Lithium Niobate Nanowaveguides fabricated by Ion-Beam Enhanced Etching

Reinhard Geiss*, Holger Hartung, Frank Schrempel, Ernst-Bernhard Kley, Thomas Pertsch, Andreas Tünnermann
Institute of Applied Physics, Abbe Center of Photonics,
Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743, Jena, Germany
geiss@iap.uni-jena.de

Nanoscale waveguides fabricated in media with strong quadratic nonlinearity such as lithium niobate ($LiNbO_3$) allow for highly efficient frequency conversion and harmonic generation. The strong spatial confinement of the waveguide mode significantly enhances the nonlinear interactions. At the same time, phase matching of the nonlinear processes can be precisely adjusted by dispersion engineering, i.e. modification of the waveguide geometry.[1] Such $LiNbO_3$ nanowires used as nanoscale second harmonic (SH) light sources have great potential as luminescent markers for imaging applications in life science.[2]
The fabrication of the nanowires was facilitated through ion-beam enhanced etching of $LiNbO_3$, which is a technique originally developed for the fabrication of freestanding photonic crystal membrane structures.[3] In a first step the mask for ion beam irradiation is patterned into layers of chromium and fused silica by means of electron beam lithography, RIE and ICP-RIE dry etching. The mask layout contains a large number of homogenous grating structures, where the individual grating ridges represent the final nanowires. The irradiation with argon ions is carried out in a series with different energies and fluencies to homogeneously damage the crystal in the unmasked regions from the sample surface down to the desired depth. After removal of the masking layer the sample is irradiated with helium ions forming a buried damaged layer at a depth of about 500 nm. Now, the sample is etched in diluted hydrofluoric acid. Since the etch rates of ion-beam irradiated and bulk $LiNbO_3$ differ significantly, the damaged crystal is removed, resulting in freestanding grids of nanowires (Fig.1). The nanowires typically have cross section areas of 300 nm by 500 nm at a length of 50 µm. The smallest wire has an equivalent diameter of about 180 nm at a length of 5 µm (Fig.2). Compared to chemically synthesized nanowires[2] the fabrication here is completely deterministic with just minor deviations in shape throughout the respective batch. To make the nanowires accessible for optical testing on a neutral substrate the sample is first sonicated in Ethanol. A droplet of this nanowire solution is then brought onto an ITO coated silica wafer where processing and manipulation was continued using FIB milling in combination with a micro manipulator needle (Fig.3). Samples thus prepared are illuminated with a laser at 1.55 µm resulting in generation and waveguiding of the SH. Those results give a first proof of the nanowires' capabilities as SH light sources. They give access to the investigation of the physics of nonlinear effects in nanoscale waveguides.

---

1 A.S. Solntsev et al., Applied Physics Letters, 98, 231110 (2011)
2 C. Hsieh et al., Optics Express, 17, 2880 (2009)
3 H. Hartung et al., Optical Materials, 33, 19 (2010)

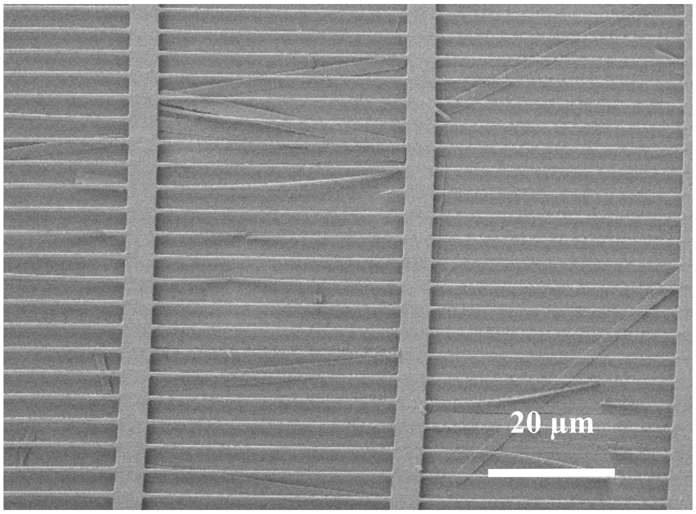

Figure 1: Grid of lithium niobate nanoscale waveguides. The grating structure was fabricated by means of ion-beam enhanced etching.

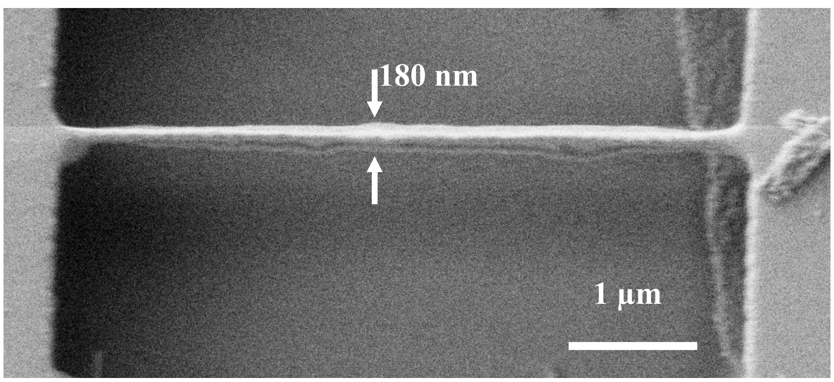

Figure 2: Lithium niobate nanoscale waveguide with an equivalent diameter of 180 nm and a length of 5 µm.

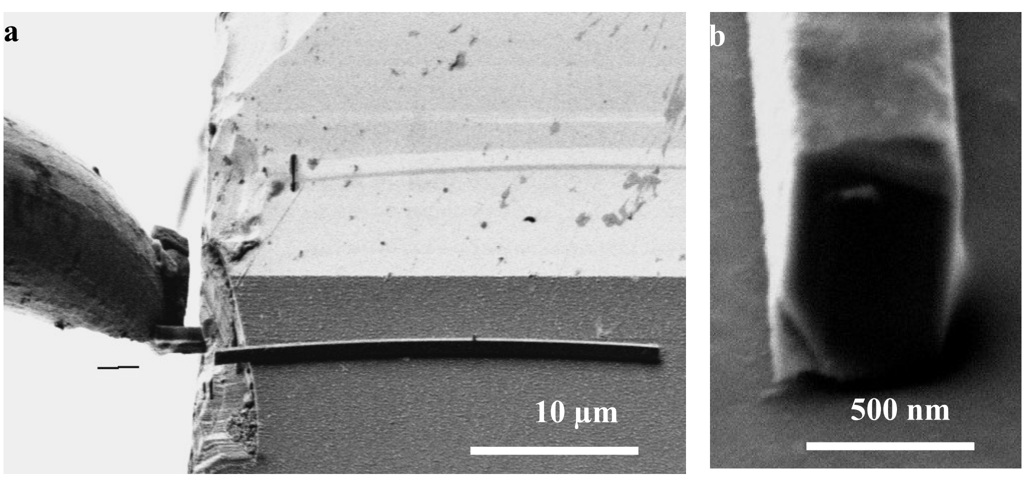

*Figure 3:*a) FIB micro manipulator needle placing a lithium niobate nanoscale waveguide on a fused silica substrate for optical testing. b) Cross section of the nanowaveguide: 500 nm by 600 nm.