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# 电子学院研制成功光谱感知超导纳米线探测器

具有光谱分辨能力的光探测器在量子光学、天文学和光谱学等中起到至关重要的作用。但是，直接具备光子能量分辨能力的探测器却极为罕见，需要实现对光子能量的线性转换。目前只有少数的几种极低温区的超导探测器，例如转变边沿探测器(TES)、超导隧道结(STJ)和动态电感探测器(KID)，实现了光子能量的分辨，但是依然存在工作温度低、时间分辨率差、探测速度慢等不足。

超导纳米线单光子探测器(SNSPD)是一种光子计数型探测器。在效率、暗计数、速度等方面具备最优的综合性能。但是，**目前的SNSPD并不具备光谱分辨能力。它的输出脉冲幅度一般由偏置电流决定，和入射波长无关。**

南京大学吴培亨院士团队改变传统设计均匀纳米线的思路，将纳米线设计成为宽度渐变结构。通过宽度调控光响应后热阻阻值的大小，再配合微波阻抗匹配读出电路，将阻值变化转化至输出脉冲幅度，在传统计数模式基础上额外增加幅度变量信息。同时，利用渐变纳米线光谱响应沿纳米线方向的分布规律，构建光子能量–幅度的对应关系(probabilistic many-to-many mapping)，再结合现代计算方法，反向求解测量过程，重构光谱。我们在实验上观测到与输入波长相关的脉冲幅度分布。通过采集百余个光子($10^{-5}$ pw)，就能够实现对光波长的鉴别。相比于基于材料能带调控或光谱响应调控的方法，渐变SNSPD提供了一种新型的方案，并能够将SNSPD的应用推广至极弱光下的光谱感知领域。

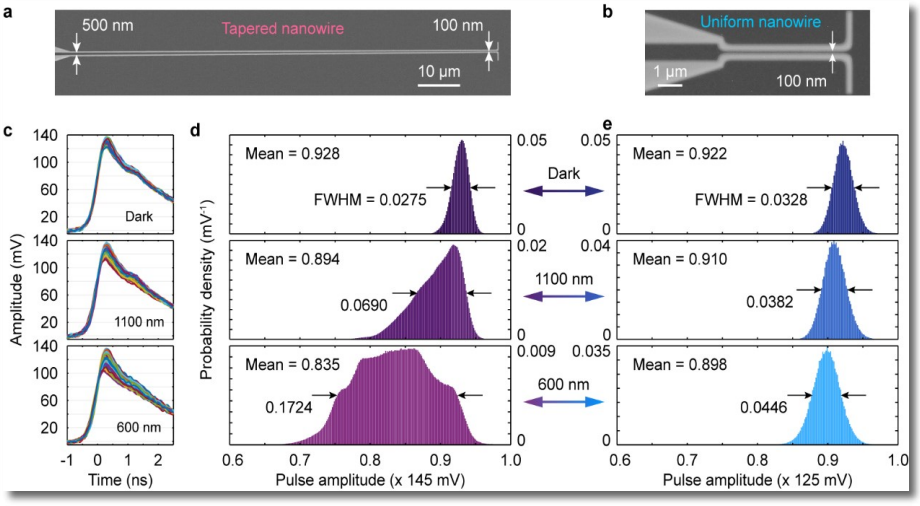
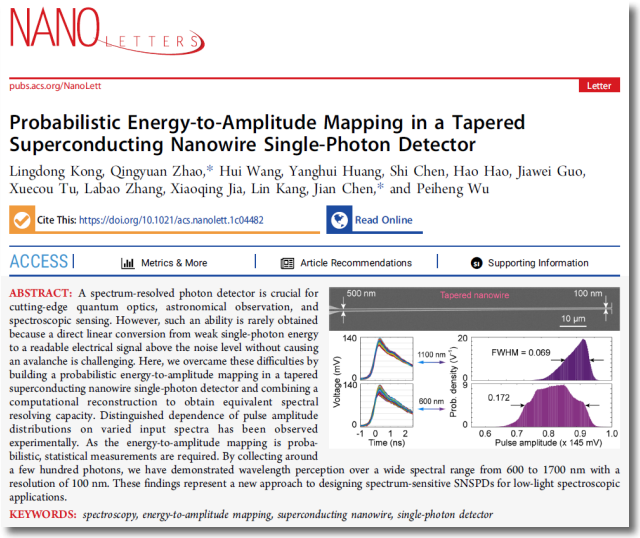



图1 渐变SNSPD独特的脉冲幅度分布

相关研究工作以"Probabilistic energy-to-amplitude mapping in a tapered superconducting nanowire single-photon detector"为题发表在《Nano Letters》上[https://pubs.acs.org/doi/10.1021/acs.nanolett.1c04482]。审稿人指出我们的方法巧妙地将光谱和幅度联系起来"... used a series of tricks to link the input photon spectrum to output pulse amplitude"。并认为我们的结果不光实现了光谱感知功能，同时也可以作为一个很有价值的平台去研究超导纳米线的一些光探测机理，为新型器件的研发奠定基础"The device architecture may serve as a valuable testbed for the fundamental studies of nanowire detectors and may lead to other novel devices."。



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**Probabilistic Energy-to-Amplitude Mapping in a Tapered Superconducting Nanowire Single-Photon Detector**

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**ABSTRACT:** A spectrum-resolved photon detector is crucial for cutting-edge quantum optics, astronomical observation, and spectroscopic sensing. However, such an ability is rarely obtained because a direct linear conversion from weak single-photon energy to a readable electrical signal above the noise level without causing an avalanche is challenging. Here, we overcome these difficulties by building a probabilistic energy-to-amplitude mapping in a tapered superconducting nanowire single-photon detector and combining a computational reconstruction to obtain equivalent spectral resolving capacity. Distinguished dependence of pulse amplitude distributions on varied input spectra has been observed experimentally. As the energy-to-amplitude mapping is probabilistic, statistical measurements are required. By collecting around a few hundred photons, we have demonstrated wavelength perception over a wide spectral range from 600 to 1700 nm with a resolution of 100 nm. These findings represent a new approach to designing spectrum-sensitive SNSPDs for low-light spectroscopic applications.

**KEYWORDS:** *spectroscopy, energy-to-amplitude mapping, superconducting nanowire, single-photon detector*

南京大学电子科学与工程学院博士生孔令东为文章第一作，赵清源教授和陈健教授为论文的通讯作者。涂学凑高工、张蜡宝教授、贾小氢教授和康琳教授协助探测器方面的制备。吴培亨院士对本工作进行深入指导。该项研究得到国家自然科学基金、国家重点研发计划、中央高校等基金项目的资助。此项研究工作还得到海外高层次人才计划（青年），江苏省双创、江苏高校优势学科建设工程，江苏省青蓝工程，江苏省电磁波特征信息调控技术重点实验室、紫金山网络通信与安全实验室的资助。