Abstract

Periodically poled $LiNbO_3$ (PPLN) waveguides have been successfully used for efficient nonlinear interactions using quasi phase matching (QPM) due to the fact that the optical wave is confined in the waveguide with a high intensity. A further increase in nonlinear conversion efficiency requires strongly reduced cross section dimensions which can be only achieved in a waveguide of a high refractive index contrast. Such a waveguide not only facilitates efficient nonlinear interactions but also enables fabrication of sub-micrometer periodical domain structures. Therefore, counter-propagating nonlinear interactions can be realized.

The aim of this work is to develop PPLN waveguides of high refractive index contrast and small cross sectional dimensions, and then to investigate various nonlinear interactions in such waveguides. Towards this goal, two different types of $LiNbO_3$ waveguides, i.e. ridge waveguides on X(Y)-cut substrates and $LiNbO_3$-on-Insulator (LNOI) photonic wires, are developed. The methods of fabricating periodical domain structures in such waveguides are investigated to enable quasi-phase-matching (QPM) nonlinear interactions.

First, ridge waveguides on X(Y)-cut $LiNbO_3$ substrates are fabricated using plasma etching and a subsequent Ti in-diffusion. A local poling technique is developed to fabricate periodical domain structures only in the body of the ridge guide. Various characterization methods have been used to evaluate the quality of the ridge guides as well as the periodical domain structures. A reduced mode size compared to a conventional Ti in-diffused channel waveguide is observed. The inverted domains inside the body of the ridge are sufficiently deep (~5 μm) to overlap the transmitted optical modes. As a result, a normalized SHG conversion efficiency of 16.5 % $W^{-1}cm^{-2}$ is obtatined, which is 50 % higher than that in a conventional Ti in-diffused channel waveguide. Moreover, as a promising feature, a strongly reduced sensitivity to photorefactive effects is observed. This could be of strong interest for the nonlinear applications using high optical power.

Second, periodically poled $LiNbO_3$-on-Insulator (PPLNOI) material platform is fabricated by direct bonding of PPLN in collaboration with Hu. PPLNOI photonic wires are then fabricated using Argon milling. 1st order SHG is demonstrated using a PPLNOI photonic wire of 3.2 μm periodicity; a parabolic dependence of the generated SH power vs. the fundamental power is observed. We also demonstrate the second approach of fabricating PPLNOI by directly poling $LiNbO_3$ thin film. The promises as well as challenges presented in our preliminary experiments are discussed in detail.