Development of readout electronics for SIS photon counting detectors

Hiroshi Matsuo[1,2], Hajime Ezawa[1,2], Ryohei Noji[3], Saho Kawahara[3]

Photon counting detectors for terahertz frequencies will open a new frontier in terahertz astronomy by measuring photon statistics and applying to intensity interferometry. To count large number of terahertz photons, we work on SIS (or STJ) photon detectors. In this presentation we present fast readout cryogenic electronics with GHz bandwidth made of semiconductor circuits for the SIS photon detectors.

Single terahertz photon creates single quasi-particle current through SIS junction by photon assisted tunneling. We have achieved the SIS leakage current of the order of pA, whose photovoltaic signal can be readout by cryogenic FETs with low gate leakage and capacitance. We selected two types of Gallium Arsenide FETs with p-n junction gates (GaAs-JFET and Junction pHEMT) for this purpose.

We have evaluated both types of FETs with various gate sizes at cryogenic temperature at 4 K, most of which show good I-V characteristics without serious anomalies such as kink or hysteresis. Transconductances of these FETs are similar or improved at cryogenic temperatures compared to the ones at 300 K. The gate leakage of GaAs-JFET have been measured as a function of operational temperature, which shows the gate leakage are lower than 100 fA at temperature less than 100 K. The gate leakage of Junction pHEMT (JPHEMT) shows similar trend except that the gate leakage shows large excess current at drain voltages larger than 2 V, and we must limit drain voltage less than 1.5 V.

Figure 1 shows an example of I-V characteristics of two types of FETs measured at 4.2 K. Compared to GaAs-JFET, JPHEMT apparently shows better performance with larger transconductance and drain resistance which are appropriate for our purpose. Slight anomalies are observed at larger drain voltage for JPHEMT, which corresponds to the anomalous gate leakage described above.

We plan to use two-stage source followers, one at 0.8 K and another at 4 K, to decrease output impedance down to 50 Ohm to feed to SiGe low noise amplifiers. The power dissipation is limited to 100 μW at 0.8 K, and the first stage source follower decreased the output impedance to an order of kΩ followed by the second source follower to achieve lower output impedance.

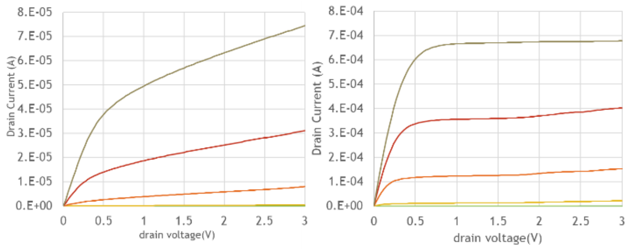

Fig. 1. I-V characteristics of GaAs-JFET and Junction pHEMT.

For detection of single terahertz photon, low gate capacitance less than 10 fF is required to obtain signal above the FETs' voltage noise. The evaluation of the gate capacitance is also underway.

The detector design themselves must be optimized for the low capacitance readout electronics. Since previous design uses a relatively large choke filter and bonding pads. Capacitance of all these structures should be optimized, which is under study and will be discussed in the presentation.

References

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[1] National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan.

[2] Department of Astronomical Science, The Graduate University for Advanced Studies, SOKENDAI, Tokyo 181-8588, Japan.

[3] Toho University, Funabashi, Chiba 274-8510, Japan.

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