Sub-ns OPO based on PPKTP with 1 mJ Idler Energy at 2.8 µm

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Recently we demonstrated that periodically-poled oxide materials can be employed in short cavity, singly-resonant optical parametric oscillators (OPOs), with very low thresholds and high conversion efficiency [1]. We demonstrated sub-ns pulse durations down to ~250 ps for the signal and idler pulses of 1-10 kHz OPOs based on periodically-poled $KTiOPO_4$ (PPKTP) and pumped at 1064 nm. However, with maximum idler energies of 110 and 50 µJ near 2.8 µm obtained with the 1-ns and 500-ps pump pulse sources, respectively, the energy scaling capability of thick PPKTP remained unexploited. Here we extend these results to the millijoule energy range for the idler by utilizing the full crystal aperture with a powerful pump source specially designed for this purpose.

The same periodically-poled PPKTP sample (d_{eff} ~ 8 pm/V), 9-mm long, with a domain inversion period of 37.8 µm [1], was used in the cavity shown in Fig. 1a. It was 3-mm thick along the z-axis, and 5-mm wide along the y-axis, with a grating pattern of 8 mm (along x-axis) to 2 mm (along y-axis). The PPKTP sample was antireflection coated for the pump and signal with low reflectivity (~4%) in the idler spectral range. The rear mirror RM was a plane Ag-reflector while the plane output coupler OC was a dielectric mirror reflecting 99.9% at the signal wave and transmitting >93% at the idler wave (~2.8 µm). Hence, the OPO can be considered as singly resonant with double pass pumping. The physical cavity length was 16 mm. The PPKTP crystal was pumped through the OC which transmitted >98% at 1064 nm. The beams were separated by a dichroic mirror DM, which had 99.5% reflection for the pump (p-polarization) and transmitted 94% (p-polarization) at the idler wavelength. The near-diffraction limited, single frequency Nd:YAG based MOPA pump system is described in detail elsewhere and can provide up to 13 mJ output pulses at 1064 nm at a repetition rate of 500 Hz [2]. For the present experiment the pump pulse duration was 714 ps and the pump beam was down collimated to a diameter of ~2 mm in the position of the PPKTP crystal. Only the idler pulse energy was measured by a power meter (PM).

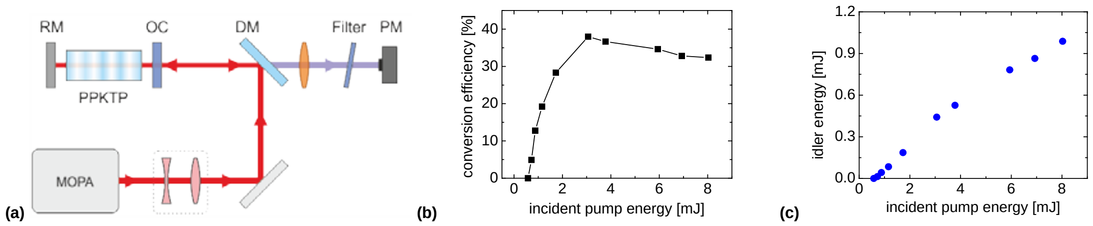

Fig. 1 (a) Experimental set-up, (b) quantum conversion efficiency calculated from the idler output, and (c) idler energy at the OPO output versus pump energy incident on the PPKTP crystal.

The OPO threshold was at 0.58 mJ of pump energy, corresponding to a peak (on-axial) intensity ~50 MW/cm^2. Maximum idler energy of 1 mJ was extracted at maximum pump level of 8 mJ with a quantum conversion efficiency of 38% (Fig. 1b,c). This is the highest energy ever reported from a sub-ns OPO while the conversion efficiency in fact exceeds the one achieved in the low energy regime [1].

The pulse duration of the signal was measured by a fast InGaAs photodiode to be 550 ps, while with the same photodiode we measured a FWHM of the frequency doubled idler equal to 270 ps. Hence, the idler pulse duration at 2.8 µm is estimated to be 380 ps (FWHM). In the pulse duration measurements a Gaussian pulse shape is assumed. Thus, the peak idler power amounts to 2.6 MW.

In conclusion, we achieved idler energy as high as 1 mJ at 2.8 µm from a PPKTP OPO in the sub-ns regime. At 500 Hz this gives an average power of 0.5 W. The parametric gain of this OPO is so high that it can operate without the OC as a double pass optical parametric generator. Thus, even higher conversion efficiency can be expected by decreasing the OC signal reflectivity in order to avoid intracavity optical damage and pumping with the full available pump energy.

References

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