Hexagonally poled lithium niobate for second harmonic and optical parametric generation

R.T. Bratfalean, N. G. R. Broderick and D. J. Richardson
Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, UK

In this paper we present results of an experimental and theoretical study on basic non-linear optical properties in hexagonally poled lithium niobate (HexLN). We measured the temperature-tuning curve in a second harmonic generation (SHG) process and we studied the theoretical dependencies of the pump-signal and pump-idler angles on the signal wavelength for an optical parametric generation (OPG) process. The pump wavelength was 1536 nm in the SHG experiment and 1040 nm in the OPG study.

Hexagonally poled lithium niobate is a two dimensional non-linear photonic crystal[1], where the sign of the 2-nd order non-linear susceptibility is periodically changed in 2D. The domains of inverted dipole moment have a hexagonal shape and their centres describe a bi-dimensional lattice of hexagonal symmetry, as shown in figure 1. This particular lattice of inverted-domains had a period of 18 μm and the end faces were polished perpendicular to the x-axis. The crystal was 1 cm long and 0.5 mm thick. As in one-dimensional periodically poled lithium niobate (PPLN), the periodical change of the HexLN's non-linear susceptibility can be used to achieve the quasi-phase-matching condition for a non-linear optical process. What is different for HexLN is that the reciprocal lattice vector (RLV) is no longer constrained to a unique direction, as it may be any linear combination of two distinct unit vectors. This means more possible geometries for the input beams of a non-linear optical process in HexLN as compared to PPLN.

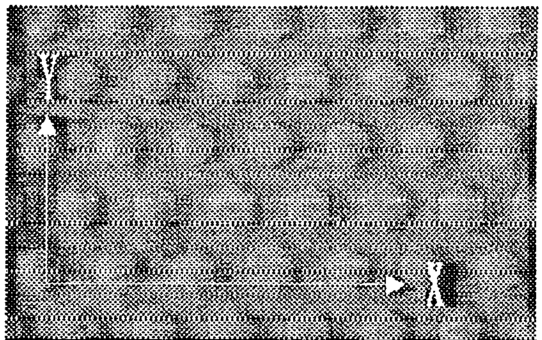

Figure 1. Picture of the HexLN showing the lattice of inverted-dipole moment domains.

We measured the SHG in the low conversion efficiency regime using 5 ns square pulses, which were gently focussed into the crystal after being amplified in a chain of erbium doped fibre amplifiers. The crystal was placed in an oven whose temperature was initially set to 125 °C. The oven sat on a rotation stage, which allowed the incident angle to be finely adjusted, around normal incidence, for maximizing the SHG signal at this particular temperature. The temperature was then tuned in the 99 - 150 °C temperature range. The variation of the SHG signal power with temperature is shown in figure 2, which also shows the variation in pump power during the scan. The temperature-tuning curve has a Gaussian shape with no apparent side peaks, which is not the case in PPLN where a sinc-shape is found. The full width at half maximum (FWHM) of the recorded peak is 8 °C, compared to a PPLN crystal of identical period and length, where the FWHM is ~ 2.5°C.

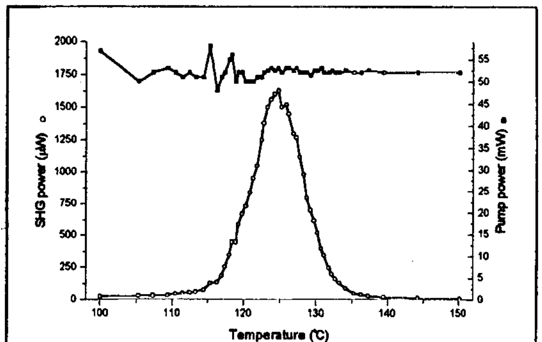

Figure 2. Temperature-tuning curve of the SHG process in HexLN.

The broad bandwidth of the SHG suggests that HexLN could be attractive as a broadband parametric amplifier for ultra-short pulses. To this end we have started looking at the inverse process, i.e. OPG. For each signal wavelength and reciprocal lattice vector, which can lead to the quasi-phase-matching condition, there are two solutions for the orientation of signal and idler beams. These solutions become degenerate when the signal and the idler are collinear. Figure 3 shows, for various reciprocal lattice vectors, one of the two solutions for the dependences of the pump-signal and pump-idler angles on the signal wavelength. It is considered that the pump beam enters the crystal at normal incidence, along the x-axis. Figure 3 shows that there is a wealth of possible OPG/OPA geometries. It is worth mentioning that in some regions the output angle changes slowly over a wide wavelength range, which means that such regions are suitable for OPA of ultra-short pulses. We also note that signal beams with same wavelength and output angle can be obtained for different RLVs, this occurring at the crossing points of the curves shown in figure 3. We hope to demonstrate an OPG in such a crystal shortly and are currently looking at predicting the relative gain as a function of the signal wavelength.

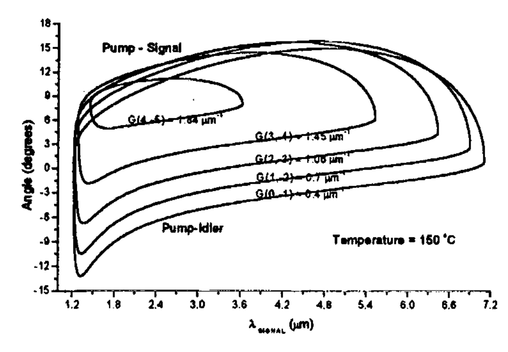

Figure 3. Dependencies of pump-signal and pump-idler angles on the signal wavelength for different possible RLVs.

In conclusion we have discussed the basic properties of optical parametric interactions in 2D poled materials and find that a broader bandwidth can be achieved compared to similar collinear processes in PPLN.

[1] N.G.R. Broderick *et al.*, Phys. Rev. Lett. **84**, 4345 (2000)