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Efficient operation of an all-solid-state synchronously-pumped lithium triborate optical parametric oscillator

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The achievement of broad tuning ranges in cw pumped lasers has generally called for the use of multiwatt pump sources, with the Argon laser being particularly widely used. The average pump power requirements for a synchronously-pumped optical parametric oscillator (OPO) can be much lower, with average pump powers in the region of a few tens of milliwatts being sufficient to allow very extensive tuning ranges. This brings the pump power requirements within the range of laser-diode-pumped mode-locked lasers, with the attractive prospect of future tunable lasers being much more compact, cheaper and more reliable than their Argon-pumped forebears. A particularly promising OPO system is based on the nonlinear crystal lithium triborate (LBO), pumped by the second harmonic of an additive-pulse mode-locked laser-diode-pumped neodymium laser[1,2]. The additive-pulse mode-locking scheme enables much shorter (and hence higher peak-power) pulses to be produced than for active mode-locking. LBO is eminently suitable for this scheme in that it allows temperature-tuned non-critical phase-matching, and hence tight focusing and high intensity to be maintained over a very broad range of signal and idler wavelengths. Results reported for such a system, using an anti-reflection (AR) coated LBO crystal, demonstrated tuning over the range 0.81 to 1.48μm[3]. A limitation of that system was posed by the reflection losses of the AR coatings, which increased rapidly towards the limits of the tuning range. Hence we report much improved results, with wider tuning range and higher efficiency using a Brewster-angled LBO crystal.

The LBO crystal was 13mm long with a 3 x 3mm^2 aperture, mounted in an oven designed to provide temperatures up to 200°C with a stability of ±0.1°C. A four mirror standing-wave resonator was used for the OPO [fig.1]. The OPO was driven by a cw mode-locked pulse train at 523nm, obtained by resonant second harmonic generation (in LBO) of the output from an additive-pulse mode-locked Nd:YLF laser pumped by a 3W laser-diode array. Pump characteristics were as follows; mean 1.047μm output power 500mW, pulse repetition rate 105MHz, pulse duration 2.0ps, hence peak pulse power 2.2kW. The second harmonic train had an average power of 330mW, pulse duration 1.9ps, hence peak power 1.5kW. The OPO threshold average pump power was 190mW, so that pumping up to 1.7 times threshold could be achieved. Pump depletion of ~75% was achieved at the highest pump levels. Using two mirror sets, the tuning ranges covered were 0.98 - 0.82μm (resonated signal wave) and 1.12 - 1.46 (idler), and 0.85 - 0.72μm (resonated wave) and 1.34 - 1.91μm (idler). A mean output power of > 30mW was obtained for both the signal and idler waves across the range 0.74μm to 1.82μm. Typical pulse durations for the OPO output were measured to be 1.5ps, and the time-bandwidth products were typically 0.9.

These results already demonstrate the excellent efficiency and extensive tuning range that can be achieved from a rather modest and non-optimum system. Further improvements to the performance capability will be reported. These include the use of a longer LBO crystal of better quality, the use of a further mirror set, to extend the tuning range to 0.65μm - 2.7μm, and the results of efforts aimed at reducing the excess bandwidths so that bandwidth-limited operation is achieved. Higher power operation will also be reported, making use of a diode-pumped Nd:YLF amplifier stage, which is already showing a promising performance, giving a 50% increase in both the fundamental and harmonic powers, to 750mW and 490mW respectively.

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References

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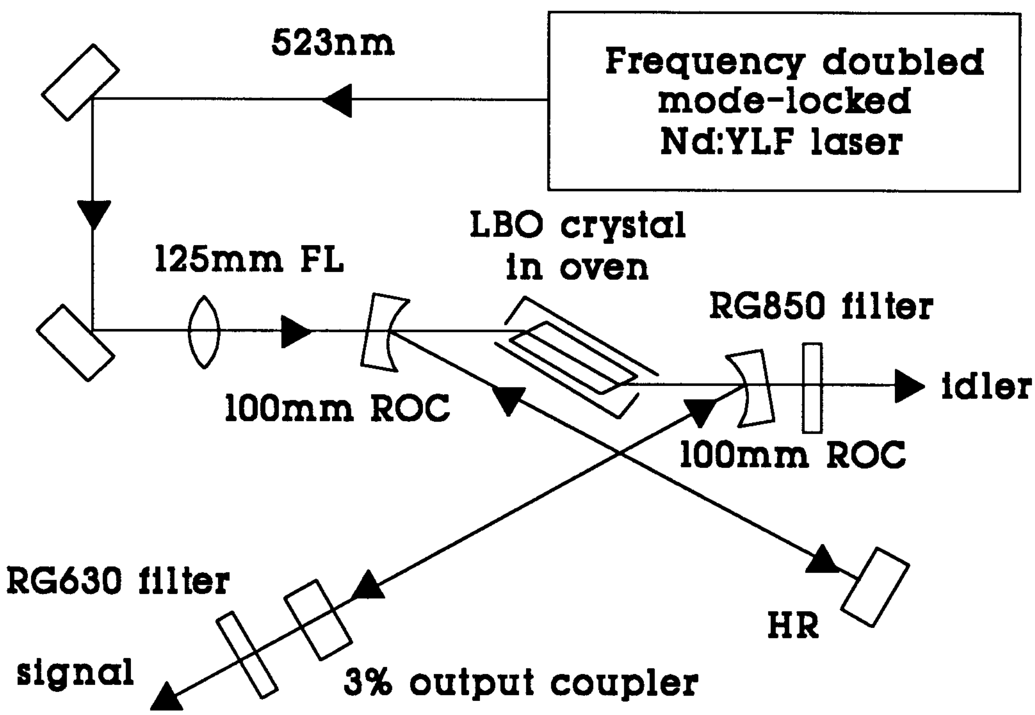

Figure 1. Schematic diagram of the optical parametric oscillator.