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10-16 um Broadband 640x512 GaAs/AlGaAs Quantum Well Infrared Photodetector (QWIP) Focal Plane Array

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1. Introduction

In recent years, quantum well infrared photodetectors (QWIPs) have shown very good imaging performance at high-background conditions using large area highly uniform focal plane arrays (FPAs) [1]. Fabricated entirely from large bandgap materials which are easy to grow and process, it is now possible to obtain large uniform FPAs of QWIPs tuned to detect light at wavelengths from 6 to 25 μm in the GaAs/Al_xGa_{1-x} As material system. Unlike the responsivity spectrums of intrinsic infrared detectors, the responsivity spectrums of QWIPs are much narrower and sharper due to their resonance intersubband absorption. However, many applications require FPAs with broadband photoresponse. This paper describes the first demonstration of broadband QWIP focal plane array.

2. Broadband QWIP

Broadband QWIP device structure is designed by repeating a unit of several quantum wells with slightly different parameters such as well width and barrier height [2]. The positions of ground and excited states of the quantum well are determined by the quantum well width (L_w) and the barrier height , i.e. the Al mole fraction (x) of the barrier. Since each single set of parameters for a bound-to-quasibound quantum well corresponds to a spectral band pass of about 1.5 μm, three different sets of values are sufficient to cover a 10-16 μm spectral region. The multi-quantum-well (MQW) structure consists of many periods of these three-quantum-well units separated by thick barriers. The device structure reported here involved 33 repeated layers of GaAs three-quantum-well units separated by $L_B \sim$ 575 Å thick $Al_xGa_{1-x}As$ barriers. The well thickness of the quantum wells of three-quantum-well units are designed to respond at peak wavelengths around 13, 14, and 15μm respectively. These wells are separated by $L_u \sim 75$ Å thick $Al_xGa_{1-x}As$ barriers. The Al mole fraction (x) of barriers throughout the structure was chosen such that the $\lambda_p = 13$ μm quantum well operates under bound-to-quasibound conditions. The excited state energy level broadening has been further enhanced due to the overlap of the wavefunctions associated with excited states of quantum wells separated by thin barriers. Energy band calculations based on a two band model show excited state energy levels spreading about 28 meV. The sample was grown on a semi-insulating 3-inch GaAs substrate by molecular beam epitaxy.

In Fig. 1, responsivity curve at $V_B = -2.5$ V bias voltage shows broadening of the spectral response up to $\Delta\lambda \sim 5.5$ μm, i.e. the full width at half maximum from 10.5 - 16μm. This broadening $\Delta\lambda/\lambda_p \sim 42$ % is about a 400 % increase compared to a typical bound-to-quasibound QWIP [2].

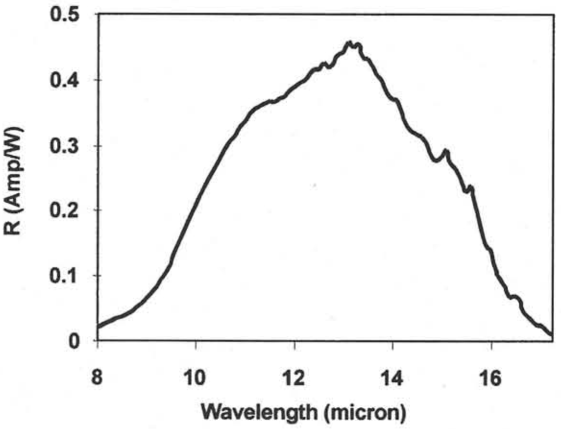

Fig. 1. Responsivity spectrum of a broadband QWIP test structure at temperature T = 55 K. The spectral response peak is at 13.5 μm and the long wavelength cutoff is at 15.4 μm

3. 640x512 Broadband QWIP Focal Plane Array

After the light coupling grating array was defined by the lithography and dry etching, the photoconductive QWIPs of the 640x512 FPAs were fabricated by dry etching through

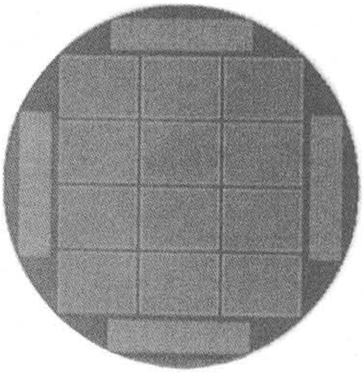

Fig. 2. Twelve 640x512 QWIP focal plane arrays on a 3 in. GaAs wafer.

the photosensitive GaAs/$Al_xGa_{1-x}As$ MQW layers into the 0.5 µm thick doped GaAs bottom contact layer. The pitch of the FPA is 25 µm and the actual pixel size is 23x23 μm^2. Figure 3 shows the experimentally measured Noise equivalent temperature difference (NEΔT) histogram of the FPA at an operating temperature of T = 35 K, bias $V_B = -2.5$ V at 300 K background with f/2 optics and the mean value is 55 mK. The peak quantum efficiency of the FPA was 9.5%.

4. Imagery with Broadband Array

A 640X512 QWIP FPA hybrid was mounted onto a 84-pin lead-less chip carrier and installed into a laboratory dewar which is cooled by liquid neon to demonstrate a LWIR imaging camera (FPA was cooled to 35K). Video images were taken at a frame rate of 15 Hz at temperatures as high as T = 35 K). Figure 4 shows a frame of video image taken with this 10-15.4 mm 640x512 broadband QWIP imager.

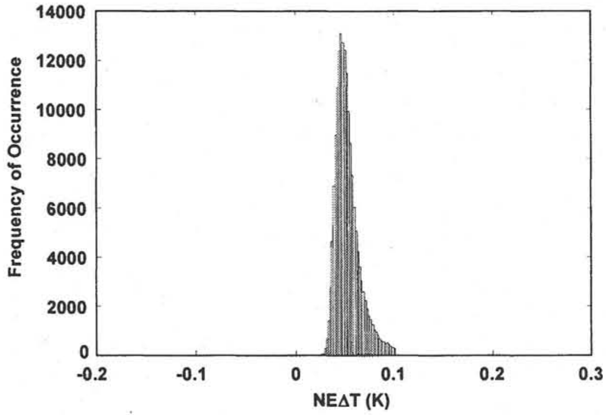

Fig. 3. NEΔT histogram of the 327,680 pixels of the 640 x 512 array showing a high uniformity of the FPA. The uncorrected non-uniformity (= standard deviation/mean) of this unoptimized FPA is only 6.3% including 1% non-uniformity of ROC and 1.4% non-uniformity due to the cold-stop not being able to give the same field of view to all the pixels in the FPA.

5. Conclusion

In summary, 10-16 µm cutoff large format broadband QWIP FPA has been demonstrated. The size of the FPA is 640x512 and its pixel pitch is 25 microns. The highest operating temperature of the FPA is 45K, and it was determined by the charge storage capacity of the readout multiplexer used in this demonstration. Excellent imagery, with a noise equivalent differential temperature (NEΔT) of 55 mK has been achieved.

Acknowledgement

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References

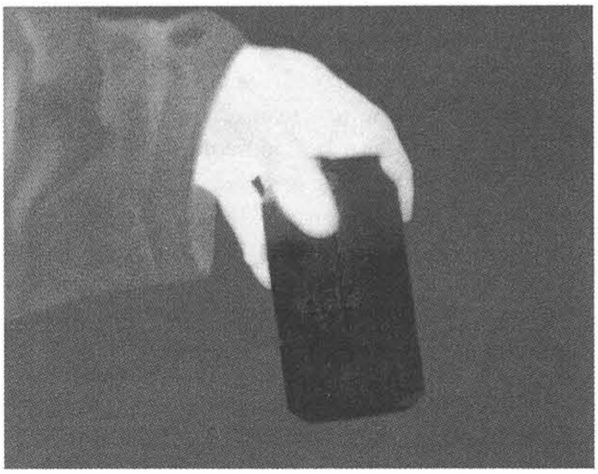

Fig. 4. This picture shows a frame of video image taken with this 10-15.4 mm 640x512 broadband QWIP imager. This image shows the liquide level of the soda can and some finger prints on the can.

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2. S. V. Bandara, S. D. Gunapala, J. K. Liu, E. M. Luong, J. M. Mumolo, W. Hong, D. K. Sengupta, and M. J. McKelvey, Appl. Phys. Lett. **72**, 2427 (1998).