An on-chip photon-counting reconstructive spectrometer with tailored cascaded detector array

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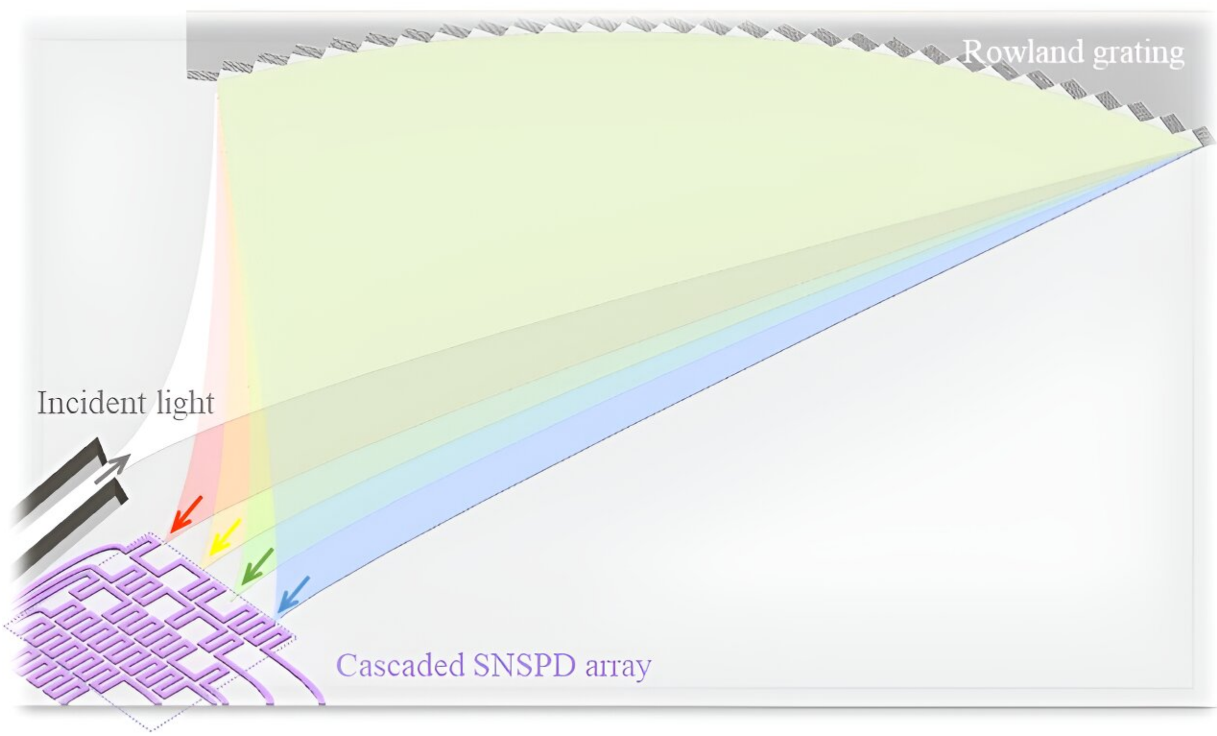

Photon-counting reconstructive spectrometer. Credit: *Advanced Devices & Instrumentation* (2023). DOI: 10.34133/adi.0021

Superconducting nanowire single-photon detectors (SNSPDs) have been widely used in various applications requiring single photon detection thanks to their attractive performances. Since SNSPDs are thin films of serval nanometers in thickness, they are convenient to fabricate on various substrates and combine with other photonic structures.

SNSPDs have been integrated with optical waveguides on several material platforms. The waveguide-integrated SNSPDs have been applied in several applications of quantum photonic circuits (QPCs), supporting some photonic quantum information functions such as the measurement of on-chip quantum interference.

The photon-counting spectrometer for single-photon-level ultra-faint light is another interesting application. Recently, several works on photon-counting spectrometers based on SNSPDs and on-chip micro/nano-photonic structures have also been reported. In these works, the micro/nano-photonic structures modulate the spectral responses of SNSPDs.

However, they also lead to scatter losses and limit the photon utilization of the measurement of single-photon-level ultra-faint light. It is an interesting topic how to realize the SNSPD spectral response modulations without any photon loss.

Prof. Wei Zhang's team from the Electronic Engineering Department at Tsinghua University, cooperating with the team of Prof. Lixing You from the Shanghai Institute of Microsystem and Information Technology (SIMIT, CAS, China), proposed a novel reconstructive photon-counting spectrometer based on the cascaded absorption effect of a SNSPD array.

In this scheme, the photons with different wavelengths are diffracted by a Rowland grating to different locations in the focusing region on the chip. The SNSPD array is across the focusing region. Each SNSPD in the array has a different pattern, which controls the absorption of the superconducting nanowire at different locations.

The work is published in the journal *Advanced Devices & Instrumentation*.

The spectral response of this SNSPD is determined by its pattern and the cascaded absorption effect of the SNSPDs before it. Based on this mechanism, the spectral response of every SNSPD in the array could be designed flexibly, supporting the function of a reconstructive photon-counting spectrometer. In the measurement, all photons would be absorbed in the SNSPD array without any photon loss in principle.

The research team fabricated a prototype device and demonstrated the mechanism of SNSPD spectral response modulation in the proposed scheme, which is based on the cascaded absorption effect of the SNSPD array. The experiment results showed that the prototype device supported the measurement and reconstruction of the light spectrum at a single photon level. The spectral resolution of the measurement is 0.4nm in the wavelength range of 1495–1515 nm.

This work proposed a reconstructive photon-counting spectrometer combining an on-chip Roland grating and a SNSPD array. It can measure and reconstruct the spectrum of single-photon-level faint light with high photon utilization in principle. A prototype device was designed and fabricated to demonstrate the principle of the scheme, showing that the spectral responses of the SNSPDs are determined by their patterns and the cascade absorption effect of the SNSPD array.

The experiment results showed that the prototype device supported the spectral measurement and reconstructions. The spectral resolution is 0.4 nm in the wavelength range of 1495 ~ 1515 nm. This research provides an interesting and promising way to develop a photon-counting spectrometer with high photon utilization.

More information: Jingyuan Zheng et al, An On-Chip Photon-Counting Reconstructive Spectrometer with Tailored Cascaded Detector Array, *Advanced Devices & Instrumentation* (2023). DOI: 10.34133/adi.0021

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