Early History of the Scintillation Counter

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One of the most impressive events in modern physics is the development of the scintillation counter. At first a very simple device, this instrument has become one of the most powerful tools in all fields in which ionizing radiations are encountered. Considering its still-growing importance, it appears justified and desirable to sketch in a brief essay the early history of the instrument.

The modern scintillation counter has its origin in the classical scintillation method that was used so extensively in the early years of radiation research by the English School under Rutherford (*1*), and by the Vienna School under Meyer, Schweidler, and others (*2*). This method, in which the scintillations were observed subjectively with a microscope, led to important discoveries. The last of these great discoveries was the first man-made disintegration of an element with artificially accelerated particles, the disintegration of lithium with accelerated protons by Cockcroft and Walton (*3*) in 1932.

At about this time the Geiger-Mueller counter had definitely proved to be one of the most advantageous instruments for nuclear research, and its outstanding ability to detect and count objectively thousands of elementary nuclear events per unit of time made it the instrument of choice for future nuclear research. Therefore the subjective, tiresome, and difficult scintillation method was shelved and was demonstrated merely from time to time to students and/or in lectures as an interesting historical device.

The first attempt to bring the scintillation method back into nuclear research in an improved form was made in 1940–41. At this time a device was developed in which, instead of the eye, a highly sensitive, fast-responding, photoelectric device was used for the detection and counting of scintillations.

A second attempt to introduce an improved scintillation method in nuclear research was started in the war year 1944. It was followed by a stormy renaissance of the principle after World War II in the years 1947–50.

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Today, two highly developed types of scintillation counters are available: the photon-tube scintillation counter and the photomultiplier scintillation counter. Both types have advantages and disadvantages, and both methods have been applied with great success in different fields.

Photon-tube counters. Photon tube counters are a combination of the classical scintillation arrangement with a photosensitive Geiger tube of special design. The device developed by Krebs (*4*) in 1940–41 is shown in Fig. 1. It consists of an arrangement in which the scintillation phosphor and the photoelectric detector are separate units.

The choice of photon tubes as scintillation indicators was dictated by the needs of the time (*5*). Photon tubes could easily be self-built and they could be "bred" to a high sensitivity—according to published data up to 12 quanta/cm^2 sec, equivalent to 9.1×10^{-11} ergs/cm^2 sec of light with the wavelength, λ, of 2600 A (*6*).

The first self-built photon tubes were relatively insensitive and the geometry of the arrangement was poor, but the first measurements showed that the principle would work. Soon, by taking advantage of earlier experience in building special G-M tubes (*7*), tubes with higher sensitivities could be built and the geometry could be improved so that the efficiency was increased considerably (*8*). With the first simple equipment, the scintillations produced by polonium alpha particles in zinc sulfide could be recorded, and the diffusion of radon and thoron in closed volumes could be measured quantitatively.

The rediscovery of the photon-tube principle by Mandeville and coworkers (*9*) in 1950 stimulated further improvements and resulted in an increased sensitivity of photon-tube scintillation counters. By bringing the scintillation phosphor into close contact with the walls of the photon tube (Fig. 2), Mandeville *et al.* could apply the counter successfully for the detection of alpha, beta, and gamma radiation. Special sensitization of the photon tubes (*10*) and the development of special counter types and amplifier circuits brought the instruments to a still higher degree of perfection (*11*). At present, commercially manufactured scintillation tubes are available that show, according to measurements by Daggs, Parr, and Krebs (*12*), a high area sensitivity and short resolving times.

Photomultiplier-tube counters. The first scintillation counter of this kind, in which the classical method is combined with a photomultiplier for the detection of the scintillations, was built in 1944 by Curran and Baker (*13, 14*) and is shown in Fig. 3.

The original report of Curran and Baker showed theoretically, as well as experimentally, that with proper arrangement of the parts, individual alpha particles with energies of 2×10^6 ev could easily be detected. Using zinc sulfide crystals as a scintillation screen, a photomultiplier tube type 1P21, and proper circuit elements, they calculated that an alpha particle with the afore-mentioned energy should produce in the oscilloscope an average pulse amplitude of 4.75 ev. The *de facto* pulse amplitude measured was 6 ev, a value in close agreement with the figures calculated from rough data. The great advantages of the instrument with regard to sensitivity, resolving time, and ease of handling were emphasized in the first report of Curran and Baker (*13*).

As in the case of the photon-tube scin-

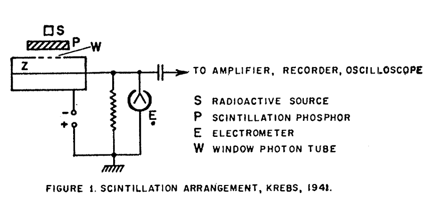

Fig. 1. Scintillation arrangement, Krebs, 1941.

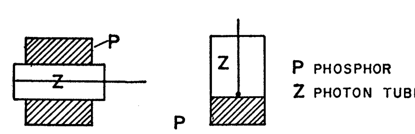

Fig. 2. Photon-tube scintillation counters, Mandeville *et al.*, 1950. (Left) Tube counter; (right) end-window counter.

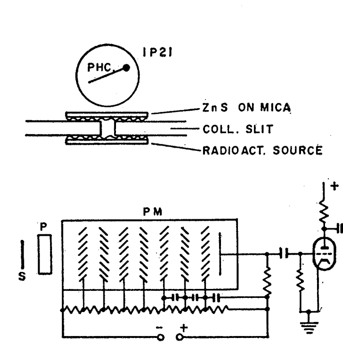

Fig. 3. Scintillation counter, Curran and Baker, 1944. (Top) Geometric arrangement; (bottom) diagrammatic representation.

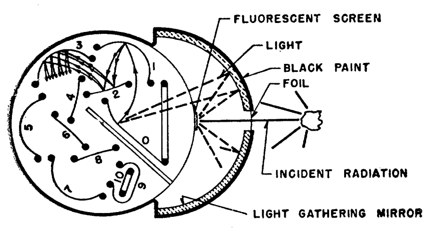

Fig. 4. Scintillation detector, Coltman and Marshall, 1947. Photocathode, 0; dynodes, 1 to 9; anode, 10.

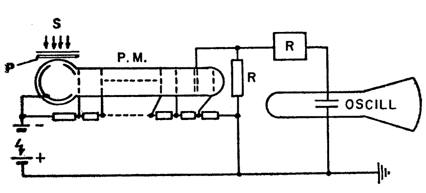

Fig. 5. Scintillation arrangement, Broser and Kallman, 1947. Alpha radiation, *S*; phosphor, *P*; photomultiplier, *P.M.*

tillation counter, the war years prevented a natural development of the photomultiplier scintillation counter and it was not until 1947–48 that the advantages of the instrument were generally recognized. At this time several new publications appeared, the timely sequence of which may be of interest in discussing the early history of the scintillation counter.

Marshall, Coltman, and coworkers, who in March 1947 submitted for publication a report on "The photomultiplier x-ray detector" (*15*), demonstrated on 22 May 1947, at the Mid-American Exposition Atomic Energy Show, a high-speed "atomic ray detector" (*16*). On 17 June 1947, they also presented papers on "The photomultiplier radiation detector" at the Montreal meeting of the American Physical Society (*17*). In these papers, later published in detail, they reported the detection and counting of single alpha particles, beta particles, gamma quanta, high-energy electrons, protons, soft x-rays, and neutrons (*18*). Marshall and Coltman also stated that at least three major improvements of the detector (Fig. 4) could be expected: better scintillators varying with regard to type, thickness, and reflective backing in accordance with the specific radiation involved; improved optical systems; and the development of auxiliary circuits adapted to the special needs of scintillation counting.

Broser and Kallmann (*19*) submitted a paper for publication on 2 May 1947 that described the detection and recording of alpha-particle scintillations in zinc sulfide with the aid of a photomultiplier tube. They used a Weiss-type photomultiplier in connection with an oscilloscope (Fig. 5). The average pulse height produced by the applied alpha particles was equivalent to several hundredths of a volt, and the pulse time was estimated to be somewhat shorter than 10^{-5} sec.

At the time of the reading of the galley proof, Broser and Kallmann added a short footnote saying that individual electrons and gamma quanta could also be recorded with the aid of different scintillators. The detailed report on these studies with ZnS, $CaWO_4$, Zn_2SO_4, naphthalene, and a few other substances was submitted for publication on 27 June 1947 (*20*). The years after 1947 brought decisive publications: a short note by Deutsch (*21*) and review articles by Bell (*22*), Hofstadter (*23*), Morton and Mitchell (*24*), Jordan and Bell (*25*), Mayneord (*26*), Pringle (*27*), and others. These studies stimulated and inaugurated the extensive development that followed. Soon it became generally recognized that the scintillation counter was ". . . one of the most important advances in devices for the detection of nuclear radiations since the invention of the Geiger-Mueller counter in 1926 . . ." (*24*), which ". . . heralded a new era of scientific development and research . . ." (*27*). This area of development and research includes many fields: nuclear physics, cosmic-ray research, medical physics, biophysics, radiobiology, carbon-14 dating, and others.

The ultimate value and importance of the instrument for development and progress in the different fields can only be guessed at present. For the field of nuclear physics, Birks (*28*) has already stated that ". . . the history of the instrument since 1949 is largely a history of experimental nuclear research. . . ." A similar formulation appears to be justified in the other fields where the scintillation counter has brought valuable insights and knowledge to problems concerning the energy-transport and energy-migration mechanisms in irradiated physical, chemical, and biological systems and to problems of the radioactivity of the human being and carbon-14 dating.

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They that know the entire course of the development of science will, as a matter of course, judge more freely and more correctly of the significance of any present scientific movement than they, who limited in their views to the age in which their own lives have been spent, contemplate merely the momentary trend that the course of intellectual events takes at the present moment.—Ernst Mach in *Science of Mechanics.*