Maximizing the guided second-harmonic in lithium niobate nanowires

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Nanowires made of a non-centrosymmetric crystal can both guide light and perform nonlinear wavelength conversion like second-harmonic generation. Such nanowires would help to develop various nanowire-based applications such as subwavelength microscopy [1] and nonlinear optical sources [2]. Strong nonlinearity and transparency in a broad wavelength range of the lithium niobate ($LiNbO_3$) crystal makes $LiNbO_3$ nanowires promising for this purpose. Indeed, the $LiNbO_3$ nanowires have been shown to both generate and propagate the second-harmonic (SH) [3,4]. Moreover, we have even demonstrated fluorescent dye excitation with the propagated SH in $LiNbO_3$ nanowires [4]. Nevertheless, it has not been studied where the propagated SH signal originates from. On one hand, the SH could be scattered into the nanowire at its input. On the other hand, the SH could be excited by the guided laser light inside the nanowire. In addition, the mechanisms to maximize this guided SH must be identified for further development of nanowire applications.

In this work, we present a study of the guided SH in free-standing $LiNbO_3$ nanowires that are produced by Ion-Beam-Enhanced-Etching method [5] and have typical cross-section of 500x800nm^2 and length up to tens of micrometers. We clearly prove with an experiment and matching simulation that the propagated SH signal is excited by the guided laser light in the nanowire. We also demonstrate SH enhancement by means of phase-matching and optimization of the nanowire length.

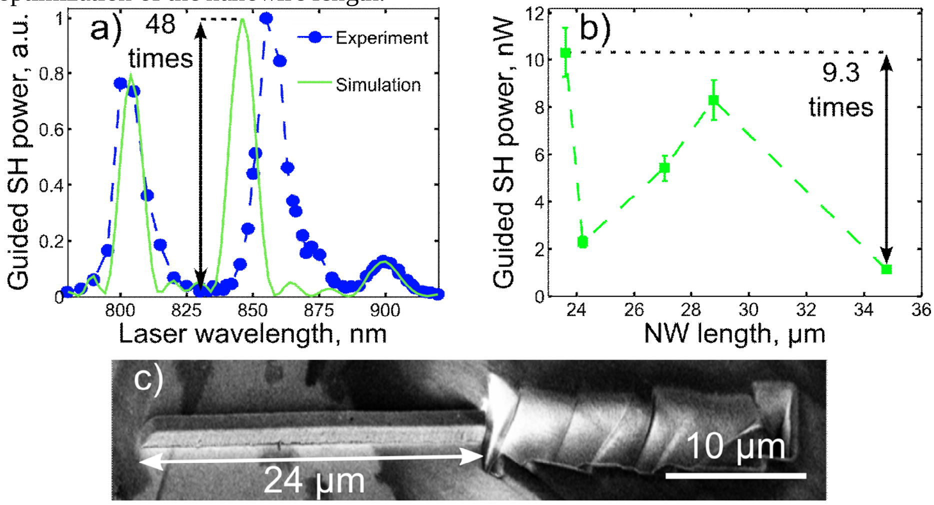

Fig. 1 a) Enhancement of the guided SH through phase-matching by a factor of 48 in a $LiNbO_3$ nanowire. The conformity of the experiment (dashed line) and simulation (solid line) proves unambiguously the waveguiding process in the nanowire; b) enhancement of the guided SH power by optimising the nanowire length with FIB milling by a factor of 9.3; c) an SEM image of the shortened nanowire.

First, we show that the guided SH power is enhanced through phase-matching by a factor of 48. For this purpose, we measure the power of the guided SH at various wavelengths of the incident laser (dashed line in Fig. 1a). The simulation of the generation and waveguiding of the SH shows conformity (solid line in Fig. 1a) and allows to define the SH guided modes detected in the experiment. Besides, this experiment gives an unambiguous confirmation that the propagated SH is generated by the guided laser field inside the nanowire.

Second, we show that the guided SH power is enhanced by a factor of 9.3 after optimising the nanowire length. For this experiment, we stepwisely shorten the nanowire length with the focused-ion-beam (FIB) and measure the guided SH power after each FIB milling (Fig. 1b). This method allows to enhance the SH at a non-phase-matched wavelength.

We expect that these results will be of a broad interest for the communities working on nonlinear wave-mixing in nanowires and developing nanowire-based applications.

References

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