Deterministic Phase-Matching of Micro-Transfer-Printed Periodically-Poled Lithium Niobate Waveguides

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Abstract: State-of-the-art periodically-poled lithium niobate waveguides struggle with extreme fabrication sensitivity, resulting in unpredictable phase-matching wavelengths. We developed a micro-transfer-printed periodically-poled lithium niobate waveguide that enables deterministic phase-matching at a predefined wavelength through optical feedback.

Introduction

The uprise of thin-film lithium niobate (LN) waveguides has set new records in both modulation and frequency conversion efficiencies due to the sub-wavelength confinement made possible [1]. That same confinement enables strong dispersion engineering through the waveguide dimensions, but simultaneously comes with much larger fabrication sensitivity. This poses a challenge for the phase-matching in $\chi^{(2)}$ processes, as the mode indices are affected by fabrication variation. It is well-known this sensitivity reduces the conversion efficiency of long periodically-poled lithium niobate (PPLN) waveguides [2], but also makes the exact phase-matching wavelength unpredictable. Therefore, it becomes problematic to reliably co-integrate frequency converters with e.g. on-chip lasers. We have developed a new type of nonlinear waveguide, where PPLN is micro-transfer-printed (μTP) onto a silicon photonics (SiPh) chip at a back-end level [3]. Its hybrid geometry makes it possible to tweak the waveguide dimensions based on optical feedback, allowing us to place the phase-matching at the desired wavelength. Together with the strength of micro-transfer printing to densely co-integrate different materials, it becomes possible to phase-match frequency converters to integrated lasers or other resonant components on a single chip.

Fabrication sensitivity of PPLN waveguides

The nonlinear waveguide is fabricated through micro-transfer printing, where a suspended PPLN film is picked and printed on a silicon nitride (SiN) waveguide (Figure 1a). This introduces a strong $\chi^{(2)}$ nonlinearity onto the silicon photonics platform, allowing for efficient frequency conversion. We consider second harmonic generation (SHG) from 1550 nm to 775 nm, with the mode profiles depicted in Figure 1b. To examine the fabrication sensitivity of the waveguide, we look at the effect of LN thickness variations on the phase-matching wavelength in

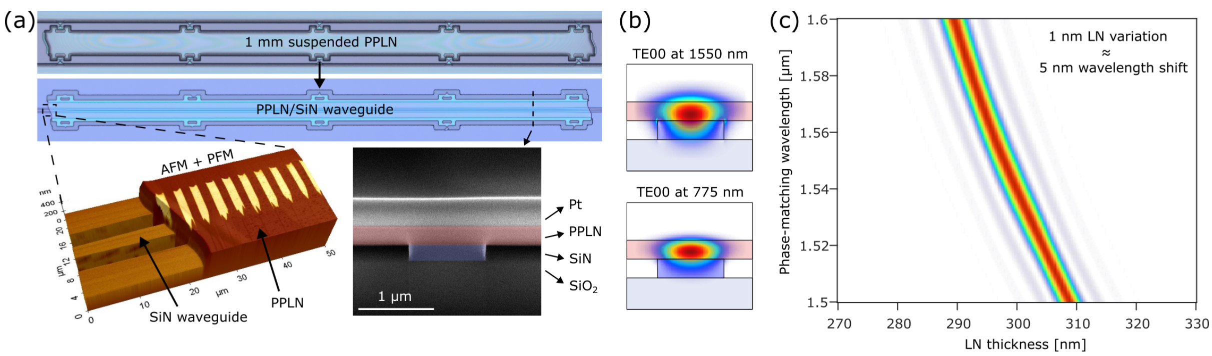

Fig. 1. (a) Fabrication of the nonlinear waveguide: suspended PPLN film is picked and printed on SiN waveguide (with AFM/PFM image and SEM cross section), (b) Waveguide mode profiles at 1550 and 775 nm, (c) Fabrication sensitivity of the phase-matching wavelength.