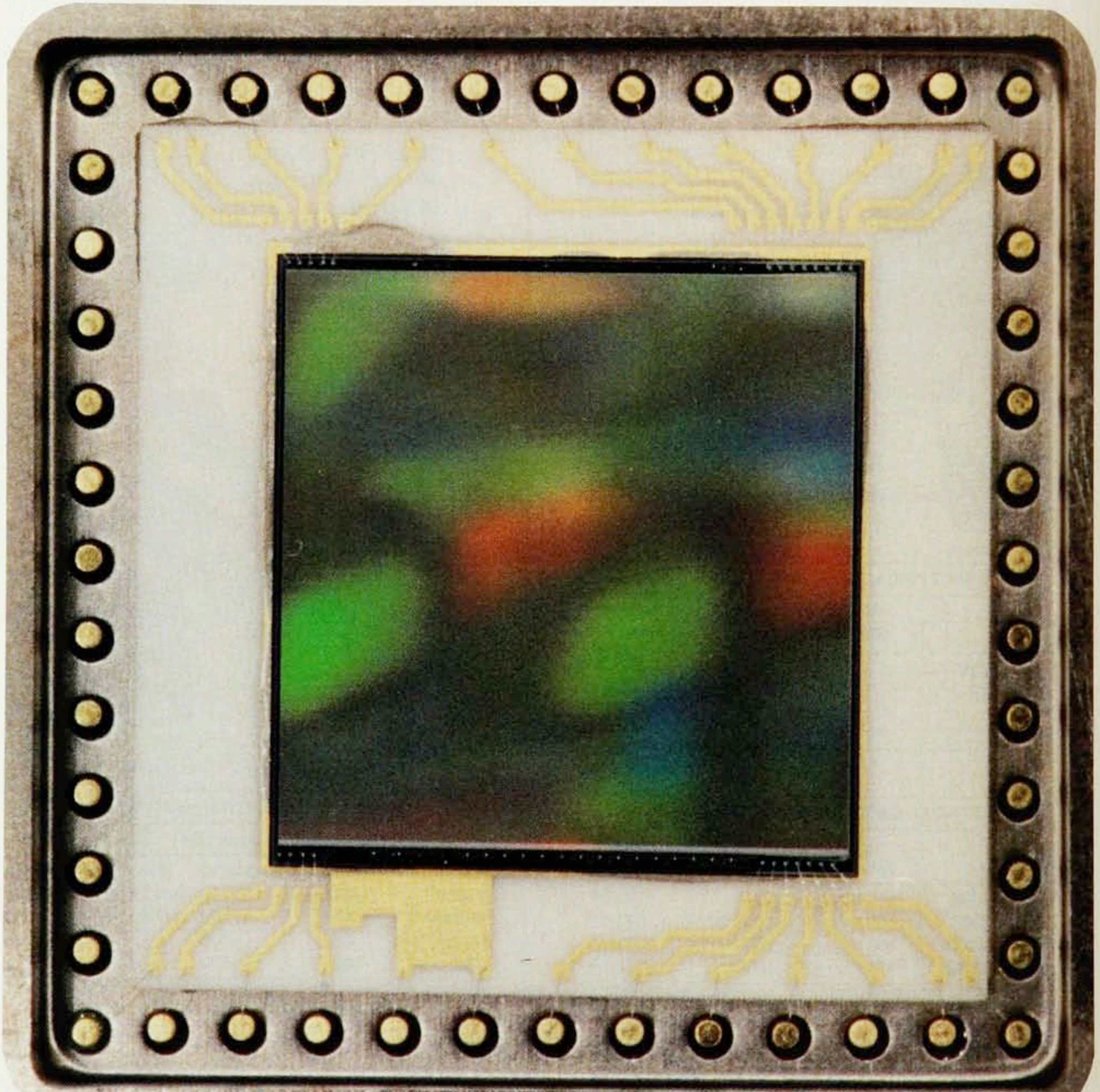
SPECIAL ISSUE:

THE PHYSICS OF



IMAGING

The science of imaging and its applications touch all aspects of physics. The response of materials to light and other forms of radiation yields insights into some of the most fundamental properties of matter. Imaging technology also provides a means for viewing and understanding physical processes, as well as for recording and sharing the results.

Silver halide photography dominated imaging technology from the time of William Henry Fox Talbot's demonstration of the catalytic development of a latent image in the mid-19th century until relatively recently. Advances in imaging system performance depended largely upon improvements in the understanding of the electronic and optical properties of silver halides, on one hand, and improvements in optical systems design and manufacturing, on the other. However, with the development of video technology, electronic imaging processes, which offer nearly real-time access to images, have displaced silver halide photography in many applications, in addition to creating entirely new ones. Developments in integrated circuitry and computers have greatly affected modern imaging technology, making electronic imaging systems more capable, more portable and less expensive than earlier systems. Integrated circuit technology has also accelerated the trend toward digital imaging systems, since inexpensive computers can now manipulate the large data files from such systems. Consequently, the physics of imaging now includes a much broader range of interests.

The two pictures on the cover of this issue symbolize the evolution of imaging technology and provide an interesting comparison of the state of the art in chemical and electronic sensors. The upper micrograph shows a small portion of a 4-million-element charge-coupled device. Several photodiode picture elements, or "pixels," of the CCD and some associated readout circuitry are visible. The lower picture shows at the same magnification the "pixels," that is, the silver halide grains—of a high-speed, ISO 1000 (equivalent to ASA 1000), photographic emulsion. The pixels of these two images are comparable in size, with lateral dimensions of about 10 micrometers. It can be seen that the resolution of solid-state focal planes now approaches that of modern photographic emulsions.

The emulsion from which the grains were taken is especially sensitive, or "fast". Slower emulsions can have much smaller grains and higher resolution. Each pixel of a CCD, however, records more than a thousand gray levels, or 10 bits, while a photographic grain can record only two gray levels, or 1 bit. The information density, in bits per unit area, of the two image-recording devices is similar, about a million bits per cm^2.

The complete CCD, of which a portion appears on the cover, is shown at the left. The device is about as large, and has about as many pixels, as current integrated circuit manufacturing techniques permit. The active area is about 4 cm^2. The scale of imaging devices has been following a growth trajectory similar to that of memory devices, with a quadrupling of the number of elements approximately every three years. Since the technology of memory fabrication and image sensor chips is similar, this trend can be expected to continue. On this basis, solid-state focal planes with 100 million pixels should be available by the mid-1990s.

Because the physics of imaging is a very broad topic, it was necessary to select just a few topics of general interest for this special issue of PHYSICS TODAY.

Albert Rose and Paul K. Weimer (page 24) discuss the fundamental limits physics imposes on the performance of imaging systems, independent of the imaging process. Comparisons of the imaging performance of the human eye with that of contemporary imaging systems serve to illustrate these limits.

The physics of practical imaging systems is discussed in the articles on the physics of the photographic latent image, by Tadaaki Tani (page 36), and on color science for imaging systems, by LeRoy E. DeMarsh and Edward J. Giorgianni (page 44). It may surprise many people to learn that the physics of latent image formation is still not completely understood. Tani discusses a current model for the process and indicates experimental directions that could lead to a more complete understanding and to improvements in photographic system performance. DeMarsh and Giorgianni describe recent developments in colorimetry that make it possible to model the performance of imaging systems with both chemical and electronic components.

Applications of contemporary imaging technology to "micro" and "macro" imaging are discussed by Gordon S. Kino and Timothy R. Corle (page 55) and by John R. Schott (page 72), respectively. In each of these areas applications have relied heavily upon physics for their development. Each, in turn, provides new tools for the development of physical understanding, from the atomic to the cosmic scale.

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