Detector Arrays for Digital Holographic Storage Applications

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This chapter discusses detectors for holographic data storage applications. While it may be possible to use a single detector or linear array of detectors, the focus here is on 2-D arrays of pixels. There are many considerations for the detector array when designing a complete system that arise from the intimate relationship between the holographic storage system, optical readout technique, and the sensor pixels. The chapter begins with a discussion of these considerations, based on the assumption that commercially viable digital holographic data storage (DHDS) systems must be “smaller than a breadbox,” be affordable, have data capacities in the hundreds of gigabytes arena, and have readout rates in the regime of hundreds of megabytes per second. Today there are two primary technology choices for realization of the sensor array: charge-coupled devices (CCDs) and CMOS (complementary metal-oxide-semiconductor) active pixel sensors (APS). Both will be introduced and their relative merits presented [1–6]. In fact the CMOS APS, a much newer technology, will be shown to offer significant advantages over its predecessor, the CCD, when applied to digital holographic data storage systems. An example of a recently-fabricated CMOS APS for use in a DHDS is shown in Fig. 1.

Fig. 1. A 816 × 616 element, 17-μm pixel pitch CMOS APS detector array designed for DHDS applications
1 General Considerations for Detector Arrays

In digital holographic data storage (DHDS) systems, the sensor array plays the critical role of converting optical data signals into electronic data signals. These optical data signals generally come in the form of a “page,” or two-dimensional array, of bright and dark spots of light. The sensor array must then be aligned and physically matched with the optical system such that each spot of incoming (readout) light is incident on one, or a small collection of, prespecified sensor array pixel(s). Such a criterion places stringent demands on the sensor array’s linear and angular attitudes, as well as its pixel pitch. The sensor array must also be highly sensitive to the particular wavelength(s) of the readout light, as average light levels will typically be quite low (<10000 photons per pixel per read). Furthermore, the sensor array must be capable of converting and delivering 10–100 user megabytes per second. These and other considerations will be addressed in the following three subsections [7].

1.1 Size, Power and Cost

Because it is preferred to have memory systems that are small, low power, and affordable, there are certain systems considerations that must be addressed in choosing or designing a sensor array for DHDS.

Perhaps the most inclusive system-based concern to consider is that of overall size. High-performance sensor array solutions must be found that are truly compact and/or self-contained (on the order of one to ten cubic centimeters).

In parallel with system size concerns are system power concerns. Most DHDS systems will want their complete sensor array subsystems to consume less than 1 or 2 W. Beyond the general system-level requirement for low power consumption is the vital requirement for low heat generation within the sensor array and its housing. Material dimensions are thermally dependent, and sensor array alignment must be maintained to within a few micrometers for good system performance. In most systems, just a few degrees of temperature change at or near the sensor array plane can shift the sensor array out of alignment with the incoming optical data page.

There is at least one point of relief for sensor array requirements. Since DHDS systems expect the “images” they are receiving to be rather noisy, containing perhaps hundreds to thousands of data bit errors in every page, pixel defects in the sensor array are not much of a problem. Embedded error correction codes (ECC) in the data pages will also correct for pixel defects. Thus the effective yield in the manufacturing of the sensors will be higher, reducing sensor manufacturing cost.