Performance of 10.5μm Quantum Well Infrared Photodetector for Astronomical applications

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Abstract. In this paper we present the optical performance of an optimized 10.5 μm Quantum Well Infrared Photodetector (QWIP) designed for astronomical purpose. The device consists of 30 GaAs well superlattice embedded between AlGaAs barriers. The device shows a measured detectivity 6.8 x 10^9 cm-Hz$^{1/2}$/Watt a diminished dark current 6.08x10^{-5} ampere at 180K at 2.1 V.

1 Introduction

Photoemission due to intersubband transition is the basic principle of operation for QWIP detection. Based on this fact several QWIP designs have been proposed for wavelength range of 8.0 - 12.0 μm [1-4]. The 10.5 μm infrared detector has many important applications for astronomical, medical and surveillance requirements including weather forecasting.

The GaAs layer sandwiched between two $Al_xGa_{(1-x)}As$ layers gives rise to an offset in the band diagram and hence the quantum well. A preliminary design was reported earlier [5] which was further optimized for its better performance. A detailed work on design and development is presented in the the thesis entitled, design and development of 10.5μm Quantum well Infrared Photodetector for Astronomical applications(6). Here the optical performance of the so developed device is presented. The achieved growth parameters of the QWIP device are shown in Table1.

Table 1: Achieved device parameters

L_w=83.556 Å
x= 0.3717.
L_b=553.685 Å
n=0.7 x 10^{18} atoms-cm^{-3}

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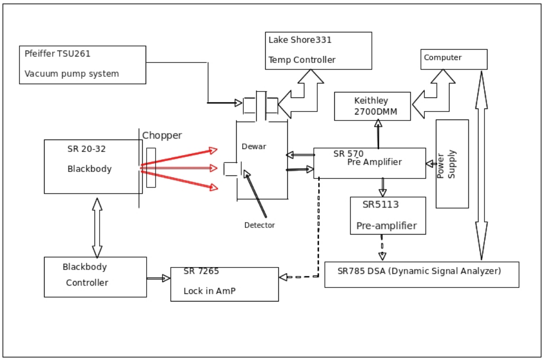

Fig. 1: Block diagram of experimenatal setup for Noise and other performance measurement

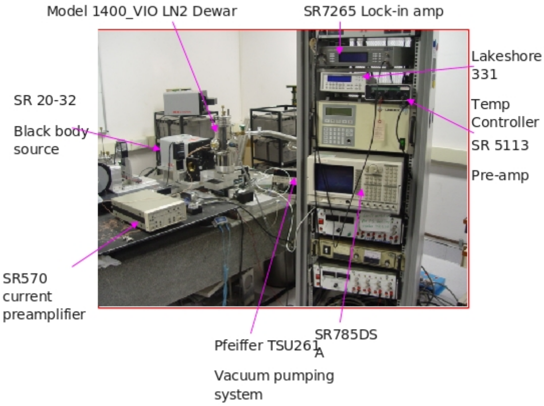

Fig. 2: Optical measurement setup used at SAC Ahmadabad

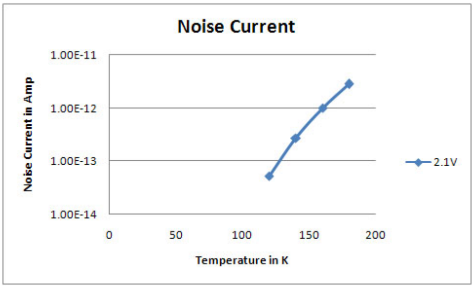

Fig. 3: Noise Current

2 Optical performance and evaluation

QWIP device does not absorb radiations that are normal to the surface unless the infra red radiations have an electric field component normal to the layers of super lattice , i.e., in the device growth direction. Hence 45^0 edge facet was given to QWIP device to enhance optical coupling. The Packaged device was mounted on the cold finger of Cryo Industries Dewar and 28 AWG Enamel coated Cu wires were soldered directly on the LCC packaged pins to take connections to the Dewar pins. To evacuate the Dewar a PFEIFFER TSU261 vacuum system was used The required temperature was maintained by the Lake Shore 331 temperature controller. QWIP optical measurements were done at the Space Applications Centre, Ahmadabad. Following is the performance characteristics of the device.

2.1 Noise current measurement

Noise is termed as the electrical output voltage incoherent with the input signal radiation power measured without radiation incident upon the detector. Dark noise measurements were carried out with the Dewar window closed with Al metal cap and the device was covered with Aluminium foil. Current output from the device was converted into voltage using SR 570 preamplifier. The output was taken to Dynamic Signal analyzer (DSA) which provides noise density at different frequencies. Noise current spectrum for different pixel sizes were carried out at different bias voltages (-5 V to +5 V). The schematic diagram and the picture of the experimental setup are shown in Figure 1 & 2. The measured noise current for temperatures from 120K to 180K at 2.1 V are plotted in Figure 3.

2.2 Responsivity measurement

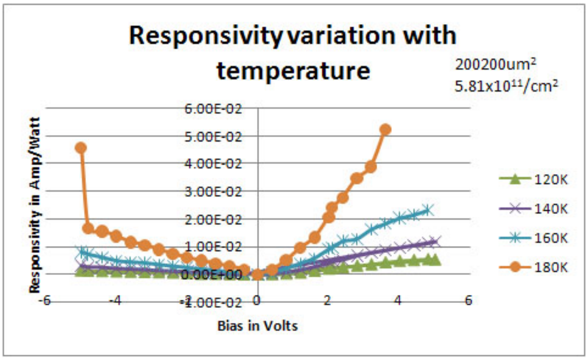

Fig. 4: Responsivity

Responsivity of the detector is the ratio of the signal output to the incident power. The Responsivity measurement was done for 200x200μ m^2 with a dopant concentration 5.81x10^{11} cm^{-2}.

Responsivity of these detectors were measured using a 700^{0}C Black Body source SR 20−32. Chopper frequency was maintained at 3 Hz.The detectors were illuminated through a 45^0 polished facet to obtain responsivity at different bias voltages. Figure 2 shows the responsivity Vs applied voltage

For this 10.5 μm device, the responsivity increases with applied bias and becomes saturated at higher applied bias. The device has shown the highest responsivity as 5.24x10^{-2} Amp/Watt at 3.6 Volt at optimum temperature 180K,for 200x200μ m^2 device area. Figure 4 shows the responsivity versus bias volatage.

2.3 Detectivity measurement

Detectivity is basically the signal to noise ratio of a radiation detector normalized to unit area and operating bandwidth of the detector. Detectivity was calculated from the measured responsivity and noise of the detector for both 200x200μ m^2 with doping density 5.81x10^{11}cm^{-2}.

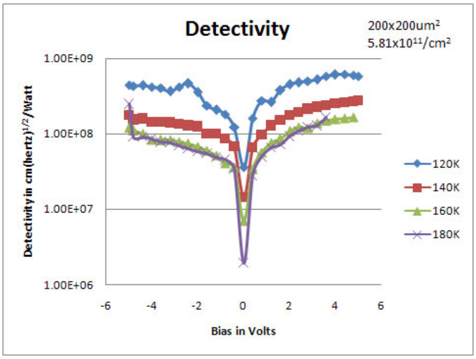

Fig. 5: Detectivity

Figure 5 shows detectivity versus varying voltage for 200x200μm^2 pixel device with dopping density 5.81x10^{11}cm^{-2} .

2.4 Spectral responsivity

To measure spectral responsivity, the detector was illuminated through 45^0 polished facet using INSAT 3D IR filters. Three filters were used in the Middle wave infrared (MWIR) region and one filter in the Long wave infrared region(LWIR). The responsivity measurements were well stabilized at the sample temperature

180K for the 1000x1000μm^2 device. Figure 6 shows the normallized spectral responsivity experimental values against the theoretical expected performance as per the design parameters.

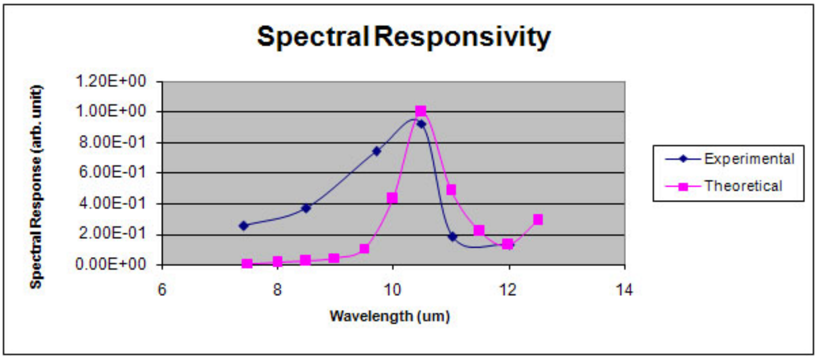

Fig. 6: Spectral Responsivity

Normalization was done according to the flux of the spectral transimission of these filters. Extrapolating and suitable fitting of the experimental values, the spectral responsivity was found to be peaking at 10.45 μm. The normalized value of responsivity is 0.95 against the theoretical value of unity. The FWHM lies between 9.2 μm to 11.4 μm

Table 2: Experimental and theoretical values- a comparison for 1000x1000μm^2

At 180 K	Theoretical	Experimental
Dark Current (in Amp)	1.09x10^{-5}	6.08x10^{-5}
Noise Current (in Amp)	1.35x10^{-12}	4.84x10^{-12}
Detectivity cm-Hz$^{1/2}$/Watt	2.26x10^{10}	6.8x10^{9}

3 Conclusion

The device shows a measured detectivity 6.8 x 10^9 cm-Hz$^{1/2}$/Watt a diminished dark current 6.08x10^{-5} Ampere at 180K at 2.1 V for a 1000x1000μm^2 device.Certain packaging defects and slightly imperfect optical coupling are some of the short comings in achieving the best results. Nevertheless the device is a promising one and suitable for astronomical applications.

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References

1. Fabio Durante P. Alves, G. Karunasiri, N. Hanson, M. Byloos, H. C. Liu, A.Bezinger, M. Buchanan, Infrared Physics & Technology, **50** (2007) .
2. M. Jhabvala, K. K. Choi, C. Monroy, A. La, Infrared Physics & Technology 50 (2007)234-239
3. N. Cohen, R. Gardi, G. Sarusi, A. Saar, M. Byloos, A. Bezinger, A. J. SpringThorpe, H. C. Liu, Infrared Physics & Technology 50 (2007) 253-259
4. H. C. Liu, D. Goodchild, M. Byloos, M. Buchanan, Z. R. Wasilewski, J. A. Gupta, A. J. Spring Thorpe, G. C. Aers, Infrared Physics & Technology**50** (2007) 171-176
5. Celine Joseph, Brijesh Tripathi, A. K. Saxena, Ratna Sircar, International Conference on Sensors and Related Networks (SENNET07), VIT University, Vellore, India
6. Celine Joseph,Design and Development of 10.5μm Quantum Well Infrared Photodetector for Astronomical Applications, manuscript of the thesis, 2011.