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Harmonic Generation in $\chi^{(2)}$ photonic crystals

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Recently Berger [1] described theoretically the concept of a nonlinear photonic crystal. In such a crystal the nonlinearity varies periodically in multiple dimensions. These are the higher dimensional analogues of the well known quasi-phase matched crystals such as periodically poled lithium niobate (PPLN). We have fabricated what we believe to be the first example of a two dimensionally periodically poled sample of lithium niobate[2] in which the domains are arranged on a regular hexagonal lattice (see Fig. 1). The hexagonal shape of the poled domains is due to the crystal structure of lithium niobate. The scale of the particular hexagonal lattice was chosen phase match 2nd harmonic generation using light at 1536nm. In principle any lattice structure can be fabricated using standard photolithographic techniques. This nonlinear periodic crystal (NPC) had dimensions of 14mm x 7mm x 0.3mm and ~30% of the area was poled.

To investigate the properties of the NPC we have used a number of different sources. Our initial measurements were made using a high power picosecond fibre laser, which produced 4ps pulses with a peak power of 250kW. Using this source we measured the conversion efficiency and temperature tuning curve for 2nd harmonic generation and these results are shown in Fig. 2. In addition have measured the wavelength dependence of the SHG process using this crystal and compared it to the response of a 1D PPLN crystal with the same length and period. These results, made with narrow bandwidth ns pulses, are shown in Fig. 3.

Note that compared to the 1D PPLN crystal the width of the wavelength tuning curve for 2nd harmonic generation is about twice as large. This is mainly due to the additional angular degree of freedom that arises from the noncolinear geometry. It should be possible to exploit this to obtain efficient doubling of femtosecond sources. In addition at high conversion efficiencies we observe the generation of both third and fourth harmonics due to additional reciprocal lattice vectors. Indeed NPC should allow for the simultaneous phase-matching of multiple nonlinear processes, which would not be possible in 1D.

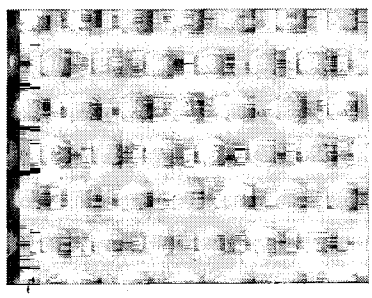

Fig 1: Picture of the NPC. The period is 18.5 microns.

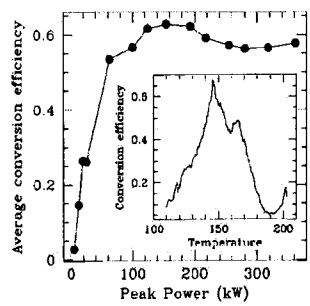

Fig:2: Conversion efficiency and temperature bandwidth

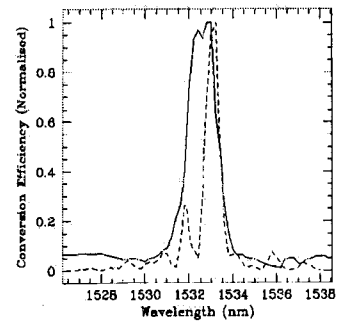

Fig. 3:Wavelength response of the NPC (solid line) and the PPLN crystal (dashed line).

In conclusion we have fabricated what we believe is the first two dimensionally poled nonlinear photonic crystal in lithium niobate. This NPC shows extremely high conversion efficiency for 2nd harmonic generation of picosecond pulses and has a wider wavelength bandwidth compared to a 1D PPLN with the same length and period.

References:

[1] V.Berger, ``Nonlinear Photonic Crystals'', Phys. Rev. Lett. **81** pp4136-4139 (1998)
[2] N.G.R. Broderick *et al.* ``Hexagonally poled lithium niobate: A two dimensional nonlinear photonic crystal'', Phys. Rev. Lett. **84** pp 4345-4348 (2000).