Introduction to the Issue on Photodetectors and Imaging

THE DETECTION of light is one of the most fundamental processes in the field of optics. The scientific exploration and technological use of optical radiation at any frequency is initially enabled and ultimately limited by the capabilities of the photodetector used. The extraction of information from an optical signal almost universally involves the creation of a corresponding electrical signal, and this optoelectronic conversion process is the function of the photodetector. Just as in the complementary realm of light creation by electrooptic sources, materials science and device design form the two pillars on which devices for photodetection are built.

The ability to detect light begins with the optical and electrical properties of candidate materials systems, and the most technologically important photodetector materials are the semiconductors. From a physics perspective, the presence of electronic bandgaps with energies comparable to those of photons makes the semiconductor an extremely capable material for detecting light by the photoelectric effect. From a technological point of view, the high level of industrialization which already exists for semiconductors as electronic devices makes these materials economically practical for optoelectronic devices. The articles in this issue bear witness to the overwhelming prevalence of semiconductor materials in the study and application of photodetectors today.

In the development of photodetectors, the importance of materials research is paralleled by the essential role of device design. The tailoring of the semiconductor p-n junction diode for detecting light has yielded the photodiode, and this device structure serves as the basis of a vast variety (though by no means all) of discrete photodetector designs.

Ultimately, the drivers of photodetector performance are the end applications. Perhaps the most spectacular of these applications has been the field of fiber-optic communications, which uses near-infrared wavelengths for which optical fiber exhibits minimal transmission loss. Although this industry is still struggling to recover from the bursting of the fiber-optic industry bubble, the last decade of research and development in this field has produced phenomenal progress in the science and technology of photodetectors, particularly those based on semiconductor compounds lattice-matched to InP.

One of the key strategies for increasing the capacity of fiber-optic links has been the persistent migration to increasingly higher transmission bit rates. The consequent need for higher bandwidth has been a primary driver in the evolution of photodetector performance, and more than one-third of the papers in this issue represent the extensive current efforts to increase the frequency response of existing photodetector designs.

Another fundamental aspect of fiber-optic links is the achievable transmission length prior to signal regeneration. Improved fiber-optic receiver sensitivity allows for the extension of this unregenerated link length and is highly dependent on the performance of the photodetector used. In particular, avalanche photodiodes (APDs), which possess an internal gain mechanism, can provide significant sensitivity improvements relative to receivers with photodiodes of a typical p-i-n design. Moreover, the gain mechanism in APDs can be exploited so that it is possible to detect just a single incident photon. Several papers in this issue focus on the current state-of-the-art of APDs and their applications.

The ability to detect radiation across the optical spectrum from ultraviolet to long-wave infrared wavelengths has numerous applications such as pollution monitoring, biological and chemical agent detection, free space optical communications, noninvasive medical diagnostics, laser radar, night vision, and thermal sensing. In the ultraviolet and mid-wave infrared spectral regions, there has been avid interest in solving the challenges of both the materials and the design of appropriate photodetectors. This issue contains a number of papers representing research done in developing photodetectors for these wavelength ranges.

The applications with perhaps the greatest potential societal impact are those for optical imaging. Arrays of photodetectors can detect the enormous amounts of information inherent in images, and the ability to do so across the optical spectrum will provide unprecedented sensing capabilities. Building on decades of silicon processing technology, CCD and CMOS imaging chips already contain arrays of millions of discrete photodetector pixels that are readily integrated with high functionality silicon electronics. Meanwhile, large-scale arrays of other semiconductor photodetectors are becoming more common. The challenges of interfacing integrated circuits to arrays and processing the copious amounts of data provided by these devices are related areas of study. The papers in this issue related to imaging technology provide a sampling of the sizable activity in this field.

The final paper in this issue provides a glimpse into the potential for the use of organic compounds as photodetectors. Organic photodetectors are ubiquitous in biological systems, but we have only just begun to exploit organic materials to

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create man-made detectors. There are numerous challenges in working with these materials, but the benefits in cost and flexibility of implementation are enormous. There has already been encouraging progress in the development of organic electrooptic sources (e.g., organic light emitting diodes), and we expect to see comparable achievements in the area of organic photodetectors in the coming decades.

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During 1994-1995, Dr. Ünlü served as the Chair of IEEE Laser and Electro-Optics Society, Boston Chapter, winning the LEOS Chapter-of-the-Year Award. He was awarded National Science Foundation Research Initiation Award in 1993, United Nations TOKTEN award in 1995 and 1996, and both the National Science Foundation CAREER and Office of Naval Research Young Investigator Awards in 1996. His recent professional contributions include serving as Chair of the IEEE/LEOS technical subcommittee on photodetectors and imaging as well as serving on the nano-optics committees for at CLEO/QELS and IQEC. He is currently an Associate Editor for IEEE JOURNAL OF QUANTUM ELECTRONICS.

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