Direct observation of photon-induced vortices in superconducting films

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The mechanism by which superconductors respond to photon absorption has not yet been fully clarified. A deeper understanding of this process is essential for improving the performance of superconducting devices, including transition edge sensors (TESs) and superconducting single-photon detectors (SSPDs). Although the nucleation of vortex–antivortex pairs (VAPs) is widely believed to underlie the photon detection mechanism, direct observation of their dynamics- crucial for validating this hypothesis- has remained a major experimental challenge [1].
In this work, we directly observe VAP dynamics as quantized voltage signals triggered by photon absorption and analyze these signals under various bias currents, base temperatures, and input photon-number states. For this purpose, we employ superconducting bilayer films consisting of titanium (20 nm) and gold (10 nm), patterned into an 8 μm × 8 μm square strip and operated in a constant-current bias mode rather than in electrothermal-feedback (ETF) mode. Remarkably, the observed signals remain quantized with identical time intervals even when the operating conditions are varied. Furthermore, we find that the time-integrated voltage of the first quantized signal corresponds to a single magnetic flux quantum, $\Phi_0 = 2.07 \times 10^{-15}$ Wb.
We also investigated the number of VAPs generated per photon and demonstrated photon-number-resolving capability by correlating the number of VAPs with the input photon number. These results deepen our understanding of the photon detection mechanism in superconductors and represent the first demonstration of photon-number resolution based on VAP dynamics. This work opens a pathway toward fast, multi-photon-resolving detectors with significant potential for quantum optics applications.

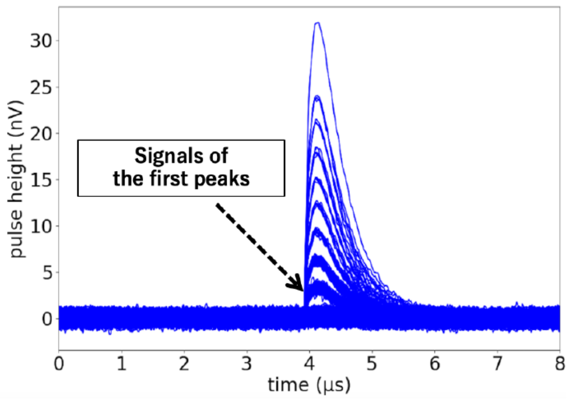

Fig.1: Example of the observed quantized signals. The superconducting strip device is operated under a constant-current bias of 5 μA. The time-integrated voltage of the first quantized signal consistently yields the fixed value of Φ_0, even under different bias conditions.

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References

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