Here begins our new MIRAI
MOONSHOT RESEARCH & DEVELOPMENT PROGRAM

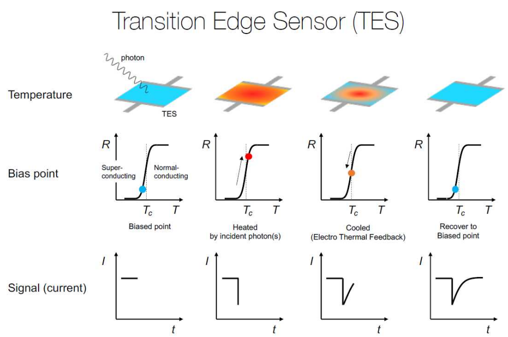
R&D Theme

Research and development on superconducting photon number discriminator

Progress until FY2022

1. Outline of the project

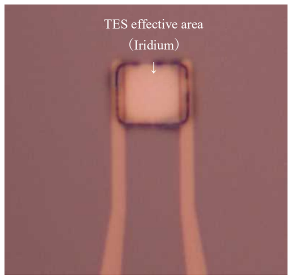
Quantum entanglement is generated by squeezed light and a beam splitter, and GKP qubits are generated by detecting a predetermined number of photons. The GKP qubit appears at the moment when a predetermined number of photons is detected. We are developing a high-speed photon number resolving detector for GHz clock optical quantum computers. A superconducting transition edge sensor (TES) in the communication wavelength band can resolve the number of photons. TES is operated at the superconducting transition edge, by setting a proper operation temperature.

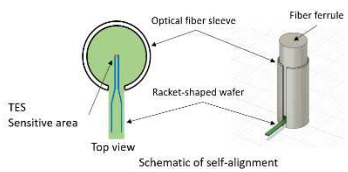


The temperature rise triggered by the absorption of near-infrared incident photons is read out as a current drop which corresponds to an absorbed energy. In order to realize high-speed TES operation, we will fabricate a device that minimizes the size of the sensor so that the temperature rise can propagate immediately over the entire sensor and the current change occurs instantaneously. The sensor size is to be minimized, thus the corresponding heat capacity is minimized, which contributes to the higher temperature rise. Therefore, higher S/N ratio, faster signal, and better identification of the number of photons are expected.

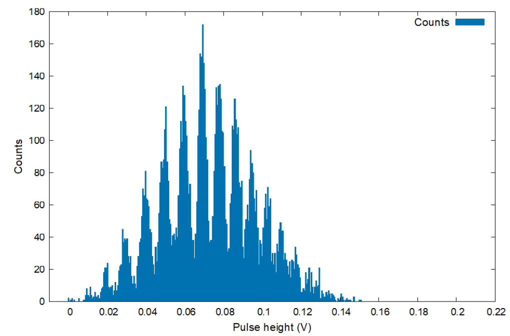
2. Outcome so far

The lower left figure shows a photograph of the fabricated 8 μm square TES. The TES is made on a silicon substrate, processed to have an outer shape that matches the size of the optical component, and is self-aligned so that it can be aligned with the optical fiber. It was confirmed that the fabricated TES showed a rise time of 16.2 ns and a corresponding bandwidth of ~20 MHz.





The TES shows a current change whose magnitude is proportional to the absorbed energy of incident photons. When we operate TES with monoenergetic photons, discrete energies are deposited on the sensor according to the number of photons. Therefore, an absorbed energy histogram shows peaks corresponding to the number of incident photons. The measured histogram below shows that the number of near-infrared photons can be identified and resolved with our fabricated device.



3. Future plans

According to our simulation calculation for tiny TES, the rise time of signal is estimated to be less than 300 ps, therefore, a signal bandwidth of GHz is expected. Further miniaturization of the device is planned. Precise structure is considered by employing Focused Ion Beam (FIB), which enables arbitrarily fine structures in the sensor design such as the use of array structures to satisfy the effective area requirement. Furthermore, the replacement of the superconducting quantum interference device (SQUID) is planned since the bandwidth of the SQUID is limited.

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