Microwave SQUID multiplexer for readout of optical TES array

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Introduction

✓ Development of photon counting device with optical transition edge sensor (TES) for biological imaging.
✓ Reduce imaging time
  \rightarrow Increase the number of TESs
  \rightarrow Multiplex readout
✓ Multiplexing method
  1. Time Division Multiplexing (TDM)
  2. Code Division Multiplexing (CDM)
    - Slow Switching (160ns)
  3. Frequency Division Multiplexing (FDM)
    - Low modulation frequency (5 MHz)
  4. Microwave SQUID Multiplexer (MW-Mux)
✓ MW-Mux has a FDM carrier wave of gigahertz. It can increase the bandwidth

Result & Discussion

✓ Voltage-Current characteristics measured by MW-Mux reproduced that of dc-SQUID.

✓ We successfully measured a pulse from an optical TES and resolve number of photons.
  • Responses of the TES to photons

  \begin{enumerate}
    \item Output signal from optical TES. Pulses were measured according to repetition frequency of pulse laser.
    \item Average pulse.
      Rise time constant: 100 ns. Fall time constant: 156 ns.
  \end{enumerate}

  \begin{equation}
  \Delta E_I = \sqrt{\Delta E_I^2 + \Delta E_R^2 + \Delta E_S^2} = 0.27^2 + 0.07^2 + 0.21^2
  \end{equation}

  \( \Delta E_I \): Intrinsic energy resolution
  \( \Delta E_R \): Readout noise = 10 pA/\sqrt{Hz}
  \( \Delta E_S \): Coarse sampling effect

  • What’s the coarse sampling effect
    - Sampling time >> Rise/Fall time constant \rightarrow sparse sampling
    - the pulse height cannot be sampled accurately.

Setup

✓ Cryogenic module (100mK)

  ① Optical TES
    - Ti/Au (20/10 nm) bilayer TES
    - Tc = 0.3 K
    - Self-aligning fiber-to-detector coupling (used only right TES)
  ② MW-Mux chip
    - 8 resonators
    - fr: 4.901620 GHz
    - Bandwidth: 2 MHz
    - Q: 2400
  ③ Bias chip
  ④ PCB
  ⑤ CPW wave-guide

✓ Pulse laser
  - Repetition frequency: 10 kHz
  - Energy: 0.8 eV / photon (wavelength: 1550 nm)