Fraunhofer IPM

Waveguide-based frequency converters

Light is coupled into a sub-micron-thick ridge waveguide made from lithium niobate.

Unique waveguides for unique applications

Optical waveguides allow for ultra-efficient frequency conversion, even at low pump powers. Fraunhofer IPM has specialized in the fabrication of customer-specific waveguide solutions. Our technological portfolio covers substrate fabrication and manipulation as well as different waveguide structuring technologies.

Boosting the nonlinear light-matter interaction

Nonlinear optical frequency conversion provides light in spectral ranges where direct laser emission cannot be realized. Waveguide-based frequency converters make it possible to reduce the spatial footprint of the overall conversion system considerably, which is crucial when a multitude of converter modules is required (e. g. for ion-based quantum computing). Moreover, waveguide-based converters provide the means to achieve an ultra-high conversion efficiency, even at very low pump powers. Thus, the need for optical preamplification is cancelled out.

This is possible due to the optical confinement of the waveguides: It keeps light focussed along the entire length of the waveguide, which boosts the nonlinear light-matter interaction.

Customer-specific waveguide solutions

Fraunhofer IPM has developed several key technologies for waveguide fabrication in-house, which allow us to provide customer-specific waveguide solutions tailored to the specific application. Our technological portfolio covers substrate fabrication and manipulation as well as different waveguide structuring technologies. Activities are centered around, but not limited to, the processing of lithium niobate crystals.

Due to our expertise in mechanical and optical engineering, we offer robust, fiber-coupled, turn-key waveguide-based frequency converter modules.

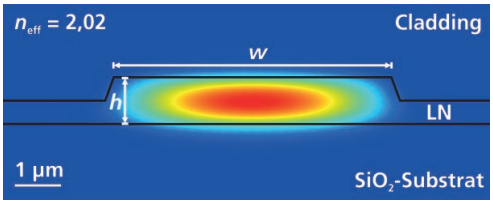
Our key competences

- **Simulations:** We are able to precisely predict optical properties via numerical simulations.
- **Periodic poling:** Our maskless poling process enables rapid prototyping of any 2D poling structure.
- **LNOI fabrication:** We offer full design flexibility regarding the thin film layer.
- **Etching technologies:** We cover the full range of etching technologies relevant for waveguide structuring.

Our key competences for waveguide fabrication

Simulations

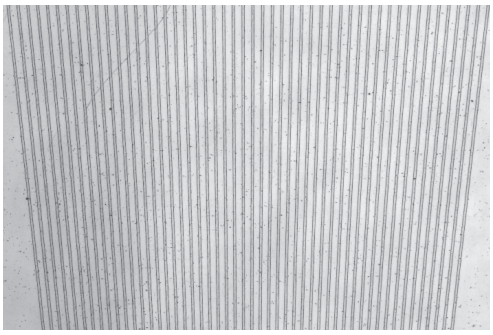
Optical properties are precisely predicted via numerical simulations.



Simulated mode profile of a ridge waveguide

Periodic poling

Non-standard target wavelengths require non-standard poling patterns to achieve quasi-phasematching. The maskless poling process we developed in-house allows for rapid prototyping of any 2D poling structure.



Fanout periodic poled nonlinear optical material for continuously tunable frequency conversion

LNOI fabrication

Lithium niobate-on-insulator (LNOI) substrates are needed for ultra-tight confining waveguides. We have developed a process to fabricate LNOI substrates via bonding, thinning and polishing. Our process offers full design flexibility regarding the remaining thin film layer (e. g. thickness, doping, periodic poling). Moreover, our process can be extended to X-on-insulator (XOI), with X being any other relevant nonlinear optical material.

Our process of LNOI and XOI fabrication

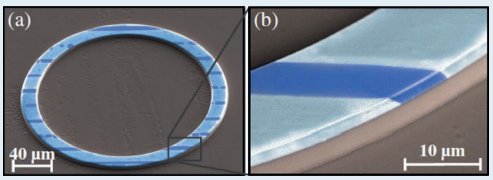
Etching technologies

Dry etching, wet etching and laser etching: Fraunhofer IPM covers the full range of relevant etching technologies for waveguide structuring.

Examples for customized waveguides

Ridge-waveguide

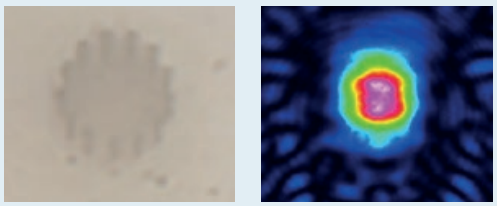
A mode field diameter in the range of only a few square microns makes ridge waveguides a perfect choice for low- to medium-power (sub-W) waveguide converters. The spatial dimensions of the ridge define the dispersion and the power-handling capability of the waveguide.



Ring-shaped ridge waveguide renders a high-Q on-chip microresonator. R. Wolf et al., Optica 5, 872 (2018)

Large mode area waveguide

A mode field diameter in the range of a few tens of microns allows for multi-W conversion at high conversion efficiency.



Left: Endfacet of a laser-inscribed waveguiding structure
Right: Typical mode profile

Contact

Dr. Simon Herr
Project Manager
Nonlinear Optics and Quantum Sensing
Phone +49 761 8857-103
simon.herr@ipm.fraunhofer.de

Fraunhofer Institute for Physical Measurement Techniques IPM
Georges-Köhler-Allee 301
D-79110 Freiburg, Germany
www.ipm.fraunhofer.de/en