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improvement in the nonlinear sensitivity is clearly possible. These lightly doped NLC films allow applications involving write-read with the same laser wavelength, and thicker or multiple films for volume holographic storage.

Stored phase gratings can also be turned off and on with an applied ac field using the linear electro-optical effect.[1] It is shown that an ac voltage (~90 V, 200 Hz) will completely align the director axis of the entire LC cell, and thus turn off the grating in ~100 μsec. When the ac field is removed, the grating recovers in ~10 msec. It is also observed that use of an ac field at intermediate strength, and at frequencies between 1-1000 KHz could improve the grating diffraction efficiency. The actual mechanism responsible for this frequency dependence, however, remains a subject of further investigation.

The research group at Penn State is currently investigating the fundamental processes and the applications of the observed effect. Studies are being conducted with a variety of NLC structures including single or multiple films, NLC-cored fiber faceplate, thin film waveguide, and polymer dispersed solid state NLC films.

References

1. I. C. Khoo, *Liquid Crystals: Physical Properties and Nonlinear Optical Phenomena*, Wiley Interscience, N.Y. (1994); I. C. Khoo and S. T. Wu, *Optics and Nonlinear Optics of Liquid Crystals*, World Scientific, Singapore (1993)
2. I. C. Khoo, "Holographic grating formation in dye- and fullerene C_{60}-doped nematic liquid crystal film," Opt. Lett. In press (1995).
3. A. Partovi *et al.*, "Volume holographic storage in hydrogen treated germano-silicate glass," Appl. Phys. Lett. **64**, 821 (1994).
4. K. Meerholz *et al.*, "A photorefractive polymer with high gain and diffraction near 100%," Nature 371, 497 (1994).

Quasi-Phasematched Optical Parametric Oscillators in Periodically Poled $LiNbO_3$

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Quasi-phasematching (QPM) is an alternative to birefringent phasematching that is especially useful for optical parametric oscillators (OPOs).[1] QPM can be implemented in ferroelectrics, such as $LiNbO_3$, by building into the crystal a grating of domain-reversed regions. Because the grating is controlled by the design of a lithographic mask, phasematching can be achieved independent of inherent material properties. Thus, QPM permits noncritical phasematching of any wavelength at any temperature, within the transparency range of the material. In addition, QPM interactions can use the largest element of the nonlinear susceptibility; for example, periodically poled $LiNbO_3$ (PPLN) has gain ~20 times larger than the most efficient birefringently phasematched process in $LiNbO_3$.

Our first QPM OPO was in a PPLN waveguide, pumped with a 100-nsec pulse Q-switched Ti:sapphire laser.[2] This device had single-pass parametric gain of up to 2.6 at 1.55 μm. The measured oscillation threshold was 5.5 W peak, and over 700 mW peak signal/idler power was generated. The output tuned from 1.4-1.7 μm by varying the pump wavelength. The high gain of PPLN combined with tight focusing over long interaction lengths of waveguides offers the potential for a useful low-threshold device. With optimized designs, we predict threshold for a singly resonant OPO of ~100 mW, which is accessible to direct diode pumping.

A significant advance in ferroelectric materials for QPM occurred with the development of room-temperature electric field poling.[3] This technique permitted fabrication of thick PPLN crystals and led to our demonstration of a bulk QPM OPO.[4] The key results of this

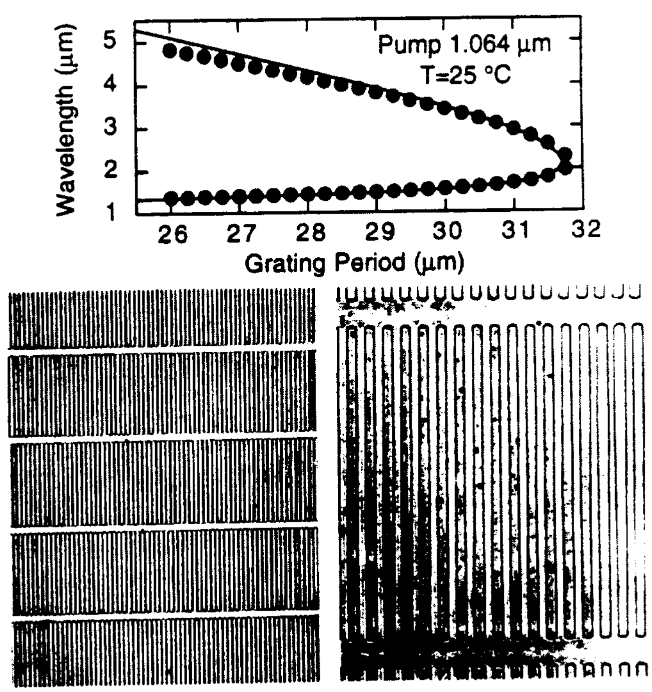

Figure 1. Upper plot: OPO tuning as a function of grating period. Lower left: Portion of PPLN chip with multiple grating sections. Lower right: Magnified view of the 29-μm period section. Tuning was achieved by translating the crystal ~1 cm through 24 different grating sections. Continuous tuning can be obtained by fine tuning with temperature.

experiment were that poling introduced no additional loss and that there was a factor of greater than 10 margin between the oscillation threshold and the damage limit.

We have built a variety of QPM OPOs using bulk PPLN.[5] With 25-mm long crystals and 1.064-μm, 7-nsec Q-switched pump lasers, we measured oscillation threshold of 6 μJ. These PPLN OPOs run robustly, with typical pump conversion of 70% at 8 times threshold, and operation at 25 times threshold without damage. Large gain and noncritical phasematching make PPLN well-suited to low peak power applications, such as with high-repetition-rate, acousto-optically Q-switched diode-pumped solid-state pump lasers and cw pump lasers. We recently demonstrated a doubly resonant OPO directly pumped by a commercial cw diode laser. Thresholds for cw singly resonant OPOs of less than 10 W are also possible.

The flexibility of QPM OPO designs is illustrated by our recent demonstration of a device consisting of multiple grating sections fabricated on a single chip. This multi-grating OPO is tuned by translating the crystal through the resonator. We demonstrated tuning from 1.36-4.84 μm with 1.064-μm pumping. This experiment shows the level of domain pattern control now obtainable in bulk PPLN. In the future, we expect to build devices with tailored phasematching curves and with multiple nonlinear processes on a single chip, as shown in Figure 1.

References

1. M. M. Fejer *et al.*, "Quasi-phase-matched second harmonic generation: tuning and tolerances," IEEE J. Quantum Electron. **28**, 2631-2654 (1992).
2. M. L. Bortz *et al.*, "Quasi-phase-matched optical parametric amplification and oscillation in periodically poled $LiNbO_3$ waveguides," Opt. Lett. **20**, 49-51 (1995).
3. M. Yamada *et al.*, "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**, 435-436 (1993).
4. L. E. Myers *et al.*, "Quasi-phase-matched 1.064-μm-pumped optical parametric oscillator in bulk periodically poled $LiNbO_3$," Opt. Lett. **20**, 52-54 (1995).
5. L. E. Myers *et al.*, "Quasi-phase-matched optical parametric oscillators in bulk periodically poled $LiNbO_3$," J. Opt. Soc. Am. B **12**, 2102-2116 (1995)

LASERS

Gain Theory of Wide Gap Semiconductors

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Semiconductor lasers based on wide-bandgap semiconductor compounds have substantial application potential because they can provide output with wavelengths covering almost the entire optical spectrum, including the range from green/blue to ultraviolet. At present, operation of II-VI semiconductor lasers has been demonstrated at room temperature with injection current pumping.[1] Light emitting diodes (LEDs) based on group III-nitride heterostructures are commercially available, and lasing in bulk GaN was recently achieved using optical pumping.[2]

Since wide-bandgap lasers are in the early stage of development, the detailed physical mechanisms affecting their behavior are under active investigation. The results of experimental investigations show that the lasing frequency is red-shifted with respect to the unexcited exciton resonance, and an absorption resonance is present at densities that are sufficiently high for gain to occur.

In recent publications[3,4] we presented theoretical results showing that the experimentally observed gain characteristics are significantly influenced by the strong Coulomb correlation effects in wide gap semiconductors. Using the Maxwell-Semiconductor Bloch Equations,[5] which provide a consistent treatment of many-body Coulomb effects at the level of the screened Hartree-Fock approximation, we analyzed gain spectra of bulk group III-nitride and II-VI quantum well structures. A typical result is shown in Figure 1. We clearly see a pronounced excitonic absorption peak for low

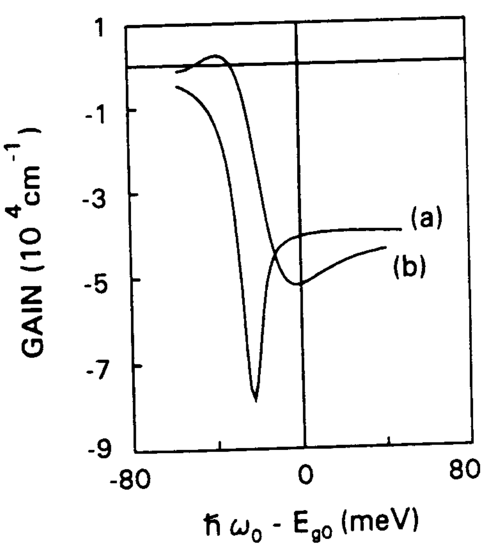

Figure 1. Computed gain spectra at T = 77K, for bulk GaN at carrier densities, N = (a) 10^{17}cm^{-3} and (b) 10^{18}cm^{-3}. E_{g0} is the unexcited GaN bandgap energy at 77K.