Picosecond Pulse Generation at 1177 nm by SRS in $PbWO_4$ Pumped by a Multi-mJ, Multi-W Sub-ns Laser System

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Abstract: We report on high energy (~1 mJ), high average power (~0.5 W), sub-500-ps stimulated Raman scattering in a $PbWO_4$ crystal, pumped by a sub-nanosecond Nd:YAG based master-oscillator power-amplifier (MOPA) laser system operating at 500 Hz.

OCIS codes: (290.5910) Scattering, stimulated Raman, (140.3540) Lasers, Q-switched, (140.3280) Laser amplifiers

Stimulated Raman scattering (SRS) is a well-established nonlinear frequency conversion technique for generation of new wavelengths and accessing spectral regions not covered by conventional laser materials or by parametric processes in non-centosymmetric crystals. Solid-state Raman crystals provide a very simple, compact, and efficient means for such frequency shifting. Additionally, the technique does not require phase-matching and can lead to significant pulse compression. Broad range of applications can benefit from such systems, including range finders, lidar and ladar devices, spectroscopic measurements etc.

Among solid-state Raman active media, diamond is a “class-by-itself” material, offering the highest steady-state gain and outstanding thermal properties. However, diamond crystal growth is a complex and expensive process, and samples larger than few mm^3 are not readily available. In recent years different alkaline earth metal (Ca, Sr, and Ba) and lead (Pb) tungstates and molybdates have been used as solid-state Raman media in both picosecond and nanosecond SRS pumping regimes [1-3]. Among them, the tetragonal $PbWO_4$, with its high steady-state gain of 3.1 cm/GW and short phase relaxation time of 2.5 ps [3], combined with availability of low-cost, large volume samples, is a very attractive material for high-energy SRS. Here we report on single-pass, traveling-wave Raman generation experiments in $PbWO_4$, pumped by a high-energy, high average power, sub-nanosecond, Nd:YAG laser system employing a master-oscillator power-amplifier (MOPA) architecture.

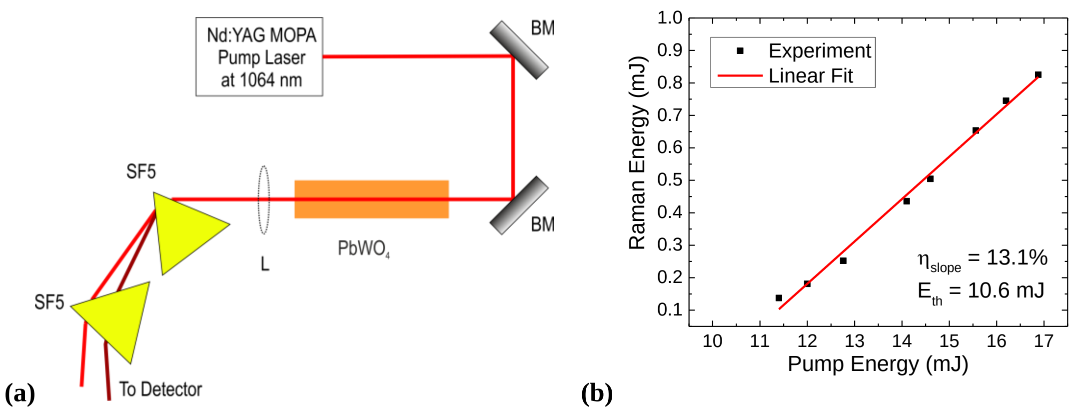

Fig. 1. (a) Setup of the SRS experiment (BM: bending mirrors, L: spherical lens, SF5: dense flint prisms). (b) Output energy of the Raman shifted radiation at 1177 nm vs. pump power.

The experimental setup is shown on Fig. 1(a). A c-cut uncoated $PbWO_4$ sample was employed, with dimensions of 16 × 16 mm^2 × 75 mm of length. The crystal was simply housed in a kinematic mirror mount, without taking extra care for heat dissipation issues. The pump laser is Nd:YAG MOPA system operating at 1064 nm [4], emitting laser pulses with a duration of 800 ps and energy of up to 16.9 mJ at a repetition rate of 500 Hz repetition rate. The pump beam at the position of the Raman crystal had a Gaussian diameter of $2w$ = 2 mm and it did not chang substantially over the length of the crystal. The polarization was aligned to be perpendicular to the crystal c-axis. A spherical lens with a focal length of 1 m was used to collimate the Raman shifted beam. For the detection after the lens, two prisms (SF5) were used in order to separate the pump and Raman shifted beams. The threshold for the first Stokes at 1177 nm occurred at ~10.6 mJ of incident pump pulse energy, corresponding to a peak pump intensity of 0.84 GW/cm^2. The first Stokes pulse had the same polarization as the pump. Its energy as a function of the incident pump energy is shown on Fig. 1(b). It reached 0.83 mJ at the maximum available pump energy of 16.9 mJ corresponding to an peak pump intensity of 1.34 GW/cm^2. This corresponds to a slope efficiency of 13.1 %, and optical to optical efficiency of 4.9% (the internal efficiency is ~6.5%). Even at maximum pump, no significant energy conversion from the first to the second Stokes, centered at 1316 nm, was observed. Also, no optical damage or self-focusing effects were observed.

Employing a 4 GHz bandwidth oscilloscope (Tektronix CSA7404) and InGaAs photodiode (Alphalas UPD-70-IR2-P), we also measured the duration of both the pump and Raman shifted pulses. The FWHM of the temporal response function of the detection system was measured to be 225 ps at 1 μm. In Fig. 2(a), the oscilloscope trace of the first Stokes pulse at 1177 nm can be seen while Fig. 2(b) shows the undepleted pump pulse. Through deconvolution with the detection system temporal response, we estimated a Raman shifted pulse duration of ~485 ps.

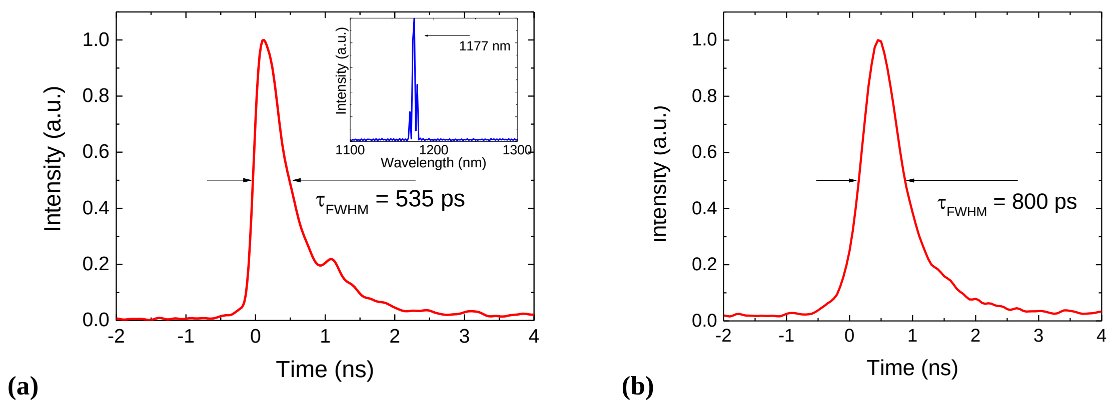

Fig. 2. Oscilloscope traces of the Raman pulse at 1177 nm (a) and the undepleted pump pulse at 1064 nm (b). The inset in (a) shows the measured spectrum of the Raman pulse.

In conclusion the generation of millijoule level, sub-500 ps pulses at 1177 nm and 500 Hz is demonstrated by the use of a $PbWO_4$ Raman crystal, pumped by a high-energy, high-average power Nd:YAG, based MOPA system. The average power level achieved reached 415 mW (pulse energy 0.83 mJ), without taking into account the 13% Fresnel reflection at the $PbWO_4$ surface. Thus, this system represents the highest energy level for an all solid-state Raman converter operating at high (~kHz) repetition rates, i.e. pumped by modern diode-pumped laser sources: e.g. 90 mW or 45 μJ and 180 mW or 90 μJ were reported with similar 2-kHz repetition rate systems in [1,5].

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