Atomically thin single-photon detection using few-layer $NbSe_2$

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Superconducting Nanowire Single Photon Detectors (SNSPD) are a crucial building block in the photonic quantum technologies, due to their ability to detect single photons with high efficiency, low dark counts and low timing jitter. Single-photon detection using ultra-thin detectors is especially promising, since the lower the thickness the lower the photon energy required to trigger the superconducting to normal conducting transition. Transition metal dichalcogenides (TMDs) are a class of Van der Waals materials exhibiting a wide spectrum of thickness-dependent optoelectronic properties. Amongst them, Niobium Diselenide ($NbSe_2$) is superconducting down to the three-atom-thick monolayer limit [1]. In addition, it can be processed with standard nanofabrication techniques, where patterned nanowires with 30 nm width have been demonstrated [2]. When light is absorbed in few-layered $NbSe_2$, the superconducting state is perturbed, and an energy dependent response is generated [3]. These properties make $NbSe_2$ a promising candidate for next generation SNSPDs. However, to date no single-photon detection has been reported yet, possibly due to its air sensitivity and the related device fabrication challenges.

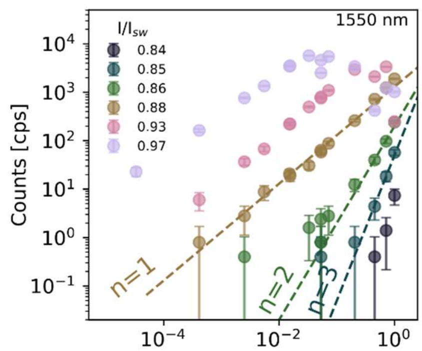

Figure 1 *Countrate vs laser power shows the single-photon sensitivity of the $NbSe_2$ SNSPD*

In this work, we present SNSPDs fabricated from few-layers-thick $NbSe_2$, using exfoliation and transfer to a Si/SiO_2 substrate, encapsulated with hexagonal boron nitride (hBN) to prevent oxidization [4]. The widths of the constriction in the electron beam patterned devices range from 100 nm to 1000 nm. The best performing SNSPDs operated at 1 K, exhibit single-photon sensitivity at 780 nm and 1550 nm as shown in Figure 1, as well as a timing jitter as low as 45 ps. Additionally, the transport characteristics reveal a critical temperature of the fabricated devices up to 6.5 K depending on the number of layers. In the superconductive state, the devices show a finite value of resistance due to non-Ohmic contact barriers with the TMD, which could be mitigated by using an intermediate graphene layer between $NbSe_2$ and the gold contacts.

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