE
PITTSBURGH, PENNSYLVANIA 15217

February 11, 1975

Mr. William Dix, Librarian
Princeton University Library
Princeton, NJ 08540

Dear Mr. Dix:

I'm afraid I've had a guilty conscience with respect to you for
several years, but am just now finally getting around to purging it.

Many years ago, we discussed the possible disposition of my
father's papers, and I told you then that the choice was between the
Princeton University Library and the Library of Congress. A year or
so ago I finally decided to give them to the latter, for a variety of
reasons, including the fact that the L.C. is in a favorable position
(I hope) to negotiate with the AEC regarding the declassification and
ultimate disposition of a good deal of von Neumann material still under
AEC (now ERDA?) jurisdiction.

Anyway, common courtesy should have dictated that I inform you
promptly of my decision, but I somehow let it get by me. I was finally
prodded into belated action by the fact that Carl Kaysen may shortly
be in touch with you regarding some von Neumann materials in the
Institute's custody which are currently physically housed in the
Princeton Library.

Please accept my apologies and warm regards.

Yours sincerely,

Marina v. N. Whitman
Distinguished Public Service
Professor of Economics

MW/ems

February 14, 1975

Dear Marina:

Thanks for your note. Here are the formal
documents for the first part of the transfer;
namely, your father's papers. I will be moving
on the second part shortly.

It was good to see you. I trust another
opportunity arises soon.

Cordially,

Carl Kaysen

Dr. Marina v.N. Whitman
Department of Economics
University of Pittsburgh
Pittsburgh, Pa. 15260

Enclosures

MARINA V.N. WHITMAN
5440 AYLESBORO AVENUE
PITTSBURGH, PENNSYLVANIA 15217

February 11, 1975

Mr. Carl Kaysen, Director
Institute for Advanced Study
Princeton, New Jersey 08540

Dear Mr. Kaysen:

I am writing to confirm our conversation of February 8, in which
I requested that all of the papers of John von Neumann over which the
Institute for Advanced Study has custody be transferred to the Library
of Congress. I have already donated those of the von Neumann papers
which were in my own custody to that Library.

I understand that you also intend to donate to the Library, along
with the von Neumann papers, the Institute's own records and papers
relating to the computer project which he headed. I think this is an
excellent disposition of those materials, and am most appreciative of
your decision.

Please let me know if there is anything I can do to help expedite
the transfer.

With many thanks,

Yours sincerely,

Marina v. N. Whitman
Distinguished Public Service
Professor of Economics

MvNW/jjs

cc. Dr. Marina v.N. Whitman
Mr. William S. Dix
Mr. Alexander P. Clark

February 14, 1975

Mr. John C. Broderick
Chief
Manuscript Division
The Library of Congress
Washington, D.C. 20540

Dear Mr. Broderick:

I am responding to your letter of January 21, 1975. In accordance with the request of Dr. Marina v.N. Whitman, I am arranging for those papers of the late John von Neumann which are in our custody and on deposit in the Princeton University library, to be transferred to the Library of Congress.

I attach copies of two letters. The first, Dr. Whitman's letter to me requesting the transfer; the second, my letter to the Librarian of Princeton University, requesting him to arrange for you to get the documents. The man at the University library who is immediately responsible for the custody of the documents is Alexander Clark, and I suggest that you be in touch with him directly.

Sincerely yours,

Carl Kaysen

Enclosure

THE LIBRARY OF CONGRESS

WASHINGTON, D. C. 20540

REFERENCE DEPARTMENT
MANUSCRIPT DIVISION

January 21, 1975

Dear Dr. Kaysen:

   The Library recently acquired the papers of John von Neumann as a gift of his daughter, Dr. Marina Whitman. We understand that the Institute for Advanced Study may have additional von Neumann materials pertaining to his years there. Should the Institute be able to retire such materials, they would form a most useful addition to Dr. von Neumann's papers, which we hope to organize soon for the uses of scholarship. I should very much like to know your feelings about this matter, and, indeed, whether there are von Neumann papers at the Institute.

Yours sincerely,

John C. Broderick

John C. Broderick
Chief
Manuscript Division

Dr. Carl Kaysen
Director
Institute for Advanced Study
Olden Lane
Princeton, New Jersey

cc. Dr. Whitman
Mr. Clark

February 14, 1975

Dear Bill:

I think the attached speaks for itself.

I am sending a copy directly to Alexander Clark.

Cordially,

Carl Kaysen

Mr. William S. Dix
Librarian
Princeton University
Princeton, New Jersey 08540

cc. Dr. Whitman
Mr. Dix
Mr. Broderick

February 14, 1975

Mr. Alexander P. Clark
Princeton University Library
Princeton, New Jersey 08540

Dear Mr. Clark:

The von Neumann papers in our custody, which are on deposit at
the library, should now be turned over to the Library of Congress.
As you can see from the attached correspondence, Dr. Marina Whitman,
Professor von Neumann's daughter, has requested the transfer, and I
have asked Mr. Broderick to be in touch with you directly to arrange
it. Please let me know if there is anything further I need to do in
this matter.

Let me close by expressing my appreciation on behalf of the
Institute for the helpfulness of the library, and your own personal
efforts in maintaining custody of the von Neumann documents.

Sincerely yours,

Carl Kaysen

Enclosures

January 24, 1975

Dear Marina:

I have just heard from the Library of Congress about your gift
to them of your father's papers. They ask about the material we have
here, as you see from the attached xeroxed copy of their letter to me.
I would be happy to give them whatever we have if that is your desire.

You may remember that I wrote to you a few years ago in response
to the first inquiry from the Library of Congress, explaining what it
is we had and what we don't have. I attach a copy of that letter and
the lists which went along with it in case you cannot lay your hands
on it easily.

If you wish the materials now in the Princeton University library,
List I, and the materials that are still here, listed under "von Neumann"
on the 3rd page of List II, can be transferred to the Library of Congress.
If you so instruct me, I will arrange that this be done. Further, to
the extent that it might be sensible for such records as remain here of
the computer project to be together with your father's own papers in a
single place, I will transfer the rest of the material contained in
List II to the Library of Congress, if they wish it. There may be some
formalities involved in doing this, but I would like to know what your
desires are before I go further.

Sincerely,

Carl Kaysen

Professor Marina v. N. Whitman
Department of Economics
University of Pittsburgh
Pittsburgh, Pennsylvania 15260

Enclosures (Library of Congress letter of January 21, 1975; CK letter to
Prof. Whitman of Dec. 14, 1972; Princeton University list of
July 31, 1970 (List I); "Index to ECP Files" (List II).

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY

September 19, 1953

Dr. Edward Teller
University of California
Radiation Laboratory
Berkeley 4, California

Dear Edward:

I am enclosing a copy of the long-promised write-up on amplification. I am sending the original to Livermore, but I am taking a copy along to the "reactor" meeting in Washington on September 21, since the agenda gives me some hope that you may be there.

Regarding the write-up itself, I would like to add these comments.

First, you will see that it is quite rough. It is not a properly written paper, but merely an attempt to put the essentials of those things on paper, that have occurred to me since our conversations this summer, and that I do not already know to be nonsense. Even this limited operation took too long, so I did not want to prolong it still more by being literally too sticky. You will notice that I am calculating too much, and surely a good deal that you have known for years, but I know that you will not have much trouble in separating the irrelevancies from the essentials. I think that this write-up, which at least does state unambiguously what points seem to me important, will facilitate your forming an evaluation.

I discussed a specific example: A sphere (p. 7, line -1) of .6 mm diameter, (p. 22, line -10), made of Ge (p. 7, line -1) with an excess of receptors of a density of about 4×10^{20} cm^{-3} (p. 21, line 2), whose electron-hole pair supply depletes in about 10^{-16} sec (p. 13, line 13), and which reacts with light (i.e. amplifies by a factor e) in 10^{-12} sec (p. 15, line 9-11, and p. 20, line 12). I do not take this choice of material and this geometry too seriously, I am proposing them mainly to have some specific target for the next stage of our discussion. Do you consider these choices good? Do you prefer some other material (i.e. other gaps, other excesses) and/or some other geometry?

Here are some questions concerning specific points in the text.

p. 4, line 1: Is this alternation of band energy maximum and minimum positions with respect to the momentum-period-cube correct?

p. 7, line 18: Is it correct that for crystal radiation the conservation of energy is approximate, while that one of momentum is exact?

Dr. Edward Teller   -2-   September 19, 1953

p. 10, line -5 to -3: Is this expression for the transition probability, and quite particularly, this assumption concerning the "surviving" p-matrix-elements, correct?

p. 11, line 4, 11 and p. 13, line 13: Correspondingly, are these w and $\triangle V$ estimates sound?

p. 24, line 13, 14, 21 or line -5 to -3: What do you think of these seemingly (?) exorbitant energy-density estimates?

p. 25, line 4, 8: Ditto, of these exorbitant current-density estimates? I think that they can hardly be produced electrically (is this so?) but there might be other ways (oscillating fields, oscillating heating). Note, that the decay time (10^{-6} sec) is 10^6 reaction times (10^{-12} sec), cf. above.

p. 25, line 14, 17: What do you think of these total energy estimates? They do not seem so awful.

p. 26, line -9 and p. 27, line -9, -8, -6: These heat conduction considerations are, of course, critical. Are they sound?

p. 28, line 13, 14: Can one work with a spectral-interval of this width? Of course, one could make it self-selecting and self-stabilizing. How much of a nuisance is it to work in this part of the near-infrared?

p. 28, line 3 and -12 to -9: Which should one work with: direction, frequency, or polarization?

p. 31, line -4 to p. 32, line 2: What do you think of this multiplication? Electron-multipliers have been used like this. (I think, making 10^{18} electrons from a single electron.)

- - - - - - - - - - - - - - - - - -

What are your general criticisms and suggestions?

Does this suggest any other plausible models or tricks to you?

The essential fact still seems to be that one must maintain a thermodynamic disequilibrium for a time t_1, which is very long compared to the e-folding time t_2 of some autocatalytic process that can be voluntarily induced to accelerate the collapse of this disequilibrium. (In our present case $t_1 \approx 10^{-6}$ sec, $t_2 \approx 10^{-12}$ sec, the autocatalytic agent is light in a band of ≈ 100 Å wavelength-width in the near infrared, i.e. near 18000 Å.) There may be much better physical embodiments for such a mechanism.

I have not gone into questions of actual use, on which I do have ideas, which would be practical, if the whole scheme made sense. I think that it will

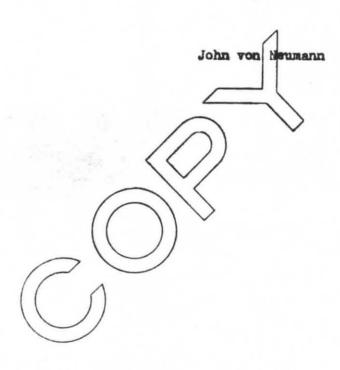Dr. Edward Teller   -3-   September 19, 1953

be better to enter into that phase of the discussion after we have satisfied
ourselves as to the sanity of this scheme, or of a better one.

With best regards,

As ever,

John von Neumann

Notes on the Photon-Disequilibrium-Amplification Scheme

(JvN) September 16, 1953

References:

I.: International Critical Tables, NRC-McGraw Hill, New York, London (1929).

H.: W. Heitler: "The Quantum Theory of Radiation," Oxford Univ. Press, 2nd ed., (1944).

Sh.: W. Shockley: "Electrons and Holes in Semiconductors," D. Van Nostrand, New York (1950).

1. Consider a crystal volume $\mathcal{U}$, in the shape of a cube with the edge L, thought to be repeated with the period L in all (x,y,z) directions. (This is the scheme of F. Bloch. Cf. Sh.: pp. 129-153. We put Sh.'s $A_x = A_y = A_z$, and write L for these.) Let d be the lattice constant (this is Sh.'s a), then $L = Nd$, $N = 1, 2, \ldots$. (Sh.'s $N_x = N_y = N_z$, we write N for these.) The general crystal-invariant translation of the general point $\vec{r} = (x,y,z)$ $(x,y,z$ are only defined mod L) is $\vec{r} \to \vec{r} + d\vec{J}$, where $\vec{J} = (J_x, J_y, J_z)$, with J_x, J_y, $J_z = 0, \pm 1, \pm 2, \ldots$, and only defined mod N. (Sh.'s i, j, k are these J_x, J_y, J_z.) We choose the complete set of stationary state wavefunctions (eigenfunctions) for electrons in the field of this crystal so, that for the state a, i.e. the eigenfunction ψ_a, the crystal-invariant translation $\vec{r} \to \vec{r} + d\vec{J}$ merely multiplies ψ_a by a constant factor of absolute value 1, $\theta(\vec{J})$:

$$\psi_a \to \theta(\vec{J}) \, \psi_a \, .$$

Then necessarily

$$\theta(\vec{J}) = \exp\left(\frac{2\pi i}{N}(\vec{n} \cdot \vec{J})\right),$$

where $\vec{n} = (n_x, n_y, n_z)$,

with n_x, n_y, $n_z = 0, \pm 1, \pm 2, \ldots$,

and only defined mod N.

We can also write

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2.

$$\vartheta\,(\vec{\mathfrak{J}}) = \exp\left(\tfrac{2\pi i}{h}\,(\,\vec{P}\cdot d\vec{\mathfrak{J}}\,)\right),$$

(1)

$$\text{where } \vec{P} = \tfrac{h}{L}\,\vec{n}.$$

$\vec{P}$ is the "crystal-momentum" of the state a.

2.   A Brillouin-Zone B contains precisely 2 (opposite spin) states for each $\vec{P}$, i.e. for each $\vec{\mathfrak{J}}$. Hence the total number of its states is $2N^3 = \dfrac{2L^3}{d^3}$, i.e. $\dfrac{2}{d^3}$ states per unit volume.

The energy of the state a, E_a, is a function of $\vec{\mathfrak{J}}$, or equivalently of $\vec{P}$. We write it in the latter form:

$$E_a = F\,(\vec{P}).$$

The points

$$\text{I:} \quad n_x = n_y = n_z = 0 \ (\text{mod } N), \text{ i.e.}$$

$$P_x = P_y = P_z = 0 \ (\text{mod } \tfrac{h}{a})$$

and $$\text{II:} \quad n_x = n_y = n_z = \tfrac{N}{2} \ (\text{mod } N)$$

(we assume, for the sake of simplicity, that N is even), i.e.

$$P_x = P_y = P_z = \tfrac{h}{2d} \ (\text{mod } \tfrac{h}{d})$$

are of special significance — E_a assumes its maximum and its minimum at I and at II, respectively, or at II and at I, respectively. We introduce $\vec{n}\,'$ and $\vec{P}\,' = \tfrac{h}{L}\,\vec{n}\,'$ as follows:

For I: $\vec{n}\,' = \vec{n}$, i.e. $\vec{P}\,' = \vec{P}$.

For II: $\vec{n}\,' = \vec{n} - \tfrac{N}{2}\,(1,1,1)$, i.e. $\vec{P}\,' = \vec{P} - \tfrac{h}{2d}\,(1,1,1)$.

At the maximum, i.e. the upper edge of the zone,

(2) $$E_a = V^u = \tfrac{1}{2m}\,|\vec{P}\,'|^2,$$

at the minimum, i.e. the lower edge of the zone.

(3) $$E_a = V^e + \tfrac{1}{2m}\,|\vec{P}\,'|^2.$$

Here m is the equivalent mass of the hole or the electron, respectively, but it is actually adequately approximated for our present purposes by the mass of the electron. (Sh.: pp. 176-182, 398.)

Note, that the distance of the energy E_a from the zone-edge, V^u or V^e,

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3.

respectively, is $\frac{1}{2m} |\vec{P}'|^2$ in either case. This is $\leq E$ when $|\vec{P}'| \leq \sqrt{2mE}$, i.e. $|\vec{n}'| \leq \frac{L}{h} \sqrt{2mE}$. As long as $\frac{L}{h} \sqrt{2mE} \ll \frac{N}{2}$, i.e. $E \ll \frac{1}{2m} (\frac{h}{2d})^2$, we may forget the mod N qualification on $\vec{J}$, i.e. on $\vec{J}'$. $|\vec{n}| \leq \frac{L}{h} \sqrt{2mE}$ defines a sphere of radius $\frac{L}{h} \sqrt{2mE}$, i.e. of volume $\frac{4\pi}{3} (\frac{L}{h} \sqrt{2mE})^3 = L^3 \cdot \frac{4\pi}{3} \frac{(2m)^{3/2}}{h^3} E^{3/2}$. This contains approximately $L^3 \cdot \frac{4}{3} \frac{(2m)^{3/2}}{h^3} E^{3/2}$ integer points, i.e. points $\vec{n}'$, i.e. twice as many states: $L^3 \cdot \frac{8\pi}{3} \frac{(2m)^{3/2}}{h^3} E^{3/2}$. Hence the number of states per unit volume and energy distance from the edge $\leq E$ is $\frac{8\pi}{3} \frac{(2m)^{3/2}}{h^3} E^3$.

For the energy distance in E, $E + dE$ this becomes (by E-differentiation)

$$(4) \qquad N(E)\, dE = 4\pi \frac{(2m)^{3/2}}{h^3} E^{1/2}\, dE =$$
$$= 6.7 \times 10^{21}\ E^{1/2}\, dE .$$

(Sh.: pp. 221-222. E in eV, $N(E)\, dE$ in cm^{-3}.) Our above limit for E is

$$(5) \qquad E \ll \frac{1}{2m} (\frac{h}{2d})^2 = 3.6\ eV.$$

(We took $d^{-3} = 4 \times 10^{22}\ cm^{-3}$, i.e. $d = 2.9 \times 10^{-8}\ cm = 2.9\ \mathring{A}$.)

Consider now a Brillouin Zone B_1, with the lower edge V_1^e, and another Brillouin Zone B_2 immediately below the former, with the upper edge V_2^u. The gap between the two is

$$V^g = V_1^e - V_2^u > 0.$$

Consider a state a in B_1, near to its lower edge, with its

$$\vec{P}_1' = \frac{h}{L} \vec{n}_1' ,$$

and the energy (cf. (3))

$$E_a = V_1^e + \frac{1}{2m} |\vec{P}_1'|^2.$$

Consider also a state b in B_2, near to its upper edge, with its

$$\vec{P}_2' = \frac{L}{h} \vec{n}_2'$$

and the energy (cf. (2))

$$E_b = V_2^u - \frac{1}{2m} |\vec{P}_2'|^2.$$

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4.

The correspondence of max.-min. to I-II alternates in consecutive zones, hence the above $\vec{P}_1{}'$ and $\vec{P}_2{}'$ are both formed according to I, or both formed according to II. I.e. they differ both from their $\vec{P}_1$, $\vec{P}_2$ respectively, by the same vector (0 or $\frac{h}{2d}$ (1,1,1)). (Correspondingly, $\vec{n}_1{}'$, $\vec{n}_2{}'$ differ both from their $\vec{n}_1$, $\vec{n}_2$, respectively, by the same vector [0 or $\frac{N}{2}$ (1,1,1)].)

Consider finally a stationary state for a photon, representing a progressive, monochromatic, polarized wave ph, in the same periodic x,y,z-space. (I.e. in the cube with the edge L, thought to be repeated with the period L in all [x,y,z] directions.) Any translation $\vec{r} \rightarrow \vec{r} + \vec{S}$ — $\vec{S} = (S_x, S_y, S_x)$, the S_x, S_y, S_z being defined only mod L — will merely multiply its (complex) potentials by a constant factor of absolute value 1, θ_o ($\vec{S}$). Then necessarily

$$\theta_o (\vec{S}) = \exp\left(\frac{2\pi i}{h} (\vec{P} . \vec{S})\right),$$

(6)   where $\vec{P} = \frac{h}{L} \vec{n}$, $\vec{n} = (n_x, n_y, n_z)$,

with n_x, n_y, $n_z = 0, \pm 1, \pm 2, \dots$.

(There is no mod N restriction here, cf. (1).) $\vec{P}$ is the momentum of the photonic state ph.

Consider now a radiative transition from the electronic state a to the electronic state b, with the emission of a photon into the photonic state ph. The matrix element of the interaction energy H', associated with this transition a $\rightarrow$ b + ph, is given in H.: p. 104. This matrix element contains a factor $\left(\mathcal{P}_e \exp\left(\frac{2\pi i}{h} (\vec{p} . \vec{r})\right)\right)_{ab}$. ($\mathcal{P}_e$ stands for H.'s p_e, it is the component of the electrons momentum — the operator $\frac{h}{2\pi i}$ grad — in the direction of the photonic state ph's polarization. $\frac{2\pi}{h} \vec{P}$ replaces H.'s $\vec{K}$. Note that our [the Planck] h is 2π times H.'s [the Dirac] $\hbar$.) Hence a crystal-invariant translation $\vec{r} \rightarrow \vec{r} + d\vec{j}$ multiplies the matrix element $\left(\mathcal{P}_e \exp(\dots)\right)_{ab}$ by the factor (cf. (1), (6))

$$\exp\left(\frac{2\pi i}{h} ((\vec{P} + \vec{P}_1 - \vec{P}_2) . d\vec{j})\right).$$

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5.

Hence the matrix element $(\mathcal{P}_e \exp(\ldots))_{ab}$ vanishes, unless the above factor is always 1 — i.e. for all $\vec{J}$. The latter means that all components of the vector $\frac{1}{h}(\vec{P}+\vec{P}_1-\vec{P}_2)\,d$ are integers, i.e. that

$$\vec{P} + \vec{P}_1{}' - \vec{P}_2{}' \equiv (0,0,0) \quad (\mathrm{mod}\ \tfrac{h}{d}).$$

In view of what was said earlier about the differences between $\vec{P}_1{}'$, $\vec{P}_2{}'$ and $\vec{P}_1$, $\vec{P}_2$, respectively, this can also be written

$$\vec{P} + \vec{P}_1{}' - \vec{P}_2{}' \equiv (0,0,0) \quad (\mathrm{mod}\ \tfrac{h}{d}),$$

i.e.

$$\vec{n} + \vec{n}_1{}' - \vec{n}_2{}' \equiv (0,0,0) \quad (\mathrm{mod}\ N).$$

The E associated with $\vec{P}_1{}'$, $\vec{P}_2{}'$, i.e. with $\vec{n}_1{}'$, $\vec{n}_2{}'$ will be $\ll 3.6$ eV (cf. (5)), hence $\vec{n}_1{}'$, $\vec{n}_2{}'$ will be $\ll \frac{N}{2}$. Also $\vec{n} \ll \frac{N}{2}$ — this means $\vec{P} \ll \frac{h}{2d}$, i.e. the energy of the photon

$$(7) \qquad E_0 = c\,|\vec{P}| \ll \frac{hc}{2d} = 1900 \text{ eV}.$$

(We took again $d = 2.9 \times 10^{-8}$ cm $= 2.9$ Å.) (In fact, all these E will be $\lesssim 1$ eV.) Hence the mod N at the end of the above relation may be removed:

$$\vec{n} + \vec{n}_1{}' - \vec{n}_2{}' = (0,0,0),$$

i.e.

$$\vec{P} + \vec{P}_1{}' - \vec{P}_2{}' = (0,0,0).$$

Conversely, if this condition is satisfied, then a crystal-invariant translation leaves not only the matrix element $(\mathcal{P}_e \exp(\ldots))_{ab}$, which is an integral over the periodic x,y,z-space, unchanged, but more precisely, it leaves its integrand unchanged. Hence this integral has the same value for each elementary crystal-cell. There are N^3 of these, hence the total integral is N^3 times that over an elementary crystal-cell. Hence it suffices to extend it over an elementary crystal-cell, if the wave functions ψ_a, ψ_b are both multiplied by $N^{3/2}$ — i.e. if they are renormalized for an elementary crystal-cell

(rather than, as originally, normalized for the entire periodic x,y,z-space, which, of course, comprises N^3 elementary crystal-cells). Within an elementary crystal-cell, however, $\exp\left(\frac{2\pi i}{h}\,(\vec{P}\cdot\vec{r})\right)$ is approximately constant, i.e. $\frac{2\pi}{h}\,(\vec{P}\cdot\vec{r})$ is approximately constant, i.e. $\frac{2\pi}{h}\,|\vec{P}|\cdot d \ll 1$. Indeed, this means $|\vec{P}| \ll \frac{h}{2\pi d}$, i.e. $E_o = c\,|\vec{P}| \ll \frac{hc}{2\pi d}$, i.e. using (7), $E_o \ll \frac{1900}{\pi} =$ 600 eV, which we know is true. Hence the factor exp (...) merely affects the matrix element with a constant factor of absolute value 1. Since only the $|\dots|^2$ of this matrix element will matter subsequently (cf. H.: p. 104), we may omit this factor altogether.

To summarize:

The matrix element H' in H.: p. 104 vanishes, unless

(8.a) $$\vec{n} - \vec{n}_2{}' - \vec{n}_1{}' ,$$

i.e.

(8.b) $$\vec{P} = \vec{P}_2{}' - \vec{P}_1{}' .$$

If this condition is met, however, then its factor $\left(\mathcal{P}_e \exp(\dots)\right)_{ab}$ may be replaced by $\left(\mathcal{P}_e\right)_{ab}$, where the integration in $\left(\mathcal{P}_e\right)_{ab}$ is extended over an elementary crystal-cell only, and the wave functions are renormalized for an elementary crystal-cell.

We continue the consideration of the radiative transition a → b + ph. It is well known, that this process, in a lapse of time t, takes place with a probability that has an initial increase $\sim t^2$, i.e. is not describable as a fixed time-rate process, if the states a, b, ph are single states as shown above. It is also known (according to P.A.M. Dirac), that the probability in question has an initial increase $\sim t$, i.e. is describable as a fixed time-rate process, if the state a is single, but b, ph involve a quasi-continuum. The latter means, that they involve a dense family of states, which gets asymptotically infinitely dense as $\mathcal{V} \to \infty$, i.e. L → ∞ . (This is

discussed in H.: pp. 87-90.) Normally, when the radiative transitions of an atom are considered, b is a single state, and ph varies over a quasi-continuum. (Cf. H.: pp. 102-107.) In the summation over these ph, the essential contribution is made by those ph for which the process a $\rightarrow$ b + ph approximately (to within the natural line width, cf. H.: pp. 110-115) conserves energy.

In our present setup, ph still varies over a quasi-continuum — in fact, over the same one as in the above case (i.e. H.: pp. 102-107). However, now b is no longer a single state, i.e. fixed. (a is a single state!) Indeed, by (8.a)

$$\vec{n} = \vec{n}_2' - \vec{n}_1',$$

i.e. by (8.b)

$$\vec{P} = \vec{P}_2' - \vec{P}_1',$$

ph determines b. I.e. b is now a function of ph. Otherwise, the summation is the same as in the above case. Let us, therefore, now reinterpret that case for the present situation.

Note, first of all, that the relation $\vec{P} = \vec{P}_2' - \vec{P}_1'$ is rigorously required, i.e. the conservation of momentum is exact, while the conservation of energy is only approximate.

Consider the relation (8.b) further. It states

$$(9) \qquad \vec{P}_2' = \vec{P}_1' + \vec{P}.$$

Note, that the balance of energy is (cf. (2), (3))

$$E' = (V_1^e + \frac{1}{2m} \left| \vec{P}_1' \right|^2 - (V_1^u - \frac{1}{2m} \left| \vec{P}_2' \right|^2) - c \left| \vec{P} \right|,$$

i.e.

$$(10) \qquad E' = V^g + \frac{1}{2m} (\left| \vec{P}_1' \right|^2 + \left| \vec{P}_2' \right|^2) - c \left| \vec{P} \right|.$$

If E' is to be $\approx$ 0, then the third term in (10) must approximately compensate the first one, while the second term $(\frac{1}{2m}(\ldots + \ldots))$ will be small compared to these two.

Indeed: We will choose for V^g the typical value of .7 eV (Sh.: p. 154.

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typical v^g

These are some/values: ~~MX~~ C (Diamond): ca. 6 eV, Si: 1.11 eV, Ge: .72 eV, Sn (gray): .1eV. Other gaps can be achieved in various ways.) $\frac{1}{2m}\left|\vec{P}_1'\right|^2$ is the order of the temperature energy, i.e. at moderate temperatures, i.e. $T \approx 300°$, which we will always assume from now on to be valid, it is $\approx \frac{1}{40}$ eV = .025 eV.

Hence

$$\frac{1}{2m}\left|\vec{P}\right|^2 = \frac{(v^g)^2}{2mc^2} \approx \frac{(.7 \text{ eV})^2}{2 \times 500\ 000 \text{ eV}} = 5 \times 10^{-7} \text{ eV.}$$

Hence $\left|\vec{P}_1' + \vec{P}\right|^2$ is very nearly $\left|\vec{P}_1'\right|^2$, and so the second term in 10. is

$$\frac{1}{m}\left|\vec{P}_1'\right|^2 \approx .05 \text{ eV} \ll v^g \approx .7 \text{ eV.}$$

This establishes our above assertions. Note, that we can write with a good approximation

(11) $\qquad E' = v^g + \frac{1}{m}\left|\vec{P}_1'\right|^2 - c\left|\vec{P}\right|.$

5. $\qquad$ Let us now consider the time-rate of transition probability formula in H.: p. 104, i.e.

$$w = \frac{1}{h}\rho\left|H'\right|^2$$

(Our [the Planck] h is 2π times H.'s [the Dirac] h. Our ρ is H.'s ρ_E.)

dE is the number of photonic states ph for which the energy balance (i.e. our above E') lies between 0 and dE. $\left|H'\right|^2$ is the mean of $\left|H'\right|^2$ over these ph, H' being given by H. at the same place.

Thus ρ dE is the number of the available P with $c\left|\vec{P}\right|$ lying in E_0, $E_0 -$ dE, where, according to (11),

(12.a) $\qquad E_0 = v^g + \frac{1}{m}\left|\vec{P}_1'\right|^2,$

or, with an approximation that is adequate for some of our present purposes,

(12.b) $\qquad E_0 \approx v^g.$

Now $c\left|\vec{P}\right| \le E$ means $\left|\vec{n}\right| \le \frac{L}{hc}E$. This defines a sphere of radius $\frac{L}{hc}E$, i.e. of volume $\frac{4\pi}{3}\left(\frac{L}{hc}E\right)^3 = L^3 \cdot \frac{4\pi}{3}\frac{E^3}{(hc)^3}$. This contains approximately

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$L^3 \cdot \frac{4\pi}{3} \frac{E^3}{(hc)^3}$ integer points, i.e. points $\vec{n}$, i.e. twice as many states ph:

$L^3 \cdot \frac{8\pi}{3} \frac{E^3}{(hc)^3}$. Hence the number of states ph per unit volume and energy

$\leq E$ is $\frac{8\pi}{3} \frac{E^3}{(hc)^3}$. For the energy in E, $E + dE$, or equally in E, $E - dE$, this becomes (by E-differentiation)

$$(13) \qquad N_o(E) \, dE = 8\pi \frac{E^2}{(hc)^3} \, dE.$$

We can now replace E by E_o in this formula.

Now, not all these states ph may be avilable, i.e. not all of them command by virtue of the (exact) relation (9) electronic states $\vec{P_2}'$, i.e. b, that are available, i.e. unoccupied. Let the relative density of unoccupied electronic states in B_2, at the energy distance E^* from the upper edge (V_2^u), i.e. at $\vec{P}'$ with

$$(14) \qquad \frac{1}{2m} |\vec{P}'|^2 = E^*,$$

be $\mathfrak{G}(E^*)$. $(\mathfrak{G}(E^*)$ is a relative density, i.e. relatively to the existing states. Hence $0 \leq \mathfrak{G}(E^*) \leq 1$.) Hence

$$dE = 8\pi \frac{E_o^2}{(hc)^3} \, dE \cdot \mathfrak{G}(E^*)$$

$$\text{where } E^* = \frac{1}{2m} |\vec{P_2}'|^2 \approx \frac{1}{2m} |\vec{P_1}'|^2$$

This expression, except for the extra factor $\mathfrak{G}(E^*)$, agrees with the ρ_E or ρ_K of H.: pp. 108-109. (The K of E of H. is our E_o or E. We know that $h = 2\pi\hbar$. We consider all directions, hence replace $d\Omega$ by 4π, and all polarizations, hence we have an extra factor 2.) Hence the final formula of H. for the total rate of energy loss by a, applies too, with the insertion of the factor $\mathfrak{G}(E^*)$.

This formula is

$$S = \frac{4(2\pi)^4}{3} \frac{e^2}{c^3} \nu^4 \cdot \left(|x_{ab}|^2 + |y_{ab}|^2 + |z_{ab}|^2 \right) \cdot \mathfrak{G}(E^*).$$

(H.: p. 206. Since H.'s T_{cv} is our $h\nu$, and $h = 2\pi\hbar$, so H.'s ν is 2π times

our ν. $|x_{ab}|^2 + |y_{ab}|^2 + |z_{ab}|^2$ is the meaning of the $|x_{ab}|^2$ of H. Note,

that $h\nu = E_o$. Now the matrix elements x_{ab}, y_{ab}, z_{ab}, i.e. the components of the

matrix vector $\vec{r}_{ab}$, were obtained in H.: pp. 105-106 from the components of the

matrix vector $\vec{P}_{ab}$ in this way: $H = \frac{1}{2m}|\vec{P}|^2 + V(\vec{r})$, hence ($[\ldots,\ldots]$ designates

the operator-commutator)

$$[H, \vec{r}] = \frac{1}{2m}[|\vec{P}|^2, \vec{r}] = \frac{1}{2m}\cdot\frac{h}{2\pi i}\cdot 2\vec{P} = -i\frac{h}{2\pi m}\vec{P},$$

and then

$$[H, \vec{r}]_{ab}\begin{cases} = h(\nu_a - \nu_v)\vec{r}_{ab} \approx h\nu\,\vec{r}_{ab}, \\ = -i\frac{h}{2\pi m}\vec{P}_{ab}, \end{cases}$$

so that

$$\vec{P}_{ab} = i\,2\pi\,m\nu\,\vec{r}_{ab}.$$

Hence the formula becomes

$$S = \frac{4(2\pi)^2}{3}\frac{e^2}{c^3}\frac{\nu^2}{m^2}\cdot(|(P_x)_{ab}|^2 + |(P_y)_{ab}|^2 + |(P_z)_{ab}|^2)\cdot\delta(E^*).$$

The time-rate of transition probability is S divided by the photons energy, $h\nu$,

i.e.

$$w = \frac{S}{h\nu} = \frac{4(2\pi)^2}{3}\frac{e^2}{c^3}\frac{\nu}{hm^2}\cdot(|(P_x)_{ab}|^2 + |(P_y)_{ab}|^2 + |(P_z)_{ab}|^2)\cdot\delta(E^*).$$

It is preferable to write this in this form:

Transition probability per light-oscillation period $=$

$$\frac{w}{\nu} = \frac{4(2\pi)^2}{3}\frac{e^2}{hc}\cdot\frac{|(P_x)_{ab}|^2 + |(P_y)_{ab}|^2 + |(P_z)_{ab}|^2}{(mc)^2}\cdot\delta(E^*).$$

It is plausible to expect that

$$(15)\quad |(P_x)_{ab}|^2 + |(P_y)_{ab}|^2 + |(P_z)_{ab}|^2 \approx |\vec{P}_1'|^2.$$

Indeed, the two states, a, b, are close together ($\vec{P}_1' \approx \vec{P}_2'$), and their deviations

over a single elementary crystal-cell are not important.

We will therefore put, according to (14), (15),

$$\left|(P_x)_{ab}\right|^2 + \left|(P_y)_{ab}\right|^2 + \left|(P_z)_{ab}\right|^2 \approx |\vec{P}_1'|^2 = 2m E^*.$$

Then

$$\frac{w}{\nu} = \frac{4(2\pi)^2}{3}\,\frac{e^2}{hc}\,\frac{2E^*}{mc^2}\,\sigma(E^*) = \frac{16\pi}{3}\,\frac{2\pi e^2}{hc}\,\frac{E^*}{mc^2}\,\sigma(E^*).$$

Now $\frac{2\pi e^2}{hc} = \frac{1}{137}$, hence $\frac{16\pi}{3}\,\frac{2\pi e^2}{hc} = \frac{16\pi}{411} = .12$. Expressing E^* and mc^2 in eV,

$mc^2 = 500\ 000$. Hence

$$\frac{w}{\nu} = 2.4 \times 10^{-7}\ .\ E^*\,\sigma(E^*).$$

Now ν (in $\sec^{-1}$) $= c\ .\ 8100\ .\ E_o \approx c\ .\ 8100\ .\ V^g$, where it was proper to use

(12.b) $E_o \approx V^g$ in eV. c, light velocity, is 3×10^{10} cm sec^{-1}. Hence

$\nu = 2.4 \times 10^{14}\ V^g$, and so

$$w = 5.8 \times 10^7\ .\ V^g\ .\ E^*\,\sigma(E^*).$$

(w in sec^{-1}, E^* and V^g in eV.)

6.   We now pass to a more general situation.

Let the density of occupied electronic states in B_1, at the energy distance E from the lower edge (V_1^e, i.e. at $V_1^e + E$) be $\rho(E)$ (≥ 0, ≤ 1), and the relative density of unoccupied electronic states in B_2 at the energy distance E from the upper edge (V_2^u, i.e. at $V_2^u - E$) be $\sigma(E)$ (≥ 0, ≤ 1). (The latter case was considered above. We write E for the E^* there.)

Under these conditions the time-rate of the spontaneous transition probability for a single state in B_1 is (cf. the end of 5.)

(16) $w = w(E) = 5.8 \times 10^7\ .\ V^g\ .\ E\,\sigma(E).$

Hence the total time-rate for spontaneous transitions from B_1 to B_2, per unit volume, is

$$W = \int N(E)\,\rho(E)\,w(E)\ dE =$$
$$= \int (6.7 \times 10^{21}\ .\ E^{\frac{1}{2}})\ .\ \rho(E).$$
$$.\ (5.8 \times 10^7\ .\ V^g\ .\ E\,\sigma(E))\ .\ dE =$$
$$= 3.9 \times 10^{29}\ .\ V^g\ .\ \int \rho(E)\,\sigma(E)\ .\ E^{3/2}\ dE.$$

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(W in cm^{-3} sec^{-1}.)

We continue by evaluating the time-rate for induced transitions from B_1 to B_2, in its dependence on the densities of photonic states present.

The above formula shows, that the time-rate of spontaneous transitions from B_1 to B_2, per unit volume, coming from states (in B_1) with an energy distance in E, E + dE from the edge, is

$$(17) \quad 3.9 \times 10^{29} \cdot v^g \cdot \rho(E) \, \sigma(E) \cdot E^{3/2} \, dE \; cm^{-3} \; sec^{-1}$$

This energy $E = \frac{1}{em} \, | \, P_1' \, |^2$ corresponds according to (12.a), to a photon energy $E_o = v^g + \frac{1}{m} \, | \, \vec{P}_1' \, |^2 = v^g + 2E$. Hence the interval E, E + dE corresponds to the photon energy interval E_o, E_o + 2 dE with

$$(18) \qquad\qquad E_o = v^g + 2E.$$

Now let the relative density of photons in the photonic states at the energy E' be $\tau(E')$. ($\tau(E')$ is a relative density for a Bose-Einstein population; hence $\tau(E') \geq 0$, but $\tau(E') \gtrless 1$.) Since there are according to (13)

$$N_o(E') \, dE' = 8\pi \frac{E'^2}{(hc)^3} \, dE'$$

photonic states in E', E' + dE', this means that there are

$$(19) \qquad N_o(E) \, \tau(E') \, dE' = 8\pi \frac{E'^2}{(hc)^3} \, \tau(E') \, dE'$$

photons, per unit volume, in E', E' + dE'.

As is well know, the time-rate of induced transitions from B_1 to B_2, per unit volume, coming from states with an energy distance in E, E + dE from the edge, is consequently

$$3.9 \times 10^{29} \cdot v^g \cdot \rho(E) \, \sigma(E) \, \tau(v^g + 2E) \cdot E^{3/2} \, dE \; cm^{-3} \; sec^{-1},$$

and the corresponding quantity for the reverse transitions is

$$3.9 \times 10^{29} \cdot v^g \cdot (1-\rho(E)) \, (1-\sigma(E)) \, \tau(v^g+2E) \cdot E^{3/2} \, dE \; cm^{-3} \; sec^{-1}.$$

Hence the total time-rate of transitions from B_1 to B_2, per unit volume,

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coming from states with an energy distance in E, $E + dE$ from the edge, is

$$3.9 \times 10^{29} \cdot v^g \cdot$$

$$\cdot \left[\rho(E)\delta(E) + \rho(E)\delta(E)\tau(v^g+2E) - (1-\rho(E))(1-\delta(E))\tau(v^g+2E)\right] \cdot$$

$$\cdot E^{3/2} \, dE \quad cm^{-3} \quad sec^{-1},$$

i.e.

$$3.9 \times 10^{29} \cdot v^g \cdot \left[\rho(E)\delta(E) + (\rho(E)+\delta(E)-1)\tau(v^g+2E)\right] \cdot$$

$$(20) \qquad \cdot E^{3/2} \, dE \quad cm^{-3} \quad sec^{-1}.$$

7.   Consider the above formula with a dE that is $\gg$ the natural line width. Note, that the natural line width, in Δv, i.e. sec^{-1}, is (cf. (16))

$$\Delta v = w = 5.8 \times 10^7 \cdot v^g \cdot E\delta(E),$$

and since $v^g \approx .7$ eV, $E \approx KT \approx \frac{1}{40}$ eV, $\delta(E) \leq 1$, therefore

$$\Delta v \leq (5.8 \times 10^7) \cdot (.7) \cdot \frac{1}{40} \cdot 1 = 10^6 \, sec^{-1}.$$

Now the natural line width in ΔE, i.e. in eV, is related to Δv by

$$\Delta v = c \cdot 8100 \cdot \Delta E = 2.4 \times 10^{14} \Delta E, \text{ hence}$$

$$E \leq 4.2 \times 10^{-9} \, eV.$$

This is indeed $\ll$ the order of magnitude of dE that concern us, which is a few percent of KT, i.e. of $\frac{1}{40}$ eV — i.e. of the order of 2.5×10^{-4} eV.

  Under these conditions the transitions from B_1 to B_2 generate photons whose energy E_0 corresponds to the energy distance E (of the relevant region in B_1) from the edge, i.e. the formula (18) applies. Hence the photon energy interval E_0, $E_0 + 2 \, dE$ corresponds to the B_1 energy interval E, $E + dE$. Hence the time-rate of transitions from B_1 to B_2, per unit volume, according to (20), increases the number of photons, per unit volume, in the corresponding photon energy interval (i.e. in E_0, $E_0 + 2 \, dE$). This number (of photons per unit volume in that energy interval) is, according to (19),

$$8\pi \frac{E_0^2}{(hc)^3} \tau(E_0) \, 2 \, dE$$

i.e. (E_0, dE in eV, $E_0 \approx v^g + 2E \approx v^g$)

$$3.5 \times 10^{13} \cdot (v^g)^2 \cdot \tau(v^g + 2E) \cdot dE \ cm^{-3}.$$

Consequently the time-rate of the increase of τ ($v^g + 2E$) obtains in this way:

$$3.5 \times 10^{13} \cdot (v^g)^2 \cdot \frac{d}{dt}\tau(v^g+2E) \cdot dE = 3.9 \times 10^{29} \cdot v^g \cdot$$
$$[\rho(E)\sigma(E) + (\rho(E)+\sigma(E)-1)\tau(v^g+2E)] \cdot E^{3/2} \ dE$$

(t in sec, so that both sides are in $cm^{-3} \ sec^{-1}$), i.e.

(21) $\qquad \frac{d}{dt}\tau(v^g+2E) = 1.1 \times 10^{16} \cdot (v^g)^{-1} E^{3/2} \cdot$
$$[\rho(E)\sigma(E) + (\rho(E)+\sigma(E)-1)\tau(v^g+2E)] \ sec^{-1}.$$

<u>8.</u> Formula (21) indicates, among other things, these two facts: First, if $\rho(E) + \sigma(E) < 1$, then $\tau(v^g+2E)$ converges exponentially (for $t \to +\infty$) to an equilibrium value — which is $\frac{\rho(E)\sigma(E)}{1-\rho(E)-\sigma(E)}$. Second, if $\rho(E) + \sigma(E) > 1$, then $\tau(v^g+2E)$ diverges exponentially (for $t \to +\infty$) — actually not from 0, but from the now negative pseudo-equilibrium value $\frac{\rho(E)\sigma(E)}{1-\rho(G)-\sigma(E)}$. In the first case the time-constant (the e^{-1}-folding time) for the exponential convergence is

$$9 \times 10^{-17} \ \frac{v^g}{E^{3/2}} \ \frac{1}{1-\rho(E)-\sigma(E)} \ sec.$$

In the second case the time-constant (the e-folding time) for the exponential divergence is

$$9 \times 10^{-17} \ \frac{v^g}{E^{3/2}} \ \frac{1}{\rho(E) + \sigma(E) - 1} \ sec.$$

<u>9.</u> The last formula shows, that for an energy E, or rather for the corresponding photon energy $E_0 = v^g + 2E$ (cf. (18) — actually we should visualize an energy interval E, E + dE, rather than a specific energy E), for which the condition

$$\rho(E) + \sigma(E) > 1$$

is satisfied, the possibility of amplification exists. It is true, however, that the possibilities of such an amplification are limited by the unavoidably accompanying depletion of the corresponding $\rho(E)$ (electrons in B_1) and $\sigma(E)$ (holes in B_2), which will in the end invalidate the above condition. Hence the effective development of this mode of amplification depends on the introduction

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of some mechanism for the replenishment of (i.e. the maintaining of the level of) the ρ (E) and σ (E) involved.

Such a mechanism can be obtained in the following way.

The temperature equilibrium between the electronic states is established by two classes of interactions: First, by those which act only within a single Brillouin Zone. Second, those which cause interactions between different Brillouin Zones. The first are primarily the interactions with crystal-lattice vibrations. They are very effective, the mean free times between these collisions are of the order of, and rather shorter than, 10^{-12} sec. (Sh.: pp. 486-492: Ca. 10^{-12} sec in Ge. Sh.: pp. 199, 214-215: In a particular case, more precisely, 5.7×10^{-13} sec in Ge.) The second are the radiative processes, which we must, however, not view here as overall equilibrising ones, since we are treating them explicitly and in detail, and in their non-equilibrium aspects also. In addition, certain surface effects also belong into this class, and regarding these we must say somewhat more.

We saw that the time-rate of the spontaneous transition probability for a single state in B_1 (i.e. for an electron in B_1) is (cf. (16))

$$(22) \qquad w_1 = 5.8 \times 10^7 \cdot v^8 \cdot E\sigma(E).$$

The surface-reaction rate is characterized by a velocity U, which describes the apparent flow of electron-hole pairs into the "sink" at the surface. According to Sh.: p. 324 this velocity may be as high as 10 000 cm sec^{-1}, and it can be reduced to 200 cm sec^{-1}. I.e. in a volume $\mathcal{V}$ with surface A, the loss-rate is

$$w_2 = \frac{AU}{\mathcal{V}} \text{ sec}^{-1}.$$

Let us assume a spherical shape, with a diameter of D cm. Then

$$\mathcal{V} = \frac{\pi}{6} D^3, \quad A = \pi D^2,$$

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hence

$$w_2 = \frac{6U}{D} \; \text{sec}^{-1}.$$

We will use for U the least favorable value: $U = 10\,000$ cm sec^{-1}. Then

(23)
$$w_2 = \frac{6 \times 10^4}{D} \; \text{sec}^{-1}.$$

These considerations imply that, if we do not insist on time resolutions that are better than 10^{-12} sec, we may assume temperature equilibrium within each zone B_1 and B_2 separately, but not between these two zones. The relationship of these two zones is then controlled by radiative transitions to which our previous discussions refer, and by the surface effect considered above.

10.   Temperature equilibrium (for electrons) in B_1 means

$$\rho(E) = \frac{1}{1 + \alpha \exp\left(\frac{E}{KT}\right)}.$$

Temperature equilibrium (for holes) in B_2 means

$$\sigma(E) = \frac{1}{1 + \beta \exp\left(\frac{E}{KT}\right)}.$$

The latter could, of course, also be stated for electrons in B_2, and reckoning on the same E-scale as for B_1 (for electrons) above:

$$1 - \sigma(E) = \frac{1}{1 + \beta_1 \exp\left(\frac{-(V^g+E)}{KT}\right)}$$

These two formulae for $\sigma(E)$ are identical, defining the relation

$$\beta_1 \beta = \exp\left(\frac{V^g}{KT}\right).$$

between β and β_1. Clearly temperature equilibrium between B_1 and B_2 means $\alpha = \beta_1$, i.e.

(24)
$$\alpha \beta = \exp\left(\frac{V^g}{KT}\right).$$

Note, that for $V^g = .7$ eV, $KT = \frac{1}{40}$ eV (cf. the remarks made in 4.)

$$\exp\left(\frac{V^g}{KT}\right) = \exp(28) \approx 10^{12}.$$

We will see, that α, β will not satisfy this relation — this is natural, since amplification is not an equilibrium process.

We will actually work with a set-up, where there are few electrons in B_1 and there is an excess of holes over electrons, so that the region $E < \bar{E}$ in B_2 is very nearly filled with holes, and there are few holes with $E > \bar{E}$ in B_2. This means

$$\alpha \gg 1, \beta \approx \exp\left(-\frac{\bar{E}}{KT}\right).$$

We will choose $\bar{E} \gg KT$, so that

$$\beta \ll 1.$$

Note, that the excess of holes over electrons per unit volume is according to (4)

$$N' = \int_0^{\bar{E}} N(E)\, dE = 4.5 \times 10^{21} \cdot \bar{E}^{3/2} \text{ cm}^{-3},$$

hence for $KT = \frac{1}{40}$ eV this is

$$1.8 \times 10^{19} \cdot \left(\frac{\bar{E}}{KT}\right)^{3/2}.$$

Now

(25)
$$\rho(E) = \frac{1}{1 + \alpha \exp\left(\frac{E}{KT}\right)} \approx \frac{1}{\alpha} \exp\left(-\frac{E}{KT}\right),$$

and

(26)
$$1 - \sigma(E) = \frac{\beta \exp\left(\frac{E}{KT}\right)}{1 + \beta \exp\left(\frac{E}{KT}\right)} \approx \beta \exp\left(\frac{E}{KT}\right),$$

provided, in the latter case, that $\beta \exp\left(\frac{E}{KT}\right) \ll 1$, i.e. $\exp\left(\frac{E - \bar{E}}{KT}\right) \ll 1$, i.e.

$$\bar{E} - E \gg KT \qquad \text{(and} > 0\text{)}.$$

Hence, using (25), (26),

$$\rho(E) + \sigma(E) - 1 = \rho(E) - (1 - \sigma(E)) \approx \frac{1}{\alpha} \exp\left(-\frac{E}{KT}\right) - \beta \exp\left(\frac{E}{KT}\right).$$

We wish that the first term be dominant, i.e. $\frac{1}{\alpha} \exp\left(-\frac{E}{KT}\right) \gg \beta \exp\left(\frac{E}{KT}\right)$, i.e. $\alpha \ll \exp\left(\frac{\bar{E} - 2E}{KT}\right)$. Since E is of the order of KT and $\bar{E} \gg KT$, this means that essentially $\alpha \ll \exp\left(\frac{\bar{E}}{KT}\right)$, hence $\alpha\beta \ll 1$, proving, as observed after (24), that we are far from equilibrium.

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18.

Now the time-rate of radiative losses of B_1 (to B_2), per unit volume, is according to (20)

$$\int 3.9 \times 10^{29} . v^g . [\rho(E)\delta(E) + (\rho(E) + \delta(E) - 1)\tau(v^g + 2E)] .$$
$$. E^{3/2} \, dE \quad cm^{-3} \, sec^{-1},$$

and since $\delta(E) \approx 1$, $\rho(E) \gg 1 - \quad (E)$, therefore this is

$$3.9 \times 10^{29} . v^g . \rho(E) (1 + \tau(v^g + 2E)) . E^{3/2} \, dE \quad cm^{-3} \, sec^{-1}.$$

The time-rate of surface-effect losses of B_1 (also to B_2), per unit volume, is according to (4), (23)

$$\frac{6 \times 10^4}{D} \int N(E) \rho(E) \, dE = \frac{6 \times 10^4}{D} \int 6.7 \times 10^{21} E^{3/2} \rho(E) \, dE =$$
$$= \frac{4 \times 10^{26}}{D} \int \rho(E) E^{3/2} \, dE \quad cm^{-3} \, sec^{-1}.$$

Now by (25) $\rho(E) = \frac{1}{\alpha} \exp(-\frac{E}{KT})$. Put $\delta = \frac{1}{\alpha}$. Then the time-rate of radiative losses of B_1, per unit volume, is by (20)

$$3.9 \times 10^{29} . v^g . \int (1 + \tau(v^g + 2E)) . \exp(-\frac{E}{KT}) E^{3/2} \, dE .$$
$$. \delta \quad cm^{-3} \, sec^{-1},$$

and the time-rate of surface-effect losses of B_1, per unit volume, is

$$\frac{4 \times 10^{26}}{D} . \int \qquad \exp(-\frac{E}{KT}) E^{3/2} \, dE .$$
$$. \delta \quad cm^{-3} \, sec^{-1}.$$

The increase of the $\tau(v^g + 2E)$, on the other hand, is controlled by the differential equation (21), and since $\delta(E) \approx 1$, $\rho(E) \gg 1 - \delta(E)$, therefore this becomes

$$\frac{d}{dt} \tau(v^g + 2E) = 1.1 \times 10^{16} . (v^g)^{-1}.$$
$$. \rho(E) (1 + (v^g + 2E)) . E^{3/2} \, sec^{-1},$$

or, with (25) for $\rho(E)$,

$$\frac{d}{dt} \tau(v^g + 2E) = 1.1 \times 10^{16} . (v^g)^{-1} . \exp(-\frac{E}{KT}) E^{3/2} .$$
$$. (1 + \tau(v^g + 2E)) . \delta \quad sec^{-1}.$$

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19.

We now put $V^g = .7$ eV and $KT = \frac{1}{40}$ eV (cf. the remarks made in 4.). Then our three expressions become:

Radiative losses:

$$(27) \quad 2.7 \times 10^{29} . \int (1 + \tau (V^g + 2E)) . \exp (-40 \, E) \, E^{3/2} . dE .$$
$$. \, \delta \quad cm^{-3} \, sec^{-1}.$$

Surface-effect losses:

$$(28) \quad \frac{4 \times 10^{26}}{D} . \int \exp (-40E) \, E^{3/2} \, dE . \delta \quad cm^{-3} \, sec^{-1}.$$

Increase of photons:

$$(29) \quad \frac{d}{dt} \tau (V^g + 2E) = 1.6 \times 10^{16} . \exp (-40 \, E) \, E^{3/2} .$$
$$. \, (1 + \tau (V^g + 2E))) . \delta \quad sec^{-1}.$$

It is worth noting for what E the coefficient on the righthand side of the differential equation (29) is largest. This coefficient depends on E only through its proportionality to $\exp (-40 \, E) \, E^{3/2}$.

Now

$$\ln [\exp (-40 \, E) \, E^{3/2}] = \frac{3}{2} \ln E - 40 \, E,$$
$$\frac{d}{dE} \ln [\exp (-40 \, E) \, E^{3/2}] = \frac{3}{2} \frac{1}{E} - 40,$$
$$\frac{d^2}{dE^2} \ln [\exp (-40 \, E) \, E^{3/2}] = -\frac{3}{2} \frac{1}{E^2}$$

Hence there is a (unique) maximum at $\frac{3}{2} \frac{1}{E} - 40 = 0$, i.e. at

$$E = \frac{3}{80} = .037 \text{ eV},$$

and there

$$\exp (-40 \, E) \, E^{3/2} = \exp (-\frac{3}{2}) (\frac{3}{80})^{3/2} = (\frac{3}{80e})^{3/2} = 1.6 \times 10^{-3},$$

and

$$\frac{d^2}{dE^2} \ln [\exp (-40 \, E) \, E^{3/2}] = -\frac{3}{2} (\frac{80}{3})^2 = -1067.$$

Hence in the neighborhood of this maximum

$$\exp (-40 \, E) \, E^{3/2} \approx 1.6 \times 10^{-3} . (1 - 533 \, (E - .037)^2).$$

The term $-533 (E-.037)^2$ expresses a relative deviation. This does not exceed 1 percent, when

$$533 (E-.037)^2 \leq .01,$$

i.e.

$$E-.037 \leq \sqrt{\frac{.01}{533}} = .0043.$$

I.e.: The factor $\exp (-40\ E)\ E^{3/2}$ has a (unique) maximum 1.6×10^{-3} at $E = .037$ eV and deviates from this less than 1 percent, when E lies between .033 eV and .041 eV

In this interval, accordingly

$$(30) \quad \frac{d}{dt} \tau (v^g+2E) = 2.6 \times 10^{13} \cdot (1+\tau(v^g+2E)) \cdot \delta \quad sec^{-1}.$$

This last expression, then, expresses the best possible amplification. Its e-folding time is

$$(31) \quad t_e = \frac{1}{2.6 \times 10^{13} \cdot \delta} = \frac{3.8}{\delta} \times 10^{-14}\ sec.$$

This is smallest, when δ is largest, and then it should be 10^{-12} sec. This gives $\frac{3.8}{\delta\ max} = 10^2$, i.e.

$$(32) \quad \delta_{max} = 3.8 \times 10^{-2}.$$

We will see in the course of the discussion in 15., that it is not necessary to consider now decreases of δ /below this value by more than a factor 2. Hence $\delta \geq 1.9 \times 10^{-2}$, $\alpha = \frac{1}{\delta} \leq 52$. The requirement $\alpha << \exp (\frac{\overline{E}-2E}{KT})$ becomes accordingly $52 \leq \exp (\frac{\overline{E}-2E}{KT})$, i.e.

$$\frac{\overline{E}}{KT} >> \ln 52 + 2\frac{E}{KT} = 4 + 2\frac{E}{KT}.$$

Hence

$$\frac{\overline{E}}{KT} = 8,$$

i.e.

$$(33) \quad \overline{E} = .2\ eV$$

is adequate. With this choice the number of excess holes per unit volume is

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21.

(cf. (4))

$$(34) \qquad N' = 4.5 \times 10^{21} \cdot E^{3/2} = 4 \times 10^{20} \text{ cm}^{-3}.$$

11.   Now consider the behavior of a specific geometry.

We have already postulated, that it be a sphere of diameter D.

Consider a chord of length D' in this sphere. Consider a photon-family progressing along this chord, measuring time by t (sec) and distance by x (cm). Its $\tau(v^2+2E)$, to be designated here, for the sake of brevity, by τ, increases according to (29)

$$(35) \qquad \frac{d\tau}{dt} = 1.6 \times 10^{16} \cdot f \cdot \delta \cdot (1+\tau) \text{ sec}^{-1},$$

$$\text{where } f = \exp(-40 \text{ E}) \text{ E}^{3/2}.$$

In terms of $x = ct$ ($c = 3 \times 10^{10}$ cm sec^{-1}):

$$\frac{d\tau}{dx} = 5.3 \times 10^5 \cdot f \cdot \delta \cdot (1+t) \text{ cm}^{-1}.$$

If there is no external stimulation, then $\tau = 0$ for $x = 0$, hence

$$\bar{\tau} = \frac{1}{D'} \int_0^{D'} \tau \, dx = \frac{1}{D'} \int_0^{D'} (\exp(5.3 \times 10^5 \cdot f \cdot \delta \cdot x) - 1) \, dx =$$

$$= \phi(5.3 \times 10^5 \cdot f \cdot \delta \cdot D'),$$

where

$$\phi(u) = \frac{1}{u} \int_0^u (e^u - 1) \, du = \frac{e^u - 1 - u}{u} = \frac{1}{2} u + \frac{1}{6} u^2 + \dots .$$

We do not want this to be large, hence we will want $u \leq 1$. This means that $\bar{\tau} = \phi(u)$ will be nearly linear in $u = 5.3 \times 10^5 \cdot f \cdot \delta \cdot D'$, i.e. in D'. We will therefore make use of this assumption.

The length D' of a chord in a sphere of diameter D averages at .6D. Hence in averaging τ, i.e. $\bar{\tau}$, over the entire sphere, we obtain a $\bar{\bar{\tau}}$ that goes with D' = .6D, i.e. with

$$u = 3.2 \times 10^5 \cdot f \cdot \delta \cdot D.$$

f depends on E, and should be averaged over E, according to the occurence of τ in the relevant integral, i.e. the one giving the radiative losses. Hence

the E-weight function is $\exp(-40\,E)\,E^{3/2}$. From this the average $\bar{f}$ is

$$\bar{f} = \frac{\int \bar{f} \cdot \exp(-40\,E)\,E^{3/2} \cdot dE}{\int \exp(-40\,E)\,E^{3/2} \cdot dE} =$$

$$= \frac{\int \exp(-40\,E)\,E^{3/2} \cdot \exp(-40\,E)\,E^{3/2} \cdot dE}{\int \exp(-40\,E)\,E^{3/2} \cdot dE} =$$

$$= \frac{\int \exp(-80\,E)\,E^{3} \cdot dE}{\int \exp(-40\,E)\,E^{3/2} \cdot dE} =$$

$$= \frac{80^{-4}\,\Gamma(4)}{40^{-5/2}\,\Gamma(5/2)} = \frac{80^{-3/2} \cdot 2^{-5/2} \cdot 3.2.1}{\frac{3}{2} \cdot \frac{1}{2} \cdot \sqrt{\pi}} =$$

$$= 160^{-3/2} \cdot \frac{4}{\sqrt{\pi}} = 1.1 \times 10^{-3}.$$

(Note, that we saw in 10., in the discussion preceding (30), that $\bar{f}$ has a very flat maximum, equal to 1.6×10^{-3}.) Hence we may use

$$u = 3.5 \times 10^{2} \cdot \delta \cdot D.$$

Now by (32) $\delta_{max} = 3.8 \times 10^{-2}$, hence $u_{max} = 13\,D$. Consequently an always moderate u, say $u_{max} \leq 1$, calls for $D \leq \frac{1}{13} = .08$ cm $= .8$ mm. Now the best e-folding time is 10^{-12} sec, hence the best e-folding distance is $c \cdot 10^{-12} = .03$ cm $= .3$ mm. Let D be equal to 2 e-folding distances, i.e.

$$D = .06 \text{ cm} = .6 \text{ mm.}$$

Then

$$u = 21\,\delta ,$$

and so

$$u_{max} = 21\,\delta_{max} = .8 .$$

Accordingly $\phi(u) = \frac{1}{2}u + \frac{1}{6}u^{2} + \ldots$ deviates from $\frac{1}{2}u$ by a relative excess $\approx \frac{1}{3}u = 7\,\delta$, which is set most $\approx \frac{1}{3}u_{max} = .27$, i.e. 27 percent. So we have

$$\bar{\bar{\tau}} = \phi(u) \approx \frac{1}{2}u = 10.5\,\delta ,$$

with an excess of at most 27 percent. Let us therefore write $12\,\delta$ for this.

Now the radiative loss expression (27) becomes

$$2.7 \times 10^{29} \cdot (1+12\delta) \, \delta \cdot \int \exp(-40\,E)\, E^{3/2} \, dE \quad cm^{-3} \, sec^{-1}.$$

The integral is

$$40^{-5/2} \, \Gamma(5/2) = 40^{-5/2} \cdot \frac{3}{2} \cdot \frac{1}{2} \cdot \sqrt{\pi} = 1.3 \times 10^{-4}$$

hence the above expression becomes

$$3.5 \times 10^{25} \cdot (1+12\delta) \, \delta \quad cm^{-3} \, sec^{-1}.$$

In view of D = .06 cm the surface-effect loss expression becomes

$$6.7 \times 10^{27} \cdot \delta \cdot \int \exp(-40\,E)\, E^{3/2} \, dE \quad cm^{-3} \, sec^{-1},$$

i.e.

$$8.7 \times 10^{23} \cdot \delta \quad cm^{-3} \, sec^{-1}.$$

12.   We repeat: The radiative losses are

$$(36) \qquad 3.5 \times 10^{25} \cdot (1+12\delta) \, \delta \quad cm^{-3} \, sec^{-1},$$

the surface-effect losses are

$$(37) \qquad 8.7 \times 10^{23} \cdot \delta \quad cm^{-3} \, sec^{-1}.$$

Let us assume that these are being replaced at the maximum rate, corresponding to (32)

$$\delta = \delta_{max} = 3.8 \times 10^{-2}$$

Then the radiative figure of (36) becomes

$$(38) \qquad 1.9 \times 10^{24} \quad cm^{-3} \, sec^{-1},$$

and the surface effect figure of (37) becomes

$$(39) \qquad 3.3 \times 10^{22} \quad cm^{-3} \, sec^{-1}.$$

We will now estimate the energy requirements of this replacement.

A radiative loss of an electron-hole pair emits the energy $V^g + 2E \approx V^g =$ .7 eV by radiation. However, the hole was removed from B_2 at an energy distance E from the edge, and the temperature equilibrium will cause it to be replaced by a hole from the margin of the hole-filled region in B_2, which is at an energy distance $\bar{E}$ from the edge. This is an energy dissipation of $\bar{E} - E$, and since

$\bar{E} \gg E$, therefore it is $\approx \bar{E} = .2$ eV. If the replacement occurs radiatively, then the electron is lifted from the energy distance E from the edge of B_2 to the energy distance E from the edge of B_1. Hence a similar dissipation $\bar{E} - E \approx \bar{E} = .2$ eV will be caused by the temperature equilibrium in B_1.

To sum up: In connection with each radiative loss there is a non-dissipative (re-radiated) energy requirement of .7 eV, and a dissipative one of .2 eV, which is doubled if the replacement is radiative.

The .2 eV requirement means

$$1.6 \times 10^{-12} \times .2 = 3.2 \times 10^{-13} \text{ erg}$$

per loss, i.e. using (38), a total of

$$1.9 \times 10^{24} \times 3.2 \times 10^{-13} \text{ erg cm}^{-3} \text{ sec}^{-1} = 6.1 \times 10^{11} \text{ erg cm}^{-3} \text{ sec}^{-1} =$$
$$= 6.1 \times 10^4 \text{ watt cm}^{-3},$$

i.e. 61 Kilowatt cm^{-3}. This may be doubled, as pointed out above. The non-dissipative requirement is $\frac{.7}{.2} = 3.5$ times this, i.e. 210 Kilowatt cm^{-3}.

A surface-effect loss of an electron-hole pair causes a dissipative loss of $\approx V^{\check{e}} = .7$ eV, i.e.

$$1.6 \times 10^{-12} \times .7 = 1.1 \times 10^{-12} \text{ erg},$$

i.e., using (39), a total of

$$3.3 \times 10^{22} \times 1.1 \times 10^{-12} \text{ erg cm}^{-3} \text{ sec}^{-1} =$$
$$= 3.6 \times 10^{10} \text{ erg cm}^{-3} \text{ sec}^{-1} = 3.6 \times 10^3 \text{ watt cm}^{-3},$$

i.e. 3.6 Kilowatt cm^{-3}. This is negligible compared to the radiative effect.

13.　　This dissipation — $\Delta = 61$ Kilowatt cm^{-3} or $\Delta = 122$ Kilowatt cm^{-3} — is very considerable. This is still enhanced by the additional, non-dissipated (re-radiated), requirement of 210 Kilowatt cm^{-3}.

Note, also, that the electron-hole pair loss rate of (38),

$$1.9 \times 10^{24} \text{ cm}^{-3} \text{ sec}^{-1}$$

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25.

(the additional 3.3×10^{22} cm^{-3} sec^{-1} of (39) is negligible compared to this)

means this in macroscopic terms: 10^5 coulomb = 1 mole = 6×10^{23} electrons

(or holes), i.e. 1 coulomb = 6×10^{18} electrons (or holes). Hence we deal with

$$3.1 \times 10^5 \text{ coulomb cm}^{-3} \text{ sec}^{-1} = 3.1 \times 10^5 \text{ ampere cm}^{-3}$$

of electrons (or holes). For our sphere with D = .06 cm, i.e. according to the

discussion in 9., preceding (23), $\frac{\upsilon}{A} = \frac{D}{6} = .01$ cm, this gives a surface current

of

$$3.1 \times 10^7 \text{ amperes cm}^{-3}.$$

14.   While injecting this energy — or this number of pairs — is difficult,

the dissipation of the energy is possible.

Note, first of all, that the volume of our sphere is

$$\frac{\pi}{6} D^3 = \frac{\pi}{6} (.06)^3 = 1.1 \times 10^{-4} \text{ cm}^3.$$

Hence the dissipation of 61 Kilowatt cm^{-3}, according to 13., gives a total of

(40)   6.7 watt.

As we saw in 13., this amount may be doubled, and there is also a non-dissipated

(re-radiated) total requirement of 3.5 times this, i.e. of

(41)   23.4 watt.

Next, consider the conductive removal of this dissipation from the interior

of the sphere to its surface. Let x,y,z be cartesian coordinates, with the

origin at the center of the sphere. Put $r = \sqrt{x^2 + y^2 + z^2}$, so that the spheres

center is at r = 0 and its surface at $r = \frac{D}{2}$. Let F be the energy released

per unit volume
(i.e. dissipated)/in the volume of the sphere, K its heat conductivity, and

T = T(r) the temperature. Then

$$\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) T = \frac{1}{r^2} \frac{d}{dr}\left(r^2 \frac{dT}{dr}\right) = -\frac{F}{K},$$

hence

$$T = T(r) = T_o - \frac{F}{6K} r^2,$$

and so

$$T_{max} - T_{min} = T(0) - T(\tfrac{D}{2}) = \frac{FD^2}{24K}$$

Now put $F = 61$ Kilowatt $cm^{-3} = 6.1 \times 10^4$ watt cm^{-3}. We have $D = .06$ cm.

Typically, $K = .6$ watt $(°C)^{-1}$ cm^{-1}. (I: p. 231. The value for Si [at 30°C,

i.e. 300°K] is .84. Other typical values: Al [30°C]: 2.08, Bi [18°C]: .0924,

C [Diamond, 0°C]: ca..2, C [Graphite, 30°C]: 3.55, Cu [0°C]: 4.1. All these

in watt $(°C)^{-1}$ cm^{-1}.) Hence

$$T_{max} - T_{min} = 15°C.$$

If the dissipation is doubled (cf. above), then

$$T_{max} - T_{min} = 30°C.$$

Note the entire surface of the sphere is not likely to be available for this

conductive process: A small part will be needed to transmit signals (cf. the

discussions in 15.), and a considerable part may be needed for the pair-injection

process and its carriers. Assuming that no more than $\frac{1}{2}$ the surface is so pre-

empted, which would seem to be reasonable, we may have to double the temperature

increment again:

(42) $$T_{max} - T_{min} = 60°C.$$

Even this is a perfectly acceptable rise in temperature between the surface

(T_{min}) and the center (T_{max}) of the sphere.

There remains the problem to remove the dissipated energy from the surface

of the sphere. The maximal (doubled) amount for the total dissipation according

to (40) was 13.4 watt. We may have to add to this the (per se non-dissipative)

normal (non-signal, cf. below) radiation according to (41), totaling 23.4 watt.

Together, these give 36.8 watt. The surface is

$$A = \pi D^2 = \pi (.06)^2 = 1.1 \times 10^{-2} cm^2.$$

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27.

Of this, at least half was assume to be available, i.e. 5.5×10^{-3} cm^2. Hence the surface flux is

$$\frac{36.8}{5.5 \times 10^{-3}} = 6700 \text{ watt cm}^{-2}.$$

Assuming spherical conduction from here on, we have this: The flux is 6700 watt cm^{-2} at $r = \frac{D}{2} = .03$ cm, hence at a general r

$$6700 \left(\frac{.03}{r}\right)^2 = \frac{6}{r^2} \text{ watt cm}^{-2}.$$

Hence from here on

$$\frac{dT}{dr} = -\frac{6}{Kr^2} \text{ °C cm}^{-1}.$$

Using, say, $K = 2$ watt (°C)$^{-1}$ cm^{-1}, gives

$$\frac{dT}{dr} = -\frac{3}{r^2} \text{ °C cm}^{-1},$$

i.e.

$$T = \frac{3}{r} + \text{Constant °C,}$$

i.e. (T_{min} is $T_{surface}$)

$$T_{min} - T = \frac{3}{r} \Big|_{r}^{.03} = 100 - \frac{3}{r} \text{ °C,}$$

i.e.

$$(43) \qquad T_{min} - T_{\infty} = 100\text{°C.}$$

Combined with our previous estimate of (42), this gives

$$(44) \qquad T_{max} = T_{\infty} = 160\text{°C.}$$

This is still a quite acceptable rise in temperature between the ultimate coolant (T_{∞}) and the center of the sphere (T_{max}).

Let us now consider the mechanism for signaling — the actual purpose of the amplification. Assume that certain specific, separated species of photons, to be enumerated by an index $i = 1, 2, \ldots$, are being used for this purpose.

Let species i have its own $\tau = \tau(v^g+2E)$, to be designated by τ_i, its own energy interval dE_i and its own direction, i.e. solid angle dw_i. (We will not separate polarizations, although this, too, could be made use of.) Let each one of these energy intervals dE_i lie in the region of best amplification, which we defined to consist of the E between .033 eV and .041 eV. (Cf. the discussion in 10., preceding (30.)

Note, that these E correspond by (18) to the photon energies $v^g + 2E$. Using again the value $v^g = .7$ eV (since E varies by .008 eV only, v^g should now be given with more precision, but the datum $v^g = .7$ eV suffices for an orientation), this gives photon energies between 7.066 eV and 7.082 eV, i.e. and interval of .23 percent. .7 eV corresponds to a wavenumber $8100 \times .7 = 5670$ cm^{-1}, i.e. a wavelength $\frac{1}{5670} = 1.76 \times 10^{-4}$ cm $= 17600$ Å. .23 percent of this is 40 Å. So we are dealing with a frequency interval of 40 Å in the near infrared, near 18000 Å.

This indicates, that the distinctions between the photon species $i(=1,2,\dots)$ may be better performed geometrically, with the help of their directions dw_i, than physically, with the help of their energies dE_i (i.e. their wavelengths). This point, however, is not entirely clear.

Consider the path of a photon of the species i. Let this be a diameter of the sphere, i.e. of length D = .06 cm. Let t (sec) be the time along this path and x (cm) the distance. Then the amplification equation (35) for τ_i is

$$\frac{d\tau_i}{dt} = 1.6 \times 10^{16} \cdot f \cdot \delta \cdot (1+\tau_i) \text{ sec}^{-1}.$$

We have to use the maximum value of f (according to the discussion in 10., preceding (30)), i.e. $f = 1.6 \times 10^{-3}$. Hence

$$\frac{d\tau_i}{dt} = 2.6 \times 10^{13} \cdot \delta \cdot (1+\tau_i) \text{ sec}^{-1}$$

In terms of $x = c\,t$ $(c = 3 \times 10^{10}\,cm\ sec^{-1})$

$$\frac{d\tau_i}{dt} = 870\ \delta\ .\ (1 + \tau_i)\ cm^{-1}.$$

From this

$$1 + \tau_i = \text{Constant}\ .\ \exp\ (870\ \delta\ .\ x),$$

i.e. the two quantities

$$\tau'_i = \tau_{i(in)} = \tau_{i(x=0)},\ \tau''_i = \tau_{i(out)} = \tau_{i(x=D)}\ (D=.06),$$

are related by

$$1 + \tau''_i = \exp\ (52\ \delta)\ .\ (1 + \tau'_i).$$

Let us see next, what the signaling use of the photon species i, i.e. its τ_i, contributes to the losses.

Clearly, the contribution is to the radiative losses. The general expression for these is according to (27)

$$2.7 \times 10^{29}\ .\ \int (1 + \tau(v^8 + 2E))\ .\ \exp\ (-40\ E)\ E^{3/2}\ .\ dE\ .\ \delta\ cm^{-3}\ sec^{-1}.$$

Hence the contribution of species i (in the volume that it affects) is

$$2.7 \times 10^{29}\ .\ (1 + \tau_i)\ .\ \exp\ (-40\ E)\ E^{3/2}\ .\ \frac{dw_i}{4\pi}\ dE_i\ .\ \delta\ cm^{-3}\ sec^{-1}.$$

Now (cf. above) $\exp\ (-40\ E)\ E^{3/2} = f = f\ max = 1.6 \times 10^{-3}$, hence the above expression becomes

$$3.4 \times 10^{25}\ .\ dw_i\ dE_i\ .\ \delta\ .\ (1 + \tau_i)\ cm^{-3}\ sec^{-1}.$$

This must be added to the total normal radiative losses, i.e. according to (36) to

$$3.5 \times 10^{25}\ .\ (1 + 12\ \delta)\ \delta\ \ cm^{-3}\ sec^{-1}.$$

(We know, that compared to these, the total surface-effect losses are negligible.) This gives

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$$3.5 \times 10^{25} \cdot (1+12\delta) \delta + \sum_i 3.4 \times 10^{25} \cdot dw_i \, dE_i \cdot \delta \cdot (1+\tau_i) =$$

$$= 3.5 \times 10^{25} \cdot [(1+12\delta) \delta + \delta \sum_i dw_i \, dE_i \cdot (1+\tau_i)] \; cm^{-3} \, sec^{-1}.$$

The ordinary losses are being replaced, i.e. the replacement is

$$3.5 \times 10^{25} (1+12\delta_{max}) \delta_{max} \quad cm^{-3} \, sec^{-1}.$$

Hence there is a gain of

$$(45) \qquad 3.5 \times 10^{25} [(1+12\delta_{max}) \delta_{max} - (1+12\delta) \delta -$$
$$- \delta \sum_i dw_i \, dE_i \, (1+\tau_i)] \; cm^{-3} \, sec^{-1}.$$

The total number of electrons per unit volume is according to (4), (25)

$$\int N(E) \rho(E) \, dE = \int 6.7 \times 10^{21} \cdot E^{3/2} \cdot \delta \exp(-40 \, E) \cdot dE =$$
$$= 6.7 \times 10^{21} \cdot \delta \cdot \int \exp(-40 \, E) \, E^{3/2} = 6.7 \times 10^{21} \cdot \delta \cdot 40^{-5/2} \, \Gamma(5/2) \cdot cm^{-3}.$$

Since $40^{-5/2} \Gamma(5/2) = 1.3 \times 10^{-4}$, therefore this is

$$8.7 \times 10^{17} \cdot \delta \; cm^{-3}.$$

In view of this, and of (45), the variation of δ is controlled by the equation

$$8.7 \times 10^{17} \cdot \frac{d\delta}{dt} = 3.4 \times 10^{25} [(1+12\delta_{max}) \delta_{max} - (1+12\delta) \delta -$$
$$- \delta \sum_i dw_i \, dE_i \, (1+\tau_i) \; cm^{-3} \, sec^{-1},$$

i.e.

$$(46) \qquad \frac{d\delta}{dt} = 3.9 \times 10^7 [(1+12\delta_{max}) \delta_{max} - (1+12\delta) \delta -$$
$$- \delta \sum_i dw_i \, dE_i \, (1+\tau_i) \; cm^{-3} \, sec^{-1}.$$

In terms of $x = ct$ $\qquad (c = 3 \times 10^{10} \; cm \; sec^{-1})$

$$(47) \qquad \frac{d\delta}{dx} = 1.3 \times 10^{-3} [(1+12\delta_{max}) \delta_{max} - (1+12\delta) \delta -$$
$$- \delta \sum_i dw_i \, dE_i \, (1+\tau_i) \; cm^{-3} \, sec^{-1}.$$

Now by (32) $(1+12\delta_{max}) \delta_{max} = 5.5 \times 10^{-2}$, and $(1+12\delta) \delta$ lies between 0 and 5.5×10^{-2}. Hence the two first terms on the right-hand side of (47) contribute between 0 and 7.1×10^{-5} to $\frac{d\delta}{dx}$. x varies from 0 to $D = .06$, hence these

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terms contribute between 0 and 4.3×10^{-6} to the changing of   . This is negligible in the short-range considerations to follow. (It would be different for long-range considerations.) Hence we may neglect these two terms, and so obtain

$$\frac{d\delta}{dx} = -1.2 \times 10^{-3} \, \delta \, \sum_i dw_i \, dE_i \, (1+\tau_i) \, cm^{-3} \, sec^{-1}.$$

If dw_i corresponds to a half-aperture of .1 Radian $= 5.7°$, then $dw_i =$ $= \pi \, (.1)^2 = .03$. Put $dE_i = .04$. (Recall the discussion in 10., preceding (30).) Then $dw_i \, dE_i \, \frac{}{} = 1.2 \times 10^{-3}$, and so

$$\frac{d\delta}{dx} = 1.4 \times 10^{-6} \, \delta \, \sum_i (1+\tau_i).$$

Thus our complete set of differential equations is this:

(48) $$\frac{d\tau_i}{dx} = 870 \, \delta \, . \, (1+\tau_i)$$

(49) $$\frac{d\delta}{dx} = 1.4 \times 10^{-6} \, \delta \, . \, \sum_i (1+\tau_i) \, .$$

From this

$$\frac{d}{dx} \left(\delta + 1.6 \times 10^{-9} \sum_i \tau_i \right) = 0$$

i.e.

(50) $$\delta + 1.6 \times 10^{-9} \sum_i \tau_i = Constant.$$

Hence a significant change of δ , i.e. a significant saturation effect, calls for such a change of $\sum_i \tau_i$: Define the former as 10 percent of the δ_{max} of (32), i.e. as 3.8×10^{-3}. Then $\sum_i \tau_i$ must change by $\frac{3.8 \times 10^{-3}}{1.6 \times 10^{-9}} = 2.4 \times 10^6$. This is clearly exorbitant: A $1 + \tau_i$ of 2.4×10^6 has been increased over its normal initial value, 1, by $\ln (2.4 \times 10^6) = 14.5$ e-foldings. Short of this, δ is essentially constant, i.e. no saturation effects occur.

Nevertheless, this is not altogether absurd: One of our spheres provides

2 e-foldings, hence 7 to 8 will provide the 14.5 e-foldings required according

to the above.

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An Introduction to the Development of the Semiconductor Laser

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Abstract

In late 1962, the first semiconductor injection lasers were reported. While earlier workers had considered the possibility of light amplification in semiconductors, the achievement in 1962 of high-efficiency electroluminescence from forward-biased GaAs p-n junctions was the event that catalyzed and accelerated efforts to demonstrate a semiconductor laser. This paper will attempt to review the experimental and theoretical work that preceded the actual demonstration of the semiconductor diode laser.

Introduction

In late 1962, four groups reported the operation of homojunction semiconductor injection lasers. These first reports are listed below in chronological order of their received dates.

[1] R. N. Hall, G. E. Fenner, J. D. Kingsley, T. J. Soltys and R. O. Carlson, "Coherent light emission from GaAs Junctions," *Phys. Rev. Lett.*, vol. 9, pp. 366-368, 1 November 1962. (Received September 24, 1962.)

[2] M. I. Nathan, W. P. Dumke, G. Burns, F. H. Dill, Jr. and G. Lasher, "Stimulated emission of radiation from GaAs p-n junctions," *Appl. Phys. Lett.*, vol.1, pp. 62-64, 1 November 1962. (Received October 6, 1962.)

[3] N. Holonyak, Jr. and S. F. Bevacqua, "Coherent (visible) light emission from $Ga(As_{1-x}P_x)$ junctions," *Appl. Phys. Lett.*, vol. 1, pp. 82-83, 1 December 1962. (Received October 17, 1962.)

[4] T. M. Quist, R. H. Rediker, R. J. Keyes, W. E. Krag, B. Lax, A. L. McWhorter and H. J. Zeiger, "Semiconductor maser of GaAs," *Appl. Phys. Lett.*, vol. 1, pp. 91-92, 1 December 1962. (Received November 5, 1962.)

This paper will discuss the development of the semiconductor laser and attempt to describe various theoretical and experimental efforts to make the semiconductor laser a reality. The author realizes that many different perspectives exist on this subject. Since only a few historical review papers exist describing the efforts at various research labs, it is difficult to determine exactly what ideas were being pursued and when the idea of making a semiconductor laser first came into being. For this reason, the authors of these first four papers describing semiconductor laser operation have been asked to write a description of their early ideas and research which led to the achievement of semiconductor laser operation in their laboratories. These papers appear in a special historical section of this issue of the *IEEE Journal of Quantum Electronics*.

Historical Literature Survey

While various ideas concerning the semiconductor laser had been discussed previously by several workers, the first demonstrations of the operation of semiconductor lasers in 1962 were realized without the benefit of many viable suggestions from earlier (i.e., prior to 1962) theoretical and experimental treatments of semiconductor lasers. The work leading up to the demonstration of the semiconductor laser has been briefly discussed by several authors. (See for example Refs. 1 and 2.) In addition, the IEEE Press has published a volume in the "Selected Reprint Series" (sponsored by the IEEE Quantum Electronics and

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Applications Society, now the Lasers and Electro-Optics Society) on semiconductor lasers.[3] This volume contains reprints of many of the important papers on semiconductor lasers from the period 1962-1978. The first four papers in this book are the four reports cited above.

The first documented discussion of the possibility of light amplification by the use of stimulated emission in a semiconductor (to the best of our knowledge) was made in an unpublished manuscript written by John von Neumann in 1953.[4] In this paper, von Neumann discussed using carrier injection across a p-n junction as one possible means of achieving stimulated emission in semiconductors. von Neumann sent this manuscript to Edward Teller along with a letter dated September 19, 1953.[4] This letter and von Neumann's previously unpublished manuscript titled "Notes on the Photon-Disequilibrium-Amplification Scheme" appear in this issue of the *IEEE Journal of Quantum Electronics.*

The collected works of John von Neumann were published in 1963.[5] While the complete manuscript that discusses von Neumann's ideas concerning a semiconductor laser was not published in this collection, John Bardeen summarized this manuscript in the following way: "By various methods, for example by injection of minority carriers from a p-n junction, it is possible to upset the equilibrium concentrations of electrons in the conduction band and holes in the valence band. Recombination of excess carriers may occur primarily by radiation... The rate of radiation may be enhanced by incident radiation of the same frequency in such a way as to make an amplifier."[5] It is clear that von Neumann had the idea of Light Amplification by the Stimulated Emission of Radiation (i.e., the concept of a LASER) about a year before the concept of the MASER was first published in July of 1954.[6]

As far as we know at this time, the first suggestion in an international public forum that it might be possible to obtain coherent light from a semiconductor was made by Aigrain in an unpublished paper given in 1958.[7] Aigrain had apparently privately discussed the possiblity of making a semiconductor laser with Jacques Pankove of RCA Laboratories in 1956.[7] At about the same time in the U.S.S.R., Basov, Krokhin, and Popov independently came up with a similar idea.[8] While these workers suggested that it was *theoretically possible* to achieve population inversion in a semiconductor, it was still uncertain exactly what semiconductor to use and what types of electronic transitions should be exploited. In addition, the concept of optical feedback and the need for an electromagnetic cavity was not contained in these early papers.

Casey and Panish [2] discuss the history of the injection laser in Chapter 1 of their book and state that the first theoretical understanding of the requirements for the realization of stimulated emission in a semiconductor was developed by Bernard and Duraffourg and published in 1961[9]. Bernard and Duraffourg used the idea of "quasi-Fermi levels" to correctly derive the equations which predict the onset of stimulated emission in a semiconductor.[9]

They suggested looking for stimulated emission of direct transitions in the materials InAs or InSb or of transitions between the conduction band and the acceptor states of Zn and In in the indirect semiconductors Ge and Si. Although the idea of achieving population inversion in indirect semiconductors was in error, Bernard and Duraffourg were the first to publish a clear account of the requirements for population inversion in a semiconductor p-n junction. However, they did not discuss the idea of optical feedback and thus one important element in achieving laser operation was missing from their work. Their work did have an influence on at least one of the groups that demonstrated laser operation in 1962. In fact, in his historical review paper published in 1976, Hall mentions discussions he had with Bernard on various concepts concerning semiconductor lasers.[10]

Basov and his group at the Lebedev Institute in Moscow were also considering how to make a semiconductor laser.[8] Basov published a paper in 1959 concerning the possibility of obtaining a semiconductor laser using "negative temperature states" generated by impact impurity ionization under a pulsed electric field.[11] This idea he later discarded in favor of the use of a degenerate p-n junction. In 1961, Basov discussed the idea of "negative temperature states" (using the quasi-Fermi level concept) in semiconductor p-n junctions.[12] However, Basov considers the case of heavily-degenerate junctions (he refers to tunnel diodes) and claims that "the high density of the majority carriers surrounding the region of negative temperature can, apparently, serve as reflecting surfaces, i.e., a "resonating cavity" is formed".[12] Further, he suggests looking for the existence of this "negative temperature state" by looking for changes in the I-V curve when the sample is illuminated with light of "suitable frequency".[12] It appears that as of about 1961, Basov's ideas about how to form the laser cavity and about what to look for in a semiconductor laser were incorrect. In addition, Basov discusses the achievement of "negative temperature states" in indirect semiconductors.[12,13] In this work, Basov refers to Pankove's paper on luminescence from Ge [14] in a discussion of "negative temperature states" and the possibility of achieving laser operation in Ge.

At about the same time as Basov's paper concerning negative-temperature states in p-n junctions was submitted to JETP (April 18, 1961), a paper by Adirovich and Kuznetsova (also of the Lebedev Institute in Moscow) was submitted to Fiz. Tver. Tela (received on May 27, 1961) in which they discussed the conditions for population inversion in degenerate semiconductors.[15] In this paper, the authors state "...one method of realizing an inverted distribution between bands might be above-the-barrier injection through the p-n junction in tunnel diodes." It is clear that these authors also had the idea of the use of a p-n junction in mind. There are no references to Basov's work in this paper, so one can assume that their work was independent of Basov's. Adirovich and Kuznetsova determined the low-temperature threshold current densities required for population inversion in p-n junctions in Si and Ge for three different acceptor doping conditions in the p-type material. They estimated

that under optimal conditions, laser operation of Ge could occur at current densities much less than $1A/cm^2$ at 20 K![16] They reported no experimental work in this paper.

In April of 1962, Nasledov at the Ioffe Institute in Leningrad published a paper (submitted in January 1962) describing a slight narrowing of the "intrinsic recombination radiation" of a GaAs p-n junction.[16] The 77K spectrum of this diode was observed to narrow from a FWHM of $\sim 255\overset{\circ}{A}$ at $10A/cm^2$ to a FWHM of $\sim 200\overset{\circ}{A}$ at a current density of $1500A/cm^2$. We know now that this was clearly not a laser. Nasledov proposed two possible explanations for this narrowing: 1) stimulated emission, and 2) effects due to internal absorption at shorter wavelengths. He stated that "the second explanation above is more likely".[16] While Nasledov did not achieve stimulated emission, he did realize that line narrowing was one way of determining if stimulated emission was occurring. Nasledov does not discuss the quantum efficiency of the GaAs diodes so it is impossible to tell if they were of high quality or not.

In many respects, the papers discussing the theoretical aspects of semiconductor lasers published up to and during early 1962 were useful only in indicating what conditions might be required to observe stimulated emission in a semiconductor. In general, these papers treated direct and indirect semiconductors and implied that laser operation of either type of semiconductor was possible. Also, these theoretical papers failed to clearly identify the changes in device characteristics which are expected to occur when stimulated emission occurs in a semiconductor. As a result, there was no clear understanding of what to expect experimentally when laser operation was achieved.

The principal event that led to the rush for injection laser operation of semiconductor p-n junction devices in 1962 was the achievement of high-efficiency electroluminescence from GaAs p-n junctions. The most widely known demonstrations of high-efficiency spontaneous emission from GaAs p-n junctions were reported at the July 1962 Solid State Device Research Conference (SSDRC). Keyes and Quist from Lincoln Labs reported on GaAs diodes that had calculated internal quantum efficiencies of 48-85% at 77 K.[17] Pankove from RCA reported high-speed modulation of a GaAs diode at 200 MHz.[18] Pankove's diodes had an estimated total internal quantum efficiency of from 50% to 100% at 77K but had an external quantum efficiency of only about 1%.[18]

After the SSDRC, Hall at the GE Research Lab in Schenectady [10] and Holonyak at the GE Advanced Semiconductor Lab in Syracuse [19] went back to their labs and began an intensive study of how to obtain stimulated emission from p-n junctions and also began to think about what it would take to make an electromagnetic cavity to provide feedback into the active region of the diode. Of course, the group of Quist, et al at Lincoln Labs was also interested in getting their high-efficiency GaAs p-n junctions to lase. In addition, Pankove at RCA was working on making an injection laser in GaAs. (See the reference

to Pankove at the end of Ref. 7.) The IBM group's work on GaAs p-n junction lasers was also accelerated in response to the reports at the 1962 SSDRC of high-efficiency injection luminescence from GaAs diodes.[10,20]

The the IBM work on the semiconductor injection laser had started in earnest sometime earlier in 1962 after a visit to IBM by Sumner Mayburg who was working on GaAs p-n junctions at GTE Labs.[10,20] Mayburg told the IBM workers of the results of his experiments that indicated that the internal efficiency of GaAs p-n junction diodes could be as high as 100%. These results excited many of the people at IBM who were interested in the semiconductor laser problem, including William Dumke.[10,20] Dumke had already been considering the theoretical aspects of semiconductor lasers and had concluded that it might be possible to observe laser action in GaAs.[20,21] Mayburg's results concerning high-efficiency GaAs p-n junction injection luminescence results were similar to the Keyes and Quist results and to Pankove's results which were presented later at the July 1962 SSDRC. Although Mayburg presented his data in a post-deadline paper at the 1962 American Physical Society "March" Meeting in Baltimore, his results were apparently not published until January 1963.[22] It appears that of the first four groups to report laser operation, only the IBM group was aware of Mayburg's results and his APS post-deadline paper.[10,20,22] Of course, by the time Mayburg's paper was published in January of 1963, the semiconductor laser was a reality and, as a result, Mayburg's work got little recognition.

Sometime after the papers describing injection laser operation of GaAs and GaAsP p-n junctions appeared in 1962, workers outside of Japan became aware of a patent by Y. Watanabe and J. Nishizawa filed in Japan in 1957 which concerns the idea of a semiconductor laser.[23,24] In this patent, the authors describe several schemes of making a semiconductor maser. The authors use an analog of the microwave maser cavity for the electromagnetic resonator and the active semiconductor (Cl-doped Te or B-doped Si are suggested) is inserted into this cavity with electrodes connected to it to inject free carriers. The patent also discusses the use of a p-n junction for increasing the injection efficiency of carriers (generated by the absorption of light from an optical pump) into "the high energy state" of the semiconductor.[24]

It is clear from the above discussion that many claims can be made concerning the *first* person to have the idea of making a semiconductor laser. The first documented ideas concerning the requirements of making a semiconductor laser were written by von Neumann in 1953.[5] Nishizawa's "semiconductor maser" patent was filed in Japan in 1957.[23,24] Aigrain appears to have considered the concept of a semiconductor laser as early as 1956.[7] Both Aigrain's first unpublished statements in public [7] and Basov's first documented ideas [8] concerning population inversion in semiconductors come somewhat later in June and July of 1958, respectively.

With regard to the actual achievement of the operation of semiconductor lasers, none of this early work mattered much. The use of the direct

semiconductors GaAs and GaAsP as the materials of choice for the semiconductor injection laser was a direct result of the achievement in 1962 of high efficiency electroluminescence from forward-biased GaAs p-n junctions.[17,18,22] In the theoretical and experimental papers published up to late 1962, there were no obvious materials of choice for the fabrication of semiconductor lasers. In fact, some workers continued to work on laser operation of Ge even after the 1962 laser papers were published.[7,25]

Summary of Historical Literature

Many claims concerning the "invention" of the semiconductor laser prior to November 1962 have been made. It would be difficult to determine exactly what merit there is to each of these claims since none of the early ideas about how to make a semiconductor laser were 100% correct and none of the early workers had the technological problems completely solved. The early theoretical and experimental work on semiconductor lasers is briefly summarized below.

von Neumann: It seems safe to say that as far as we know at this time, the first person to propose the concept of stimulated emission in a semiconductor was von Neumann who developed a theoretical analysis of the use of a semiconductor material as a light amplifier using a p-n junction for the injection of carriers. von Neumann worked on the theoretical aspects of the problem as early as the summer of 1953. In September of 1953, he sent a detailed analysis of the semiconductor light amplifier to Teller. A summary of his unpublished manuscript appeared in the book *John von Neumann, Collected Works, Volume 5* which was published in 1963.[5] von Neumann's theoretical work is quite detailed and discusses some of the practical aspects of the problem. (See von Neumann's complete manuscript, published in this issue.)

Nishizawa: Nishizawa claims to have invented the semiconductor laser in 1957.[23] This claim is based upon Japanese patents issued to Watanabe and Nishizawa.[24] In any event, it was not brought to light outside of Japan until some time after the actual achievements of laser operation in 1962. There were apparently no published attempts to reduce this patent to practice.

Aigrain: Aigrain made a verbal presentation of ideas about obtaining coherent light from a semiconductor at a conference in Brussels in 1958. As early as 1956, he had encouraged Pankove to work on the problem of making a semiconductor laser.[7] He did not publish a paper describing these ideas in the proceedings of this conference and his work on the subject of the semiconductor laser was not published until 1964. I can find no reports of any experimental work on this problem by Aigrain until 1964 when photoluminescence from InAs was reported.[7]

Basov: Basov and co-workers first published their ideas concerning "negative temperature states" (population inversion) in a semiconductor in 1958 using impact ionization for the creation of electron-hole pairs.[8,11] They first

proposed using a p-n junction in June 1961.[12] While this group published many experimental and theoretical papers on light emission from semiconductors, most of their work was on Ge until February 1963 when they first reported a p-n junction laser in GaAs.[25,26]

Adirovich and Kuznetsova: These workers discussed population inversion in a degenerate semiconductor p-n junction in a paper published in November 1961.[16] They treated the specific cases of Si and Ge. No experimental work was reported in this paper.

Nasledov and co-workers: Nasledov, et al published a paper in April 1962 showing slight line narrowing in the luminescence from a GaAs p-n junction.[16] They suggested one explanation was stimulated emission but concluded that some other explanation involving selective absorption was more likely. We know now that this was not stimulated emission. They did not discuss the quantum efficiency of their GaAs diodes.

Summary

At this time, we believe that John von Neumann in his 1953 manuscript was the first to treat the idea of a semiconductor light amplifier. Several individuals did work independently on the concept of a semiconductor laser during the middle and late 1950's and early 1960's and a number of theoretical and experimental papers were published on the subject of the injection laser prior to the actual demonstrations of injection laser operation in 1962. However, the most important single event that led to the drive to make a semiconductor laser from GaAs and direct alloys of GaAsP was the report of high-efficiency electroluminescence from GaAs p-n junctions reported in 1962.

Acknowledgments

References

[1] *Semi-Conductor Diode Lasers*, R. W. Campbell and F. M. Mims III, Indianapolis, IN: Howard W. Sams Co., 1972, pp. 15-16.

[2] *Heterostructure Lasers, Part A: Fundamental Principles*, H. C. Casey and M. B. Panish, New York: Academic Press, 1978, pp. 1-4.

[3] *Semiconductor Injection Lasers*, J. K. Butler, Ed. New York: IEEE Press, 1980, pp. 4-12.

[4] John von Neumann, "Notes on the Photon-Disequilibrium-Amplification Scheme," an unpublished manuscript written before September 16, 1953. The typed original and two copies (one with additional notations and changes written in pencil) are located in the "von Neumann Collection" of the Manuscript Division of the Library of Congress of the United States, James Madison Memorial Building, Room 101, Washington D.C. and are part of an extensive collection of von Neumann's correspondence and other works. (This collection was dontated to the Library of Congress by the Institute of Advanced Study in Princeton, New Jersey, where von Neumann had worked for several years before his death in 1957.) von Neumann sent a copy of this manuscript, dated September 16, 1953, to Edward Teller with a cover letter dated September 19, 1953. This file also contains a copy of this letter in which von Neumann states that this manuscript is "the long-promised write-up on amplification," and that von Neumann had mentioned these ideas to Teller during the summer of 1953. This letter to Teller is also reprinted in this issue.

[5] *John von Neumann Collected Works, Volume 5*, A. H. Taub, Gen. Ed., New York: The Macmillan Co., 1963, p. 420. This short summary of the complete manuscript is titled, "Notes on the Photon-Disequilibrium-Amplification Scheme," and was edited from von Neumann's unpublished notes by John Bardeen. The original manuscript was written by von Neumann before September 16, 1953 and discusses in detail the requirements for achieving amplification of light in a semiconductor including extensive calculations of the necessary experimental conditions. von Neumann's calculations were also summarized in a letter Bardeen and Taub published in *Scientific American*, vol. 208, No. 2, Feb. 1963, p. 12. See also Ref. 4.

[6] J. P. Gordon, H. J. Zeiger and C. H. Townes, "Molecular Microwave Oscillator and New Hyperfine Structure in the Microwave Spectrum of NH_3'" *Phys. Rev.*, vol. 95, p. 282 (1954).

[7] P. Aigrain, unpublished lecture at the "International Conference on Solid State Physics in Electronics and Telecommunications," Brussels, 1958. This paper does not appear in *Solid State Physics in Electronics and Telecommunicatons, Proceedings of an International Conference held in Brussels, June 2-7, 1958*, M. Desirant, Ed., New York: Academic Press, 1960. These ideas are apparently discussed in P. Aigrain "Masers a

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Semi-Conducteurs" in *Quantum Electronics, proceedings of the third international congress*, P. Grivet and N. Bloembergen, Eds., New York: Columbia University Press, 1964, p. 1762. Aigrain had discussions on the subject of semiconductor lasers with Jacques Pankove of RCA Laboratories in the fall of 1956 as described in the introduction to the *IEEE Journal of Quantum Electronics* first Special Issue on Semiconductor Lasers: J. Pankove, "1967 Semiconductor Laser Conference--Introduction ", *IEEE J. Quantum Electron.*, vol. QE-4. p. 109, 1968. See also Ref. 8, Note 2.

[8]   N. G. Basov, B. M. Vul, and Yu. M. Popov, in an unpublished paper registered with the Committee on Discoveries and Inventions of the Council of Ministers of the U.S.S.R. dated July 7, 1958. See also Ref. 10.

[9]   M. G. A. Bernard and G. Duraffourg, "Laser Conditions in Semiconductors," *Phys. Stat. Sol.* vol. 1, p. 699, 1961.

[10] R. N. Hall, "Injection Lasers," *IEEE Trans. Elect. Dev.*, vol. ED-23, p. 700, 1976.

[11] N. G. Basov. B. M. Vul, and Yu. M. Popov, "Quantum-Mechanical Semiconductor Generators and Amplifiers of Electromagnetic Oscillations," *Zh. Eskp. Theo. Fiz.*, vol. 37, p. 587, 1959. [*Sov. Phys. JETP*, vol. 10, p. 416, 1959.]

[12] N. G. Basov, O. N. Krokhin, and Yu. M. Popov, "Production of Negative-Temperature States in P-N Junctions of Degenerate Semiconductors," *Zh. Eskp. Theor. Fiz.*, vol. 40, p. 1879, 1961. [*Sov. Phys. JETP*, vol. 13, p. 1320, 1961.]

[13] N. G. Basov, O. N. Krokhin, and Yu. M. Popov, "Use of Indirect Transitions in Semiconductors for the Determination of States with Negative Absorption Coefficients." *Zh. Eskp. Theor. Fiz.*, vol. 40, p. 1203, 1961. [*Sov. Phys. JETP*, vol. 13, p. 845, 1961.]

[14] J. I. Pankove, "Influence of Degeneracy on Recombination Radiation in Germanium," *Phys. Rev. Lett.*, vol. 4, p. 20, 1960.

[15] E. I. Adirovich and E. M. Kuznetsova, "Possible Inverted Distribution of Electrons in Degenerate Semiconductors," *Fiz. Tver. Tela*, vol. 3, p. 3339, 1961. [*Sov. Phys. Solid State*, vol. 3, p. 2424, 1962.] Ref. 3 is missing from the English translation of this paper. Unfortunately, this is the reference the authors give to the use of injection in a p-n junction.

[16] D. N. Nasledov, A. A. Rogachev, S. M. Ryvkin, and B. V. Tsarenkov, "Recombination Radiation of Gallium Arsenide," *Fiz. Tver. Tela*, vol. 4, p. 1062, 1962. [*Sov. Phys.-Solid State,* vol.4, p. 782, 1962.]

[17] R. J. Keyes and T. M. Quist, 1962 IEEE Dev. Res. Conf., Durham, NH. (unpublished) See also: "Recombination Radiation Emitted by Gallium Arsenide," *Proc. IRE*, vol. 50, p. 1822, 1962.

[18] J. I. Pankove and J. E. Berkeyheiser, 1962 IEEE Dev. Res. Conf., Durham, NH. (unpublished) See also: "A Light Source Modulated at Microwave Frequencies," *Proc. IRE*, vol. 50, p. 1976, 1962.

[19] N. Holonyak, Jr., private communication, April 1986.

[20] J. L. Bromberg, "The Laser History Project", Invited Paper given at the March 1985 Southwest Optics Conference, unpublished. This work is part of the Laser History Project co-sponsored by the APS, IEEE-LEOS, LIA, and OSA. A volume is being prepared for publication.

[21] W. P. Dumke, "Interband Transitions and Maser Action", *Phys. Rev.* vol. 127, p. 1559, 1962.

[22] Mayburg's March 1962 APS postdeadline paper is mentioned in Ref. 4 of the 1962 laser paper by Nathan, et al. It does not appear in the abstracts of this meeting given in *Bulletin of the American Physical Society*, vol. 7, no. 3, March 26, 1962. Mayburg's data is probably published in: J. Black, H. Lockwood, and S. Mayburg, "Recombination Radiation in GaAs," *J. Appl. Phys.*, vol. 34, p. 178, 1963 which was submitted July 16, 1962. In this paper, the authors report an estimated internal quantum efficiency near 100% for GaAs p-n junctions.

[23] Nishizawa's claim is based on a Japanese patent filed by Watanabe and Nishizawa in 1957. This invention is referred to in *Semiconductor Technologies, 1982*, J. Nishizawa, Ed., Amsterdam: North Holland, 1981, p. ii. See also Ref. 21.

[24] J. Nishizawa, Japanese patent No. 35-13787 as cited in W. Susaki, "Progress in Semiconductor Lasers" in *Semiconductor Technologies, 1982*, J. Nishizawa, Ed., Amsterdam: North Holland, 1981, p. 174. There is another patent by Watanabe and Nishizawa (Japanese patent no. 273217) titled "Semiconductor Maser" filed in 1957 (application no. 32-9899) and granted in 1960.

[25] N. G. Basov, "Inverted Populations in Semi-conductors", in *Quantum Electronics, proceedings of the third international congress*, P. Grivet and N. Bloembergen, Eds., New York: Columbia University Press, 1964, p. 1769.

[26] V. C. Bagaev, N. G. Basov, B. M. Vul, B. D. Kopylovsky, O. N. Krokhin, Yu. M. Popov, E. P. Markin, A. N. Khvoshev, and A. P. Shotov, "Semi-Conductor Laser on P-N Junction in GaAs," in *Quantum Electronics, proceedings of the third international congress*, P. Grivet and N. Bloembergen, Eds., New York: Columbia University Press, 1964, p. 1861.

December 14, 1972

Dear Mrs. Whitman:

I am writing to you at the request of Nathan Einhorn at the Library of Congress, with whom you have had some discussion about your father's papers. It is my understanding that you are the owner of all the papers which are your father's property. These, shown in the attached list, are now in the custody of Princeton University Library, although they are technically in the Institute's possession. Should you wish to arrange for a different disposition of them, I would be happy to be of assistance in so doing.

In addition to these documents there is an inventory of reports, papers, etc. connected with the computer project which in-cludes some work of your father. A copy of that inventory is also attached. It appears that there are some documents of your father's not represented in the Princeton collection.

My understanding, not informed by consultation with the records or legal counsel, is that the reports of the computer projects are the Institute's property, while the papers listed on the third page of the document entitled "Index to ECP Files" under "von Neumann" might be your property. In any event, I would be glad to arrange for copies of such appropriate items as you want that are not your property to be made, should you desire to do so.

Please do not hesitate to call on me for any further assistance I can give.

With cordial greetings,

Sincerely yours,

Carl Kaysen

Mrs. Marina von Neumann Whitman
Council of Economic Advisers
Washington, D.C. 20500

Attachments (2)

cc: Mr. Nathan R. Einhorn *with enclosures*

MESSAGES -

Thursday, January 30

1.   Dr. Herman Goldstine called re your conversation on von Neumann
unpublished papers, and to give you the name of someone at the
Smithsonian: Dr. Uta Merzback, Curator of Mathematical Instruments,
Smithsonian.

Contract DA-36-034-ORD=1646 Corres. 1954-56

/Contract DA-36-034-ORD-1646

Non5-1358(04) - Corres. 1956-57

Contract Nonr-1358 (03) - Corres. 1955-56m

Contract N7onr-388(01)

Contract N7-9nr-379)01)

January 6, 1971

Retd. 1-12-71

Dr. Goldstine   1-7-71

December 8, 1970

<u>Memorandum for the Record</u>

     Today Dr. Goldstine is taking the following from the IAS files to be reproduced at IBM in connection with his doing a history of IBM computers:

     Office, Chief of Ordnance - Corresp. 1947-51
Meetings at IAS and RCA, 1945
Minutes, Steering Comm. Meetings, 1950-54
Problems Run on IAS Machine, 1952-55

     He will return these within the next two weeks when he returns to Princeton.

            Ruth E. Bortell

THE LIBRARY OF CONGRESS

WASHINGTON, D. C. 20540

PROCESSING DEPARTMENT
EXCHANGE AND GIFT DIVISION

December 7, 1972

Dear Mr. Kaysen:

      I am writing at the request of Mrs. Marina von Neumann Whitman, daughter of the late John von Neumann, with whom I recently discussed the disposition of the papers of von Neumann. As I explained to Mrs. C. M. Cundell of your staff in a recent telephone conversation, Mrs. Whitman is giving some thought to the preservation of her late father's papers and believes that some of Dr. von Neumann's papers are still in the keeping of the Institute for Advanced Study. She would very much appreciate your informing her:

1)   Whether or not the papers at the Institute are her property

2)   The extent of the papers which do belong to her

3)   Whether or not a listing of such papers has been prepared

      Mrs. Whitman would like to have this information as soon as possible and I presume you would wish to write to her directly at the following address:

      Mrs. Marina von Neumann Whitman
      Council of Economic Advisers
      Washington, D. C. 20500

      With kindest regards,

                  Sincerely yours,

                  Nathan R. Einhorn
                  Chief
                  Exchange and Gift Division

Mr. Carl Kaysen
Director
Institute for Advanced Study
Princeton, New Jersey 08540

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY 08540

Telephone-609-924-4400

THE DIRECTOR

December 8, 1970

Memorandum for the Record

Today Dr. Goldstine is taking the following
from the IAS files to be reproduced at IBM in connection
with his doing a history of IBM computers:

Office, Chief of Ordnance - Corresp. 1947-51
Meetings at IAS and RCA, 1945
Minutes, Steering Comm. Meetings, 1950-54
Problems Run on IAS Machine, 1952-55

He will return these within the next two
weeks when he returns to Princeton.

Ruth E. Bortell

Herman Goldstine

Returned folders 12-14-70

12-14-70

Computer Patents: Bigelow Correspondence 48-52
Computer Patents: Gen Correspondence 45-49
Ballistic Research Labs. Correspondence 1947-56
Contract N7 onr- 388(01) - Corresp. 1946-55
Office of Naval Research-Corresp. 1946-57
Surveys on Computing Machines, 1952-55
Office, Chief of Ordnance - Corresp/ 1947-51
Minutes, Steering Comm. Meetings, 1950-54
Problems Run on IAS Machine, 1952-55

Returned 12-18-70

SMITHSONIAN INSTITUTION
THE NATIONAL MUSEUM OF HISTORY AND TECHNOLOGY
WASHINGTON, D.C. 20560

30 September 1970

Mrs. Paul Bortell, Jr.
Secretary to Dr. Kaysen
The Director
The Institute for Advanced Study
Princeton, New Jersey 08540

Dear Mrs. Bortell:

Many thanks for your kindness in supplying me with
the index to ECP files on hand at the Institute. I tentatively
plan to visit the Princeton area some time during late October,
at which time I should like to avail myself of the opportunity
to review these materials. Once my travel plans have become
more definite, I shall get in touch with you. Again I should
like to express my appreciation for your thoughtfulness.

Sincerely yours,

Richard R. Mertz
Research Associate
Computer History Project

<u>CROSS REFERENCE</u>

FILE: von Neumann - unpublished papers

RE: Papers given to Dr. Bigelow

LETTER DATED: 9-30-70

SEE: Permanent Ʀx Members - Julian H. Bigelow

September 1, 1970

Dr. Richard R. Mertz
REsearch Associate
Section of Mathematics
Smithsonian Institution
Washington, D.C. 20560

Dear Dr. Mertz:

I certainly had not intended to take
so long to be in touch with you and apologize for
the delay.

Enclosed is a record of the von Neumann
materials in the Institute files. If you think there
is anything here which would be useful to you, please
let me know and we can arrange to have the drawers
available to you should you wish to come here.

Sincerely yours,

Mrs. Paul Bortell, Jr.
Secretary to Dr. Kaysen

Enclosure

July 31 1956

PRINCETON UNIVERSITY

THE LIBRARY

MEMORANDUM FOR: Mrs. Bortell

Here is the inventory of the
John von Neumann manuscripts, in the
Library, the deposit of the Institute, as
listed by Mr. Mertz from the Smithsonian.
I have writen Mrs. Whitman
about the request from Hungary, as you
suggested. Many thanks,

Alexander Clark

AT&T
Bell Laboratories

Dr. Russell D. Dupuis
Member of Technical Staff
Solid State Electronics
Research Laboratory

Room 7C-327
600 Mountain Avenue
Murray Hill, NJ 07974
Phone (201) 582-4075

INVENTORY OF JOHN VON NEUMANN'S PAPERS IN THE CUSTODY OF
THE CURATOR OF MANUSCRIPTS OF PRINCETON UNIVERSITY LIBRARY

(N. B. Materials are contained in two file cabinet drawer; upper drawer,
ca. 22 1/2" of file material; lower drawer, ca. 20 1/2" of file material.
Files are arranged in four file groups, lettered A, B, C and D, followed by
numerical subsequences. The upper drawer contains the entire A file and
the first four of file B; the lower drawer contains the remainder of the B. file
and all of the C and D files.)

FILE A: Mss Reviewed and Papers First Published in the Collected Works,
comprising a series of manila file folders numbered from A. 1
through A. 23, inclusively. The A file is cross-referenced to the
volume and paper number of the Collected Works (cited below):

Vol. II, No. 27
Vol. III, No. 10
Vol. IV, Nos. 15, 16, 17, 18, 31, 32
Vol. V Nos. 1, 11 (memoranda and three versions of the paper).
    12, 19, 20
Vol. VI, Nos. 8, 9, 10, 14, 15, 16, 17, 18, 31, 32, 33

FILE B: Lecture notes, drafts of these, and materials absorbed in these,
comprising a series of manila folders numbered from B.1 through
B. 12, inclusively.

B. 1: Methods of Mathematical Physics: Princeton University
    Lectures, 1931-1932.
B. 2: Quantum Electrodynamics, Princeton University lectures,
    1933.
B. 3: Lattices and Dimension; preliminary notes on continuous
    geometry, 1935.
B. 4: Normal Hypercomplex Number Systems (Rings) and continu-
    ous geometries (miscl. notes, 1936).

-2-

B.5: Continuous Geometry; IAS Lectures, 1936.

B.6: Introduction of a Ring for a Complemented Modular Lattice of Order n ≧ 4 (1936).

B.7: First Draft of AMS Colloquium Publication on Continuous Geometry, about 1937.

B.8: Continuous Geometry. Pennsylvania State College Lectures, 1937.

B.9: Quantum Mechanics of Infinite Systems, 1937.

B.10: Quantum Logics; Summary of IAS Lectures, 1938.

B.11: Invariant Measures; IAS Lectures 1940-41.

B.12: Unsolved Problems of Mathematics. Amsterdam Congress Speech, 1954 (wire recorded).

FILE C: Unpublished Manuscripts

C.1: An Inequality Concerning Rational Functions of Non-Hermitian Matrices

C.2: On Generalized Matrix Algebras with a Unique Trace.

C.3: Aleph-Boolean Algebra.

C.4: Notes on Operator Theory.

C.5: Decomposition of Simple Ring with d.c.c...

C.6: Real Analytic Functions and Elliptic Operators.

C.7: Notes on Closures and Adjoints of Linear Differential Operators.

C.8: Group Theory. Topology.

C.9: Notes Related to Rings of Operators.

C.10: Arithmetic of Continuous Rings.

C.11: Ergodic Theory.

C.12: Shock Waves.

C.13: Motion of a Cavity in a Fluid--Collapse and Rebound.

C.14: Theory and Technique for Design of Electronic Digital Computers (Lecture No. 4, August 13, 1946)

C.15: Discussion of the Cylinder Symmetrical Geometry of Points and Trajectories.

C.16: The Fourier Transformation Method for 2-Dimensional (Baratropic).... Prediction.

C.17: Remarks Concerning Various Forms of the "Relaxation Method".

C.18: Imbedding of F(Em) in $\mathcal{H}$.

C.19: Carter Oil Company Reports to which JvN Contributed.

-3-

FILE:D: Notes Not in Manuscript Form

D.1: Economic Theory.
D.2: Operator Theory. Analysis, Lattices.
D.3: Lebesque-Type Measure Theory.
D.4: Discussion with R. Post and J. Tuck, June 9, 1953.
D.5: Performance Statistics of Meteorology.
D.6: General Relativity; Quantum Mechanics.
D.7: Discussion of a $= \left| \frac{sh\,z}{x} \right|, a > 0$

real, z complex.
D.8: Stability of Finite Difference Schemes for Wave Equations in 2 Variables.
D.9: Hydrodynamics with Energy Eq. and Momentum Eq. Having "Source" Terms.
D.10: Algebraic Treatment of 3 Shock Configurations for Weak Incidence and Reflected Shocks.
D.11: Weak Shocks and Weak Prandtl-Meyer Waves.

RRMertz/vdg
3/6/70

EXHIBIT #1 ⟶ INDEX TO ECP FILES ✓

Drawer 1

Reports (incomplete)

Progress Reports (Navy)

Contract N6-ori-139, T. O. I - July 1, 1946 to Sept. 30, 1952
Contract N7-onr-388, T. O. I - Nov. 1949 to Sept. 1954
Contract Nonr 1358(03), (04) - July 1955 to June 1957

Progress Reports (Army)

Contract W-36-034-ORD-7481 - July 1947 to June 1950
Contract DA-36-034-ORD-19 - July 1950 to June 1952
Contract DA-36-034-ORD-1023-RD - July 1952 to June 1953
Contract DA-36-034-ORD-1330-RD - July 1953 to June 1954
Contract DA-36-034-ORD-1646 and Nonr-1358 - July 1954 to Dec. 1956

Technical Reports

No. 55-01, July 1955 by Gilchrist, Pomerene and Wong, "Fast Carry
Logic for Digital Computers."
No. 55-02, Aug. 1955 by M. Kochen and S. Y. Wong, "Automatic Network
Analysis With a Digital Computational System."
No. 56-01, Jan. 1956 by J. P. Roth, "A Method for Finding the General
Solution to an Arbitrary Nonsingular System of Linear Equations In-
volving $n^3/2$ Multiplications."
No. 56-03, June 1956 by J. P. Roth, "An Algebraic Topological Approach
to Kron's Method I."

———————

Barricelli, N. A., "Experiments in Bionumetric Evolution Executed by Electronic
Computer at Princeton, N. J.," Aug. 1953.
Elsasser, W. M., "Boundary-Value Problems of Hydromagnetics," Sept. 1950.
Elsasser, W. M., "Causes of Motions in the Earth's Core," July-Sept. 1949.
Elsasser, W. M., "Magnetic Field Energy of Large Conducting Fluids," July-Sept. 1949
Estrin, G., "The Electronic Computer at the I. A. S.," MTAC VII, 108, April 1953.
Shuman, F., "A Method of Interpolating Heights Between Isobaric Levels," Apr. 1952.
Thompson, P. D., "A Class of Permanent Waves in Two-Dimensional Flow of
Homogeneous Fluids."

———————

Preliminary Discussion of the Logical Design of an Electronic Computing Instru-
ment, by Burks, Goldstine and von Neumann, Part I, Vol. I, 28 June 1946.
Solution of Linear Systems of High Order, by Bargmann, Montgomery and von
Neumann, 25 October 1946.
Interim Progress Report on the Physical Realization of an Electronic Computing
Instrument, by Bigelow, Pomerene, Slutz and Ware, 1 January 1947.
Second Interim Progress Report on the Physical Realization of an Electronic
Computing Instrument, by Bigelow, Hildebrandt, Pomerene, Snyder, Slutz
and Ware, 1 July 1947.
Planning and Coding of Problems for an Electronic Computing Instrument, by
Goldstine and von Neumann, Part II, Vols. I-III, 1947-1948.

Numerical Inverting of Matrices of High Order, by Goldstine and von Neumann.
I. A. M. S. Bull. 53, 1021 (1947); II. A. M. S. Proc. 2, 188 (1951).

Third Interim Progress Report on the Physical Realization of an Electronic
Computing Instrument, by Bigelow, Hildebrandt, Pomerene, Rosenberg,
Slutz and Ware, 1 January 1948.

First Progress Report on a Multi-Channel Magnetic Drum Inner Memory for
Use in Electronic Digital Computing Instruments, by Bigelow, Panagos,
Rubinoff and Ware, 1 July 1948.

Fourth Interim Progress Report on the Physical Realization of an Electronic
Computing Instrument, by Bigelow, Hildebrandt, Panagos, Pomerene,
Rosenberg, Rubinoff, Slutz and Ware, 1 July 1948.

Fifth Interim Progress Report on the Physical Realization of an Electronic Com-
puting Instrument, by Bigelow, Goldstine, Melville, Panagos, Pomerene,
Rosenberg, Rubinoff and Ware, 1 January 1949.

Sixth Interim Progress Report on the Physical Realization of an Electronic Com-
puting Instrument, by C. V. L. Smith, September 1951.

Final Progress Report on the Physical Realization of an Electronic Computing
Instrument, by Goldstine, Pomerene and C. V. L. Smith, January 1954
[Drawings, Part II only.]

Final Report on Contract DA-36-034-ORD-1023, by Staff, Electronic Computer
Project, April 1954. [Is identical with Report on Contract N-7-ONR-388,
T. O. 1, April 1954.]

Final Report on Contract DA-36-034-ORD-1330, by Staff, Electronic Computer
Project, December 1954.

Final Report on Contract No. DA-36-034-ORD-1646 (Part I - Engineering,
Part II - Computer Use), by Staff, Electronic Computer Project, December 1956.

Final Report on Contract No. Nonr 1358(03), by Hans J. Maehly, 31 July 1957.

Drawer 2
ECP Contracts, Correspondence, Computer Drawings, Coding, etc.

Ballistic Research Laboratories - Corresp. 1947-1956

#2 → Computer Development at IAS, Description of, 1948 *(one copy of Report only)*

Computer Patents:

#3 → General Corresp. 1945-1949 ✓

Bigelow Corresp. 1948-1952

#4 → Reports Corresp. and Distribution Lists for "Preliminary Discussion ..."
and "Planning and Coding ..." 1946-1960   #5, #6 are 2 stacks of cards

Computer Utilization, 1956-1957, by H. J. Maehly

Contracts:
N7onr-379(01)
N7onr-388(01)
N7onr-388(01) - Corresp. 1946-1955
Nonr-1358(03) - Corresp. 1955-1956
Nonr-1358(04) - Corresp. 1956-1957
DA-36-034-ORD-1646
DA-36-034-ORD-1646 - Corresp. 1954-1956

Distribution Lists and Reports Corresp. 1947-1963

Drawings, Coding, etc.

7 → Meetings at IAS and RCA, 1945

Minutes of Steering Committee Meetings, 1950-1954

8 → Office, Chief of Ordnance - Corresp. 1947-1951

9 → Office of Naval Research - Corresp. 1946-1957

Problems Run on IAS Machine, 1952-1955

Property

Surveys on Computing Machines, 1952-1955

von Neumann

Items not used in Collected Works of John von Neumann

1. Appendix to bibliography, items described in, p. 12 (identified by the number appearing in the bibliography):
      77. 2 copies of typescript
      81. 2 copies of typescript
      92. 1 copy of typescript
      97. 2 copies of LASL report
      100. 2 copies of typescript
      114. 1 copy of BRL report

2. Calculation to e to a large number of places. Related to no. 122 on bibliography (typescript). Also detailed notes for programming (handwritten).

3. Functional Operators, comments relating to Chap. X, Ann. Math. Studies 22 (1950) (handwritten).

4. Hilbert Space, Paris lecture 1935 (typescript in French).

*5. Invariant Measures, IAS lectures 1940-41. Notes by Paul R. Halmos (photostatic negative of typescript). Referred to in B. 11, p. 62, of Scientific Files of JvN.

6. Memo to R. Oppenheimer, 23 Oct. 1944. Concerns remarks on report of R. R. Halverson, "The Effect of Air Burst from Bombs and Small Charges, Part II" (handwritten). Referred to in Addendum to bibliography, no. iii, p. 14.

7. Eine Spektraltheorie ... unitären Raumes (photostatic negative of original MS). No. 125 on bibliography and published in Collected Works of JvN.

Drawers 3 and 4

Operating Logs 1952-1958

*Also in the Scientific Files of JvN in Firestone Library (File B).

July 16, 1970

Mr. Alexander P. Clark
Curator of Manuscripts
Princeton University Library
Princeton, New Jersey 08540

Dear Mr. Clark:

      I apologize for the delay in replying
to your letter of June 26. Dr. Kaysen has been in
and out of the office because of overseas meetings,
and I have also been taking some vacation time.
However, we have had an opportunity to discuss the
letter from Budapest, and it is Dr. Kaysen's opinion
that it would be perfectly agreeable to reply by
indicating the several locations of the von Neumann
papers and giving Mrs. Whitman's name and address.
You may include any descriptive information that you
feel would be useful to the Society and perhaps send
to Mrs. Whitman a copy of the letter from Budapest
together with a copy of your reply. She might be in-
terested to know what is in the Society's possession.
All of this seems to me to be along the lines you
suggest in your letter, and I regret to have been
so long in confirming your thoughts.

      Sincerely yours,

      Mrs. Paul Bortell, Jr.
      Secretary to the Director

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

HOWARD C. RICE, JR.
Assistant University Librarian
for Rare Books & Special Collections

June 26, 1970

Mrs. Ruth Bartell
Institute For Advanced Study
Princeton, New Jersey 08540

Dear Mrs. Bartell:

I am enclosing herewith a letter from the John
von Neumann Society for Computer Sciences, in Hungary.

Although their letter is not entirely clear as
exactly what they wish to know about, I think the
logical answer from this Library would be to say that
we have two filing drawers of the unpublished manu-
scripts of Professor von Neumann in our custody, as
the deposit of the Institute For Advanced Study.

Probably we should not do this, except with your
permission. And there is also the matter of the papers
owned by Professor von Neumann's daughter, Mrs. Whitman.
Do you feel that she would wish to have this particular
Society informed of the fact that the larger part of
the von Neumann papers are in her possession? This may
be a matter of public record, somewhere, although I do
not know that it is. I thought probably I should have
some advice from you for answering this letter.

As far as I can see, the only way anyone here can
be of any help to this Society is to tell them of the
existance of whatever papers we are permitted to mention.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC/bjs

Enclosure

MŰSZAKI ÉS TERMÉSZETTUDOMÁNYI EGYESÜLETEK SZÖVETSÉGE

FEDERATION OF TECHNICAL AND SCIENTIFIC SOCIETIES

Budapest V., Szabadság tér 17 - Telephone: 126-361, 311-725 - Cables: Metesz Budapest - Telex: 774

Princeton University
Library
P r i n c e t o n

New Jersey

Budapest, June 9th 1970.

131970

Gentlemen:

The John v. Neumann Society for Computer Sciences
is going to compile memoirs and documents on the
life and work of John v. Neuman.. Many a references
from Hungary have been collected so far, well, he
had been at school here 1909 through 1922.

You are kindly requested to be of our help in finding
people, or issues dealing with the life and work of
John V. Neumann. As far as we know he had spent the
greatest part of his life in Princeton, in the U.S.A.

In return we readily make available photoprints of
documents, or any other description on John v. Neumann's
life for those who are in possession of some sort of
memories.

Looking forward to your good news,

Yours truly

M. PHILIP
Deputy General Secretary

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

HOWARD C. RICE, JR.
Assistant University Librarian
for Rare Books & Special Collections

May 6, 1970

Mrs. Ruth Bartell
Institute For Advanced Study
Princeton, New Jersey 08540

Dear Mrs. Bartell:

Herewith is the listing of the information on the
labels for the several verticle file folders which
contain the papers of John von Neumann. I have not
inspected them for accuracy but see no reason why we
should not assume that this is a careful listing of
the entire series of folders. You will notice that
it bears the name of Dr. R. R. Mertz, March 6, 1970.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC/bjs

Enclosure

INVENTORY OF JOHN VON NEUMANN'S PAPERS IN THE CUSTODY OF
THE CURATOR OF MANUSCRIPTS OF PRINCETON UNIVERSITY LIBRARY

(N. B. Materials are contained in two file cabinet drawer; upper drawer,

ca. 22 1/2" of file material; lower drawer, ca. 20 1/2" of file material.

Files are arranged in four file groups, lettered A, B, C and D, followed by

numerical subsequences.   The upper drawer contains the entire A file and

the first four of file B; the lower drawer contains the remainder of the B. file

and all of the C and D files.)

FILE A: Mss Reviewed and Papers First Published in the Collected Works,

comprising a series of manila file folders numbered from A. 1

through A. 23, inclusively.   The A file is cross-referenced to the

volume and paper number of the Collected Works (cited below):

Vol. II, No. 27
Vol. III, No. 10
Vol. IV, Nos. 15, 16, 17, 18, 31, 32
Vol. V Nos. 1, 11 (memoranda and three versions of the paper),
        12, 19, 20
Vol. VI, Nos. 8, 9, 10, 14, 15, 16, 17, 18, 31, 32, 33

FILE B: Lecture notes, drafts of these, and materials absorbed in these,

comprising a series of manila folders numbered from B.1 through

B. 12, inclusively.

B. 1: Methods of Mathematical Physics: Princeton University
       Lectures, 1931-1932.
B. 2: Quantum Electrodynamics, Princeton University lectures,
       1933.
B. 3: Lattices and Dimension; preliminary notes on continuous
       geometry, 193 .
B. 4: Normal Hypercomplex Number Systems (Rings) and continu-
       ous geometries (miscl. notes, 1936).

B.5: Continuous Geometry; IAS Lectures, 1936.

B.6: Introduction of a Ring for a Complemented Modular Lattice of Order $n \gtrless 4$ (1936).

B.7: First Draft of AMS Colloquium Publication on Continuous Geometry, about 1937.

B.8: Continuous Geometry. Pennsylvania State College Lectures, 1937.

B.9: Quantum Mechanics of Infinite Systems, 1937.

B.10: Quantum Logics; Summary of IAS Lectures, 1938.

B.11: Invariant Measures; IAS Lectures 1940-41.

B.12: Unsolved Problems of Mathematics. Amsterdam Congress Speech, 1954 (wire recorded).

FILE C: Unpublished Manuscripts

C.1: An Inequality Concerning Rational Functions of Non-Hermitian Matrices

C.2: On Generalized Matrix Algebras with a Unique Trace.

C.3: Aleph-Boolean Algebra.

C.4: Notes on Operator Theory.

C.5: Decomposition of Simple Ring with d.c.c...

C.6: Real Analytic Functions and Elliptic Operators.

C.7: Notes on Closures and Adjoints of Linear Differential Operators.

C.8: Group Theory. Topology.

C.9: Notes Related to Rings of Operators.

C.10: Arithmetic of Continuous Rings.

C.11: Ergodic Theory.

C.12: Shock Waves.

C.13: Motion of a Cavity in a Fluid--Collapse and Rebound.

C.14: Theory and Technique for Design of Electronic Digital Computers (Lecture No. 4, August 13, 1946)

C.15: Discussion of the Cylinder Symmetrical Geometry of Points and Trajectories.

C.16: The Fourier Transformation Method for 2-Dimensional (Baratropic).... Prediction.

C.17: Remarks Concerning Various Forms of the "Relaxation Method".

C.18: Imbedding of $F(Em)$ in $\mathcal{H}$.

C.19: Carter Oil Company Reports to which JvN Contributed.

FILE:D: Notes Not in Manuscript Form

D.1: Economic Theory.
D.2: Operator Theory. Analysis, Lattices.
D.3: Lebesque-Type Measure Theory.
D.4: Discussion with R. Post and J. Tuck, June 9, 1953.
D.5: Performance Statistics of Meteorology.
D.6: General Relativity; Quantum Mechanics.
D.7: Discussion of a $= \left| \frac{Sh\,z}{x} \right|, \; a > 0$

real, z complex.
D.8: Stability of Finite Difference Schemes for Wave Equations in 2 Variables.
D.9: Hydrodynamics with Energy Eq. and Momentum Eq. Having "Source" Terms.
D.10: Algebraic Treatment of 3 Shock Configurations for Weak Incidence and Reflected Shocks.
D.11: Weak Shocks and Weak Prandtl-Meyer Waves.

RRMertz/vdg
3/6/70

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY 08540

Telephone-609-924-4400

THE DIRECTOR

March 18, 1970

Memorandum for the Record

On March 16 (Monday) I talked to Mr. Dix
about Mr. Mertz's letter; he referred me to Mr. Clark,
the Curator of Firestone Library. Mr. Clark explained
that Mr. Mertz had been given the von Neumann papers
and allowed to read the tabs which are fully descriptive
of what the folders contain. He had not made any notes
nor gone into any of the folders because Mr. Clark felt
reluctant to make the material available in view of
Dr. Oppenheimer's letter of 1 October, 1965 which re-
stricted access to the documents to "a specific scholar,
and not to a team or a laboratory or an institution."
Mr. Clark expressed uncertainty as to whether Dr. Kaysen's
letter of June 9, 1967 superseded this and made the state-
ment no longer applicable. In conversation with Dr. Kaysen
he reassured me that this was indeed the case and that
Mr. Clark should be instructed to consider the letter of
June 9, 1967 as the existing regulation and that the
material should be available to any legitimate scholar;
the earlier restriction (and the present) was designed
particularly to limit access to the papers on the part
of businesses or corporations, particularly in regard to
law suits, etc.

On Wednesday, March 18, I tried to reach Mr. Clark
but instead got Mrs. Randall who said she was familiar with
the situation (as Mr. Clark had indicated on Monday). I
therefore gave her the above message and suggested that
Mr. Clark determine whether or not he should contact Mr. Mertz
again. After Mr. Mertz had left, Mr. Clark had had Jay Lucker
go through the von Neumann papers to determine whether they
did in fact contain any material useful to Mr. Mertz, and it
was Mr. Lucker's opinion that they did not. It seemed to me
Mr. Clark might want to mention this to Mr. Mertz, but I
did not press the point.

Ruth E. Bortell

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY 08540

SCHOOL OF HISTORICAL STUDIES   March 13, 1970

Dr. Carl Kaysen
Director
Institute for Advanced Study
Princeton, New Jersey

Dear Carl:

First of all, I enclose a xerox of a letter which I received from
Richard Helms in answer to my question regarding Who's Who in CIA.
Secondly, I enclose a copy of a letter which I received from Talmon.
You will remember that in a previous letter he had asked whether we
could invite Professor Scholem as a member to the Institute and I told
him that we were entirely filled up for 1970/71 but that we might be
able to invite Professor Scholem for something like a month as a visitor.
I suppose that I ought to write Talmon in answer to his last letter
that Scholem could have, for three or four weeks, a bachelor's apartment,
use the privileges of the Institute (cafeteria, etc.) and that we might
be able to give him a stipend of $500 (does this seem to you the right
figure?). I would add that this whole arrangement would be dependent
on the agreement of my colleagues in the School of Historical Studies.
I think I ought to tell Talmon that we could not pay for any traveling
expenses.

Furthermore, I enclose a letter which I received from Dr. Richard
Mertz. Mr. Mertz visited me two or three weeks ago here in Princeton.
Previously I had had some correspondence with him because he was doing
some work on recent Italian history, and on the request of my friend,
Hajo Holborn, I gave him some recommendations to Italian historians. In
the course of the conversation which I had with him here in Princeton he
told me that he was working on the history of the computer on behalf
of the Smithsonian Institution and that he had come to Princeton in
order to look at the papers of John von Neumann. However, he had run
into some difficulties because of restrictions which were placed on the
use of these papers. I told him I had no knowledge about the papers of
John von Neumann nor about the regulations regarding their use by
scholars, but that if he would write me a letter I would submit this
letter to you. I can't say that I find his letter particularly clear.
But the issue might be more comprehensible if one knows the relevant
documents. I don't know much about Mr. Mertz, but he seemed to me a
serious and thoroughly reliable person.

Felix Gilbert

FG:rf
Encl. (3)

3164

SMITHSONIAN INSTITUTION

THE NATIONAL MUSEUM OF HISTORY AND TECHNOLOGY

WASHINGTON, D.C. 20560

March 4, 1970

Professor Felix Gilbert
Institute for Advanced Study
Princeton, New Jersey

Dear Professor Gilbert:

In accordance with our conversation on the 27th ultimo, I am
writing to describe a rather unusual restriction which I have en-
countered concerning the von Neumann Nachlass in the custody of
the Curator of Manuscripts of the Princeton University Library. I
understand that the Director of the Institute, in a letter of June,
1967, indicated that the von Neumann papers were to be made available
to any legitimate scholar; however, there is a prior restriction
limiting access to the materials to a specific scholar, not a team
or a laboratory or an institution. The linguistic vagaries of the
pre-existing restriction are such that the librarians in whose
custody the documents repose have in practice referred all applica-
tions for access to the Director of the Institute. While this was
perhaps the original intent of the restrictive language, I felt
that this apparent inconsistency with the June 1967 letter might
be brought to Dr. Kaysen's attention.

If there are any other documentary materials relating to
von Neumann and the Institute Computer available at the Institute,
I should be most grateful to have the opportunity to review them.
Thank you for your kind hospitality during my brief visit last
month to the Institute and for your generous offer to inquire about
the above matter.

Very truly yours,

Dr. Richard R. Mertz
Research Associate
Section of Mathematics

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LAWYERS
135 SOUTH LA SALLE STREET
CHICAGO, ILLINOIS 60603

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CC

October 20, 1969

Mr. Charles G. Call
Bair, Freeman & Molinare
135 South LaSale Street
Chicago, Illinois - 60603

Dear Mr. Call:

I have your letter of October 10th which
arrived just after we had talked on the phone.

The duplicates have gone out to the
correct addressees, I hope. At your request I
am enclosing our statement of the expenses of the
reproduction to the Institute.

Cordially yours,

Minot C. Morgan, Jr.
General Manager

MCM/op
Encl.

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WILL FREEMAN (1920-1965)
EDWIN S. BOOTH (1932-1967)

Mr. Minot C. Morgan, Jr.
General Manager
Institute for Advanced Study
South Olden Lane
Princeton, New Jersey

Re: Honeywell Inc. v. Sperry Rand et al.
Minnesota Civil Action No. 4-67 Civ. 138

Dear Mr. Morgan:

I have enclosed an uncorrected copy of the transcript of your deposition taken in the above-noted action on September 16, 1969.

I would appreciate it if you would notify me (with a copy to Mr. Dodds) of any corrections which you would like to make to the transcript of your testimony. If you do not wish to make corrections, please notify us of that as well and we will arrange with Mr. Silver, the court reporter, to have the original transcript filed with the exhibits.

As you will remember, arrangements were made to obtain three copies of the exhibits identified during your deposition. The addresses to which these copies should be sent appear at page 15, beginning at line 19, of the deposition transcript. The cost of providing these copies should be billed to me.

Please feel free to contact me if you have any questions - and please accept my thanks for your taking time off from your busy schedule to cooperate with us on this matter.

Sincerely,

Charles G. Call

CGC/rr
encl.
c.c.: James T. Halverson
Dorsey, Marquart, Windhorst,
West & Halladay
2400 First National Bank Building
Minneapolis Minnesota 55402

BAIR, FREEMAN & MOLINARE

cc: Laurence Dodds
160 Middle Neck Road
Great Neck, New York 11021

Edwin Silver
12 Van Saun Drive
Trenton, New Jersey 08628

1

UNITED STATES DISTRICT COURT
DISTRICT OF MINNESOTA
2   FOURTH DIVISION

3   CONSOLIDATED CIVIL ACTION
NO. 4-67   CIV. 138
4

5   HONEYWELL, INC.   :

6   Plaintiff,   :

7   -v-   :   DEPOSITION OF:

8   SPERRY RAND CORPORATION and :   MINOT C. MORGAN, JR.
ILLINOIS SCIENTIFIC DEVELOPMENTS,
9   INC.,   :

10   Defendants.   :
- - - - - - - - - - - - - - - - -

11

12   Transcript of stenographic notes in the above

13 entitled matter taken before EDWIN SILVER, Certified Short-

14 hand Reporter and Notary Public of the State of New Jersey,

15 at Institute for Advanced Study, Fuld Hall, S. Olden Lane,

16 Princeton, New Jersey, on Tuesday, September 16, 1969,

17 commencing at 9:45 a.m.

18

19   - - -

20

21   JOSEPH F. READING
Certified Shorthand Reporter
22   13 Ramson Avenue
Trenton, New Jersey 08628
23

24   882-3088
587-3251

25

1   A P P E A R A N C E S:

2   MESSRS. BAIR, FREEMAN & MOLINARE,
                         BY: CHARLES G. CALL, ESQ.,
3   and JAMES T. HALVERSON, ESQ.,
                         For the Plaintiff.

4
                         LAURENCE B. DODDS, ESQ.,
5   and MARSHALL A. LERNER, ESQ.,
                         For the Defendants.

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I N D E X

W I T N E S S

	Direct	Cross	Redirect
Minot C. Morgan	6	18	27

E X H I B I T S

No.	Descriptions	Ident.
IAS-1	Index to ECP Files	9
IAS-2	Report	11
IAS-3	Manila Folder	11
IAS-4	Manila Folder	12
IAS-5	Stack of Cards	13
IAS-6	Stack of Cards	13
IAS-7	Folder	13
IAS-8	Folder	14
IAS-9	Folder	14

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(Counsel for the respective par-
ties stipulate that all objections, except
as to form, are reserved to the time of
trial.)

MINOT C. MORGAN JR.
sworn:

MR. CALL: Before we begin, I would
like to make a statement for the record.

This is the deposition of the cus-
todian of documents of the Institute for
Advanced Study, Princeton, New Jersey.

The documents with which we will
be dealing here today will be produced volun-
tarily by the Institute, which is under sub-
poena. In giving his consent to the produc-
tion of these documents, Dr. Carl Kaysen,
director of the Institute, has observed that
there may be materials among those produced
today which are actually the property of the
estate of John von Neumann and, therefore, not
the property of the Institute to reveal. Dr.
Kaysen has, accordingly, requested that per-
mission also be obtained from Mrs. Marina
Whitman, Dr. von Neumann's daughter. I tele-

Records of the Office of the Director / Faculty Files / Box 34 / von Neumann, John / Papers - Personal and ECP
From the Shelby White and Leon Levy Archives Center, Institute for Advanced Study, Princeton, NJ, USA

5

1   phoned Mrs. Whitman at her office in Pitts-

2   burgh last week and she agreed that we may

3   have access to materials of this kind, but

4   requested that any copies which are made be

5   used only for the purpose of this lawsuit.

6   And I have assured her and Dr. Kaysen that

7   we would observe that request. And I am

8   sure I am safe in assuming that Mr. Dodds,

9   counsel for defendants, will follow her

10   wishes as well.

11   MR. DODDS: We would be glad to

12   adhere to that request.

13   MR. CALL: The files that we re-

14   quested be produced here today relate, gen-

15   erally, to the Electronic Computer Project

16   called ECP, which I understand was undertaken

17   here at the Institute beginning in late 1945

18   and concluding in the late 1950's.

19   Although neither Mr. Halverson nor

20   myself have previously seen these files, they

21   have been reviewed by Mr. John Tuttle, of

22   Mr. Halverson's office.

23   I am sure counsel for defendants

24   would like an opportunity to review these

25   files, as well. And I have, accordingly,

1   suggested that it would be appropriate to

2   take a recess immediately following the exami-

3   nation of Mr. Morgan so that an opportunity

4   for at least a limited inspection will be

5   available to counsel for defendants.

6   If possible, Mr. Morgan, we will

7   try to request that you come back to this

8   room, if necessary, prior to your appoint-

9   ment around eleven o'clock.

10   THE WITNESS: Or, conceivably, after

11   it.

12   MR. CALL: Right.

13 DIRECT EXAMINATION BY MR. CALL:

14   Q   Would you state your full name and office

15 address, for the record, please.

16 A   My name is Minot C. Morgan, Jr. I am general mana-

17 ger of the Institute for Advanced Study, Olden Lane, Prince-

18 ton, New Jersey.

19   Q   How long have you held the position of gene-

20 ral manager of the Institute?

21 A   Since December 1st, 1953.

22   Q   Can you tell us a little bit about the nature

23 of your duties during this period?

24 A   Well, I have several hats which would be divided

25 between a number of people in a larger institution. I am

1   the comptroller and, therefore, I have complete charge of the

2   dispensing of funds, payroll, accounts receivable, accounts

3   payable, etc.; have a staff of four or five bookkeepers and

4   assistants. At the time I first came here, one of these

5   assistants was actually employed by the Electronic Computor

6   Project, and her salary was supported by a navy contract.

7   My general managerial duties involved supervision of

8   non-academic personnel, grounds and buildings, and the en-

9   tire physical well-being of the institute.

10   Q   How many people do you have under your super-

11   vision?

12   A   Eighty to 85.

13   Q   This is essentially the entire clerical staff

14   of the Institute?

15   A   And the maintenance and the business staff.

16   Q   When did you first become aware of the exis-

17   tence of the so-called Electronic Computor Project?

18   A   Even before I came to work, because I had a kind of

19   two hour a day apprenticeship during the fall of '53, when

20   I picked the brains of the former comptroller, who was

21   leaving, so that I knew something about it before I ever

22   came on the job.

23   I was in daily contact with invoices and in frequent

24   contact with the then director, Dr. Herman Goldstine.

25   Q   Do you recall how long Dr. Goldstine was the

1 director of that project?

2 A   I couldn't be sure when he started. But this would

3 only be hearsay evidence. I would think it was fairly close

4 to the beginning of the project, in 1946.

5   He terminated his directorship about a year before

6 the project folded. So I would date that sometime in the

7 spring or summer of 1956.

8   Q   When Dr. Goldstine left, who assumed the

9 responsibilities which he had had previously?

10 A   A gentleman by the name of Dr. Hans Maehly.

11   Q   Spell that, please.

12 A   M-a-e-h-l-y, I think. He is deceased.

13   Q   Did Dr. Maehly continue to be the director

14 of the project until it was terminated?

15 A   I believe so.

16   Q   Approximately when was the project terminated,

17 if you know?

18 A   Very close to June 30, 1957.

19   Q   Can you tell us specifically what, if any,

20 duties you had in connection with the Electronic Computor

21 Project?

22 A   Well, I was a paymaster, with the help of the girl

23 I previously described. I administered the financial aspect

24 of the contracts. There were contracts from the navy, with

25 the army ordnance, and I think one with the air force.

1   The building itself was built with army funds. They

2   had their own purchasing department. But the bills were

3   all paid up here, right across the hall from my office.

4   I also consulted with both Dr. Goldstine and Dr.

5   Maehly on personnel matters, when they were terminating the

6   project. It was a matter of, you know, trying to find jobs

7   for some of the people that were being terminated. And I

8   helped in that.

9   Q   Last week, Mr. Morgan, when I first met you,

10   I asked if you would bring here today whatever files were

11   remaining and which related to the Electronic Computer

12   Project.

13   Have you done that?

14   A   Yes, sir. They're right behind this four drawer

15   Columbia file.

16   MR. CALL: At the time I was here,

17   I obtained an index, which I believe relates

18   to these files.

19   And I am asking the reporter if he

20   would mark this index as IAS deposition exhi-

21   bit number one.

22   (Index to ECP Files received and

23   marked IAS-1 for Identification.)

24   Q   I want you to look at that, Mr. Morgan, if

25   you would, and tell me what relation, if any, that index

1   has to the materials produced in the file cabinet here in

2   the room today.

3   A   To the best of my knowledge, it's an accurate index

4   of the contents of the file and was put together by Mrs.

5   Elizabeth Gorman, at the request of the director, Dr. Kaysen,

6   shortly after he came on board three years ago.

7   Q   I notice that the index is divided into three

8   areas, subdivided by topic headings, entitled "Drawer 1,"

9   "Drawer 2," and "Drawers 3 and 4."

10   Our interest here today is centered on docu-

11   ments in Drawer number 2. And we begin, in particular,

12   with the second item on that index, entitled "Computor De-

13   velopment at IAS, Description of, 1948."

14   I would like to ask you, Mr. Morgan, if you

15   would go to Drawer number 2 and try to find that folder for

16   me, if it is a folder, I'm not sure. Would you remove that

17   from the file and present it here, please.

18   (Off the record.)

19   Q   Mr. Morgan, I would like you to verify with

20   me the file which I have asked you to remove, entitled "Com-

21   putor Development at IAS, description of, 1948," contains

22   two reports bound in black covers and what appears to be

23   a draft of the text of the reports. These reports appear

24   to be identical. And, accordingly, I am going to mark one

25   of them, and one only, as IAS deposition exhibit number 2

1 for identification.

2 A   I concur. This is the contents of the folder.

3   (Report received and marked IAS-2

4 for Identification.)

5   MR. CALL: I am going to return

6 IAS deposition exhibit 2 to the folder and

7 ask you, if you would, to return it to your

8 file.

9   While you're standing near the

10 file, Mr. Morgan, I would like you to remove,

11 if you would, an item designated on the index

12 as "Computor Patents: General

13 Correspondence 1945-1949," and lay it on

14 the table, please.

15   Without describing the contents of

16 this file, I am going to merely mark the

17 Manila folder in which the papers are held

18 as IAS deposition 3 for identification and

19 note that we would like the entire contents

20 of this file copied.

21   (Manila folder received and marked

22 IAS-3 for Identification.)

23   MR. CALL: Would you return that

24 to the file, please.

25   Next, I would like you to remove

1   what I assume is a folder entitled "Computor

2   Patents: Reports Correspondence

3   and Distribution Lists for 'Preliminary Dis-

4   cussion...'"

5   I am going to ask the reporter to

6   mark the outer Manila folder as IAS deposi-

7   tion 4 for identification and request that

8   the entire contents of that folder be copied.

9   (Manila folder received and marked

10   IAS-4 for Identification.)

11   Q   Next, Mr. Morgan, you have laid before me

12   two stacks of three by five cards, and I find on the in-

13   dex no reference to these cards.

14   Can you tell me to which of these files, if

15   any, they relate?

16   Perhaps I should first ask, where were they

17   filed in the file?

18   A   Immediately behind the folder you just asked for.

19   Q   IAS deposition Exhibit 4?

20   A   Right.

21   Perhaps I can be helpful here. The folder I am

22   looking at here is entitled "Computor Patents: Reports

23   Correspondence and Distribution Lists (see also cards)."

24   I would assume these are mailing lists.

25   MR. CALL: I am going to attach

1 slips of paper to these two stacks, and

2 rather than marking up any of the cards

3 themselves, we will, in this fashion, iden-

4 tify the two stacks as IAS deposition Exhibit

5 5 and 6 respectively. I will ask the re-

6 porter to so mark them.

7 (Two stacks of cards received and

8 marked IAS-5 and IAS-6 for Identification.)

9 MR. CALL: You may return these

10 to the file, if you would, please.

11 Next, Mr. Morgan, I would like you

12 to remove what I assume is a folder entitled

13 "Meetings at IAS and RCA, 1945," and place

14 that on the table.

15 I am going to ask Mr. Silver to

16 mark this folder as IAS deposition Exhibit

17 number 7 for identification.

18 (Folder received and marked IAS-7

19 for Identification.)

20 MR. CALL: And you may return that

21 to the file, Mr. Morgan.

22 The next item which we would like

23 to have copied is, I assume, a folder bear-

24 ing the legend "Office, Chief of Ordnance -

25 Correspondence 1947-1951."

Morgan - direct

1   I am going to ask the reporter to

2   mark this as IAS deposition exhibit number 8

3   for identification.

4   (Folder received and marked IAS-8

5   for Identification.)

6   MR. CALL: Finally, Mr. Morgan,

7   would you produce for us the file correspond-

8   ing to the item on the index, identified as

9   "Office of Naval Research - Correspondence

10   1946-1957."

11   I am going to ask the reporter to

12   identify that by marking it as IAS deposition

13   exhibit number 9.

14   (Folder received and marked IAS-9

15   for Identification.)

16   MR. CALL: You may return that to

17   the file.

18   Q   Mr. Morgan, except for the markings that we

19   have placed on the items in that file, the file is in its

20   original condition, is it not?

21   A   Yes, sir.

22   Q   I would like to ask you, Mr. Morgan, if you

23   would, to arrange to have the materials which we have iden-

24   tified here today copied either here with your own facili-

25   ties or with an outside copying firm and provide copies to

1   counsel for Honeywell. You may mail Honeywell's copies to

2   me, and the copies for counsel for Sperry Rand mailed to--

3   MR. DODDS: To Mr. John P. Dority,

4   Director, Patents and Licensing, P.O. Box 8100,

5   Philadelphia, Pennsylvania 19101.

6   MR. CALL: The address of counsel

7   for both sides will be on the transcript,

8   which you will receive. I suggest you wait

9   until you receive the transcript before you

10   attempt to make the copies.

11   THE WITNESS: Could you describe

12   the time factors here?

13   (Off the record.)

14   MR. CALL: While we have been off

15   the record, it was agreed that Mr. Morgan

16   will arrange promptly to make the copies and

17   has assured us that within a matter of two

18   weeks, or so, the copies will be forwarded,

19   one copy to Mr. Dority, at Sperry Rand, Post

20   Office Box 8100, Philadelphia, Pennsylvania

21   19101; one copy to me, at 135 South LaSalle

22   Street, Chicago, Illinois 60603; and the

23   third copy to Mr. Silver, the court reporter,

24   12 Van Saun Drive, Trenton, New Jersey 08628.

25   Q   Mr. Morgan, with the exception of IAS deposi-

1   tion exhibit number one, which is the index to the file

2   which I believe you testified was created a matter of three

3   years ago, or so, are the remaining deposition exhibits,

4   2 through 9, which have been marked, to the best of your

5   knowledge and belief, materials which were in the original

6   Electronic Computor Project file and placed in that file

7   on or about the dates which they bear?

8   A   I have no knowledge of anything other than that.

9   Q   Can you tell us what you know about the care

10   and feeding of this ECP file since the termination of the

11   project?

12   A   Well, I'm certain that through the years '55, '56 and

13   '57 the two directors, Dr. Goldstine and Dr. Maehly, win-

14   nowed out such things as the invoices and payroll authori-

15   zations and destroyed them, and that this file constitutes

16   the remaining documents at the termination of the project.

17   And they were then placed in the custody of Mrs Gorman, who

18   had worked in several capacities: the first was as private

19   secretary to Dr. von Neumann, when he was still at the

20   institute; secondly, as secretary to, first, Dr. Goldstine,

21   and then Dr. Maehly in the years when the project was ter-

22   minated; and finally, as a secretary in the school of what

23   is now natural sciences, with an office in what we call

24   Building B, on the westerly side of the campus.

25   Q   Excuse me for interrupting.

1   Was Mrs. Gorman among the 80 people you men-

2   tioned before who were employed here under your supervision?

3   A   She is today. She was in 1953 and has been ever

4   since.

5   Q   When did Mrs. Gorman's custody of the file,

6   or direct custody of the file terminate, if at any time?

7   A   I am not absolutely certain of this, but the ques-

8   tion of the custody of the file arose shortly after Dr.

9   Kaysen became director, and he felt that it conceivably

10   should be a safer place than in Mrs. Gorman's office, al-

11   though it was always locked, her office was locked. So

12   that it was transferred to a vault which we have in the

13   basement of Fuld Hall that very few people have the combi-

14   nation to.

15   And at that time, also, before it was put in the

16   vault, I believe Dr. Kaysen had asked Mrs Gorman to make

17   the index, which is Exhibit 1.

18   Q   Am I correct, then, that the materials in

19   the file cabinets were produced here in this room today

20   and brought directly from the vault which is below us in

21   this building?

22   A   Yes, sir. They came up this morning. And the

23   file was not unlocked until the first of you gentlemen

24   arrived.

25   MR. CALL: I have no further

1   questions.

2   MR. DODDS: I have a few questions,

3   Mr. Morgan.

4   CROSS-EXAMINATION BY MR. DODDS:

5   Q   I would like to trace back again a little

6   bit the question of the custodianship of these files.

7   As I understand, at the present time they're

8   in the vault of this building and under whose custody?

9   A   I suppose under mine.

10   Q   Would anyone that wanted to have access to

11   these files apply to you for permission to see them?

12   A   Or the director.

13   Q   The director of the Institute?

14   A   Yes. And, in fact, if anyone asked me to see them,

15   I would probably check with him first.

16   Q   And might they also apply to Mrs. Gorman?

17   A   I would guess that she would certainly not show

18   them to anyone without checking with me, or, if I were

19   away, with Dr. Kaysen.

20   Q   Can you tell me how long the documents in

21   question have been in the vault in this building?

22   A   It must be about three years.

23   Q   And during that three year period did the

24   same rules as to access apply that you just described?

25   A   Yes.

1   Q   And prior to their location in the vault, I

2   understand they were in Mrs. Gorman's office?

3   A   Right. Or in the room adjacent to it.

4   Q   For what period of time was that?

5   A   It's quite a long time. '57 or eight to '66.

6   Q   That's close enough.

7   When the files were in Mrs. Gorman's office,

8   or the adjacent room, who would have had access to them

9   during that period?

10   A   Well, the access then would have been--any access

11   would have been brought to my attention. She would not

12   have made them available to anyone without--

13   Q   Then, would it have been possible for one

14   of the professors at the Institute, who might have an

15   interest, to look in the files for any particular document?

16   A   I would think it highly unlikely.

17   Q   You can't say with assurance that no one did

18   do such a thing, did make such an inspection or take such

19   a look at the documents?

20   A   Well, I think I should perhaps give a little back-

21   ground.

22   The Institute is concerned almost entirely in mathe-

23   matics and physics, with theoreticals. And this was our

24   only venture in a practical hardware field. Once the pro-

25   ject was closed, there were no people on the faculty, the

1   permanent faculty, that really had an interest in this sort

2   of thing.

3   So that when I say it's highly unlikely, I suppose

4   if a permanent professor in natural science had asked Mrs.

5   Gorman if he could look in the file, she probably would

6   have opened it up and said yes. But it seems to me simply

7   from the standpoint of interest, there were no people

8   around.

9   Q   Were not some of the people who worked on

10   the ECP project, did they continue to be employed here at

11   the Institute after the completion of the project?

12   A   There were only two exceptions. Both Herman Gold-

13   stine and Julian Bigelow were made, what we call, perma-

14   nent members, as a kind of recognition of their contribu-

15   tion.

16   Goldstine stayed around for a year or two and then

17   went to work for IBM.

18   Bigelow is still here. He is also a consultant to

19   RCA. It's conceivable that if he came up and wanted to

20   look at something, Mrs. Gorman would have said sure, be-

21   cause he was the chief engineer.

22   Q   Either Dr. Bigelow or Dr. Goldstine, during

23   the year he was here, after the project was completed?

24   A   Yes. But no other employees. Not even clerical,

25   except for Mrs. Gorman.

1   Q   You mean that no other professors would have

2   been entitaed to? Or it's just your conclusion that no

3   other professors would have been interested in it?

4   A   I believe you asked me if there were staff members

5   who continued on after the termination of the project.

6   Q   As to that question, you have answered.

7   A   Yes. And I am answering that question. It was

8   completely liquidated as to personnel.

9   Q   Except for the two you mentioned.

10   A   And Mrs. Gorman.

11   Q   Now, that takes us back to 1956 or 1957.

12   Can you tell us who had custody of the files just prior

13   to that?

14   A   Dr. Hans Maehly was the director in the year that

15   it closed out. And immediately prior to him--

16   Q   How far back would he have had any responsi-

17   bility for these files?

18   A   Just the one last year, or year and a half, at the

19   most.

20   Q   Say, from '55 to '56 or '57?

21   A   From mid '55 to June of '57, something like that.

22   Q   And did you know where the files were located

23   at that time?

24   A   They were located in what we call the electronic

25   computor building, which is now used for offices for

1   mathematicians. And the director, in both cases, had the

2   same office. And I am sure these files were, if not in

3   the office, were in the secretarial office immediately

4   adjacent.

5   Q   Do you know what conditions for access to

6   the files were obtained at that time?

7   A   No, sir, I do not.

8   Q   And then prior to 1955 do you know where the

9   files were kept?

10 A   In Dr. Goldstine's office.

11   Q   And that is, they were kept there as of the

12 time when you joined the Institute, which I think you said

13 was 1953?

14 A   Right.

15   Q   And during that period of time, do you know

16 what the conditions of access to the files were?

17 A   No, sir.

18   Q   Prior to your joining the Institute in 1953,

19 do you know where the location of the files was?

20 A   I would assume they were in the same place, but I

21 have no personal knowledge.

22   Q   And you certainly don't have personal knowledge

23 going back to 1945, which is the date of some of these

24 documents?

25 A   No, sir.

1   Q   Do you know who had custody of the documents

2   prior to 1953?

3   A   Well, I would assume that the director of the pro-

4   ject--

5   Q   But you don't have any knowledge of that?

6   A   No.

7   Q   Do you have any personal knowledge of the

8   contents of any of these documents that have been identi-

9   fied?

10   A   I have never read through the files, no.

11   Q   So that your identification of them is based

12   entirely upon the question of the custodianship of the do-

13   cuments?

14   A   Right. I am not familiar with any of the individual

15   correspondence.

16   Q   Do you have any personal knowledge of the

17   distribution of this exhibit 4, which was the computor pa-

18   tent report correspondence, and so forth, followed by the

19   two stacks of cards, which I think you believed represented

20   the distribution of the item in the folder, exhibit 4? Did

21   I understand that correctly?

22   A   Yes. I assumed it was a mailing list for all re-

23   ports.

24   Q   You don't have any personal knowledge of that,

25   do you?

1   A   Except my observation today.

2   Q   These are just deductions you have made from

3 the documents themselves?

4   A   Yes.

5   Q   You don't have any knowledge independent of

6 those documents?

7   A   Well, I do know this much, that there are certain

8 reports that had a distribution list based on the contracts

9 that they had with the army, the navy, and the air force,

10 and also colleagues in similar fields at other universi-

11 ties.

12   Q   But you don't have any personal knowledge

13 of the distribution of the particular report in this

14 exhibit 4, this reports correspondence, and so forth?

15   A   No.

16   Q   Mr. Morgan, would you describe what previous

17 contacts you have had with Mr. Call or other counsel or

18 representatives of Honeywell prior to your deposition

19 this morning?

20   A   I can't even put a date on it, but Mr. Call visited

21 here sometime within the last week and asked to arrange

22 for this deposition. I referred him to Dr. Kaysen, be-

23 cause an earlier colleague--

24   MR. HALVERSON: Mr. John Tuttle,

25   from our office.

1   A   (Continuing) Mr. Tuttle had arrived here when I

2   was partially on vacation, and Dr. Kaysen was here. So

3   that he talked with Mr. Tuttle. And I thought it was ap-

4   propriate that he should also talk with Mr. Call so that

5   we don't cross any wires.

6   Q   You did not talk to Mr. Tuttle, then, upon

7   occasion of his visit here?

8   A   I met him once in the hall when I was on the dead

9   run, but that's about all.

10   Q   What was the nature of your discussion with

11   Mr. Call, as you say, within the last week or so?

12   A   Well, he asked that this be set up, and I told him

13   that I felt it was beyond my portfolio to make this decision

14   and, therefore, I referred him to Dr. Kaysen. And I have

15   no knowledge, except hearsay, of what transpired in their

16   conversation.

17   Q   You didn't participate in any discussion

18   with Professor Kaysen?

19   A   I was not there when Mr. Call was in the room,

20   except at the very last five minutes of it when he and

21   Dr. Kaysen had arrived——had an understanding about this

22   meeting this morning. And then he called me in and he

23   asked me to implement.

24   Q   Was there any discussion at that time as to

25   the nature of the presentation you would make or what sort

Records of the Office of the Director / Faculty Files / Box 34 / von Neumann, John / Papers - Personal and ECP
From the Shelby White and Leon Levy Archives Center, Institute for Advanced Study, Princeton, NJ, USA

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1 of a story you would tell?

2 A   No, I don't think so. He asked me a few questions

3 about the custodianship factor.

4   Q   Were there any other contacts that you know

5 of either between yourself or other representatives of

6 the Institute, other than the ones that you mentioned

7 with Mr. Tuttle and Mr. Call?

8 A   Not to my knowledge in the last few months, no, sir.

9   MR. DODDS: I have no further

10   questions.

11   I did want to perhaps say on the

12   record at this time that I would like the

13   opportunity after the conclusion of this

14   deposition--I understand Mr. Morgan is

15   anxious to get away--to just glance through

16   the documents which you have not identified

17   to see if there is anything further that we

18   might want to have identified and marked in

19   evidence.

20   MR. CALL: Surely. I doubt if

21   we will have time to resume here today.

22   (Off the record.)

23   MR. CALL: I have just one more

24   question, Mr. Morgan.

25 REDIRECT EXAMINATION BY MR. CALL:

1   Q   Mr. Morgan, you commented that Dr. Goldstine

2   was, I believe, made a permanent member of the Institute.

3   Can you tell me how many people are presently

4   permanent members of the Institute, or at least approxi-

5   mately?

6   A   Only two others in residence.

7   This is a strange breed. We have 23 permanent facul-

8   ty, and they act as a faculty would in any institution.

9   They have life tenure, and so on.

10   And then we have about 130 or forty people that we

11   call members, that are transient. They are here for a

12   term, a year, sometimes two years. The permanent members

13   are halfway in between. He has a long term appointment.

14   But he is not a member of the faculty. And it's a cate-

15   gory that we are not very happy with because they are hy-

16   brid.

17   Q   This was a position assigned to Dr. Goldstine

18   by what, the board of directors of the Institute?

19   A   The board of trustees.

20   Q   In recognition of something?

21   A   In recognition of distinguished service to the

22   Institute.

23   MR. CALL: I have no further ques-

24   tions.

25   MR. DODDS: I have no further

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From the Shelby White and Leon Levy Archives Center, Institute for Advanced Study, Princeton, NJ, USA

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1   questions.

2   (Whereupon, the deposition of Mr.

3   Morgan was concluded.)

4

5

6

7   I, EDWIN SILVER, the officer before whom

8   the foregoing deposition was taken, do hereby certify that

9   the witness whose testimony appears in the foregoing depo-

10   sition was duly sworn by me, and that said deposition is

11   a true record of the testimony given by said witness; that

12   I am neither attorney, nor counsel for, nor related to or

13   employed by any of the parties to the action in which the

14   deposition is taken; and further that I am not a relative

15   or employee of any attorney or counsel employed by the par-

16   ties hereto, or financially interested in the action.

17

18

19

20   _Edwin Silver_
                 CERTIFIED SHORTHAND REPORTER

21

22

23   DATED: 10/4/69

24

25

THE INSTITUTE FOR ADVANCED STUDY, Princeton, New Jersey

Office of the Director

COPY

September 12, 1969

Memorandum for the File

Re: von Neumann papers

See ECP FILES--Index in IAS Files

I spoke with Mr. Call (Charles G. Call of
Bair, Freeman & Molinare, 135 South LaSalle St., Chicago)
at 10:30 a.m. Wednesday, September 10, in the Director's
Office, about his proposal to subpoena the Institute
documents relating to the computer. I said again
that I wished to be guided by Mrs. Whitman's views and
were she willing to make available whatever papers in
the file were really her father's property, I would
then make available the rest. Were she unwilling, I
would take advise of counsel. I further said that,
if an attempt were made to get a subpoena without con-
sulting Mrs. Whitman, I would resist.

Carl Kaysen

CROSS REFERENCE

FILE: von Neumann, John - unpublished papers

RE: Visit by Mr. Tuttle to see our files on ECP

LETTER DATED:

SEE: Memorandum to file from Dr. Kaysen (Aug. 5, 1969) - ECP FILES - INDEX

Mrs. Gorman brought a Mr. Tuttle to the office this morning
who wanted to see a particular file of Prof. von Neumann's
on patents which is stored at I.A.S. in the vault. Prior to
his visit he phoned Mr. Morgan and discussed this with him.
Mrs. Gorman and I told him we couldn't give permission for
him to see this and he is returning tomorrow.

Mr. Morgan is phoning tomorrow and going to mention this
to you.

You might recall from last year a Mr. Zink (Honeywell, Inc.,
Electronic Data Processing Div.) who came here enquiring
about the papers regarding a litigation matter. Apparently
Mr. Tuttle is following up on this.

DORSEY, MARQUART, WINDHORST, WEST & HALLADAY

JAMES E. DORSEY (1889–1959)
DONALD WEST
WALDO F. MARQUART
JOHN W. WINDHORST
HENRY HALLADAY
JULE M. HANNAFORD
ARTHUR B. WHITNEY
RUSSELL W. LINDQUIST
DAVID R. BRINK
HORACE HITCH
VIRGIL H. HILL
ROBERT V. TARBOX
DeFOREST SPENCER
ROBERT J. JOHNSON
M. B. HASSELQUIST
PETER DORSEY
GEORGE P. FLANNERY
CURTIS L. ROY
ARTHUR E. WEISBERG

DUANE E. JOSEPH
FREDERICK E. LANGE
JAMES B. VESSEY
WILLIAM A. WHITLOCK
E. J. SCHWARTZBAUER
THOMAS M. BROWN
CORNELIUS D. MAHONEY
THOMAS S. ERICKSON
MICHAEL E. BRESS
PAUL G. ZERBY
RAYMOND A. REISTER
JOHN J. TAYLOR
BERNARD G. HEINZEN
WILLIAM J. HEMPEL
JOHN S. HIBBS
ROBERT O. FLOTTEN
JOHN D. LEVINE
ROBERT J. STRUYK

MICHAEL A. OLSON
LARRY W. JOHNSON
THOMAS S. HAY
CURTIS D. FORSLUND
G. LARRY GRIFFITH
CRAIG A. BECK
DAVID L. McCUSKEY
THOMAS O. MOE
JAMES H. O'HAGAN
JOHN M. MASON
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CHARLES A. GEER
JOHN C. ZWAKMAN
JOHN R. WICKS
EUGENE L. JOHNSON
ROBERT O. KNUTSON
JOHN W. WINDHORST, JR.
MICHAEL PRICHARD
RICHARD G. SWANSON
RICHARD W. DuFOUR, JR.
FAITH L. OHMAN
DAVID A. RANHEIM
ROBERT J. SILVERMAN

OF COUNSEL
DAVID E. BRONSON
HUGH H. BARBER
LELAND W. SCOTT
LEAVITT R. BARKER

LAW OFFICES

2400 FIRST NATIONAL BANK BUILDING

MINNEAPOLIS, MINNESOTA 55402

TELEPHONE: 333-2151

AREA CODE: 612

CABLE ADDRESS: DOROW

July 29, 1969

Mr. M. C. Morgan
General Manager
Institute of Advanced Study
Princeton, New Jersey

       Re: Honeywell vs. Sperry Rand -
              von Neumann files

Dear Mr. Morgan:

     As you requested in our telephone conversation today, this letter is to confirm my intentions and request concerning your files on the work of Dr. John von Neumann.

     Our firm, in which I am an associate, is representing Honeywell Inc. in litigation concerning basic computer patents. Because of Dr. von Neumann's significant contributions to the computer art and his association with others who were also involved in the early work in this field, we feel it important to review his work, particularly, as it concerns the Institute for Advanced Study computer.

     At this time we would prefer to keep our investigation informal in order to provide the least possible inconvenience to the Institute. In the event something of significance is turned up in my review we would, of course, take nothing without your permission and would also subpoena the needed file or documents to protect the Institute's neutrality.

     As I explained, I would like to go through your von Neumann files during the week of August 4. Since you indicated that both Mrs. Gorman, who has possession of the files, and the Director of the Institute would be back on August 1, I will call again on that date so that we can make appropriate arrangements.

     Thank you for your time and attention.

              Sincerely yours,

              Jon F. Tuttle

JFT:j

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

HOWARD C. RICE, JR.
Assistant University Librarian
for Rare Books & Special Collections

August 17, 1967

Miss Janet Smith
Office of the Director
Institute for Advanced Study
Princeton, New Jersey

Dear Miss Smith:

Please let me thank you for the carbon copies of
your letters of August 14th to Mr. Robert Zinn, of
Honeywell, and to Mrs. Robert Whitman, concerning the
request made by Mr. Zinn to consult the von Neumann
papers, in connection with a litigation matter.

This is to assure you and Dr. Kaysen that this
Library will not make the von Neumann papers available
to any representative of Honeywell without having per-
mission from Mrs. Whitman or your office.

Thank you very much for your attention to this
matter, which is somewhat exceptional.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC/bjp

August 14, 1967

Mr. A. P. Clark
Princeton University Library
Princeton, New Jersey 08540

Dear Mr. Clark:

    I am enclosing copies of letters that I
have written today to Mrs. Robert Whitman and
to Mr. Zinn about Dr. von Neumann's papers.

    Thank you very much for your help.

                Sincerely yours,

                Janet Smith
                Office o f Dr. Kaysen

August 14, 1967

Mr. Robert Zinn
Honeywell, Inc.
Electronic Data Processing Division
60 Walnut
Wellesley, Massachusetts

Dear Mr. Zinn:

    I have discussed with Dr. Kaysen your
request for access to the papers o f Dr.
von Neumann on deposit in the Princeton
University Library.

    Dr. Kaysen has asked me to advise you
that permission, in this instance, must be
sought from the owner of the papers, who is
Dr. von Neumann's daughter. Her name and
address are: Mrs. Robert Whitman, 5308
Ellsworth Avenue, Pittsburgh, Pennsylvania
15232.

                Sincerely yours,

                Janet Smith
                Office of the Director

(Mr. Zinn's telephone number is (617) 235-7450, Ext. 263)

August 14, 1967

Mrs. Robert Whitman
5308 Ellsworth Avenue
Pittsburgh, Pennsylvania   15232

Dear Mrs. Whitman:

A Mr. Robert Zinn of the Honeywell
corporation in Boston called this morning to
ask permission to see Dr. von Neumann's papers
in the Princeton Library. A telephone check
with Mr. Clark at the Library revealed that
he wants to review the entire collection, for
purposes of a litigation.

Under the circumstances, Dr. Kaysen would
not accede to the request. He asked that I
suggest to Mr. Zinn that he contact you for
permission. Dr. Kaysen is sorry to bother
you with this, but because litigation is
involved, he doesn't feel that he should
decide.

Sincerely yours,

Janet Smith
Office of Dr. Kaysen

September 23, 1968

Mrs. Betty Lundsted
Worth Publishers, Inc.
171 Madison Avenue
New York, New York 10016

Dear Mrs. Lundsted:

In response to your letter of September
19 I am sorry to inform you that we do not have
a suitable photograph of Professor von Neumann.
May I suggest that you contact his daughter –
Mrs. Robert Whitman, 5308 Ellsworth Avenue,
Pittsburgh, Pennsylvania 15232 who is the owner
of his papers.

Yours sincerely,

Angela Wakeham
Secretary to the Director

WORTH PUBLISHERS, INC.   171 MADISON AVENUE NEW YORK, NEW YORK 10016   889-3993

September 19, 1968

Institute for Advanced Study
Public Relations Department
Princeton, New Jersey

Dear Sirs:

Worth Publishers is presently preparing a college mathematics textbook by Professor Michael N. Bleicher of the University of Wisconsin. We wish to obtain a picture of the late Professor John Von Neumann to reproduce as an illustration.

If you have a photograph of Professor Von Neumann in your files, we would greatly appreciate your sending us a print or negative. We would of course give proper credit for its use in the text.

Thank you for your consideration.

Sincerely,

Betty Lundsted

Betty Lundsted
Production Manager

June 20, 1968

NOTE TO FILE:

A lady from the American Institute of Physics (History Division)
phoned regarding other Von Neumann papers which are not at the
Firestone Library. I told her that as far as we were concerned
there were "no other" papers and should she wish to pursue this
any further she should contact Mrs. Robert Whitman. She took
Mrs. Whitman's address.

                         Angela Wakeham

NOTE FOR FILE   July 12, 1968

Prof. J. B. Denrus of the Dept. of Electrical Engineering,
MIT, presently working in the Elec. Eng. Dept. of Princeton
University came into the office enquiring about the Von
Neumann papers. I have examined the file in my office and
I am reasonably confident that there is nothing here that
would interest him. He was given the name ᴂ£ and address
of Mrs. Robert Whitman to contact for further information.

                        CARL KAYSEN

CROSS REFERENCE

FILE: von Neumann, John - Former Faculty and Members (Permanent)

                Unpublished Papers

RE: Permission to reprint Dr. von Neumann's remarks about

                Prof. Gödel in Ohio Academy of Science Gödel Anniversary

                Volume

LETTER DATED: December 19, 1967

SEE: Gödel, Kurt - Faculty file

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

WILLIAM S. DIX
University Librarian

June 14, 1967

Dear Carl:

    The Princeton University Library will be honored
and pleased to continue to hold as an indefinite deposit
the papers of Professor von Neumann deposited by the
Institute for Advanced Study under the conditions listed
in your letter of June 9th. There seems to be no rea-
son to change the original deposit form (#9376, dated
December 18th, 1964), of which you have a copy in your
files, and I shall simply attach a copy of your letter
to this form in our files to bring it up to date.

                Yours sincerely,

                Bill

Dr. Carl Kaysen
Director
The Institute for Advanced Study
Princeton, New Jersey 08540

cc: Mrs. Robert Whitman
      Mr. Alexander Clark

June 9, 1967

Dear Bill:

I write about the von Neumann papers, which my predecessor
deposited with you. I wish to reformulate the conditions
under which we would ask you to continue to hold them. They
are as follows:

1. The papers to continue on indefinite deposit (loan)
   in the Princeton University Library.

2. The papers to be made available to any legitimate
   scholar for scholarly purposes, including the right
   to permit such photo duplication in single copies as
   is customary.

3. The librarian of Princeton University, or his agent,
   to decide who is a legitimate scholar and what
   scholarly purposes are.

I have the consent of the owner of these papers, Mrs. Robert
Whitman (the late Professor von Neumann's daughter) to these
arrangements. She recognizes that although she is the owner,
we continue to be the party responsible for the deposit.

If there are any further formalities involved, please let me
know.

Cordially,

Carl Kaysen
Director

cc: Mrs. Robert Whitman

Mr. William Dix, Librarian
Princeton University Library
Princeton, New Jersey 08540

June 9, 1967

Mrs. Robert Whitman
5308 Ellsworth Avenue
Pittsburgh, Pennsylvania 15232

Dear Mrs. Whitman:

This letter to the Princeton University librarian completes the arrangements about which we spoke on the telephone this morning.

Thanks, again, for your helpfulness in this matter.

Cordially,

Carl Kaysen

~~Mrs. Robert Whitman (Marina von Neumann)~~
~~5508 Ellsworth Avenue~~

Pittsburgh, Pa. 15232   412 - 681 - 6774

or
Dept. of Economics
University of Pittsburgh
Pittsburgh, Pa. 15213   →   mayflower 1-

35-71-

x. 7256

x. 6167

June 9, 1967

5308 Ellsworth Avenue
Pittsburgh
Pa. 15232

June 5, 1967

Dr. Carl Kaysen
Director
The Institute for Advanced Study
Princeton, N.J. 08540

Dear Dr. Kaysen:

Thank you for your letter of June 1, explaining some problems
which have arisen in connection with the conditions attached to the
deposit of my father's unpublished papers in the Princeton University
Library and suggesting some modifications which might clear up the
difficulty.

For the moment, I find the arrangements you propose, which would
give the University librarian the right to decide who is a legitimate
scholar and what scholarly purposes are, thoroughly satisfactory.
As for the alternatives you suggest, I do not want to remove the
papers from the Library, but I am reluctant to make a permanent
gift of them until I decide what to do with my father's letters and
other unpublished material currently in my possession. I think the
collection should stay together. At present, the Princeton Library
and the Library of Congress are the two institutions which I am
seriously considering as ultimate recipients; until the decision is
made, I should prefer to leave the papers on loan.

If you will have a copy of the new arrangement sent to me, I
will be glad to sign it. Or is this letter sufficient?

Yours sincerely,

Marina von Neumann Whitman
(Mrs. Robert F. Whitman)

MW/eap

June 1, 1967

Mrs. Robert Whitman
5308 Ellsworth Avenue
Pittsburgh, Pennsylvania 15232

Dear Mrs. Whitman:

I write to ask your help on a question which has arisen
about your father's unpublished papers, of which I understand you
are the legal owner. The papers are now on indefinite deposit in
the Princeton University Library as a loan. The deposit was made
on behalf of the Institute by Dr. Oppenheimer, and I assume that
your mother or you consented to it, but I am afraid there is no
record to that effect here.

When making the deposit, Dr. Oppenheimer specified that
the papers should be available to any scholar for his individual
use but should not be made available to any organization. All use,
of course, was subject to the usual restrictions that safeguard
your common law copyright in the material. The restriction has
proved a bit troublesome to interpret, and its purpose as now stated
is unclear. Accordingly, I would like to change the conditions of
the deposit slightly. If you agree, I would propose new arrange-
ments as follows: (1) the papers to continue as before on indefinite
deposit (loan) in the Princeton University Library; (2) the papers
to be made available to any legitimate scholar for scholarly pur-
poses; (3) the librarian at Princeton University to have the right
to decide who is a legitimate scholar and what scholarly purposes are.

Are these arrangements suitable to you, or would you
prefer some others? In particular, if you would like, you could
simply give the papers to Princeton University in a permanent way,
thus passing the responsibilities to them. Alternatively, you could
take possession of them yourself, or give them to some other library.
This, of course, assumes that there is no further publishable material
contained therein, which I understand is the judgment of your father's
associates and collaborators who have been through the material and
assisted in producing the six-volume collection of his papers.

Mrs. Robert Whitman - 2   June 1, 1967

> From my point of view the present arrangement with the modifications I suggest would be perfectly suitable, and I am not in any way urging any other change on you; I simply raise the question in order to give you the opportunity to express your wishes.

                          Sincerely yours,

                          Carl Kaysen
                          Director

June 9, 1967

Mrs. Rachelle Ortiz
Archives Cataloger
American Institute of Physics
335 East 45th Street
New York, New York 10017

Dear Mrs. Ortiz:

This is in response to your inquiry of May 11.

The bulk of the papers of the late Professor John von Neumann are on deposit in the Princeton University Library, where the librarian has the authority to decide who can use them. In general, they are available to any person for scholarly use. It is my expectation that the papers will continue to be deposited in the Library for the future. However, Mrs. Robert Whitman, daughter of the late Professor von Neumann, is the legal owner of the papers and she has not yet decided what the ultimate disposition of these papers will be. Nonetheless, both she and I expect that they will remain in the University Library for the indefinite future.

Cordially,

Carl Kaysen
Director

May 19, 1967

Mrs. Rachelle Ortiz
Archives Cataloguer
American Institute of Physics
335 East 45th Street
New York, New York 10017

Dear Mrs. Ortiz:

    Your letter of May 11, to the Director, has been referred
to me in his absence. I am sure that you will be hearing
from him early next month, after his return and after he
has had an opportunity to consult with the Physics Faculty
here.

               Cordially,

               Minot C. Morgan, Jr.
               General Manager

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY

OFFICE OF THE GENERAL MANAGER

May 16, 1967

MEMORANDUM to: Professor Freeman Dyson

FROM: Minot C. Morgan, Jr.

SUBJECT: <u>von Neumann Papers</u>

Dear Freeman:

Since I am certain that Dr. Kaysen will want your advice on this matter upon his return, I am sending on the enclosed request from the American Institute of Physics.

As you probably know, the von Neumann papers are in the custody of the Firestone Library. The restrictions referred to are simply that access to them is limited to an "individual scholar" pursuing his own research.

My guess is that we would rather have the papers in their present location and custody than turn them over to the A.I.P.--but you would be better qualified to know

1) Where they would be in the best hands and

2) Where they would do the most good.

Cordially yours,

Mike

Minot C. Morgan, Jr.

P.S. Would you please return all of the material to the Director's Office?

I have no opinion about this. I suggest ~~that~~ we ask Gillispie who has some connection with A.I.P. and is also a Princeton historian.

F. Dyson.

AMERICAN INSTITUTE OF PHYSICS

335 EAST 45 STREET, NEW YORK, NEW YORK 10017 MURRAY HILL 5-1940

CENTER FOR HISTORY AND
PHILOSOPHY OF PHYSICS
CHARLES WEINER, *Director*

May 11, 1967

Office of the Director
The Institute for Advanced Study
Princeton, New Jersey 08540

Dear Sir:

I am addressing this inquiry to you at the suggestion of Mrs.
Shaner, Secretary to the late Dr. J. Robert Oppenheimer.

As you may already know, the Center for History and Philosophy
of Physics, a division of the American Institute of Physics, is
compiling a National Catalog of Sources to aid scholars in
locating important source materials pertaining to physics.
In my attempts to clarify our information on the archival holdings
of the Princeton University Library, I was informed by Mr.
Alexander Clark, Curator of Manuscripts, that John von Neumann's
papers had been placed under the custody of the Princeton Library
by Dr. Oppenheimer, under certain restrictions limiting their use.
If you have any information on the future deposition of these
important papers, I would appreciate your writing me.
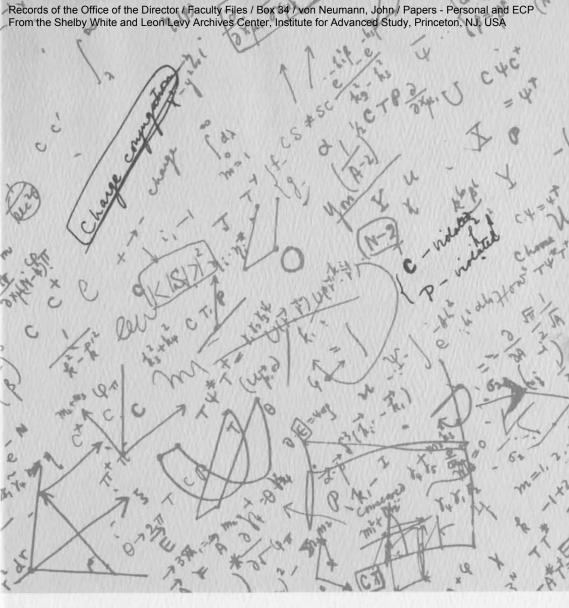
Enclosed is a brochure describing the goals and programs of
the Center. I fully appreciate any help you may be able to
give in this matter.

Sincerely yours,

Rachelle Ortiz (Mrs.)
Archives Cataloger

RO
enc.

Member Societies: *American Physical Society · Optical Society of America · Acoustical Society of America · Society of Rheology · American Assn. of Physics Teachers*

THE AMERICAN INSTITUTE OF PHYSICS

CENTER FOR HISTORY AND PHILOSOPHY OF PHYSICS

"We are so engulfed by the changes in the current scene in physics: by their ferocity, their brashness, their virtuosity, their diffusion, that we don't understand them very well, and it may not be possible for us to understand them. The enterprises which are now under way, for which this room will serve as heart, should in the future make it possible for serious students of the human predicament to know very much more about what has befallen us than we who are actually living in the present."

—J. Robert Oppenheimer
at the dedication of the American Institute of
Physics' Niels Bohr Library, September 26, 1962.

COVER — Scratch pad used by T. D. Lee in discussions with C. N. Yang, summer of 1956. Their suggestion that under certain conditions the parity (P) principle is violated was confirmed experimentally later the same year, provoking a still-continuing inquiry into the validity of other physical symmetry laws. The notes were saved by a Brookhaven staff member for their "aesthetic appeal," and later preserved because of the "P-violated" notation. *Courtesy Brookhaven National Laboratory.*

PURPOSE

The Center for History and Philosophy of Physics was founded to expand awareness of the development and impact, both social and intellectual, of modern physics. For scholars to begin to understand the processes of scientific change, they must have access to the sources that document the history of physics. Sensitive to this fundamental need, the Center, largely through its direct ties with the ever-growing physics community, undertakes the preservation of valuable source materials.

The Center conducts systematic nationwide programs enlisting physicists, historians and philosophers of science, archivists, administrators, and others in efforts to locate, evaluate, preserve, and catalog significant source materials. In addition, the Center acts as a clearing house for information on existing manuscript and apparatus collections, and provides a research center for scholars and educators.

The Center for History and Philosophy of Physics is a division of the American Institute of Physics, the federation of leading societies in the field of physics in the United States. Financial support for the Center comes from the physics community through the general funds of the AIP and is supplemented by grants for special projects, including support from the National Science Foundation, the Ford Foundation, and the American Academy of Arts and Sciences. Funds for library acquisitions are supplied by the Friends of the Niels Bohr Library, a voluntary organization of patrons.

The policies and programs of the Center are guided by an Advisory Committee set up by the AIP, consisting of physicists and scholars in the history, philosophy and sociology of science.

The Center's offices and research facilities are located at the AIP headquarters building in New York City, at 335 East 45th Street. Scholars, scientists, textbook authors, university students, and all others with a serious interest in the history and philosophy of physics are welcome to make use of the Center's resources. To determine how these resources may be useful for specific research purposes, direct inquiries addressed to the Center are invited.

FACILITIES

THE NIELS BOHR LIBRARY FOR THE HISTORY AND PHILOSOPHY OF PHYSICS

The Niels Bohr Library of the Center collects published works, and organizes them for scholarly research.

Physicists' original writings constitute more than half the library's growing collection of published materials. The collection emphasizes nineteenth and early twentieth century physics, but earlier contributions of special importance are included. It is complemented by relevant biographical, historical, philosophical and sociological works.

The library subscribes to major journals in these disciplines and acquires microfilm copies of selected nineteenth and early twentieth century periodicals in the physical sciences. The Karl Taylor Compton Memorial Room, adjacent to the Niels Bohr Library, contains bound volumes of journals published by the AIP and its member societies.

In addition to its holdings, the library has available the following services: reference service; interlibrary loans; referral to other libraries and archival collections; photoduplication; and microfilm reader-printer equipment.

The library staff and the Director of the Center, a professional historian of science, provide guidance in the selection and use of published and unpublished materials.

"Historic studies are an important tool for understanding mankind's position in the world, and in this century the history of science assumes particular significance. It is therefore gratifying to see so great an increase of creative scholarship in that field, and I hope that its further development will be greatly encouraged and facilitated by the opening of this Library."

Niels Bohr, summer 1962.
From a letter to the Director of AIP.

HISTORY OF PHYSICS ARCHIVES

The Archives of the Center contain unpublished manuscripts, correspondence, autobiographies, oral history interviews, notebooks, drawings, and photographs of individual physicists, as well as records of academic and industrial research institutions and professional societies. These materials are stored in the archives after they have been organized for research and listed in the National Catalog of Sources for the History of Physics. They offer scholars original sources that illuminate the processes through which the concepts, techniques, applications and institutions of 20th century physics have developed. Materials from the History of Physics Archives are made available for study in the Niels Bohr Library to scholars whose planned use of archival documents is in accordance with Center procedures, including its commitment to safeguard the specifications placed by the donors of unpublished materials.

BELOW: Published and unpublished source materials are used by researchers in the Center's Niels Bohr Library.

PROGRAMS

To locate and evaluate historical source materials, including manuscripts and apparatus.

To preserve and catalog such materials, either at the Center or in other repositories.

To enlist the aid of the physics community in creating new source materials through oral history programs and topical conferences.

To encourage and assist scholarly inquiry into the history and philosophy of physics, and to aid in the diffusion of the results of such studies.

ACTIVITIES

In connection with these programs, the Center

☐ identifies, evaluates, and arranges for the preservation and organization of source materials.

☐ assists in cataloging and microfilming source materials held elsewhere, including those in relatively inaccessible locations.

☐ compiles and maintains a National Catalog of Sources for the History of Physics which lists the location of materials by name, subject, and repository throughout the United States.

☐ compiles and maintains files documenting the life and work of a representative group of physicists who have been especially productive in the United States since the 1890s in the development of physics.

☐ conducts research to establish guidelines to document the development of fields of contemporary physics that have shown especially rapid growth since about 1930.

☐ brings together physicists and scholars concerned with the development of physics in conferences to review the needs and opportunities for historical documentation of fields of contemporary physics.

☐ conducts tape recorded interviews with physicists who have been involved in historically significant events in the development of recent physics.

. . . to locate and evaluate historical source materials.

PUBLICATIONS

NEWSLETTER OF THE CENTER FOR HISTORY AND PHILOSOPHY OF PHYSICS.

A quarterly publication that serves as an exchange for information about Center acquisitions, research, publications, meetings, and other activities that are significant to the history and philosophy of physics.

NOTEBOOKS, CORRESPONDENCE, MANUSCRIPTS: SOURCES FOR THE FULLER DOCUMENTATION OF THE HISTORY OF PHYSICS.

This brochure explains why the historian of science considers the preservation of manuscripts and other documents to be indispensable to his research and outlines how such research materials may be preserved.
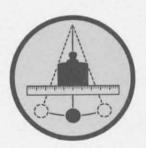
SCIENTIFIC INSTRUMENTS AND APPARATUS: SOURCES FOR THE FULLER DOCUMENTATION OF THE HISTORY OF PHYSICS.

This brochure urges both scientists and historians of science to pay greater attention to the preservation of scientific apparatus and their accompanying records.

FRIENDS OF THE NIELS BOHR LIBRARY ANNUAL.

A special publication available only to the Friends of the Niels Bohr Library.

The Newsletter and brochures are available upon request.

THE AMERICAN INSTITUTE OF PHYSICS
CENTER FOR HISTORY AND PHILOSOPHY OF PHYSICS
Charles Weiner, *Director*

Advisory Committee

Betty Hubbard Gorman.

1) List of papers to be selected?

2) Owner legal heir
   Marina v. N Whitman, daughter, of U of Pittsbg
   (an address to be supplied).

3) Computer files NOT included.   how in
   Question of patents etc.   Gorman's
   Check with H. Horgan   possession.

                                        [vault?]

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

WILLIAM S. DIX, *Librarian*
HOWARD C. RICE, JR., *Assistant Librarian*
for *Rare Books & Special Collections*

5 October 1965

Dr. J. Robert Oppenheimer
Director
The Institute for Advanced Study
Princeton, New Jersey 08540

Dear Dr. Oppenheimer:

I thank you very much for your letter of
October 1st. This helps us considerably in
dealing with the papers of John von Neumann.
Should any serious question arise in the future,
with respect to the use of the papers, we will
consult you again. Meanwhile, please accept
our thanks for your assistance on this occasion.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC:wmr

1 October 1965

Dear Mr. Clark:

    Thank you for your letter of September 29th. Randall's
letter clearly qualifies him for access to the von Neumann
papers. There is no question of using this access for the
Knolls Laboratory, or even for a collaborator, since he says
that he hopes to have help in developing his doctoral thesis
at the Rensselaer Polytechnic Institute.

    I think it best to give access to these documents to a
specific scholar, and not to a team or a laboratory or an
institution.

    With good wishes,

                             Robert Oppenheimer

Mr. Alexander P. Clark
Curator of Manuscripts
Princeton University Library
Princeton, New Jersey

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY 08540

WILLIAM S. DIX, *Librarian*
HOWARD C. RICE, JR., *Assistant Librarian*
for Rare Books & Special Collections

29 September 1965

Dr. J. Robert Oppenheimer
The Institute for Advanced Study
Princeton
New Jersey

Dear Dr. Oppenheimer:

Some time ago, as you will remember, the Institute for
Advanced Study deposited at Princeton University Library the
papers of John von Neumann. We have had an inquiry from a
Mr. Charles H. Randall, of the General Electric Company's
Knolls Atomic Power Laboratory, who would like copies of cer-
tain of Mr. von Neumann's manuscripts which I have located
among his papers. I am including a copy of Mr. Randall's
letter to me, July 15, 1965.

In discussing any possible restrictions on the use of
this collection with the Librarian, Mr. William S. Dix, I
have learned that you are willing that we may show, and make
photocopies of, any portion of the papers of John von Neumann
"so long as the photocopy is provided for study by an individual
scholar." We realize, of course, that permission to publish must
be obtained from Professor von Neumann's daughter, Professor
Marina von Neumann Whitmann.

I am inquiring now only as to whether or not, in your belief,
Mr. Randall may be designated an "individual scholar." He is,
of course, connected with an institution. His work may well be
in pursuance of personal research projects, but also, conceivably,
there may be some connection between his work and that of the
Knolls Atomic Power Laboratory. I am inquiring to ask if I am
raising the correct question here. Is a researcher's professional
affiliation a point to consider? Might, for instance a team of
scientists consult the von Neumann papers? Is the emphasis, in
fact, on the word "individual?"

I am enclosing the customary form which we ask all researchers
to sign who are dealing with modern papers. This is the Library's
way of reminding the individual that they are responsible to the
estate of anyone whose manuscripts they wish to publish in full
or in part.

It is quite possible that future applicants for the use of
the von Neumann Papers may well be working in conjunction with

THE PRINCETON UNIVERSITY LIBRARY

work being done in a laboratory or a similar organization. I
wonder if it would not be simplest, and entirely satisfactory to
you, if we were to take the position that the von Neumann Papers
are accessible, in accordance with the usual Princeton University
Library procedures, whereby all applicants are automatically no-
tified of their responsibilities in the matter of literary rights.
We, ourselves, would rarely be in a position to judge to what ex-
tent a researcher's work would be done in close connection with
other researchers and it is this phrase "individual scholar" which
seems to raise the problem which has prompted this letter.

I thank you for your attention to this very small matter.

Sincerely yours,

Alexander P. Clark
Curator of Manuscripts

APC:wmr
encl.

GENERAL ⊕ ELECTRIC
COMPANY

KNOLLS ATOMIC

POWER LABORATORY

BOX 1072, SCHENECTADY, NEW YORK . . . . TELEPHONE EX 3-6611

July 15, 1965

Mr. Alexander P. Clark
Curator of Manuscripts
Princeton University Library
Princeton, New Jersey

Reference: Letter, A.P. Clark to Miss Helyn M. Walton, Technical Library, KAPL -
General Electric Company, Schenectady, N.Y., July 9, 1965

Dear Mr. Clark:

This letter is in response to your referenced letter of July 9, 1965. In
addition to being employed at the General Electric Company - Knolls Atomic Power
Laboratory, I am also a doctoral candidate in the Mathematics Department at the
Rensselaer Polytechnic Institute. For a number of years now I have been doing
research on the mathematical and logical foundations of Quantum Theory, as a
thesis project. During a visit to Harvard, Dr. G. Mackey - Chairman of their
Mathematics Department - suggested that I carefully examine the subject unpublished
von Neumann notes.

I am interested in obtaining copies of the 17 page summary of "Quantum
Logic" - Institute of Advanced Study Lectures, 1938 and also of the 217 page
"Continuous Geometries with a Transition Probability". I have a copy of
"Continuous Geometry", Princeton University Press, 1960, which is an edited
(by Israel Halperin) version of von Neumann notes; however, I believe these
differ from the "...Transition Probability" article. Thus, I would appreciate
it if you would advise Miss H. Walton of our Technical Library of the steps
necessary to accomplish this.

Yours very truly,

Charles H. Randall

CHR/eck

Copy for Dr. Oppenheimer.

OPERATED BY THE GENERAL ELECTRIC COMPANY FOR THE U.S. ATOMIC ENERGY COMMISSION

PRINCETON UNIVERSITY LIBRARY

Request for Access to

Manuscripts

I request the Princeton University Library to make available to me the manuscript material described below:

I intend to use this material for the following purposes:

I understand that Princeton University has only the limited right to hold these manuscripts, reproduce them, and make them available for the purposes of research and scholarship. I agree not to copy, reproduce, recirculate or publish them without the permission of the owner of the literary property rights, if any, and the Princeton University Library. I assume all responsibility for any infringement by me of the literary property rights held by others in the material requested.

DATE .... SIGNATURE ....

AFFILIATION ....

PERMANENT ADDRESS ....

....

....

*Neumann
unpublished
papers*

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

WILLIAM S. DIX, *Librarian*   April 23, 1965

Dear Dr. Oppenheimer:

    Thank you very much for signing
and returning to me the deposit agree-
ment covering the von Neumann papers.
Now I can relax, knowing that the
documents are in order.

              Cordially yours,

              Bill

Dr. Robert Oppenheimer
Director
Institute for Advanced Study
Princeton, New Jersey

For von Neumann
unprb'd papers

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

April 15, 1965

WILLIAM S. DIX, *Librarian*

Dear Dr. Oppenheimer:

    In response to a call from your secretary
I enclose two copies of our standard deposit
form, filled in to cover the papers of Dr. von
Neumann deposited by the Institute and signed
by me. If you approve the language and if you
wish this group of papers to be considered a
relatively permanent deposit, I hope that you
will sign one copy and return it for our files. *done 4/17/65*

    I am sorry that the copies of this form
which I thought I had sent to you earlier evi-
dently went astray, probably in our office.

               Cordially yours,

               William S. Dix

Dr. Robert J. Oppenheimer
Director
Institute for Advanced Study
Princeton, New Jersey

PRINCETON UNIVERSITY LIBRARY
PRINCETON NEW JERSEY

The Princeton University Library acknowledges the receipt from

The Institute for Advanced Study *of* the unpublished

papers and notes of John von Neumann

which the said Institute for Advanced Study *has requested the Library*

to hold in its custody and use as exhibits or make available to scholars or

not, as it sees fit, and to be returned to the said Institute for Advanced Study

their
upon ~~his~~ written request, on the understanding, however, that the Princeton

University Library does not insure the above items for the benefit of the

owner, and assumes no liability for any loss or injury thereto beyond that

of the ordinary care required of a voluntary bailee without compensation.

In witness whereof the Library has caused its seal to be attached

under the hand of

THE PRINCETON UNIVERSITY LIBRARY

By _William S. Dix_
William S. Dix, Librarian

APPROVED:

Robert Oppenheimer
Owner
Robert J. Oppenheimer, Director
for
The Institute for Advanced Study
Date 4/17/65

von Neumann papers
Firestone

10/22/65

Call from Dearborn, Michigan. Dr. James C. P. Pool, referred to
this office by Firestone Library. Wants permission to look at
von Neumann papers.

He is with Math and Theor. Sciences Dept., Scientific Laboratory,
Ford Motor Co., P.O. Box 2053, Dearborn, Michigan 48121.

Wants to study ms relating to the logic of quantum mechanics.
Has been talking with Birkhoff, and this has left some unanswered
questions.

He is engaged in basic research, and although the Ford Motor Co.
will be paying for his trip, his interest is that of an
individual scholar.

Gave for reference the names of Arthur Wightman, and Max Dresden
(his thesis adviser).

Can be reached through secy, 323-0848.

10/28

Dr. Pool called, just as I was about to write him. I told him, per
VH, that the permission must be dealt with by Firestone, and he was going
to try them again.

*Fac - von Neumann
unpubl'd papers*

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

April 7, 1965

WILLIAM S. DIX, *Librarian*

Dear Dr. Oppenheimer:

I enclose a formal acknowledgment for the additional paper by Dr. von Neumann which you have sent over and which we shall add to the other group. It occurs to me however that this is probably not the proper form to use, since it indicates that this paper is a gift to the University.

Am I correct in thinking that we have never worked out the exact status of the group of von Neumann manuscripts? I seem to remember that we agreed that they should be considered an indefinite deposit, but I do not seem to find in my file a copy of the standard deposit form which I think I sent to you for signature. I should be glad to send another if that one went astray.

*— called.
They will
send*

I am looking forward to the dedication of the new library.

Cordially yours,

Bill

Dr. Robert J. Oppenheimer
Director
The Institute for Advanced Study
Princeton
New Jersey

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

5 April 1965

Dear Dr. Oppenheimer:

On behalf of the Trustees of Princeton University, I have the honor to acknowledge the receipt of

a copy of a paper by John von Neumann, entitled
"Adaptation of the Maddida..."   30 pages

which you have presented to the Library of the University, and I beg you to accept their sincere thanks for the gift.

I am

Yours sincerely,

William S. Dix

Librarian

Dr. Robert J. Oppenheimer
Director
The Institute for Advanced Study
Princeton
New Jersey

December 9, 1964

Received 1 set of Von Neumann files from The Institute for

Advanced Study.

Two drawers were given to this man by I. Linderos

11 December 1964

Dear Dr. Dix:

The Institute for Advanced Study is grateful to you
for undertaking the custody of the unpublished papers and notes
of John von Neumann, of which we have until now been custodians.

In the publication of the collected works of von Neumann,
it is stated that these papers may be consulted by scholars at
the Institute. From now on we should like to direct enquiries
about them either to you or to a member of your staff whom you
may designate.

With good wishes,

Robert Oppenheimer

original notarized

Dr. W. S. Dix
Firestone Library
Princeton University
Princeton, New Jersey

cc Miss Sachs

Verna:

If your office handles this
matter, the attached page
should go with the MS.   I
would appreciate having Prof.
Taub's letter returned to me,
or a copy of it.

Betty

March 19 1965

file sent Dix
Firestone

T. letter returned
to B Gorman -
3/19/65

From

THE GEORGE WASHINGTON UNIVERSITY
LOGISTICS RESEARCH PROJECT

Logistics Papers Prepared Under
Various Auspices
Extracted from Appendices to
Quarterly Progress Reports 2, 3
Contract N7onr-419- Task Order 4

PRINCETON UNIVERSITY LIBRARY

PRINCETON, NEW JERSEY

December 17, 1964

WILLIAM S. DIX, *Librarian*

Dear Dr. Oppenheimer:

I enclose two copies of our standard
deposit form, filled in to cover the von Neumann
Papers and signed by me. If you will sign both
copies and return one to me, your files and mine
should be accurate in recording this whole trans-
action. I always prefer an outright gift to a
deposit, since it always simplifies the handling
of manuscript material, but I understand your
wish under the circumstances to retain title.
If you should decide later that a gift would be
in order, I shall of course be pleased to sub-
stitute a simple deed of gift for this deposit
agreement in the files.

I am pleased to have these papers, and
we shall make them available to any scholars re-
ferred to the Library by the Institute and to other
qualified scholars.

Yours sincerely,

William S. Dix

done 12/23/64

Dr. Robert Oppenheimer
Director
Institute for Advanced Study
Princeton, New Jersey

Deposit No: ~~9570~~ Institute for Advanced Study
Depositor's copy.

PRINCETON UNIVERSITY LIBRARY
PRINCETON NEW JERSEY

The Princeton University Library acknowledges the receipt from The Institute for Advanced Study, Princeton, N.J. *of* unpublished papers and notes of John von Neumann.

which the said Institute *has requested the Library to hold in its custody and use as exhibits or make available to scholars or not, as it sees fit, and to be returned to the said* Institute *upon his written request, on the understanding, however, that the Princeton University Library does not insure the above items for the benefit of the owner, and assumes no liability for any loss or injury thereto beyond that of the ordinary care required of a voluntary bailee without compensation.*

In witness whereof the Library has caused its seal to be attached under the hand of

THE PRINCETON UNIVERSITY LIBRARY

By William S. Dix

William S. Dix, Librarian

APPROVED:

Owner
Robert Oppenheimer
for
The Institute for Advanced Study.
Date 12 / 18 / 64

Called Dix again, and said that it was the
scientific papers that we had here, and that
our collection was already complete and in
our hands. Also said that if Mrs. Whitman's
papers, presumably of some other nature, were
of interest to the University Library, we would
have no objection.

Mr. Dix said that he would have to find out what
indeed Mrs. Whitman has, and that he thinks it
would probably make sense for them to try to
acquire anything that we did not want, so that
the whole von Neumann collection would be in one
town.

request we are keeping the von Neumann archive here,
and will be able to house it properly in our new
building. He said fine, but that he wonders whether
Marina Whitman knows of that--the way that he heard
of the papers was, through a friend, that Marina
was thinking of giving them to the library of congress.
Of course, it might be a different set of papers,
but Dix said he thought it important that if so they
be together with ours.

We left it that you would call him in a few days.

3/19/64

Former Fac von Neumann

PRINCETON UNIVERSITY LIBRARY
PRINCETON, NEW JERSEY

WILLIAM S. DIX, *Librarian*   March 16, 1964

Dear Dr. Oppenheimer:

In the belief that the Library of the
Institute for Advanced Study does not propose
to enlarge the scope of its collecting policy
to include the papers of distinguished scholars,
I have just written to Professor Marina Whitman
to suggest that she consider depositing the
manuscripts and files of her father, Dr. von
Neumann, in the Princeton University Library.
This assumption is based on your past policy,
but it occurred to me after writing that I
should at least let you know what I am doing.
We shall of course withdraw immediately if the
Institute wishes to keep Dr. von Neumann's papers.

We have both the physical facilities and the
curatorial staff to give papers of this sort the
treatment they deserve, and it would seem parti-
cularly appropriate to me for Dr. von Neumann's
papers to remain in this community of scholars.

Cordially yours,

William S. Dix

Dr. Robert Oppenheimer
Director
Institute for Advanced Study
Princeton, New Jersey

Fae Von Neumann

C/R Inst Year
Library

THE INSTITUTE FOR ADVANCED STUDY
THE LIBRARY
PRINCETON, NEW JERSEY

V O N   N E U M A N N   P A P E R S

1. Suggest photostating (xerographing, microfilming) entire
   collection, one copy to be placed in main library, one
   copy to be made available for interlibrary loan. Are there
   any legal restrictions?

2. This would eliminate use of originals on premises (supervision)
   and resulting individual requests for photoreproduction and
   solve problem of interlibrary loans.

3. Since there is nothing to prevent borrowers from re-copying
   material for their own use, it might be advisable to permit
   copying if legally possible.

4. Should all requests for consultation on premises and for loan
   be honored?

May 22, 1963

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY

VON NEUMANN PAPERS

Library Copy 1:   Complete but for 6 items

                       Bound

                       Rosenwald Room

Library Copy 2:   Incomplete, lacking 12 items

                       Bound: 1935-56

                    *Unbound: 1922-34

*see Bibliography: o - lacking

                      o - borrowed by Dr. Ulam

C O P Y

2 November 1961

Dear Klari:

With the advancing publication of the Collecta, this has seemed
the time to transfer the file of Johnny's papers from Mrs. Gorman's
custody to the Institute library. The file is now in what we call
the Rosenwald Room—appropriately enough, a room devoted to the
history of science. This room is kept locked, somewhat to my sorrow,
but it has seemed right that these papers be as completely protected
as anything we had.

Mrs. Gorman undertook to be responsible for making the papers
available to such mathematicians and other scholars as might wish to
see them; but Dr. Sachs, our librarian, has said that she and her staff
will be glad to do this. Thus the custody of these files is now an
Institute responsibility.

I would like to thank you for the warm and heartening letter
that you wrote almost a year ago.

With good wishes to Carl and to you,

Robert Oppenheimer

Mrs. Carl Eckart
347 Vista de la Playa
La Jolla, California

cc: Mrs. Gorman
Dr. Sachs

347 Vista de la Playa
La Jolla, California
November 11, 1961

Dr. Robert Oppenheimer
The Institute for Advanced Study
Princeton, New Jersey

Dear Robert:

Thank you very much for your good letter and for letting me know that the file of Johnny's papers has now been transferred to the Rosenwald Room and is now under the supervision of the Library and Dr. Sachs rather than under the curatorship of Mrs. Gorman.

I certainly do not want to interfere with any of the arrangements that you feel are most appropriate to make at this time. Frankly I do not think that there will be too many requests for these papers even after the full set of Johnny's "Collecta" has come out, but I do believe that it might be a safety valve against absent-minded professors if it was possible to make photostatic copies of the file and hand those out for reading rather than the originals. Of course I realize that this costs money and I do not know whether such funds are available now. Abe Taub, who was here recently, mentioned that with some effort he might be able to get some funds for the photostating. On the other hand, I believe that one should be realistic and perhaps not go into anything as extensive as that until there is some experience of how frequently the file is used.

I believe that having Mrs. Gorman keep some contact with the files might be a help. She has worked with them for such a long time and is so well acquainted with each paper that she could be of valuable help if someone is looking for a specific item.

I want to thank you again for the thoughtful care that you are giving these matters. It is good to know that the details are being taken care of by you.

With best wishes from house to house,

Klari Eckart

Fac   von Neumann

THE INSTITUTE FOR ADVANCED STUDY
PRINCETON, NEW JERSEY

SCHOOL OF MATHEMATICS   October 31, 1961

Dear Dr. Oppenheimer:

When I spoke to Verna about the following matter she sug-
gested I write to you.

I have just learned from Klari that the latest information
from Pergamon Press is that the von Neumann volumes should be
coming out about 6 weeks apart. Which means that Vol. II, containing
one review of an unpublished manuscript, will probably be published
soon. Subsequent volumes will contain many more reviews. As you
know, it is stated in Vol. I that these manuscripts are in the I.A.S.
library where people may come to read them. As a matter of fact,
they are still in my care and as long as they remain here I have been
instructed that they cannot be taken from this building.

My problem is: Where do I seat a guest to read them when
there is not a single vacant office or desk in this building? Obviously,
they belong in the library and I cannot understand why there is not
room there for such a small file.

I shall greatly appreciate any advice you can give me.

Sincerely,

Betty Gorman

Elizabeth S. Gorman

Dr. Robert Oppenheimer
Institute for Advanced Study

May 7, 1957

Dear Robert:

    Your kind letter was received and appreciated
very much. I regret exceedingly that I have been un-
able to answer it for, as you may know, I have been quite
ill these past six weeks. At the moment there is nothing
I can say because I am "out of business" for several months.
However, I do want to thank you most warmly for handling
the matters concerning Johnny's papers, and I hope some
day to thank personally you and all the others who are
giving so generously of their time to read these manuscripts.

    With best wishes,

Sincerely,

Klara von Neumann

Klara von Neumann

(By telephone message to
Mrs. Gorman.)

Dr. Robert Oppenheimer
Institute for Advanced Study

Klari Von Neumann

THE INSTITUTE FOR ADVANCED STUDY
PRINCETON, NEW JERSEY

OFFICE OF THE DIRECTOR

1 April 1957

Dear Klari:

Thank you for your letter of March 29th; the points that you list all agree with my understanding of our talk, and all seem consistent with the proper handling of the papers recording Johnny's work.

With regard to 2. and 5. in your letter, there have been some minor developments which I should report to you: Mrs. Gorman asked whether she could have a little more help than she was getting from Julian Bigelow in identifying and listing papers on the applied side; I told her that she should be free to call on Herman Goldstine for such help. Two people have been in to visit, both close collaborators of Johnny's: Stan Ulam and Kakutani. Deane Montgomery suggested that we encourage Kakutani to come again; he has a proper reverence, and I think he would welcome this suggestion; and I have told him that we would take care of his expenses. I hope that this seems right to you. Mr. Bailey of Princeton University Press is interested in anything that we can find on continuous geometries and has communicated with Givens; so far, we have not heard directly from him. If any of these arrangements seem bothersome to you, please do not hesitate to let me know. I will also assume that, if Deane or I should think it desirable to enlist Gödel's help on problems of logic, you will not object to that.

About ten days ago, I called Los Alamos to tell them of our thoughts and to learn of theirs. Perhaps as a result of this, we had a whirlwind invasion and a great proliferation of phone calls and letters from the dashing Captain Maxwell of Pergamon. Despite his florid style and monstrous honorary editorial board, what he intends to do, to what we call the Los Alamos Project, does seem to me inherently good and rather hard to spoil; and much of it would be quite beyond our competence here. For instance, he wants to try to get some of Johnny's secret work declassified and published, and will try to get a number of articles that summarize the present state of fields of research, which were either started by Johnny, or to which he made seminal contributions. I don't think that I can do much to watch out for the Pergamon Press adventure, but if I see anything in the account of it, that will no doubt reach us here, that alarms me, I will be in touch with Marx Leva or with you.

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY

Your last paragraph calls for special comment: We would be
grateful and very much pleased if the technical books that belonged to
your husband were to be given to the Institute. I know that both his
colleagues on the Faculty, and the Institute's trustees, would welcome
and would accept this bequest, as would I.

With good wishes,

Very sincerely,

Robert Oppenheimer

Mrs. John von Neumann
Apt. B-1037
3636 - 16th Street, N.W.
Washington 10, D.C.

March 29, 1957

Dr. Robert Oppenheimer
Institute for Advanced Study
Princeton, New Jersey

Dear Robert:

This letter will confirm the oral discussions which I had with you and Mrs. Gormam during the course of my recent visit to Princeton, as follows:

1. The arrangements outlined below are designed to apply to both the published and unpublished papers of my late husband, Dr. John Von Neumann.

2. Julian Bigelow and Deane Montgomery, and perhaps some other people whose names you and I may subsequently agree to add, will assist with completing the listing of the published and/or unpublished papers.

3. Mrs. Gorman will act as custodian of such papers as are at the Institute. You have generously agreed to permit the papers to remain in their present location at the Institute at least for the next several months.

4. Any scientific person within the Institute may see these papers, may if necessary remove them briefly from the office where they are presently located, but may not keep any papers away from such office overnight.

5. The papers at the Institute under Mrs. Gorman's custodianship may be made available (for study or reference work to be done at the Institute) to such persons outside the Institute as may have a legitimate academic interest therein, including in particular former co-workers of Dr. Von Neumann. In most cases, Mrs. Gorman will know the persons falling into this category. Should there be any request from some person who is not known either to her or to the people with whom she may discuss the matter in the Mathematics Department at the Institute, she will clear the request to see the papers with you in your capacity as Director of the Institute.

6. Some of the published and/or unpublished papers are still in Washington, and if feasible will be sent to the Institute in the near future to be added to the papers that are already there. Once these papers are so added, the procedures outlined above shall apply.

Dr. Robert Oppenheimer
Page Two
March 29, 1957

     7.   With respect to any proposals or suggestions having
to do with either republication of previously published
papers, or publication for the first time of papers not
heretofore published, all such matters should be referred
to my attorney, Mr. Marx Leva, 1701 K Street, N. W.,
Washington, D. C., since the estate of Dr. Von Neumann
is being administered in Washington.

*   *   *   *   *

In addition to the arrangements set out above with respect
to the published and/or unpublished papers, it is my hope, in
which Marina joins, that the various technical books which belonged
to Dr. Von Neumann can be presented to the Institute. Before ex-
ploring the ways and means by which this objective may be accom-
plished, I thought that I should acquaint you with our intentions
in this regard, to make sure that such a presentation, assuming
it can be worked out, is acceptable from your standpoint.

                  Sincerely,

                 Klari

                 Klara D. Von Neumann
                 Administratrix, Estate of
                 Dr. John Von Neumann