Cryogenic-Compatible Ultrahigh-Rejection and Narrowband Filter for Integrated Quantum Photonics

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Cryogenic integrated photonics provides a promising platform for fully integrated quantum systems due to its low-noise characteristics and compatibility with superconducting nanowire single-photon detectors (SNSPDs) and quantum dots. To harness the full potential of cryogenic integrated quantum photonic circuits, high-performance on-chip optical filters are essential. In particular, for nonlinear processes such as spontaneous four-wave mixing, near-100 dB pump rejection is required to extract weak single-photon signals from intense pump light.

We demonstrate a cryogenic-compatible sinusoidal Bragg filter on a silicon-on-insulator platform. A coherency-broken cascaded architecture is employed to achieve ultrahigh rejection. The sinusoidal modulation enables sub-nanometer bandwidth with tens-of-nanometer feature sizes. To improve practical extinction, subwavelength gratings are integrated to suppress residual TM modes, and a 6-nm-thick niobium nitride (NbN) layer is deposited to absorb scattered photons.

The fabricated device achieves 82 dB rejection with a 0.9 nm (40 dB) bandwidth at room temperature. Cryogenic characterization at 2.2 K shows stable operation with 76 dB rejection and a 0.8 nm bandwidth [2]. The preserved extinction and bandwidth confirm robust cryogenic performance and compatibility with cryogenic integrated quantum photonic circuits.

This work provides an on-chip solution combining ultrahigh rejection, narrow bandwidth, and validated cryogenic compatibility, providing critical device support for cryogenic integrated quantum photonic systems.

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References

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