Fiber-Laser-Pumped High-Power, High-Repetition-Rate, Ultrafast Optical Parametric Oscillators in near to mid-Infrared

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Summary

Synchronously pumped optical parametric oscillators (SPOPOs) are attractive sources of high-repetition-rate, wavelength tunable picosecond and femtosecond pulses from the UV to mid-IR. Picosecond SPOPOs are of particular interest for applications where pulses of narrow bandwidth and high average power are required. A key factor in achieving this goal is the exploitation of suitable nonlinear materials capable of withstanding the large average powers without thermal effects while at the same time fulfilling the requirements of long interaction length, phase-matching for the wavelength range of interest, high nonlinear gain, and noncritical phase-matching to achieve the high focused intensities. Quasi-phase-matched (QPM) ferroelectric crystals can fulfill such simultaneous requirements. Among them, MgO-doped periodically-poled $LiNbO_3$ (MgO:PPLN) has been established as the most effective material for the generation tunable picosecond pulses at high average powers in the infrared [1]. A major step in this direction is the deployment of more simplified, compact, portable and cost-effective pump sources based on fiber laser technology to replace the more complex mode-locked picosecond lasers predominantly deployed to date. Recently, the operation of a picosecond SPOPO at a low repetition rate of 15.3 MHz providing an average power of 1.09 W was reported [2].

Here we report the generation of high-repetition-rate picosecond pulses at multiwatt average powers in the near- to mid-infrared using a SPOPO based on MgO:PPLN and synchronously pumped by a cw mode-locked Yb fiber laser 81 MHz repetition rate.

A schematic of the experimental setup is shown in Fig. 1. The 20-ps (FWHM) pulses from the Yb fiber laser (Fianium, FP1060-20) at a wavelength of 1064 nm are focused into a 50-mm-long MgO:PPLN crystal. Figure 2 shows the average output signal power as a function of pump power at the input to the MgO:PPLN crystal. The measurement was performed at signal wavelength of 1.55 μm (idler at 3.393 μm) and at crystal temperature of 53 ºC. The SPOPO exhibits a threshold of 830 mW (with ~25% output coupling at 1.55 μm) and SPOPO output increases with increased pump power. We measured the signal output power, shown at Fig. 2, for an output coupling of 20-25% for three different pump powers of 5 W, 9.37 W and 16 W. Figure 3 depicts the corresponding average output idler and total. At the highest pump power, we generated 9.58 W of total power (6.53 W signal, 3.05 W idler) from 16 W of pump with ~60% extraction efficiency in excellent TEM_{00} spatial beam quality. At all three pump powers, depletion was ~85% and the pulse spectrum exhibited a clean single peak with a bandwidth of ~0.47 nm

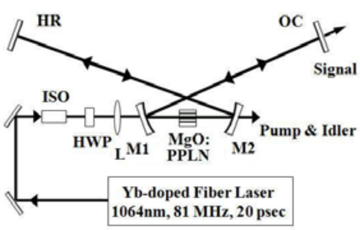

Fig. 1. Experimental setup of picosecond optical parametric oscillator. OC: Output Coupler, HR: High-Reflector, M1 and M2: curved mirrors, ISO: optical isolator, HWP: a half-wave plate, L: focusing lens.

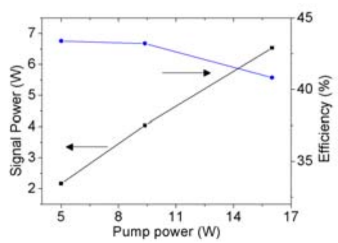

Fig. 2. SPOPO signal output power and efficiency at 1.55 μm versus pump power at the input to the crystal.

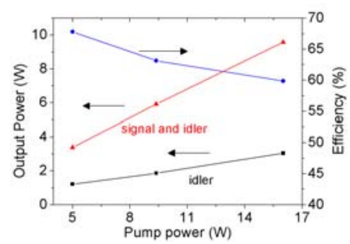

Fig. 3. SPOPO idler (at 3.393 μm), total average power, and total power efficiency versus pump power.

In conclusion, we successfully demonstrated the operation of a picosecond SPOPO based on MgO:PPLN pumped by a high-power picosecond Yb fiber laser at 1.064 μm, continuously tunable from 1.45 to 1.75 μm and capable of delivering 9.58 W of output power in the near- and mid-infrared at an external efficiency as high as 60%.

References

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