High power 1.57-μm OPO pumped by MOPA with SBS

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A Nd:YAG master oscillator power amplifier (MOPA) system, pumped by a pulse flash-lamps as the pump source of optical parametric oscillator (OPO), is employed to improve the pump beam quality of OPO pump source. A back amplifying configuration with stimulated Brillouin scattering (SBS) phase conjugation mirror is used. OPO pump laser energy of 611 mJ/pulse with 30-ns pulse duration is obtained, and near diffraction limited beam quality is achieved. Based on the type II degenerate non-critically phase-matched KTP crystal, the OPO is used to convert pump beam from 1.064 μm to 1.57 μm, eye-safe near infrared laser range source. 1.57-μm output energy of 209 mJ/pulse with 18-ns pulse duration is attained with a short cavity KTP OPO, when pump laser energy is approximately 611 mJ. OPO conversion efficiency is up to 38.7% when pump laser energy is approximately 200 mJ.

OCIS codes: 290.5900, 190.5040, 190.5940, 190.2620.

Interest in the long-range laser finder systems operating at the eye-safe wavelength region has generated a need for optical parametric oscillator (OPO) capable of generating high pulse energies and high powers[1,2]. Because of the lack of laser material for these wavelengths, its range sources have relied on nonlinear conversion of existing sources such as Nd:YAG. A high power eye-safe laser system based on OPO has been developed as the laser range source. One-micron-pumped type II degenerate non-critically phase-matched KTP crystal has the potential to meet the bandwidth constraint imposed by atmospheric transmission window, which has the suitable optical damage threshold and is commercially available in useful sizes[3,4]. In order to meet some specific applications, a high power laser with good beam quality and a small beam divergence angle can be obtained in a KTP OPO[5]. The quality of pumped laser is the key to improve beam quality of OPO outputs. The use of stimulated Brillouin scattering (SBS) phase conjugation can improve beam quality of laser[6,7]. In this paper, a Nd:YAG master oscillator power amplifier (MOPA) system pumped by a pulse flash-lamp is setup, in which a back amplifying configuration with SBS phase conjugation mirror is involved. The laser output of 611 mJ/pulse with 30-ns pulse duration and the near diffraction limited beam quality are obtained. An OPO based on the Type II degenerate non-critically phase-matched KTP crystal is used to convert 1.064 μm pump beam to 1.57 μm eye-safe near infrared laser range source[8,9]. The OPO conversion efficiency is up to 38.7%, with approximately 200-mJ pump laser energy.

The pump laser consists of a flash-lamp pumped master oscillator power amplifier (MOPA) system. The setup is shown in Fig. 1.

In this work, in order to obtain high reflectivity of SBS, we adopt a twisted-mode resonator cavity technology to achieve narrower line-width output in single longitudinal-mode operation. The master oscillator is composed of a parallel resonator, a Nd:YAG crystal, two quarter-wave plates (QWP1, QWP2), a polarization plate (P1), and a passively Q-switching $\mathrm{Cr^{4+}}$:YAG crystal. M_1 is the full reflector, M_2 is the output mirror made of Fabry-Perot (F-P) etalon with low reflectivity, which is used to compress the line-width of output laser. The Nd:YAG is placed between two QWPs with their fast axes perpendicular to each other. The two axes also make an angle of 45° from the polarization direction of P1 in the resonator cavity. In this way, the corresponding laser master oscillator with twisted-mode technology can achieve a standing wave pattern of axially uniform energy density in the laser material. Spatial hole burning, which is responsible for multimode oscillation in homogeneously broadened laser material such as Nd:YAG, is avoided in this way[10,11].

The output beam from the master oscillator passes through a telescope (T1), polarizing element (P2), and QWP3 into the two amplifiers. The amplified beam is directed into SBS system (f and SBS cell) through the spatial filter (T2) which is composed of two lenses and an aperture. When the back phase conjugation beam generated from the SBS system returns to the polarizing element through T2, two amplifiers (AMPs), and QWP3, the output laser is reflected by P2. Because the beam passes through the QWP3, its polarization direction is rotated 90°. With the energy input of the two 50-J amplifiers, the OPO's pump energy up to 611-mJ/pulse with approximately 30-ns pulse durations and near diffraction

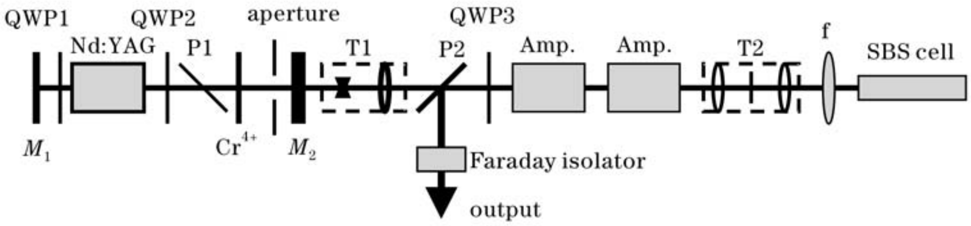

Fig. 1. Optical layout of Nd:YAG pump laser.

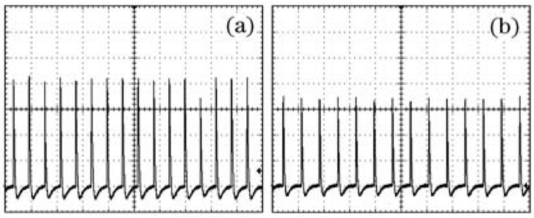

Fig. 2. Output laser energies with different pulse input energies of 50 J (a) and 36 J (b).

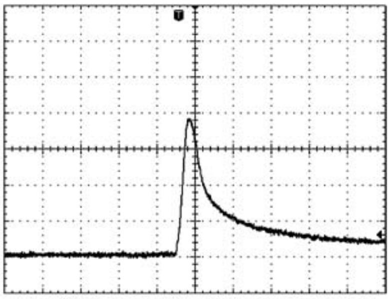

Fig. 3. Pulse shape of pump laser.

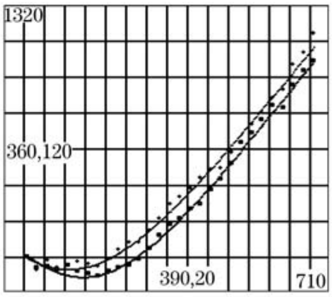

Fig. 4. M^2 of OPO pump laser.

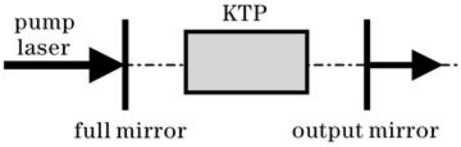

Fig. 5. Optical layout of KTP OPO.

limited beam quality are achieved. In this system, SBS phase conjugation technology has compensated the aberration produced by the optical elements of the system.

Figure 2 shows the energy of the output laser at frequency of 1 Hz. The energy of the detector is ED500, the sensitivity is 1.4 V/J. The largest energy is 611 mJ/pulse. When the input energy is 36 J/pulse, the output energy is stable. When the input energy is 50 J/pulse, the output energy is unstable. This is because that the power input into SBS system is larger than the SBS breakdown threshold. Figure 3 shows the pulse shape with 40-ns scanning time. Figure 4 shows the beam quality of the output laser, the M^2 is approximately 1.4.

Figure 5 shows a schematic layout of KTP OPO. It adopts a compact of plane-parallel resonator. The size of the KTP crystal is $5 \times 5 \times 20$ mm^3, the type II degenerate non-critically phase-matched is cut. The length of cavity is 30 mm.

Figure 6 shows the output of KTP OPO against the input energies of 50 and 36 J/pulse. The largest energy is 209 mJ/pulse. When the input electric energy is 36 J/pulse, the output energy is stable. When the input energy is 50 J/pulse, the output energy is unstable. The reason is that the power input into SBS system is larger than the SBS break-down threshold. Figure 7 shows the conversion efficiency of KTP OPO output energy as a function of pump energy. The largest value is up to 38.7% at which the pump energy is 200 mJ/pulse. The threshold of OPO is approximately 60 mJ/pulse in this OPO system. In this system, because the SBS phase conjugation technology is involved, the pulse width of pump laser is a function of pump energy. Figure 8 shows the pulse width of the pump laser and OPO laser output as functions of pump energy. Figure 9 shows the pulse width of KTP OPO at pump energy of 200 mJ with 10-ns scanning time. Figure 10 shows the distribution of KTP OPO output. The diffusion angle of output is approximately 5 mrad by method of far spots with 1-m focus length lens.

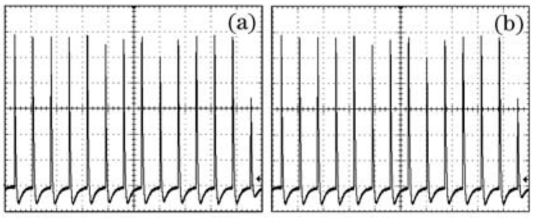

Fig. 6. Energies of KTP OPO with different pulse input energies of 50 J (a) and 36 J (b).

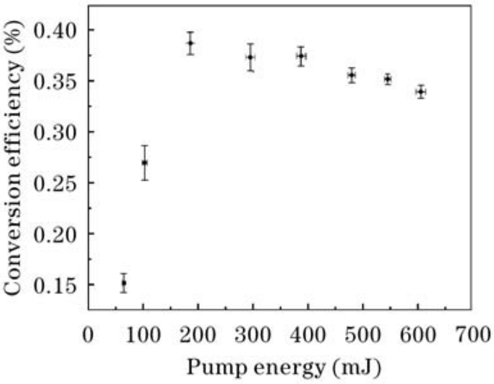

Fig. 7. Conversion efficiency of KTP OPO versus pump energy.

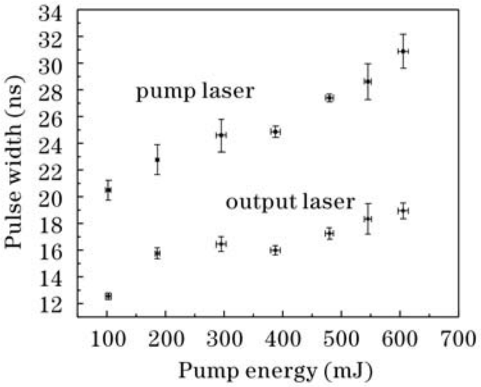

Fig. 8. Pulse width of output and pump of KTP OPO versus pump energy.

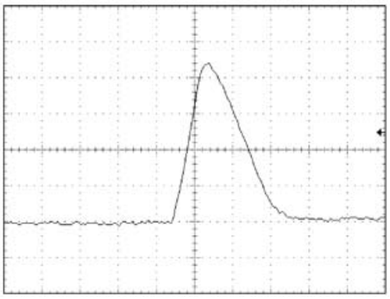

Fig. 9. Pulse width of KTP OPO output.

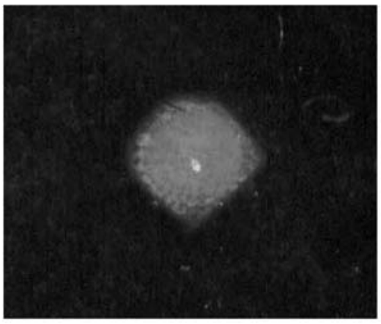

Fig. 10. Distribution of KTP OPO output.

In conclusion, the KTP OPO pump laser energy of 611 mJ is obtained with SBS phase conjugation technology. In this way, the electro-optical efficiency of amplifier is improved up to 1.3%, and the KTP OPO output energy of 209 mJ at the 1.57-μm eye-safe range wavelength is obtained. The conversion efficiency of KTP OPO is up to 38.7%.

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