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Single photon detection in micron scale NbN and α-MoSi superconducting strips

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Abstract. We experimentally demonstrate the single photon detection in straight micrometer-wide NbN and α-MoSi bridges. Width of the bridges is 2 μm, while the wavelength of the photon changes from 408 to 1550 nm and critical current exceeds 50% of the depairing current. Obtained results offer the alternative route for design of detectors without resonator and meander structure and indirectly confirm vortex assisted mechanism of single photon detection.

Until recently the operation of superconducting single photon detectors SSPD [1] was described by the "geometric hot spot model" first presented in Ref. [2] and improved further in subsequent works (a good review is given in Ref. [3]). In the framework of this model it is assumed that the single photon detection occurs only in a superconducting strip with a width comparable to the size of the hot spot, being in the range of 50 to 150 nm. It has led to devices consisting of fairly narrow and very long strips arranged in such a way that they fill a much larger area for good optical coupling. Recently, a more thorough theoretical approach [4] was applied to the problem of photon-detection in a superconductor. It is based on the standard theory of non-equilibrium superconductivity capable of treating processes depending on space and time. It predicts that in samples with a supercurrent up to about 0.7 to 0.8 of the depairing current, and uniform over the cross-section of the strip, the detection efficiency is not dependent on the width of the strip. We have experimentally demonstrated single-photon detection in 5-micron-wide constriction-type bridges made of polycrystalline NbN, using radiation of wavelength ranging from 408 nm to 1550 nm [5].

In this work we obtain the similar results for straight 2-μm-wide and 10-μm-long NbN strips. We measure close to unity internal detection efficiency (Fig. 1) at wavelengths 408 nm and 637 nm in agreement with the theoretical expectations [4]. As an additional check on the generality of this finding we also made wide strips of the amorphous silicide α-

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MoSi. Unlike polycrystalline films, this amorphous material can be brought more easily in the required regime of a uniform superconducting gap and supercurrent. Additionally, amorphous α-MoSi is claimed to be attractive due to its lower critical temperature T_c compared to NbN which allows to obtain larger hot spot (for the same photon energy and film thickness). Experimentally α-MoSi wide bridge demonstrates IDE close to unity at wavelength up to 1 μm (Fig.1 b). We will present the results of the single-photon detection with the emphasis on the straight strips and compare them with the theoretical predictions.

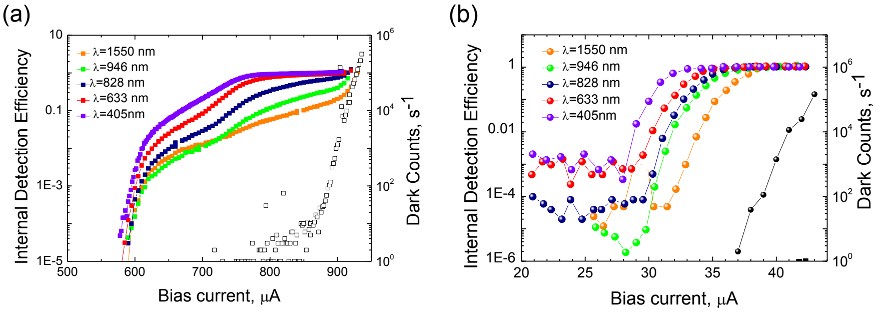

Fig. 1. Internal detection efficiency (detection efficiency normalized to absorption) and dark counts rate of NbN (a) and MoSi (b) samples.

Table 1. Parameters of the studied samples at the temperature T=1.7 K. The thickness of the film d was determined from time of deposition and deposition rate, w, width of the bridge, T_c is the critical temperature determined from the midpoint of the resistive transition, ρ(20K) is resistivity at T=20 K, j_c is critical current density, j_{dep} is the calculated depairing current density at T=1.7 K, using $j_{dep}(0)$ the calculated critical depairing current at $T = 0$ following from Eq.1 and Eq 2 from Ref.[5]

Sample	**d (nm)**	**w (μm)**	**T_c (K)**	**ρ(20K) (μΩ cm)**	**D (cm^2 s^{-1})**	**j_c (A/cm^2)**	**j_{dep} (A/cm^2)**
NbN	5.8	2	8.35	396	0.31	5.3×10^6	7.8×10^6
MoSi	2.8	1	3.1	203	0.19	0.79×10^6	1.7×10^6

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