Efficient second harmonic generation in thin film lithium niobate nanowaveguides

N. Benon[1,*], A. De Sousa Lopes Moreira[1], T. Dutron[1], L. Gauthier-Manuel[1], M. Chauvet[1]

1: Marie and Louis Pasteur University, CNRS, FEMTO-ST Institute, F-25000 Besançon, France
**Email: nathanaell.benon@femto-st.fr*

Nathanaëll Benon is a second-year PhD student at Marie and Louis Pasteur University, affiliated with the FEMTO-ST Laboratory in Besançon, France. Their subject encompasses nonlinear photonics in lithium niobate thin films, focusing on second-order nonlinearities. They graduated in 2024 from Institut d'Optique Graduate School, with a double degree in the master Quantum, Light, Matter and Nanosciences, with specializations in optics and microfabrication. During their studies, Nathanaëll did an internship at the 'Laboratoire Interuniversitaire des Systèmes Atmosphériques' on Fourier Transform spectrometry of atmospheric gases. They completed their studies with a six-month internship at Fraunhofer IOSB, developing a polarimeter for the 2µm band.

Summary:

Thin-Film Lithium Niobate (TFLN) makes the material's wide transparency window and high nonlinearities accessible in tightly confined nanowaveguides. The enhanced nonlinearities are harnessed within 600nm thick X-cut LN via quasi phase-matched operation. Low loss nanowaveguides are fabricated via Reactive Ion Etching, and periodic poling is obtained by electric field inversion and monitored by Piezoresponse Force Microscopy. Second Harmonic Generation with normalized conversion efficiency as high as 3094%/W/cm² is demonstrated and investigated.

Abstract:

Lithium niobate ($LiNbO_3$, LN) is known for its wide transparency region (VIS-MIR) and strong nonlinear tensor ($d_{33} = 27pm/V$). Combined with the advancements of Thin Film Lithium Niobate (TFLN) providing the possibility to fabricate nanowaveguides with small cross-sections, LN enables tight optical mode confinement. This allows for a large enhancement of the nonlinear effects, thus leading to high conversion efficiencies while using low input powers [1], preventing photorefraction. This work focuses specifically on Second Harmonic Generation (SHG) within Periodically Poled LN (PPLN) nanowaveguides, and takes place in the frame of the French national project NanoFiLN funded by the National Research Agency, encompassing the establishment of a French technological sector on TFLN optical chips. SHG is obtained in 600nm thick X-cut LN films, dictating the fabrication steps required to obtain fitting PPLN nanowaveguides. The periodic poling needed for quasi phase-matched operation is achieved through electric field inversion using electrodes of matching period. Monitoring of the current generated in the process and Piezoresponse Force Microscopy (PFM) imaging afterwards allow for double control of the poling process and its quality. Ridge nanowaveguides are obtained by standard Reactive Ion Etching, enabling propagation loss as low as 0.6dB/cm. With this configuration, a normalized conversion efficiency of 3094%/W/cm² was obtained, in the range of other state-of-the-art results (2600-3757%/W/cm² [2-3] for similar waveguide geometries). Further study of this harmonic signal is to be done and presented.

References

[1] Andreas Boes et al., 'Lithium niobate photonic: Unlocking the electromagnetic spectrum', Science, 379, Issue 6627 (2023).
[2] Cheng Wang et al., 'Ultrahigh-efficiency wavelength conversion in nanophotonic periodically poled lithium niobate waveguides', Optica 5, 1438-1441 (2018).
[3] Jie Zhao et al., 'Shallow-etched thin-film lithium niobate waveguides for highly-efficient second-harmonic generation', Opt. Express 28, 19669-19682 (2020).

Acknowledgment – this work is supported by the French RENATECH network through its FEMTO-ST technological facility and staff. This work was funded by the NanoFiLN project (ANR-23PEEL-0004) and the EIPHI Graduate School (Contract N° ANR-17-EURE-0002).