High Efficiency Superconducting Nanowire Single Photon Detector at Wavelength 940 nm

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***Abstract*—Superconducting nanowire single photon detectors with an optical resonant cavity structure are fabricated directly on the single crystal substrate. In order to enhance the photons absorption of incident light and improve system detection efficiency (SDE) efficiently, the structure of SNSPD was designed and optimized using the finite-difference time-domain analysis for different kinds of substrates. The NbN-SNSPDs fabricated on different substrates are measured and compared. The SDE of NbN-SNSPD on MgO substrate reaches 66 % at the wavelength of 940nm at a dark count rate of 100 cps by illuminating from the back of the device through single mode optical fiber.**

I. INTRODUCTION

Superconducting nanowire single photon detectors (SNSPDs[1]) are interesting candidates in several applications such as quantum information[2], quantum key distribution[3], quantum computation and integrated circuit diagnosis, because of their high single photon detection efficiency, low dark count rate and wide spectral responsivity[4].

In this paper, we present a SNSPD working at wavelength 940 nm. Considering the absorption loss of incident light, we selected magnesium oxide, sapphire, strontium titanate as substrates and calculated the photon absorption in the optical resonant cavity which consists of these single crystal substrates and double layers SiO_x. The analysis result indicate that the absorption efficiency of 10-nm-thick NbN-SNSPD is 99% while that of 6-nm-thick NbN-SNSPD is only 90%.

II. EXPERIMENTS AND RESULTS

According to the simulation results, we first fabricated SNSPD on MgO substrate. The dimensions of the optical cavity are as follows: the thickness of top SiO_x is 140 nm and the bottom SiO_x is 150 nm, the thickness of NbN film is 6 nm, the width of nanowire is 100 nm, the filling factor is 50%, and the active area is $10\times10\ \mu m^2$.

In our experiments, SiO_x is deposited by plasma enhanced chemical vapor deposition, NbN film is fabricated by DC magnetron sputtering, and the meander structure of the nanowire is obtained and etched out using electron beam lithography and reactive ion etching respectively.

The packaged device is placed in GM cryocooler, which can provide 2.2 K to meet the needs of measurement. The laser signal reaching the active area is guided by a standard optical fiber, which is connected to a pigtail fiber inside the GM cryocooler. To achieve single photon level, the photon number feed to the single mode fiber is fixed at 10^6 per second by variable attenuator monitored by power meter.

Fig.1 is the I-V characteristic of the SNSPD on MgO measured at 2.2K. The critical current is 8.1μA and current hysteresis is 2.05μA. The dependence of SDE and DCR to normalized bias current is shown in Fig.2. It is clear that the SDE is 66% at a DCR of 100 cps and 46% at a DCR of 1 cps.

The SNSPDs on the other substrates is under fabrication, and by comparing the measurement results, we will get the most suitable substrate for SNSPD working at wavelength 940 nm. And by optimitizing the parameter of cavity and improving the process, higher SDE will be achieved.

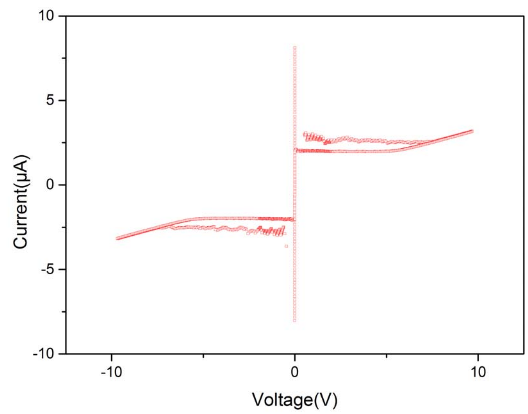

Fig. 1 I-V characteristic of SNSPD measured at 2.2K with critical current 8.1μA and current hysteresis 2.05μA

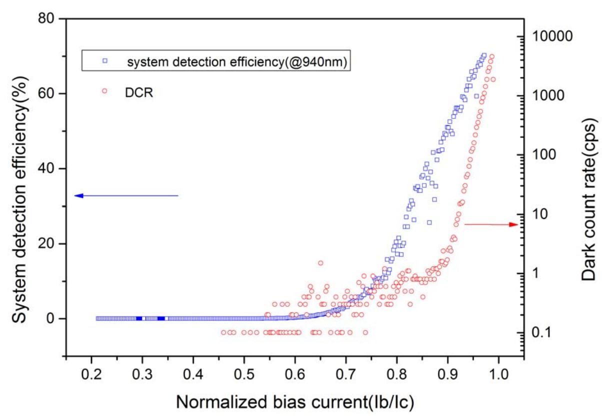

Fig. 2 System detection efficiency and dark count rate versus bias current

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