Widely tunable second harmonic generation in low-loss thin-film $LiNbO_3$ membrane

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The growing demand for broadband and tunable frequency converters in fields such as quantum computing, environmental sensing, and optical communications has driven significant advancements in nonlinear photonic platforms. However, existing solutions based on type-0 quasi-phase-matching face spectral limitations [1], offering tunability of ≈ 10 nm or less [2]. In addition, $LiNbO_3$ (LN) nano-waveguide-based platforms encounter two primary challenges: (1) stringent fabrication tolerances, requiring sub-nanometer thickness precision down to 2.2 nm for a 5 mm interaction length [3], and (2) a trade-off between fabrication simplicity and low insertion losses, where additional processing steps are required to achieve coupling losses below 1 dB/facet [4]. These constraints significantly affect their applicability in demanding applications that require both broad spectral tunability and efficient frequency conversion such us broadband spectroscopy [5] or high brightness single photon sources [6].

To address these challenges, we introduce an original LN frequency conversion platform that leverages air-suspended rib waveguides and type I birefringent phase matching. This architecture achieves an exceptional tunability bandwidth of up to 900 nm, relaxing fabrication tolerances by a factor of five. Moreover, it enables precise control of LN film thickness (≈ 2 µm), and avoids periodic poling. This thickness is a critical condition for efficiently achieving the high tunability bandwidth of 900 nm.The fabrication process integrates precision saw thinning with reactive ion etching post-thinning to precisely reach the targeted thickness in the 700 nm to 7 µm range. The rib waveguides are adiabatically coupled to titanium-diffused waveguides at both input and output, achieving low coupling losses (0.8 dB/facet), single-mode operation and supports on-chip powers more than 100 mW. This new architecture addresses the dual challenges of tunability and fabrication constraints, offering a compact, broadband, and energy-efficient solution. Its versatility makes it a powerful candidate for next-generation applications in nonlinear optics, quantum technologies, and broadband optical communications.

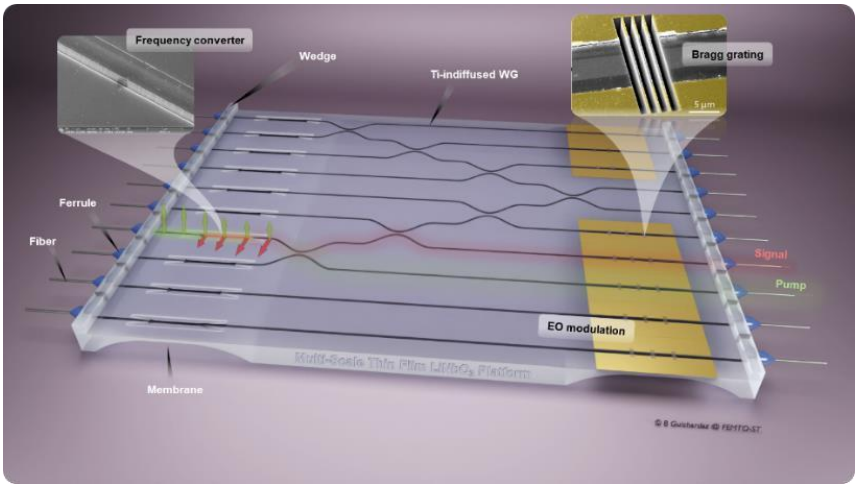

Fig. 1 Artistic representation of a LN air-suspended thin-film platform, showcasing its versatility for applications such as EO modulators, photonic crystals, and nonlinear devices. The design enables independent control of the thickness of each membrane, offering flexibility beyond the uniform thickness constraints of entire wafers.

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