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Efficient Second-Harmonic Generation in a Directly-Bonded, Buried, Periodically-Poled $LiNbO_3$, Planar Waveguide

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Abstract

We report efficient second-harmonic generation in the first periodically-poled $LiNbO_3$ (PPLN) waveguide to be fabricated by direct bonding. This technique maintains the full non-linearity of bulk PPLN and allows the construction of novel waveguiding geometries.

Periodic poling of $LiNbO_3$ to achieve quasi-phase matching for non-linear frequency conversion has generated a great deal of interest due to the fact that it allows the use of a large non-linear coefficient and eliminates walk-off effects. Combining such material with a waveguide geometry to increase average pump intensities is a promising route to the realisation of various compact non-linear devices based on harmonic[1] or parametric[2] generation. Here we present the first fabrication of a PPLN planar waveguide by direct bonding. This technique, which has previously been used to fabricate laser waveguides[3], is based on the precision polishing of bulk material to waveguide dimensions. Hence the full non-linearity of the bulk PPLN should be maintained while offering versatility in the fabrication of exotic waveguide structures.

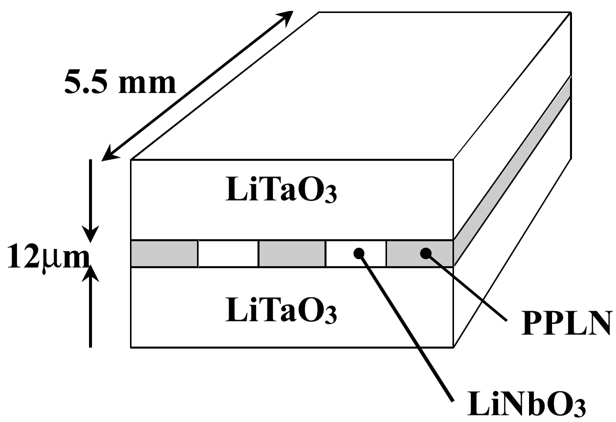

Fig.1 Directly-Bonded, PPLN, Planar Waveguide Structure

The buried waveguide constructed for this first demonstration had a 12μm deep PPLN core, surrounded by 500μm thick $LiTaO_3$ substrate and cladding layers. As shown schematically in fig.1, the waveguide was 5.5mm long and the core had both PPLN and ordinary $LiNbO_3$ regions. The PPLN grating, which was fabricated in the bulk material via standard procedures of electric field poling[4], had a period of 6.50μm. This was selected to be suitable for frequency doubling of a 1.064μm pump at an elevated temperature to avoid photorefractive effects. A cw, multi-axial mode, diode-pumped, Nd:YAG laser was used as the pump source. The initially circular output beam was passed through a X2.4 cylindrical-lens telescope in the non-guiding plane before being focussed by a X10 objective. This gave a line focus with measured pump spot sizes of 4±1μm in the guided direction and 11±1μm in the non-guided direction. The beam was then end-launched into the waveguide which was held in an oven tuned to174^{o}C, corresponding to the temperature at which maximum second-harmonic output power was obtained. For 204mW of launched power we obtained 1.8mW of second harmonic at 532nm. This value is consistent with an estimate of the expected efficiency allowing for the non-optimum focussing conditions and using the effective non-linear coefficient found for the bulk PPLN material (14pmV^{-1}). It is also higher than would be expected for optimal focussing in a bulk PPLN crystal of the same length, with greater enhancement to come with longer guides.

We observed that the modal properties of the PPLN and $LiNbO_3$ sections of the waveguide were not the same and found unexpectedly that, despite the large (nominal) numerical aperture, both the pump and second-harmonic beams were in the fundamental mode of the PPLN waveguide, with guided spot sizes of 3±1μm and 2±1μm respectively.

Future material fabrication is aimed at producing longer waveguides and patterning of the planar guide into channel structures, while a wide variety of device developments will include optical parametric oscillators and generators.

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