editorial

Photon detectors: from yesterday to tomorrow

Discovery and development of the means to detect and measure electromagnetic radiation have a history extending over nearly two centuries. Thus the field is almost as old, and yet as free of the symptoms of aging, as the Constitution of the United States. The two basic methods underlying detection of electromagnetic radiation—by energy-integrating thermal effects and by individual quantized transitions induced by photons—were involved right at the beginning in two major discoveries. In 1800, Sir William Herschel observed the existence of an infrared region by the heat developed in the solar spectrum beyond the red; and in 1801, Johann Ritter identified ultraviolet radiation by its effect of blackening silver chloride.

The recognition of the photochemical reaction as a quantum process was delayed by more than a hundred years. In fact, however, the quantum theory could have been postulated on the basis of the photographic process alone. It was already known in the nineteenth century that the dissociation of a silver-halide molecule required a certain minimum energy. On the other hand, the silver grain density of a photographic plate at a given wavelength was found to be constant for a constant total amount of radiation received. With hindsight the conclusion seems inescapable that the photochemical process is caused discontinuously by light quanta of fixed energy. It was instead the external photoelectric effect, discovered by Heinrich Hertz and interpreted by Albert Einstein, that established the theory of light quanta and the concept of photon detectors.

Physics is concerned with photon detectors in two aspects. First, the basic processes underlying detection, such as photoemission, photoconduction or scintillation, are in themselves of interest from the point of view of solid-state and radiation theory. Second, practical detectors for laboratory or sensor-systems applications must be adapted to continuously varying and expanding requirements. These two research pursuits are, of course, closely coupled so that advance in one benefits the other. Characteristically, this state of affairs has existed since the beginning of photodetection.

Exploration of the external photoelectric effect started early in this century with experiments on the dependence of quantum yield and electron velocity distribution on photon energy, band-gap structure, and temperature. Yet even this ancient subject is still a matter of inquiry as illustrated in the article by Richard Pehl on germanium gamma-ray detectors on page 50. The renewed interest results from the expansion of spectroscopy into the gamma-ray region. Similarly, the topical subject of coherence involves the photoelectric effect intimately in the phenomena of photon statistics and photon correlations. There are other such examples, and a related situation exists in photoconductivity.

The second aspect of detector research (if indeed it can be separated so easily from the first) has had, in recent years, more visible and dramatic results. It is now possible to use photon detectors of high performance characteristics virtually over the entire range of the electromagnetic spectrum from millimeter waves to gamma rays. This is a feat that few believed possible not so long ago and, incidentally, one that argues by analogy against the present-day doubt that it will be possible to provide a powerful laser line at any desired frequency.

Thus one might conclude that the work of developing photon detectors for every need is largely done. That this is not the case is amply demonstrated by the four articles devoted to the special topic of this issue. It is quite surprising how the field of photon detectors keeps encountering new demands and opportunities. From particle physics come requirements such as high-resolution germanium detectors for the x-ray spectroscopy of exotic atoms. The photomultiplier is a nearly ideal detector in that its noise level is the irreducible minimum given by the statistical fluctuations in the number of arriving photons. But that is no longer enough. Aside from high resolution in amplitude, one must now also have high resolution in time and space of photon arrival. Thus the multichannel photomultiplier is created. The laser with its high flux density promised to make little demands on the sensitivity of photon detectors. In fact, its development might have been greeted by the supplier of high-performance detectors with the same enthusiasm that the proliferation of pocket calculators generated in the manufacturer of slide rules. Instead, the laser offers the opportunity of long-distance communication at enormous bandwidth, contingent, however, on the development of high-speed photodiodes, preferably with a response to longer wavelengths and including such features as avalanche amplification.

The message in this account is this: Even some practicing physicists believe that in physics the age of discovery, and indeed of creative activity, is over except for one or two "frontier" fields such as high-energy particle physics. The history of photon detection, however, shows that even a mature field such as this still provides mysteries, challenges, and opportunities for progress that can excite new generations of physicists.

MAX GARBUNY
Westinghouse Research and Development Center