Long-wavelength operation of synchronously pumped optical parametric oscillators based on periodically poled $LiNbO_3$

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Synchronously-pumped parametric oscillators based on periodically-poled $LiNbO_3$ operating in the region of strong idler absorption are described and a design strategy outlined. Results include ~30m W average power at 5 .3 μm and 4m W average power at 6.1 μm.

The very high parametric gain achievable in periodically poled lithium niobate (PPLN), when pumped by intense short pulses, has allowed synchronously pumped oscillation at wavelengths where very strong idler absorption is present [1,2]. With appropriate design practical sources operating at idler wavelengths well beyond 6μm are possible. A general design strategy is outlined and results from its implementation are presented.

An element in the design strategy includes careful minimisation of signal losses, since these strongly affect performance. For this reason a ring configuration is preferable. The strategy also favours short pulses, and tight focussing at the exit end of the crystal, to maximise signal and pump intensities over the last idler extinction-length of the crystal. Despite the strong idler absorption coefficient α_i it is not essential to use a crystal length L which makes $\alpha_i L$ small, and we have operated successfully with $\alpha_i L \sim 30$.

For operation in the picosecond regime an APM mode-locked Nd:YLF laser (Microlase DPM-1000-120) followed by an amplifier (Q-Peak MPS-1047 CW-10) has been used as the pump, providing 4 ps pulses at 120 MHz, with a maximum average power of 3.6W delivered to the PPLN crystal. A four-mirror ring resonator was used, with all mirrors highly reflecting over the signal wavelength range 1.2μm - 1.4μm. AR coatings on the PPLN crystal had an estimated loss of ~0.5% per surface over this signal wavelength range. Representative results include: for 5.3μm ($\alpha_i \sim 4$ cm^{-1}), 30mW measured average power leaving the output mirror (35mW incident on the mirror); for 6.1μm ($\alpha_i \sim 8$ cm^{-1}, corresponding to a local minimum in the IR absorption), 4mW average o/p power (8W peak pulse power). The available PPLN gratings limited the longest idler wavelength to 6.6μm for which the threshold pump power was ~2.6W.

To investigate the use of shorter pump pulses we have used a tandem OPO scheme, in which a PPLN SPOPO operating at ~1.5μm, producing compressed pulses [3] (down to ~300fs) pumps a second PPLN OPO (with 19mm long crystal). The first SPOPO can provide higher peak pump powers than those available from the Nd:YLF laser. Initial results show a reduced threshold for operation at an idler wavelength of 5.3μm. Further results from this system at longer wavelengths will be reported, providing guidance on the expected performance of a long-wavelength PPLN SPOPO using an EDFA source in place of the Nd:YLF pump.

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[2] P. Loza-Alvarez, C. T. A. Brown, D. T. Reid, and W. Sibbett, "High-repetition-rate ultrashort-pulse optical parametric oscillator continuously tunable from 2.8 to 6.8 μm", Opt. Lett. **24** (21), 1523-1525 (1999)
[3] L. Lefort, K. Puech, S. D. Butterworth, Y. P. Svirko, and D. C. Hanna, "Generation of femtosecond pulses from order-of-magnitude pulse compression in a synchronously pumped optical parametric oscillator based on periodically poled lithium niobate", Opt. Lett. **24** (1), 28-30 (1999)