Sub-nanosecond, tunable between 3 µm and 3.5 µm OPO based on PPSLT, pumped by 0.5 kHz Nd:YAG laser

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Sub-nanosecond coherent sources in the mid-IR spectral region (2.5-4 microns) combining high average power and high pulse energy with broad tunability are of fundamental interest for both scientific and industrial applications, e.g. remote sensing, molecular spectroscopy and wide-ranging medical applications targeting water absorption band around 3 µm (Jean and Bende 2003). One of the effective ways to cover this spectral region is by utilizing optical parametric oscillators (OPO) that are based on periodically poled quasi phase-matched (QPM) nonlinear materials. These coherent sources are especially promising due to their exceptionally large nonlinearity and the complete absence of spatial walk-off. One relatively new nonlinear material for a QPM based OPO in the mid-IR is periodically poled stoichiometric lithium thantalate (PPSLT). Its low coercive field (<2 kV/mm), high photorefractive damage threshold and transparency up to 5 µm make it suitable for large aperture crystals and an attractive opportunity to produce high power OPOs at high repetition rates. Here, we present a compact sub-nanosecond, short cavity, singly resonant OPO based on PPSLT, pumped by a single frequency Nd:YAG microchip laser amplified in a two stage rod amplifier, which offers high pulse energy at relatively high repetition rate and tunability around the peak absorption band of water.

We employ an 11 mm long, 10 mm wide, and 2 mm (along z axis) thick PPSLT crystal with three different polled zones with domain inversion periods (30.2, 30.3 and 30.4 µm respectively). The crystal is antireflection coated for the pump, the signal and idler waves. The OPO cavity length is 23 mm with plane parallel mirrors. The rear mirror of the OPO is a silver coated mirror and the output coupler is a dielectric mirror on a 3-mm thick YAG substrate that has high reflection for the signal and high transmition for the idler wave. The pump source is a diode pumped Nd:YAG microchip laser oscillator amplified in a two stage rod amplifier emitting up to 10 mJ at 0.5 kHz, 1 ns 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 set of filters depending on the wavelength of the idler wave.

By changing the temperature of the PPSLT crystal from room temperature up to 265ºC we were able to achieve a continuous tuning from 3 to 3.5 µm, employing the three domain inversion periods respectively, Fig.1. The experimental results are in good agreement with the theoretically calculated curves, with the Sellmayer equations derived by (Dolev, Ganany-Padowicz et al. 2009).

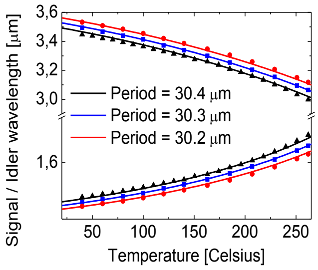

Fig. 1. OPO temperature tuning versus domain inversion period, measured data (dots) and calculated tuning curves (solid curves).

The maximum output idler energy is 290 µJ at 3422 nm (idler conversion efficiency of ~13 %), whilst the overall quantum conversion efficiency is ~42 %. The idler output power remains almost constant (±15%) in the whole tuning range. The OPO threshold is around 500 µJ (~76 MW/cm^2). The pump intensity applied in the present work is limited by the average power incident on the rear mirror. By reducing its thermal loading through lowering the repetition rate we achieved up to 0.45 mJ idler energy. After deconvolution with the response function of the measurement setup, the pulse duration (FWHM) of the frequency doubled idler is found to be 505 ps, corresponding to 714 ps idler duration, shorter as expected than the undeleted pump pulse duration (1 ns).

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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Dolev, I., A. Ganany-Padowicz, et al. (2009). "Linear and nonlinear optical properties of MgO:LiTaO(3)." Applied Physics B-Lasers and Optics **96**(2-3): 423-432.

Jean, B. and T. Bende (2003). "Mid-IR laser applications in medicine." Solid-State Mid-Infrared Laser Sources **89**: 511-544.