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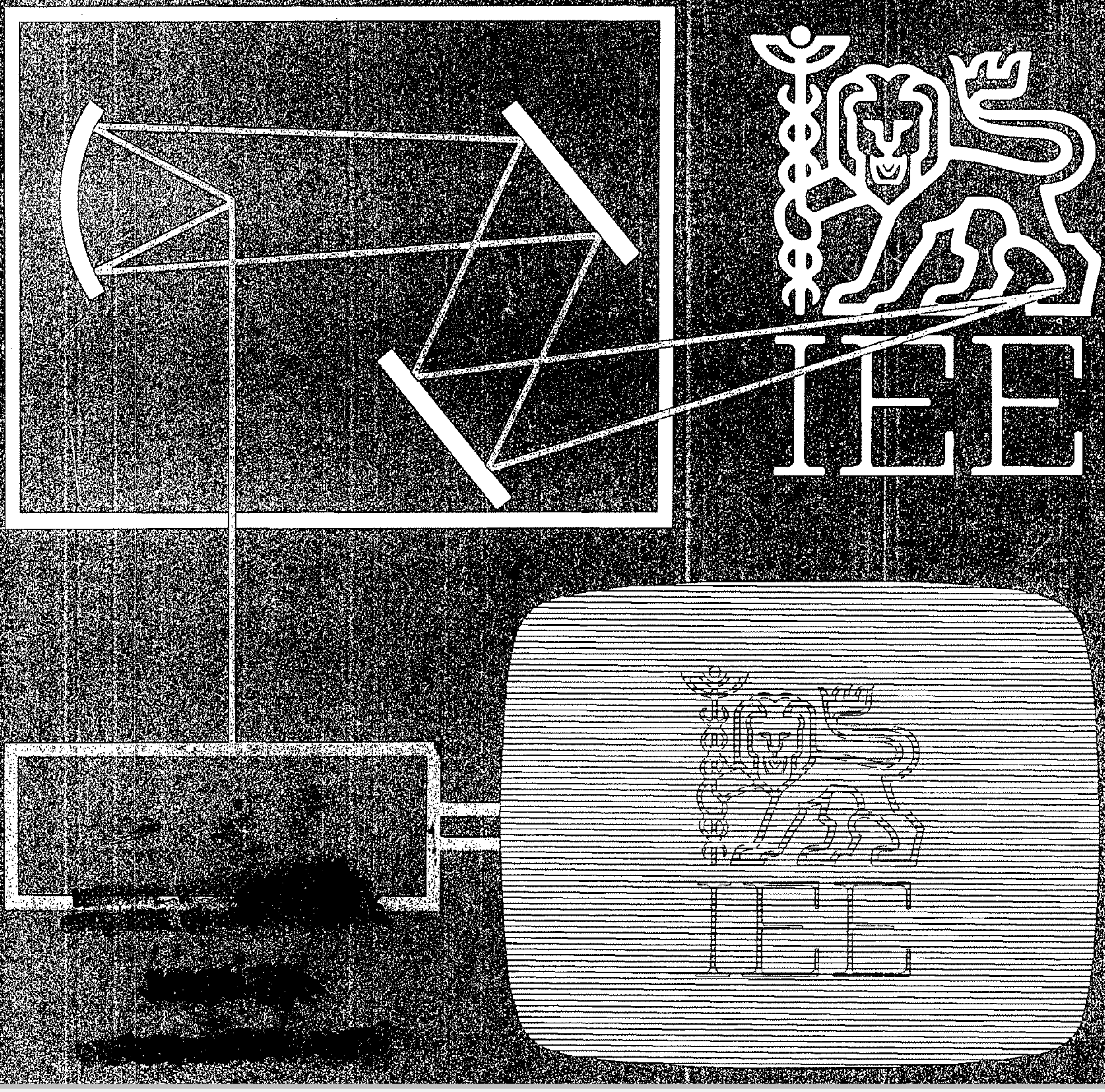

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TWO DIMENSIONAL RANDOM ACCESS INFRARED ARRAYS

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INTRODUCTION

Many future infra-red systems find it desirable to use two dimensional arrays of electronically scanned or "staring" arrays. Many schemes have been suggested ranging from a monolithic approach using silicon or cadmium mercury telluride as both the detector and read-out, to a hybrid approach where the detector and read-out are made from the most suitable materials and then combined using an interface technology. The approach taken by most research groups has been based on a hybrid combination of CMT photovoltaic detectors interfaced to silicon charge coupled devices. This has been very successful in the 3-5μm band but so far there has been no published report of an 8-12μm array.

An alternative to the CCD read-out, which has been developed during the past few years, is a co-ordinate addressed approach (1,2 and 3). This consists of a two dimensional array of CMT photovoltaic detectors connected on a one to one basis to silicon MOS switches (Fig. 1). The IR diodes are read-out by addressing the appropriate row with a shift register. The output of each column is integrated on a capacitor of an integrating amplifier. In this way a line of IR detectors is electronically scanned across the scene. In the 8-14μm band this approach has a number of advantages over the CCD. These are briefly listed below.

1. Lower RoA diodes can be used. This is because the input impedance of the amplifier is much lower than a CCD.

2. Higher dynamic range is achieved. This is due to the absence of well size limitations that limit the CCD. Consequently the longer end of the 8-13μm band can be used.

3. Removal of the background radiation pedestal is easy. This is performed before A/D conversion.

4. Uniformity correction is easier. It is a simple linear correction.

5. Simple high yield MOS technology is used.

6. If one element of the array is damaged the remainder of the array continues to work.

7. The combination of 1,4 and 5 leads to a cheaper focal plane array.

8. Random access capability.

The principle disadvantage is that at present only one line equivalent performance is obtainable. It is for this reason that it is uncompetitive with CCD's in the 3-5μm band.

Line Sampled Array (LSA)

Before discussing random access arrays, a brief review of the line sampled array is useful. The construction of the array makes it ideal for detailed assessment and testing. Each diode can be addressed in turn for as can be made on any particular diode. The following important parameters can be measured on a routine basis for every element in the array.

a. Current-voltage characteristic of the IR diode (Fig 2 shows a 32 x 32 element plot and Fig. 3 an expanded plot of one of the array diodes).

b. Short circuit photocurrent using a 300K background (Fig. 4 shows a 32 x 32 element plot).

c. Zero bias resistance derived from Fig. 2 (Figure 5 shows a 32 x 32 element plot using the sensitive areas of the diodes(5)).

d. Responsivity using 300K and 394K black bodies (Fig 6 shows a 32 x 32 element plot).

e. Spectral response (Fig. 7 shows a 5 x 5 element sample taken from a 32 x 32 plot) in this particular case showing an average cut-off wavelength of 11.4μm. Relative response per watt is plotted versus wavelength.

The detector noise can be calculated from the short circuit photocurrent and the zero bias resistance

$$i_n^2 = \frac{4kT}{Ro} + 2qI \ (A^2/Hz)$$

Based on the above measurements the D* (λp, 2π, 500K) of each detector can be calculated (Fig. 8).

It can be seen from Figures 2-8 that some form of structure exists in the array. This clearly manifests itself in increased short circuit photocurrent and reduced zero bias resistance. The array shown was chosen to illustrate the structure which can be seen radiating from a point just below the centre of the array. This type of structure has been reported before, particularly good examples are shown in (4). The structure results in low resistance diodes and correlates well with low angle grain boundaries in the CMT observed in the scanning electron microscope. This structure is of limited importance in linear arrays since the starting material may be chosen to be relatively free of defects. However, as the area involved in 2D arrays increases, this becomes more difficult. Except in the most serious cases the effects of this structure on the image can be removed by signal conditioning electronics.

In order to give an easier appreciation of the current status of the LSA arrays a typical image is shown in Fig. 9. This image was produced after correction for non-uniformities and consists of two 32 x 32 images taken with the LSA and joined. The total losses in the window and f/1 lens were about 40% (ie τ = 0.6). The measured MRTD using a calibrated thermal target is 0.15K.

Continued progress in materials preparation and diode fabrication has reduced the struccurrent arrays with much reduced structure. Both short circuit photocurrent and zero bias resistance are shown.

Random Access Line Sampled Arrays (RALSA)

If the shift register in Fig. 1 is replaced by a decoder the line sampled array can be made random access. This allows any part or parts of the array to be addressed independently of the rest. The information from these selected detectors can be read more frequently. As a consequence the sensitivity of the randomly addressed array is increased by $(N/R)^{\frac{1}{2}}$, where N is the number of IR detectors in a column and R is the total number of IR detectors that are randomly addressed in the column direction. For example if 8 columns are selected from a 32 x 32 array a factor of x2 increase in sensitivity is achieved. This facility may be used to selectively enhance parts of the image on a frame to frame basis.

Focal Plane Multiplexing

At present both LSA and RALSA require one row of leads to be taken through the dewar interface. For a 64 x 64 array this results in 64 signal leads plus 19 addressing and power supply leads crossing the dewar interface. Some systems would prefer this number to be reduced. Depending on the requirements of dewar design and heat loading the amplifiers may be placed outside the dewar, inside the dewar at intermediate temperatures or on the focal plane at 77K. By fabricating silicon amplifying integrators on the focal plane at cryogenic or intermediate temperatures the outputs from the IR array may be multiplexed to one signal line that crosses the dewar interface. In order to achieve this, small low power, low noise amplifiers operating at or above 77K are needed. These are currently being researched. The requirements for low current noise, low 1/f noise, low input offset and bias current dictate that a J.F.E.T input circuit should be used.

The main problem is the increase in transistor 1/f noise at 77K. These devices may be used directly as integrators or as current preamplifiers followed by integrators.

In either case the multiplexer can include sample and hold circuits to allow signal integration and read-out to occur simultaneously.

Uniformity Correction Electronics

A major problem with all infrared arrays that are directly coupled to the scene is that of achieving sufficient uniformity to avoid excessive fixed pattern noise. It is unrealistic to expect the required uniformity, which is about 0.1%, to be achieved with existing focal planes. It is doubtful if focal planes will ever achieve this degree of perfection. Uniformity correction electronics are therefore required. Using the coordinate addressed type of array described here, the major non-uniformity is due to the IR diode. Unlike the CCD approach, there is very little non-uniformity due to the interaction between the IR diode and the read-out electronics (1). Hence the arrays described in this paper require only a simple correction process.

Because of the low contrast of the infrared scene and the non-uniformity of infrared provide sufficient dynamic range to reduce the fixed pattern noise to acceptable levels.

In the system employing integrators and sample and hold circuits (Fig. 11), the serial signal from the multiplexer has a dc pedestal subtracted from it.

It is then converted to a 12 bit digital signal. In this laboratory demonstration system, timing and arithmetic of the correction process is handled by a 16 bit microprocessor.

The signal conditioning system performs background subtraction and division operations on the input data using pairs of factors for each array element. This results in a corrected 8 bit video output, which in this case is displayed on a TV monitor, but which would normally pass directly to signal processing electronics. The appropriate correction factors are generated in an initial setting-up phase in which the array is exposed sequentially to uniform cold and warm targets. The resulting 12 bit numbers are stored in pairs in an area of random access memory.

This system demonstrates the practicability of such a correction scheme, but is limited in speed by the performance of the microprocessor used. Dedicated circuitry should permit frame rates of several hundred Hertz to be achieved.

Some idea of the degree to which the signal correction electronics is effective can be seen by comparing uncorrected and corrected images. Figure 12 shows an image before correction and Fig. 9 after. It can be seen that very substantial improvement is achieved with relatively simple correction electronics, made from commercially available parts.

Conclusion

A relatively simple and cheap way of achieving electronically scanned arrays in the 8-14μm band has been demonstrated. The facility of random access permits flexible interactions between the signal processing electronics and the detector array.

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