High Energy, Sub-nanosecond, 0.5-kHz, Mid-IR OPO based on PPSLT Pumped at 1064 nm

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Sub-nanosecond coherent sources in the mid-IR spectral region (2.5-4 microns) with high average power and high pulse energy are of fundamental interest for both scientific and industrial applications, e.g. remote sensing, molecular spectroscopy and broad medical applications taking advantage of the high water absorption around 3 µm [1]. Optical parametric oscillators (OPO) based on periodically poled quasi phase-matched (QPM) nonlinear materials are especially promising sources due to the exceptionally large nonlinearity and the complete absence of spatial walk-off. Typical nonlinear material for a QPM based OPO in the mid-IR is periodically poled lithium niobate (PPLN). However, its low photorefractive damage threshold together with its high coercive field (21 kV/mm), largely limits its use in high power OPOs [2]. On the other hand, periodically poled $KTiOPO_4$ (PPKTP) and periodically poled stoichiometric $LiTaO_3$ (PPSLT) have much lower coercive field (2 kV/mm and 1.7 kV/mm respectively) and higher photorefractive damage threshold. Thus, larger aperture crystals and higher pump energies can be employed. Additionally, PPSLT is transparent up to 4 µm presenting an attractive opportunity to produce high power OPOs at high repetition rates, when used with high power sub-nanosecond laser sources.

In this work we present a short cavity PPSLT singly resonant OPO with double pass pumping, emitting in the mid-IR with high conversion efficiency, high average power at kilohertz repetition rate with considerable potential for energy scaling. We employ a 11 mm long, 10 mm wide, and 2 mm (along z axis) thick PPSLT crystal (manufactured by Deltronic Crystal Industries Inc., NJ) with three polled zones with different domain inversion periods (30.2, 30.3 and 30.4 µm), equally spaced along the width of the crystal. The crystal is antireflection coated for the pump, the signal and idler waves. The OPO cavity is 23 mm in length with plane parallel mirrors. The pump source is a diode pumped Nd:YAG microchip laser oscillator amplified in a two stage rod amplifier emitting up to 8 mJ at 0.5 kHz, 830-ps pulse duration with high beam quality (M^2<1.4). The pump beam is collimated to a beam diameter of 1 mm in the position of the PPSLT crystal. After the separation mirror only the idler wave is measured, the residual pump radiation and the signal are blocked with a 3.2 µm long pass filter (the filter has a transmission of ~53% at the idler wavelength).

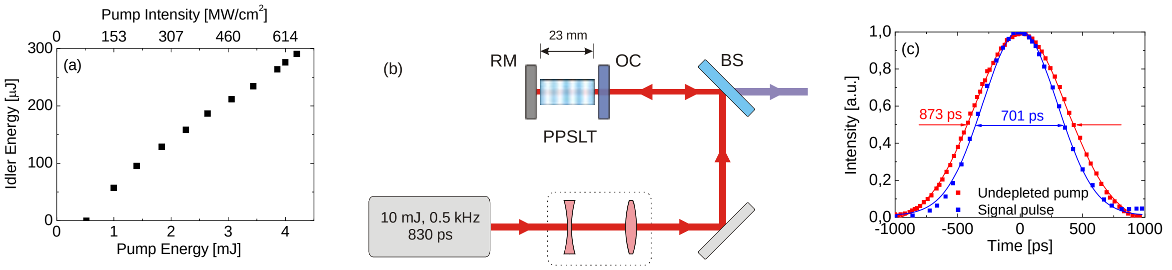

Fig. 1 Idler energy versus pump energy, incident on the PPSLT crystal (a) at 65 °C; Setup layout (b) – rear Ag-mirror (RM), output coupler (OC) HR 1.4-1.8 µm, HT 2.7-4 µm, pump/idler separation mirror (BS); oscilloscope traces of the incident pump and signal pulse (c).

The maximum output idler energy is 290 µJ at 3422 nm, which corresponds to ~640 µJ for the signal wave (1544 nm) (Fig.1). The idler conversion efficiency is ~13 %, whilst the overall quantum conversion efficiency is ~42 %. When working in the other two domain inversion periods we achieved similar energy parameters at idler wavelengths 3462 nm and 3498 nm. Heating of the nonlinear crystal above the presently set work point of 65° C will enable additional idler tuning in the range 3.1- 3.5 µm. The OPO threshold is around 500 µJ (~76 MW/cm^2 average pump intensity). The maximum pump intensity applied in the present work is limited by the damage threshold of the used rear mirror. The signal pulse duration after deconvolution with the response function of the detection system is 660 ps, shorter, than the pump pulse duration (830 ps) Fig1(c).

In conclusion, we have developed a sub-nanosecond mid-IR laser source with up to 145 mW average power at 3.4 µm and 0.5 kHz repetition rate. To our knowledge this is the first source with such simultaneously high average power and high pulse energy (290 µJ). Further power scaling is possible and in progress.

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