THE LOCKHEED DIODE ARRAY MAGNETOGRAPH

ROBERT C. SMITHSON

Lockheed Solar Observatory, Burbank, Calif., U.S.A.

(Received 20 September, 1974)

Abstract. A new magnetograph using a solid state monolithic linear silicon diode array has been constructed at Lockheed Solar Observatory. This magnetograph uses a digital image processor, and makes data available both in digital and analog form. The diode array detector is capable of a signal-to-noise ratio of 2000:1 or better when cooled to a temperature of −40 deg centigrade. Thus, intensity differences of the order of one part in a thousand may easily be detected without signal averaging. This instrument may be considered a prototype for an instrument using a two-dimensional array. The magnetograph is now fully operational, and is being used to produce data for statistical studies of solar magnetic field diffusion.

The recent development of solid state self-scanned silicon diode detectors has opened a new technology for use in solar instrumentation. Advantages of silicon diode detectors include high quantum efficiency (approaching 80%) and good sensitivity over a wide spectral range. Advantages of monolithic silicon diode arrays over other silicon detectors such as silicon vidicons include excellent geometric and photometric accuracy, simple associated circuitry, and ease of integration with a digital processing system.

Among the first such arrays to become commercially available were those manufactured by the Reticon Corporation of Mountain View, California. These units contain 512 diodes arranged in a line on 0.001 inch centers, each having an effective light gathering aperture of 0.001″ × 0.001″. Such a linear array is ideally suited to use with a spectroheliograph, and may be used with a narrow band filter by mechanically stepping the array across the image.

In order to provide an opportunity to become familiar with diode array technology and to provide a usable solar magnetograph, an instrument was built using a Reticon array mechanically stepped across a solar image formed by a birefringent filter tuned to 6302 Å. Images in right and left circularly polarized light are sequentially presented to the detector by use of an electro-optical (KDP) analyzer. Each scan of the array (one line of 512 diodes) is digitized. Lines may be stored in digital form in a 512 word shift register memory, or may be combined with the previous contents of the memory to form subtractions or averages. The final processed line may be read out in digital form, or may be stored on a silicon scan converter tube and displayed on a television monitor. A typical magnetograph consists of 683 such lines. After each line is processed, the diode array is mechanically stepped 0.001″ across the image and the next line is processed. Since there is insufficient memory in the magnetograph to store one line while processing the next, each line must be transferred to a bulk storage medium before the next line is processed. Figure 1 shows the optical arrangement of the magnetograph. Figure 2 is a block diagram of the electronic system.

Table I gives the important parameters of the magnetograph system. For the solar
Fig. 1. The optical system of the magnetograph. The filter is a hybrid Fabry-Perot/Lyot filter operated in a telecentric beam. The diode array is mounted on a micrometer stage driven by a stepping motor so that the line of photodiodes may be stepped across the solar image to build up a two dimensional magnetogram.

Fig. 2. The electronic system. The analog signal from the diode array passes through a preamplifier, an integrator, and a sample-and-hold circuit before being converted to digital data by the analog-to-digital converter. After one line of the magnetogram is processed digitally, it is reconverted to analog form for presentation as slow scan video. Analog data paths are shown by a dotted line, digital control paths by a single solid line, and digital data paths by a double solid line.

The parameters of interest are the differential sensitivity, the absolute sensitivity or quantum efficiency of the detector, the spectral response, and the required exposure times for a typical monochromatic system.

In order to achieve the performance parameters shown in Table I, it is necessary to cool the detector to approximately -40 deg centigrade. Cooling is required to improve the signal-to-noise ratio of the diode array, and to allow the relatively long (greater than \( \frac{1}{10} \) second) exposures necessary for some applications in solar astronomy.

As an example of typical light levels which may be encountered in the operation of a solar magnetograph, it is worthwhile to calculate the expected light level obtained at the detector of the Lockheed magnetograph. At 6300 Å, the Sun produces about 183