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Periodically Poled Ridge Waveguide on X-Cut $LiNbO_3$ and its Application for Second Harmonic Generation

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To enhance the efficiency of nonlinear interactions, ridge waveguides can be developed leading to a strong enhancement of the guided mode intensity. If fabricated in a ferroelectric, highly nonlinear material like Lithium Niobate (LN), a periodic domain inversion is required to enable quasi phase matching (QPM) for second order nonlinear processes. Several methods have been used to get periodically poled (PP) ridge structures; they all use a PP substrate for waveguide fabrication [1-3]. In contrast, we report here periodic poling localized in the body of Ti in-diffused ridge waveguides (Ti:PPLN) on X-cut LN and demonstrate the high waveguide quality by efficient second harmonic generation (SHG).

Ridge waveguides on X-cut LN (Fig.1 (a)) were fabricated using inductively coupled plasma (ICP) etching followed by Ti in-diffusion into the body of the ridge only [4]. Local poling was enabled by comb like electrodes defined on the side walls of the ridge using lift-off lithography (Fig.1 (b, c)). The poling experiments were done in an oil bath to maintain a high resistance between counter electrodes and to avoid surface currents. A single voltage pulse (~600V; 50 ms) has been used to achieve periodic poling. The resulting domain structure was investigated in all three dimensions by preferential chemical etching and optical microscopy; a hexagonal shape of the inverted domains is observed as marked with dashed lines (Fig.1 (d)).

SHG was investigated in a Ti:PPLN ridge waveguide of 3.5 µm height and 9 µm width on X-cut LN. The length and the period of the periodically poled section are 14 mm and 16.6 µm respectively. An external cavity laser was used to tune the fundamental wavelength λ_f in steps of 1 pm around λ_f = 1548 nm. The light was coupled to the waveguide by fibre butt coupling with index matching oil between fibre and waveguide end faces. Fig. 2 presents the SHG tuning characteristic as generated SH power versus λ_f together with the transmitted fundamental power. Fabry-Perot resonances are observed determined by the waveguide cavity formed by the end face mirrors of 3.6 % and 14 % reflectivity. They allow evaluating precisely the propagation losses of here 1.0 dB/cm at λ_f. Fitting a theoretical SHG tuning characteristic to the average of the experimental result yields a good agreement of theoretical and measured bandwidths of 0.8 nm demonstrating the excellent homogeneity of the Ti:PPLN ridge guide along the interaction length. A power normalized efficiency of 17 % W^{-1} (or 8.5 % W^{-1} cm^{-2}) was calculated as the ratio of out-coupled SH-power and the square of in-coupled fundamental power. There is still a large potential to improve this efficiency by optimizing the duty-cycle of the periodic microdomains.

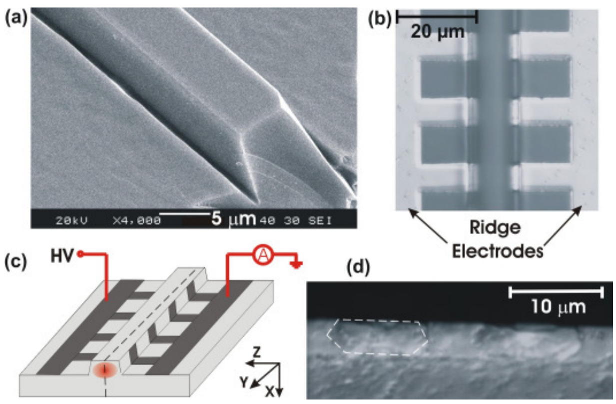

Fig. 1 (a) SEM micrographs a Ti in-diffused ridge waveguide on X-cut LN; (b) Top view of the electrodes of 16.6 µm period for a 9 µm wide ridge; (c) Scheme of the poling configuration for a ridge on X-cut LN; (d) Micrograph of ridge cross section along the dashed line in (c) with domain structure after chemical etching.

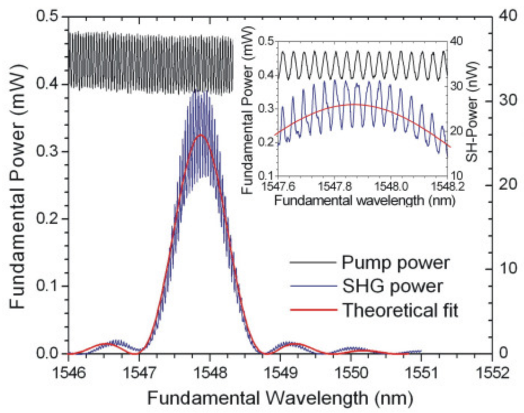

Fig. 2 Generated SH- and transmitted fundamental powers as a function of the fundamental wavelength for a 14 mm long, Ti:PPLN ridge guide on X-cut LN. Inset: Results around maximum efficiency plotted with higher resolution.

References

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