

Detection of Optical Single Photon with STJ Device in RIKEN

S. Shiki(1), H. Sato(1), Y. Takizawa(1), T. Taino(2), C. Otani(3), and H.M. Shimizu(1)

(1)Image and Information Division, the Institute of Physical and Chemical Research (RIKEN)

(2)Dept. of Electrical and Electronic Systems, Saitama Univ.

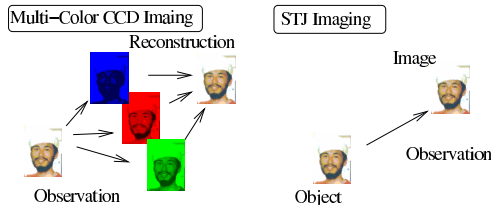
(3)Kawase Initiative Research Unit, the Institute of Physical and Chemical Research (RIKEN)

Abstract

The objective of our study is to construct the realtime multi-band imaging system at optical wavelengths with superconducting tunnel junction (STJ) device. We have fabricated Nb/Al/AlO_x/Al/Nb STJ detector, and succeeded to detect optical single photon. High quality STJ detector with a thin tunnel barrier was fabricated in the fabrication system at RIKEN. The STJ detector was operated at 0.35K with ³He cryostat. The normal resistance of the STJ was around 2×10^{-6} ohm square centimeter. The ratio of normal resistance and dynamic resistance (R_n/R_d) at 0.2mV was about 10^4 [-5]. The STJ detector was illuminated by optical photons by pulsed source of blue and UV LED (470nm, 405nm and 370nm) through optical window. Response of STJ detector was integrated with charge sensitive amplifier (Ortec 142C). Output of CSA was shaped with shaping amplifier (Ortec 572). Energy resolution for 2.64eV photon (470nm) was 1.0eV after subtracting the effect of electrical noise of 1.0eV. The good linearity of the pulse height obtained from different wavelength was successfully observed.

Introduction

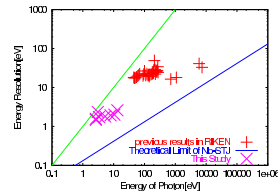
STJ is only detector which is energy dispersive with high count rate. Goal of this study is realtime spectroscopic camera for astronomical observation.



Problem: Signal of lower energy photon could not detected because of read-out noise.

What we studied to achieve good S/N ratio

1. fabricate a STJ device with thin insulator layer to increase probability of back tunneling
2. fabricate a STJ device with low leakage current to reduce shot noise
3. try various attempt to reduce electrical noise



Experiment(1) Response of STJ detector for Pulsed LED

STJ detector was illuminated by fast pulsed blue LED (Fig.1, Fig.2)
→ It is expected that responses of STJ detector are proportional to the number of absorbed photon.

Results

- Single optical photon was clearly detected. (Fig.3a,b)
- Single photon peak and multi-photon peak were clearly seen. (Fig.4)
- Good linearity was observed. (Fig.5)
- Energy resolution was 1.0eV (FWHM) for a 2.64eV (470nm) photon. (Fig.6)

Fig.1. Structure of STJ device

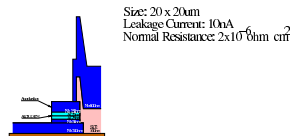


Fig.2. Setup of the Experiment

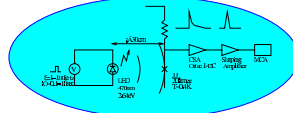


Fig.4. Pulse Height Distribution

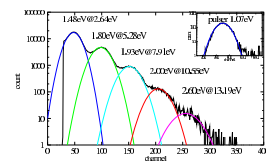


Fig.5. Linearity between peak channel and energy

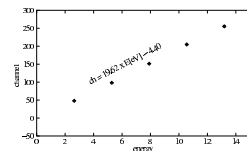


Fig.6. Energy Resolution

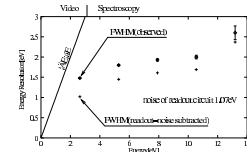


Fig.3a. Observed Response of CSA

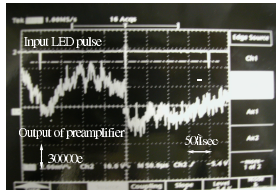
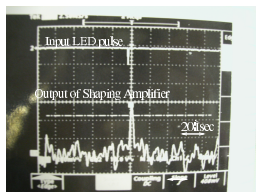


Fig.3b. Observed Response of Shaping Amplifier



Experiment(2) Response of STJ detector for Three LED

STJ detector was illuminated by one of three LEDs. (Fig.7, Fig.8)

→ It is expected that the response of STJ detector is proportional to the energy of LED photon.

Results

- The response for single optical photon was detected.
- Pulse height distributions of three LED show clear shift of peak channel. (Fig.9)
- The peak channels show good linearity. (Fig.10)

Fig.7. Structure of STJ device

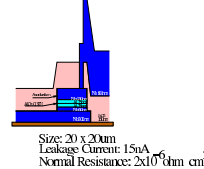


Fig.8. Setup of the experiment

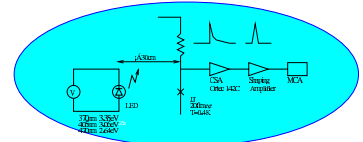


Fig.9. Pulse height distribution

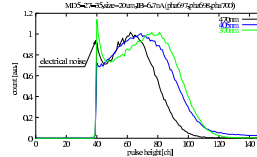
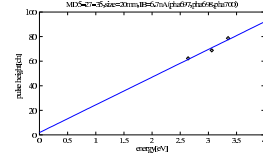


Fig.10. Linearity



Conclusion

Results

- We successfully detected single optical photon with Nb-based STJ.
- Energy resolution for 2.64eV photon was 1.0eV
- Good linearity was observed.

Future Work

- Install single element STJ on small telescope
- Fabricate STJ Camera (10x10 array)
- Develop fabrication technique
- Try Ta-STJ