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Blue Light Generation in Bulk Periodically Domain-Inverted Lithium Niobate Crystals

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We report the generation of blue light in bulk domain-inverted lithium niobate by 3rd order quasi-phase-matching. High voltage pulses were used to induce periodic domain inversion in z-cut plates. The smallest domain width we have attempted to invert in these initial experiments is 4 μm, and inversion was achieved without difficulty. Since the field strength required for inversion is about 25 kV/mm along the z-axis and our high-voltage switch gives a maximum output of 5.5 kV, we are limited to processing 0.1 mm and 0.2 mm thick plates.

For second order nonlinear optical processes, phase-matching is essential. So far, birefringent phase-matching has most commonly been used: The disparity in refractive indices caused by dispersion is compensated for by the offset in refractive index between beams of different polarisation states. Another possibility exists, however, which was recognised very early [1], namely quasi-phase-matching (QPM). Here the quadratic nonlinearity is periodically inverted at the phase mismatch length, thus compensating for the phase velocity mismatch between the interacting fields. The conditions for optimum conversion will be discussed in the talk.

There are several advantages in using QPM. Birefringent phase-matching in a specific crystal only works in the wavelength interval where the magnitude of the birefringence of that crystal compensates for its dispersion. In addition, birefringent phase-matching is limited to the off-diagonal nonlinear tensor elements. With the recent advent of effective techniques for *bulk* domain inversion, QPM crystals can now potentially be fabricated that give high figures of merit for any wavelength combination for which the crystals are transparent. For lithium niobate, this means that the interacting wavelengths should fall between 0.4 μm and 4 μm. Furthermore, any nonlinear tensor element can be used. Since the largest coefficient is often an on-diagonal element (describing interaction between extraordinary rays) this is a real advantage. As an example, QPM in lithium niobate using the d_{33} coefficient gives more than an order of magnitude higher conversion efficiency than birefringent phase-matching with d_{31}. The application that has attracted most interest is generation of blue light by coupling a laser diode to a periodically inverted channel waveguide. This confines the light to a small cross section over its whole length and generation of up to 21 mW with a conversion efficiency of 600 %/Wcm^2 has been reported [2].

In the present experiment (December 1993), a 0.1 mm thick sample was inverted with a domain period of 9 μm, which gives 3rd order quasi-phase-matched frequency doubling from 834 nm to 417 nm and also 4th order generation of ultraviolet light. The crystal length was 4.5 mm, which is appropriate for confocal focusing through a 0.1 mm thick crystal. A tunable Ti:sapphire laser was used in the experiments. Further details, up-to-date results and various applications involving solid-state lasers will be presented at the meeting.

References

1. J.A. Armstrong, N. Bloembergen, J. Ducuing, and P.S. Pershan, " Interactions between light waves in a nonlinear dielectric", *Physical Review* **127** (1962) 1918-1939.
2. M. Yamada, N. Nada, M. Saitoh, and K. Watanabe, "First-order quasi-phase matched $LiNbO_3$ waveguide periodically poled by applying an external field for efficient blue second-harmonic generation", *Appl.Phys.Lett.* **62** (1993) 435-436.