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All-solid-state synchronously-pumped lithium triborate optical parametric oscillator

S.D. Butterworth, M.J. McCarthy and D.C. Hanna

Optoelectronics Research Centre

University of Southampton

Southampton SO9 5NH, UK

Tel: 0703 593136

Fax: 0703 593142

Abstract

New developments to the performance capability of a picosecond pulse synchronously-pumped optical parametric oscillator based on Brewster angled lithium triborate crystal will be presented.

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The attainment of broad tuning ranges with ultrashort pulses in cw pumped lasers has generally called for the use of multiwatt pump sources, with the Argon ion laser being extremely widely used. The synchronously-pumped optical parametric oscillator (OPO) is potentially the ideal source for the many applications requiring widely tunable ultrashort pulses. For high stability, cw pumped operation is essential, with only one of the two generated waves being resonated in a singly resonant oscillator (SRO). Pump power requirements for a synchronously-pumped OPO can be much lower with average pump powers in the region of 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. 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 higher peak-power pulses to be produced than for active mode-locking. LBO is particularly suitable for this scheme in that it allows Type-I temperature-tuned non-critical phase-matching, and consequently 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. Here we report much improved results, with wider tuning range and higher efficiency using a Brewster-angled LBO crystal[4].

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 $\pm$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 three mirror sets, the tuning ranges covered were 0.65-0.98μm (resonated signal wave) and 1.12-2.7μm (non-resonated idler) [fig.2]. A mean output power of > 30mW was obtained for both the signal and idler waves across the range 0.7μm to 2.0μm [fig.3]. Pulse durations across the tuning range of the OPO were measured to be 1.5ps, with time-bandwidth products of ~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 presented. These include the use of a higher quality and longer LBO crystal, 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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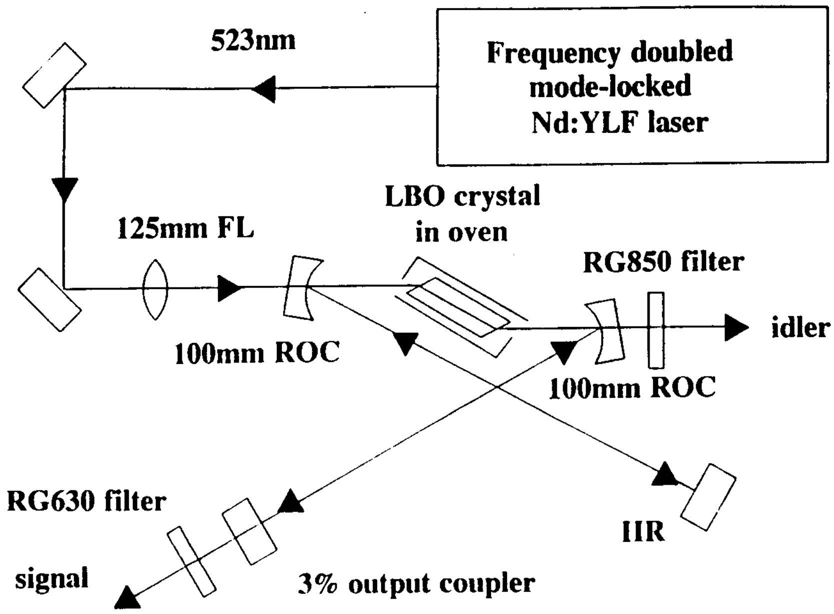

Figure 1. Schematic layout of the optical parametric oscillator

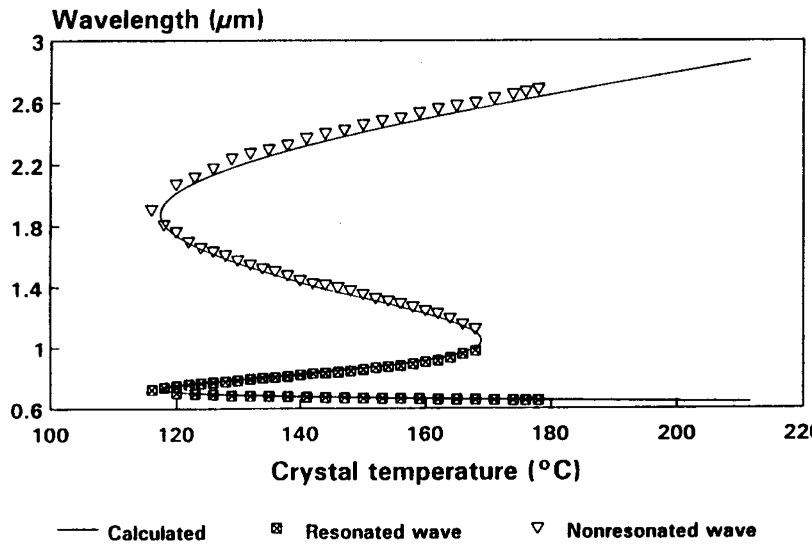

Figure 2. Wavelength tuning versus LBO crystal temperature.

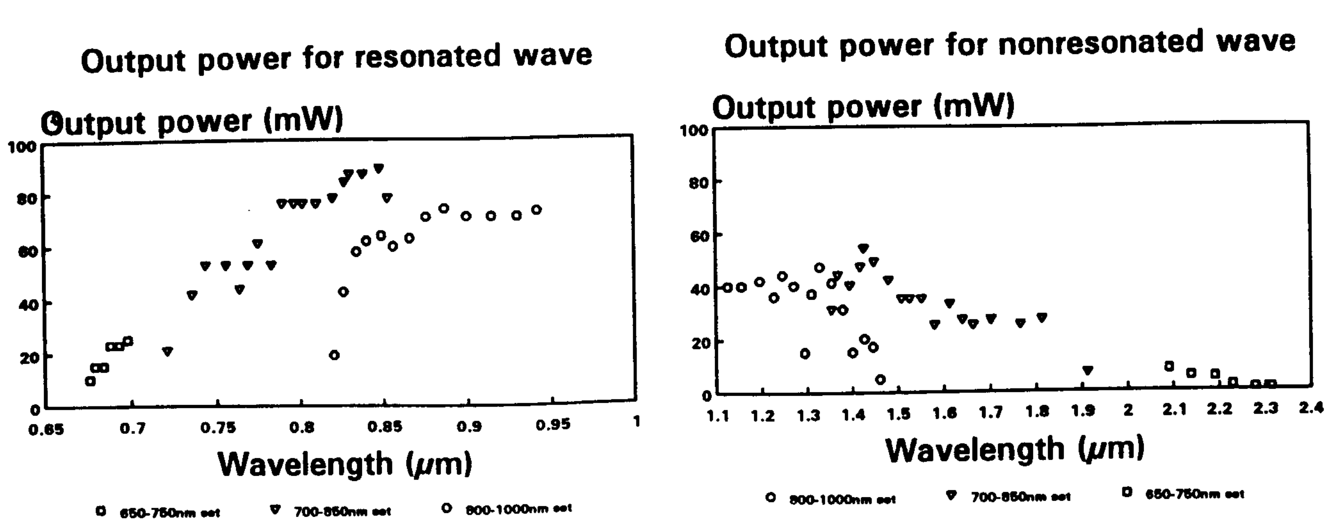

Figure 3. Signal and idler output power across the tuning range.