1 W, 2 mJ-Kilohertz, Sub-nanosecond, 3 - 3.5 µm Tunable, PPSLT OPO Pumped at 1064 nm

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Coherent laser sources in the 3-5 µm spectral range, with high pulse energy and average power and broad spectral tunability are of fundamental importance for a number of applications, e.g. remote sensing and spectroscopy in the mid IR "molecular fingerprint" window, resonant infrared pulsed-laser deposition, as well as wide-ranging medical and countermeasure applications. Although, a number of techniques aim to exploit this spectral region (mid-infrared quantum cascade lasers, semiconductor lasers, fiber lasers and solid state lasers based on new laser materials), obtaining both high-pulse energy and average power is still problematic. The most simple and effective way to generate such radiation is with nonlinear frequency down-conversion devices such as OPOs, pumped by well established Q-switched neodymium lasers. High-power continuous-wave (CW) and quasi-CW mid-infrared parametric sources with periodically polled (PP) materials (PPKTP, PPLN, PPKTA, etc.) and mid-infrared crystals (ZGP, $CdSiP_2$, $AgGaS_2$, etc.) are well established for low pulse energy and/or low average power. However, recently large aperture PP Rb-doped KTP crystal [1] is targeted for high energy and high power applications. High aperture stoichiometric lithium tantalate (PPSLT) is also a suitable candidate for more efficient and high power/energy devices which is not exploited yet. Currently, excising OPO technology in this spectral region is forced to the two extremities (based on repetition rate and pulse energy), mainly by the laser sources used for pumping. On the one hand, there are high repetition rate sources (1-10 kHz) with very modest output energy (~µJ) [2] and on the other hand are low repetition rate sources (<100 Hz) with high output energy (mJ range) and consequently low average power (x10 -100 mW) [3]. However, both types of sources are impractical for the high impact applications, requiring simultaneously high pulse energy and average power. Here, we describe a compact sub-nanosecond, short cavity, singly resonant OPO based on PPSLT for the mid-infrared range, pumped by a single frequency, Neodymium based laser amplifier [4]. The OPO simultaneously provides high pulse energy at relatively high repetition rate and tunability around the peak absorption band of water (3-3.5 µm).

We employ a 20 mm long, 10 mm wide, and 3.2 mm (along z axis) thick PPSLT crystal (manufactured by Deltronic Crystal Industries Inc., NJ) with three different polled zones with domain inversion periods (30.2, 30.3 and 30.4 µm respectively), equally spaced along the width of the crystal and antireflection coated for the three interacting waves. The OPO cavity length is 27 mm with plane parallel mirrors: rear mirror is silver coated and the output coupler is a dielectric mirror on a 3-mm thick YAG substrate with a reflection of >99.9% for the signal wave and transmission >98% for the idler wave. The PPSLT crystal is pumped through the output coupler, which transmits >99% at 1064 nm. The laser pump source emits high energy pulses at 1064 nm with 0.5 kHz repetition rate, 0.83 ns pulse duration and high beam quality (M^2<1.4) [4]. The pump beam(slightly elliptical) is collimated to a beam size of 2.2x2.4 mm in the position of the PPSLT crystal and is separated from the idler wave by a separation mirror, which has 98% reflection for the pump (p-polarization) and transmits 90% at the idler wavelength, respectively. After the separation mirror only the idler wave is measured, the residual pump radiation and the signal are blocked with a set of filters depending on the wavelength of the idler wave. The maximum idler output energy at 3 µm reaches 2.1 mJ, at pump energy of 11.5 mJ. This corresponds to idler conversion efficiency of 18.3% and overall quantum conversion efficiency (both idler and resonating signal) of nearly 52 %. At the working pulse repetition rate (0.5 kHz) the generated average power in the Mid-IR is 1.05W. The measured OPO threshold is $40MW/cm^2$ of peak pump power density. We demonstrate continuous temperature tunability from 3 to 3.5 µm, taking advantage of the three domain inversion periods, from room temperature up to 265 ºC. The idler pulse duration is measured to be 700 ps (FWHM).

In conclusion, to the best of our knowledge, this is the first sub-nanosecond PPSLT based OPO, tunable in this highly interesting spectral region, reaching pulse energy above 2 mJ at kilohertz repetition rate. Further energy scaling of the system is under development.

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