



Multi-pixel Series SNSPD Interconnecting A High Input Impedance Cryogenic RF Integrated Circuit

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Abstract

To improve the dynamic range of SNSPD series nanowire array and distinguish between n & $n+1$ photon response state of multi-pixel series nanowire detector, We designed and measured a cryogenic RF amplifiers with high input impedance for interconnecting multi-pixel series SNSPD array.

Introduction

- Series nanowire detectors (SNDs)^[1] have the capability of photon-number resolving and the potential of photon-positioning. But there is a current redistribution in the SND interconnecting with typical 50Ω input impedance cryogenic circuit, leading to trouble of discriminating n & $n+1$ photon response state and a constraint of the dynamic range of series nanowire array^[2]. Fig. 1 shows the response voltage statistical graph of a three-pixel SND with different resistance, which indicates that conventional readout can't meet the requirement of multi-pixel SNSPD arrays.
- A cryogenic RF amplifiers with high input impedance is a good method to read out series nanowire arrays. Here we introduce a high input impedance RF amplifier interconnecting a typical SNSPD, followed with multi-pixel SNDs.

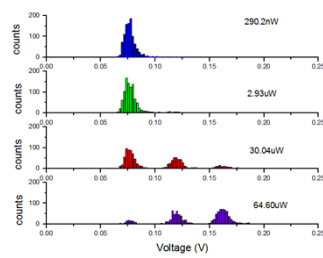


Figure 1. Response distribution of three-pixel SND combined with 50Ω conventional readout

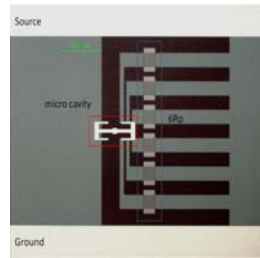


Figure 2. Optical micrograph of the device.

Device

- Fig. 2 shows the optical micrograph of a six-pixel SND we fabricated. The NbN meander is under the central of the cavity with an area of $20\mu\text{m} \times 20\mu\text{m}$.
- Fig. 3 shows two different screen shot captures of a 50GHz sampling oscilloscope with different input light power. The relation between the count rates and light power of different category of pulses was measured.

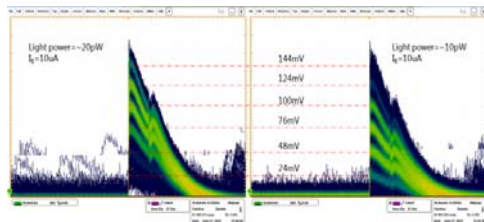


Figure 3. The observation of different photon responses from the 50GHz sampling oscilloscope. The color indicates the density of the pulses.

References

- [1] A. Divochiy et al. "Superconducting nanowire photon number-resolving detector at telecommunication wavelengths", *Nature Photonics*, 2(2008), pp. 302 - 306..
- [2] Jahanmirinejad S et al. "Photon-number resolving detector based on a series array of superconducting nanowires", *Appl. Phys. Lett.* **101** 072602 (2012).

- The critical temperature of the 5nm NbN film was 6.7K. The I_C of the device was about $6\mu\text{A}$. Fig.4 shows a 10% SQE of the SND at 1550 nm and DCR as a function of the bias current. Fig. 5 indicates that the six-pixel SND resolve up to 6 photons well.

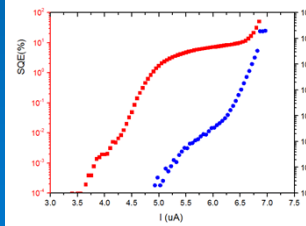


Figure 4. SQE & CR of the device

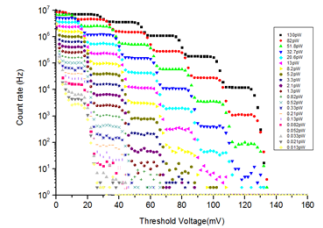


Figure 5. CR followed with the threshold voltage, proving the capability of resolving 6 photons.

Circuit

- Making use of a differential structure RF cryogenic circuit, we interconnect a typical SNSPD and the readout circuit in a normal working state.

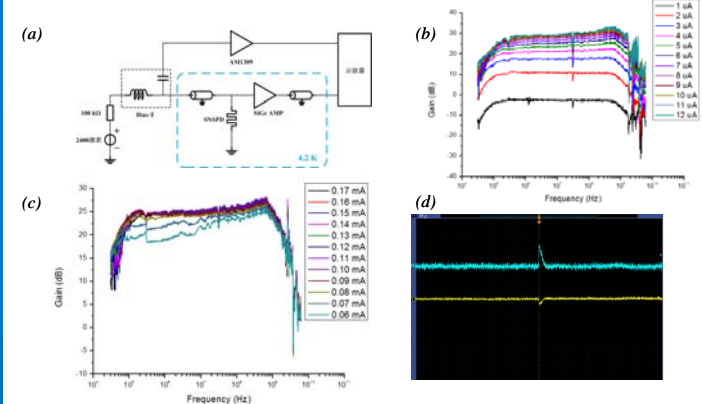


Figure 6. (a) Block diagram of the RF cryogenic circuit with high input impedance interconnecting SNSPD; (b) Gain at 4.2K by regulating the bias current ICS1; (c) Gain at 4.2K by regulating the bias current ICS2; (d) Output voltage pulse interconnecting the RF circuit with SNSPD.

Summary

- The performance of the PNR devices with six-pixel SND fabricated was tested and analyzed, which indicates that the device has the functionality of resolving 6 photons.
- A kind of cryogenic RF amplifiers with high input impedance interconnecting a typical SNSPD was designed and measured in advance preparation for six-pixel SND and multi-pixel series nanowire arrays later.

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