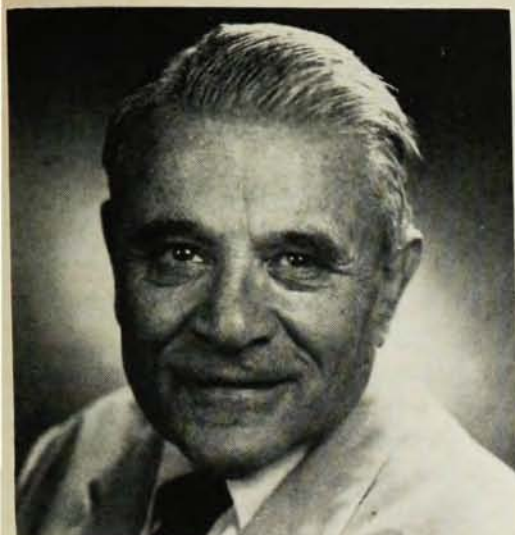




A Young Physicist at Seventy

HARTMUT KALLMANN

In Berlin and New York the inventor of scintillation counting has studied matter-radiation interactions

by Gerald Oster

HARTMUT KALLMANN was seventy years old on 5 Feb. As director of the Radiation and Solid State Laboratory of the physics department of New York University at Washington Square, where he has been since 1949, he is the dynamic leader of an active group of 40 physicists concerned with interactions of radiation with matter. His career spans the whole period of modern physics starting with his doctoral thesis under Max Planck.

Kallmann regards as his most formative scientific period the time when he was directing the laboratory of atomic physics in the Fritz Haber Institute in Berlin. His collaborators, however, regard Kallmann as being in his formative period *today*; his keen and fertile mind constantly leads to new and unexpected ideas. Despite the years of forcible inactivation imposed on him by the Nazis between 1935 and 1945, Kallmann has published over two hundred papers (the majority after his fiftieth birthday), many of which are fundamental to the development of physics.

The many contributions Kallmann has made demonstrate both variety and coherence. They vary from theoretical analyses of quantum effects to

experimental demonstrations of neutron radiography and x-ray polarization. Their coherence is that almost all have something to do with radiation and its interactions. For example, theoretical analyses of energy transfer between molecules contributed years later to the development of liquid scintillators. The work continues with investigation of ionizations, molecular excitations and scintillations in living matter. And in the midst of scientific pursuits, Kallmann is deeply concerned with the welfare of world science and scientists, the relation between theory and experiment and the proper allocation of government research funds.

Scientific career

The scintillation counter, with which Kallmann's name is most often associated, could have been invented in 1937 except for the lack of incentive in Hitler's Germany. In those days the standard scintillator was zinc sulfide, and one evaluated different samples by watching them glow under ultraviolet light. During such an investigation a technician walked into the darkened room. "First," says Kallmann, "I told him he had a false tooth. (It looked black under the ultraviolet.) But I also told him that he had some prominent seams in his clothing." To find out what caused the seams to glow, Kallmann called the clothing manufacturer and found that they contained coronene. Recognition of this organic scintillator was the first step

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toward a scintillation counter. (Kallmann has recently come back to coronene in studying scintillating materials in living tissues; much of the fluorescence in teeth is caused by organic compounds.)

When the war was over it was not easy to get back to the development of the scintillation counter. Both organic scintillators and photomultipliers were hard to get. But a gift of 10 000 cigarettes from an American friend enabled Kallmann to purchase all the moth powder (naphthalene) in Berlin. Research toward the scintillation counter was under way again.

The invention of the scintillation counter, which Kallmann announced in 1947,¹ is a direct outgrowth of his long studies on radiation-matter interactions. He appreciated that inorganic phosphors excited by ionizing radiation emit light with high efficiency (about 30%). If electrons are to be detected, large single crystals of inorganic material are required; but this represents a formidable problem in crystal growing. Then with his coronene experience Kallmann hit on the idea of using organic crystals, which can easily be grown large. From theoretical considerations Kallmann showed that organic fluorescent materials such as naphthalene would serve the purpose, and he predicted that when used in conjunction with an electron-multiplier phototube it should be possible to detect a single electron. His experiments bore him out.

Organic and liquid scintillators

The counting rate of the scintillation counter is nearly a hundred times that of a Geiger counter of the same volume. Moreover the volume of the scintillation counter (more specifically, the liquid scintillation counter) can be large. Thus it is one of the most important devices in atomic physics and of inestimable value in modern medicine. Kallmann further appreciated that another advantage of using organic fluorescent materials is their great speed of response (of the order of nanoseconds, as we now know).

Liquid scintillators grew from an urgent need for still larger scintillation counters, which could not be made practically by growing crystals, even organic ones. Kallmann utilized his earlier theoretical and experimental work on energy transfer. In 1929 he and Fritz London had shown from quantum-mechanical considerations that energy can be transferred between molecules over distances much larger than the size of molecules.² Soon afterward Kallmann showed experimentally that this resonance energy transfer does indeed take place between gaseous molecules.³ This knowledge suggested to him, in connection with the scintilla-

tion counter, that it might be effective to use solutions of fluorescent organic materials in which the bulk solvent (for example, benzene) absorbs most of the ionizing radiation.

In 1950, after having been only one year in the United States, Kallmann published a paper⁴ that is the basis of all liquid scintillation counters. Subsequent work with Milton Furst⁵ of Hunter College and others has elucidated the mechanism of energy transfer in liquid scintillators. Kallmann has further shown⁶ that even for such liquids as water, which are not energy-transfer media, the addition of another solvent such as dioxane produces effective energy transfer. This technique considerably extends the use of the scintillation counter in medicine. Recently some thousands of gallons of such scintillating mixtures have been sent to hospitals in Africa. Kallmann was also the first to apply coincidence-counting techniques to scintillation counters.⁷

Ionization in matter

Kallmann's interests have extended to ionization processes in matter. In 1922 he and Paul Knipping of the Kaiser Wilhelm Institut für Physikalische Chemie were among the first to apply mass spectroscopy for the determination of ionization potentials in gases.⁸ Kallmann returned to this problem and, in collaboration with Martin Pope of NYU, applied it to solids to open up a new branch of solid-state physics.

Their basic finding was that under light excitation (or even under excitation induced by chemical reactions) positive ions can be injected into organic crystals.⁹ This charge induction can render organic insulators highly conducting. Kallmann and his collaborators have extended this work to organic liquids.¹⁰ Because of their research we now have information about the conductive states in organic materials that, it is hoped, will guide the molecular biologist.

More recently, in collaboration with his daughter, Gisela K. Oster, Kallmann has undertaken a study of the upper electronically excited states of organic substances.¹¹ By a comparison of free-radical formation and luminescence it appears that energy transfer can also take place from the higher states of molecules excited by either ionizing radiation or short ultraviolet radiation. This work considerably extends sensitivity of the counter.

Kallmann and his collaborators undertook a study of the luminescence of organic and inorganic materials with regard to energy storage and the effects of various types of radiation, including infrared. They showed that the anomalously high

dielectric constant exhibited by inorganic phosphors when excited was, in fact, due to photoconductivity.¹² Light induces displacement of free charges. This displacement produces persistent internal polarization, which is charge accumulation inside the material excited by radiation. The effect can also be erased by radiation. Kallmann applied this technique to organic materials.¹³ Aside from its scientific interest, persistent internal polarization has application in reproducing images and, in general, for the storage and retrieval of information. Recently he has employed electron-spin resonance to detect the trapped charges directly.¹⁴

Neutron radiography

Kallmann is also the inventor of neutron photography. A paper on this subject, suppressed by the Nazis in 1939, appeared in 1948.¹⁵ It showed that a neutron-photographic image can be produced by bombarding a foil of lithium, the image being rendered visible by the emitted alpha particles falling on a screen of inorganic phosphor. Indeed, this was the experiment that led Kallmann to the scintillation counter.

Immediately after the war, when the physical conditions were such that he could not pursue his experimental problems, Kallmann devoted himself to purely theoretical questions. In a series of papers he showed that a number of quantum-mechanical problems could be readily solved by using Laplace transforms.¹⁶

Kallmann's earlier contributions have also made an impact on modern physics. In 1925 he and Herman Mark, now of the Polytechnic Institute of Brooklyn, discovered that Compton radiation is polarized¹⁷ but incoherent.¹⁸ He and Mark also studied both theoretically and experimentally the dispersion of x rays.¹⁹ This subject is now being revitalized in connection with the x-ray microscope.

A short paper by Kallmann²⁰ in 1932 introduced the notion of long-range forces between colloidal particles, a subject of current interest in connection with chromosomal mechanisms.

Kallmann continues to have an interest in biology and medicine and is collaborating with researchers in these areas. Among his main efforts at the present time is the question of energy storage of metastable states and its implication in laser technology. He also is probing the question of using upper excited states in improving the scintillation counter.

Why—not how

Although Kallmann has no scientist forebears, he attributes his early scientific interests to his father,



EXPERIMENTAL PHYSICS, says Kallmann, is currently better than theoretical. Here he sits in his NYU laboratory.

who was a Berlin lawyer and a director of a company making mantles for gas lamps. The father early realized the potential value of the Edison light bulb and saw that its success required a high-melting filament. Learning that tungsten was the metal with the highest melting point, he insisted that company chemists learn to make it into filaments. The result was a working bulb, the trade-name "Osram," which is still used, and an agreement with the General Electric Co. in the United States for exchange of patent rights. ("Osram" was actually an intentional misnomer: for many years competitors seeking the secret of good filaments were misled into thinking that an ingredient was osmium, but there was none in the filaments.)

His background leads one to think Kallmann might have become an engineer, and I asked him once how he turned into a physicist. "I was interested in the question 'Why,' not 'How,'" he answered. He went on to say that he started out to be a chemist but realized early in his undergraduate training that he was not a good one. So he changed to physics.

Experiment and theory

Today, says Kallmann, experimentalists are answering the question "Why" better than theorists. He himself has been both and has strong feelings that a good physicist should combine both. But nowadays, he says, we make it easy to be a theorist, difficult to be an experimentalist. The theorist, he says, makes his assumptions, performs calculations and expresses results that do not necessarily have

to agree with nature. But of the experimentalist we demand not only results but also explanations.

He feels strongly about what makes good scientists and describes himself as "a very belligerent man." The belligerence takes the form of many letters to Congressmen and appearances in Washington in support of his ideas. He feels that more money should be allotted to research and that it should be given with fewer strings. The basis of a grant, he feels, should be faith in the man to whom it is given. If the man has published and has demonstrated real accomplishments, he should be supported. Support should *not* be issued for proposals, for what a man *hopes* to do in the future. "The scientist should lead," he says, "one can not push an accomplished scientist."

Emphasis on freedom

It is not surprising that Kallmann's favorite in a collection of recorded operas is Beethoven's *Fidelio*; the word "freedom" recurs frequently in his conversation like a repeating motif. To freedom he attributes the past and present success of German science and the present success of the United States in attracting scientists.

He knows whereof he speaks, for he has seen freedom from both sides. When the Nazis came to power he would have liked to leave Germany. But he had recently proposed a patentable idea to I. G. Farben, and as a valuable scientist he was not allowed to leave Berlin. He was given a laboratory and permitted to work but was virtually a prisoner of the regime. Later even the possibility to work disappeared, but he was not allowed to leave. Those years, he feels, saw the destruction of German science.

Earlier, in the 1920's, German productivity was at its peak. The reason, according to Kallmann, was freedom. Much money was available and one was not asked questions as to how it would be used. Moreover foreigners were readily accepted for work in research laboratories.

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YOUNG PEOPLE are essential to research, says Kallmann, and this picture shows him exchanging ideas with students.

The present "fantastic" resurgence in West Germany, he says, has the same roots. The Max Planck Institutes are more successful than United States national laboratories. Researchers are comparatively free; there is no overemphasis on results; staff members are encouraged to hold joint appointments at the research institutes and also on university faculties. "Researchers," he says, "need young people."

And that, he finds, is the key to the success of United States science. Young people come here because they are "accepted human beings."

Youth and vigor are his outstanding characteristics as Professor Kallmann enters his eighth decade. One of his favorite hobbies is walking, despite affliction in his youth with osteomyelitis and a series of nearly 100 operations to cure it, and he estimates that during last summer's vacation in Germany he and his wife walked several hundred miles. He is a young man in spirit, and with the impetuosity of youth he feels that physics is "now only beginning to get hot." □

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