Periodically Poled Lithium Niobate for Visible Light Generation

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Primary CNF Tools Used: JEOL 9500, AJA ion mill, CVC SC4500 odd-hour evaporator, Veeco Icon Atomic Force Microscope, DISCO Dicing Saw

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Abstract:

We report efficient quasi phase matched second harmonic generation of 532 nm green light in periodically poled nanophotonic waveguides on the Lithium-Niobate on Insulator (LNOI) platform.

Summary of Research:

Visible light generation on an integrated photonic platform is of great interest for applications ranging across quantum optics, atomic physics, sensing, biophotonics, and AR/VR, to name a few. The (LNOI) platform boasts a broad transparency window, with low loss into the visible band [1], and exceptional quadratic optical nonlinearity for efficient conversion of long wavelength pump light into the visible spectrum [2,3]. Here we demonstrate efficient chip-scale generation of green light by second harmonic generation of a NIR source.

Quasi phase matched second harmonic generation of a 1064 nm pump source is realized by periodically poling the LN waveguide to bridge the phase mismatch between the 1064 nm and 532 nm optical modes. The fundamental TE_{00} modes are utilized for their near-unity nonlinear mode overlap and alignment with the largest quadratic nonlinear tensor element (d_{33} = 25pm/V) of LN. A relatively short poling period $\Lambda = \lambda_{SH}/\Delta n_{eff}$ of ~ 2.2 μm is necessary for quasi phase matching due to the difference in effective refractive indices Δn_{eff} of the TE_{00} modes. Poling with close to 50% duty cycle ensures optimal efficiency of the devices.

The PPLN waveguide devices are fabricated on MgO doped x-cut thin film lithium-niobate-on-insulator (LNOI), with 400 nm LN sitting upon a 2 μm silica layer. ZEP-520A resist is used for a first e-beam lithography step (JEOL 9500), followed by 300 nm Ar-ion milling (AJA Ion Mill) to create the alignment marks. A second e-beam writing step is performed on PMMA resist, and 300 nm poling electrodes are created using a gold evaporation and lift-off process (CVC SC4500 odd-hour evaporator). High voltage pulses realize the periodically inverted domains in the unprocessed LN thin film [4] and are verified by Piezo Response Force Microscopy (Veeco Icon AFM) (Figure 1b). The electrodes are removed in an acid clean step, and a third e-beam lithography step with ZEP-520A, followed again by Ar-ion milling, is used to define the waveguides along the periodically poled domains.

The 1064 nm light is amplified by a ytterbium-doped fiber amplifier and coupled to the waveguide facet by a 780HP lensed fiber. The residual pump light and generated visible light is collected from the output facet by a 780HP lensed fiber as well. A narrow sinc^2-like phase matching spectrum is observed (Figure 1d), indicating good uniformity of the periodically poled domains along the waveguide length. An absolute on-chip conversion efficiency in excess of 12% is measured with 16 mW of pump power, generating slightly more than 2 mW of green light on chip (Figure 1e). The sublinear efficiency trend agrees well with pump-depletion theory of colinear SHG, verifying strong pump conversion efficiency of the nonlinear waveguides.

References:

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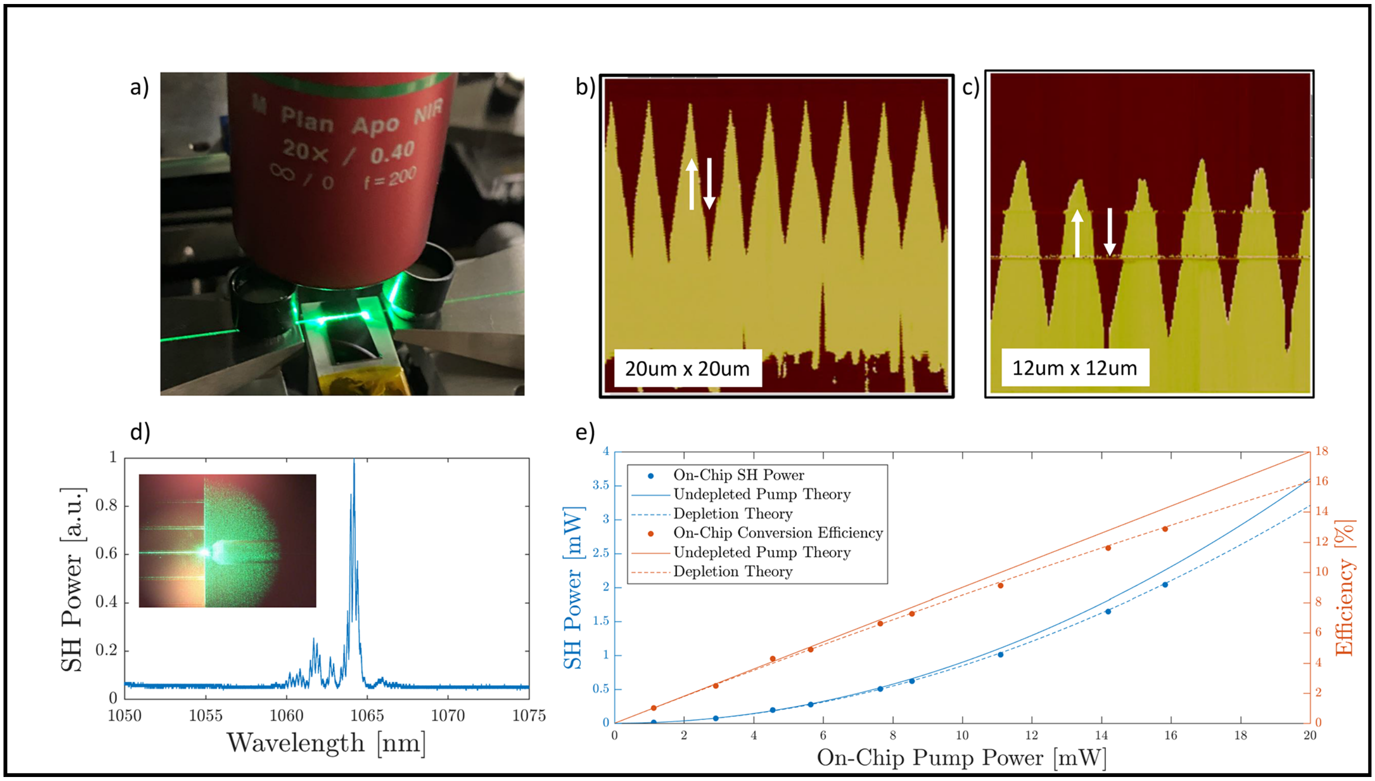

Figure 1: (a) Image of efficient green light generation on the PPLN chip. Piezo Response Force Microscopy of the periodically inverted domains before (b) and after (c) waveguide fabrication. (d) Measured phase matching spectrum of the device, centered around 1064 nm. (e) On-chip conversion efficiency and generated visible light power from the quasi phase matched SHG process.