

Laser-written waveguides for frequency conversion

Several laser-written waveguides in lithium niobate

Unique waveguides for unique applications

Optical waveguides are a proven tool for efficient nonlinear-optical frequency conversion, even at low pump powers. Fraunhofer IPM has specialized in the design and fabrication of customer-specific, laser-written waveguide devices.

High conversion efficiencies

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

This is made possible by the optical confinement of the optical waveguides, which keeps the light focused along the entire length of the waveguide, enhancing the nonlinear light-matter interaction.

Robust, turn-key converter modules

Fraunhofer IPM has developed several key technologies for waveguide fabrication in-house, which allow to provide waveguide solutions tailored to the specific application. Our technological portfolio covers periodic poling, direct laser writing of waveguides as well as mechanical preparation of end facets. Activities are centered, but not limited, to the processing of lithium niobate crystals.

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

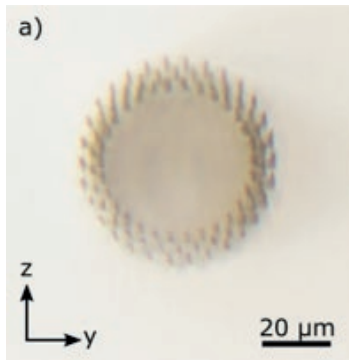
Our key competencies

- **Simulations:** We are able to precisely predict optical waveguide properties via numerical simulations.
- **Flexibility:** The waveguide writing process provides high flexibility for tailored mode areas.
- **Periodic poling:** Our maskless poling process enables rapid prototyping of any 2D poling structure and provides quick and simple access to non-standard wavelengths.
- **High-power handling:** Laser-written waveguides can provide multi-Watt frequency conversion.
- Different nonlinear-optical host materials available

Our key enabling technologies for waveguide fabrication

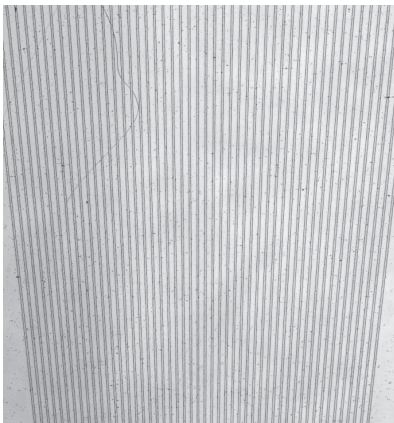
Simulations – Optical properties are precisely predicted via numerical simulations.

Direct laser writing of waveguides – Tightly focused femto-second laser pulses are used to generate a circular-shaped low-index cladding into bulk crystals. The core preserves its nonlinear optical properties, as its crystalline structure stays unchanged.



End facet of a direct laser written waveguide in lithium niobate

Periodic poling – non-standard target wavelengths require non-standard poling patterns to achieve quasi-phase matching. Our in-house developed maskless poling process allows for rapid prototyping of any 2D poling structure.



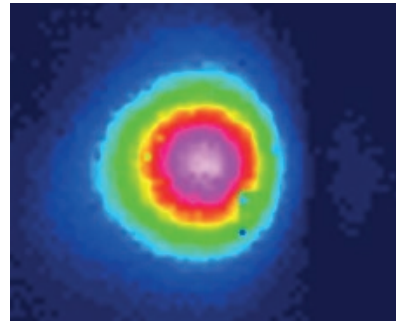
Fanout periodic poled nonlinear-optical material for continuously tunable frequency conversion

Example: Frequency doubling in laser-written waveguides

A mode field diameter in the range of some tens of microns allows multi-Watt conversion at high conversion efficiency.

Validated performance parameters:

- Single-mode waveguiding
- Propagation loss: ≤ 0.1 dB/cm
- Input power: up to 12 W
- SHG-power: up to 4 W
- Conversion efficiency: up to 15%/W
- Single-mode SHG beam profile



SHG-beam profile at a multi-Watt power level

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
79110 Freiburg, Germany
www.ipm.fraunhofer.de/en