Novel bi-directional pump geometry for synchronously pumped optical parametric oscillators with a nonlinear increase in output power for application in microscopy

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KEY WORDS: Optical parametric oscillator, nonlinear optics, multi-photon microscopy

Advances in OPO technology have led to the realization of reliable, commercially available sources of coherent radiation which have various applications in optical microscopy including three photon and third harmonic imaging [1]. Efficient and turnkey high power ultra-short pulsed (>50 mW, <1 ps) synchronously pumped OPO systems are increasingly sought-after for nonlinear optical imaging due to the provision of longer wavelengths (>1000 nm). However, since most optical microscopes are not designed for operation at longer wavelengths, high output powers from OPO systems are required in order to overcome the optical loss presented by the imaging system. There are however several limitations to the routine and practical development of OPO platforms with a high output power. In particular, despite the prevalence of multi-Watt ultra-short pulsed laser sources that are suitable for synchronous pumping of nonlinear optical crystals used in OPO systems, these materials have low damage thresholds and hence high power operation is difficult.

We address this problem by employing a bi-directional pump geometry that enables a nonlinear increase in the OPO output power. In addition to the conventional single-pass pump in the forward direction (1 W, 300 fs, 1064 nm), a second counter-propagating pulse (1 W, 300 fs, 1064 nm) in the 'reverse' direction was synchronized with the circulating singly resonant OPO signal wavelength pulse. By selecting forward and reverse direction pump intensities which were below the damage threshold of the crystal and by also ensuring that only one pump pulse was present in the crystal at any time, the pump power could be increased two-fold. This resulted in a nonlinear increase of the overall peak output of the OPO (from 10 kW to 18.8 kW) without causing damage to the nonlinear crystal and with no significant change to the signal wavelength spectral profile.

With fs-pump pulse durations, the OPO cavity length must be closely matched to the length of the pump resonator. However, through the application of this bi-directional pump geometry, the OPO cavity length detuning tolerance was extended two-fold, thus providing a wider stability region.

This unique and effective pump arrangement is compatible with wavelength tuned OPO systems and at all spectral regions, thus providing opportunities for improved laser systems in all areas of optical microscopy where OPO technology is required.

References

[1] E. Beaurepaire *et al*, Nat. Methods **3** 1, (2006).