High power intracavity infrared PPMgLN OPO

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***Abstract*—An intracavity degenerate optical parametric oscillator (OPO) was demonstrated with a 3-mm-thick PPMgLN crystal placed inside the resonator of a pulsed Nd:YAG laser. An output power up to 12.5 W in the 2 µm wavelength region was generated with a compact configuration at the crystal temperature of 110^{0}C.**

Keywords- intracavity OPO, PPMgLN, degenerate

I. INTRODUCTION

Two-micron laser sources are of interest for several applications in remote sensing and medical applications. An alternative method for generating such wavelengths with high power is to use a 1 µm acousto-optically Q-switched solid-state Nd-laser to pump a degenerate intracavity OPO based on PPLN or PPKTP[1-4]. Compared to extra-cavity ones, this configuration, besides its simplicity, has other important benefits. It takes advantages of the maturity of diode-pumped Nd-doped laser technology and the intense fluence inside the cavity, and of the increases of the effective nonlinear interaction length that is due to the many round trips of the pump inside the OPO cavity [5].

Here we demonstrate results of a degenerate intracavity OPO based on 3-mm-thickness PPMgLN. Average output power of 12.5 W at 2 µm with circularly symmetric beam profile are achieved with a compact cavity configuration pumped by a commercial Nd:YAG module.

II. EXPERIMENT AND DISCUSSION

The experimental setup of our intracavity OPO is shown in Fig. 1. The OPO is pumped with an unpolarized Nd:YAG laser instead of a polarized laser. This avoids the problem of depolarization loss due to the thermally induced birefringence which results in across-shaped laser beam. The pump cavity is formed by a Nd:YAG crystal, acousto-optical (AO) Q-switch and two flat mirrors. The Nd:YAG pump module consists of a 4 mm diameter, 120 mm long, cw diode side-pumped Nd:YAG crystal. Both of its surfaces are flat and antireflection coated at 1 µm. The laser cavity is only 30 cm in length. Output coupler (OC) M_0 has reflectivity R=98% at 1µm. Mirror M_2 is highly reflective for 1 µm, and R=60% for 2 µm with a 100 nm bandwidth. The intracavity OPO consists of two flat mirrors M_1 (HT@1 µ m, HR@2 µ m), M_2 and a 20 mm long uncoated PPMgLN crystal with a 32 µ m poled period. This poling period resulting in degenerate wavelength of 2.1 µ m at crystal temperature of 110^{0}C, this was confirmed by an extra-cavity OPO experiment. The OPO cavity length is ~60 mm due to mechanical constraints.

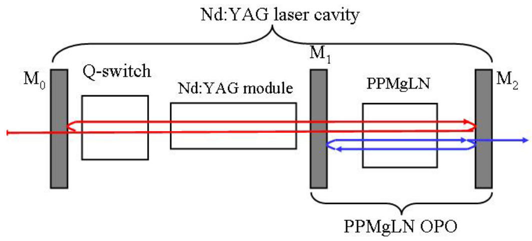

Fig. 1. Experimental setup of the intracavity PPMgLN OPO within a diode-pumped Nd:YAG laser.

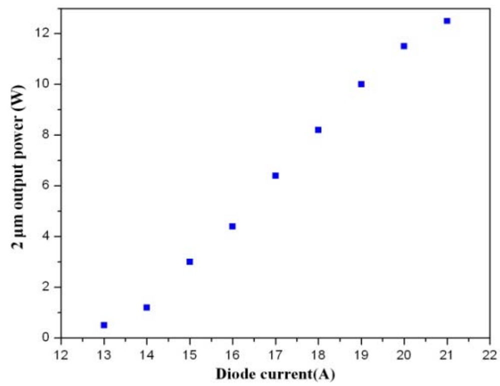

Fig. 2. Average output power of 2 µm versus the diode pump current.

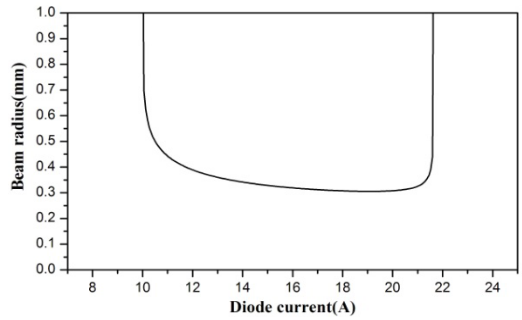

Fig. 3. The calculated beam radius at the principle plane of rod near the 1µm output coupler M_0.

The maximum diode pumping power available is approximately 500 W at the diode current of 25A. Without the intracavity OPO, the Nd:YAG laser can produce about 58 W of 1 µm radiation at 10 kHz when pumped at 385 W (diode current=20 A) with a 30% OC. The pulse width is ~70 ns. The AO Q-switch could no longer hold off the laser when increasing the diode current over 20 A. When the OPO is

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placed inside the laser cavity, the output power dropped to ~45 W. This is mainly due to the loss introduced by the relatively smaller size of the 3-mm-thick PPMgLN compared to the laser crystal. One can highly decrease the loss of the laser, if consider using Nd:YAG rod with less than 3 mm diameter. We have achieved the maximum output power of 12.5 W at 2μm with R=60% reflectivity for M2 and at a repetition rate of 10 kHz. The diode current is 21 A, corresponding diode pump power of 380 W. The 2 μm power was measured as a function of the diode pumping current, and the results was plotted in Fig. 2. The output power drops when increase the diode current to 22 A. This is caused by the splitting of the stability ranges which causes significant high losses in the resonator, as shown in Fig. 3, that match well with the theoretical indications. Figure 3 shows that the cavity is stable when the diode current increased from 14 A to 21 A, corresponding diode pump power from ~180 W to 380 W. That means our Nd:YAG laser is stable over a wide range of diode pumping power. At the maximum output power, the efficiency of power conversion of diode power to 2 μm power is 3.1% for our intracavity PPMgLN OPO.

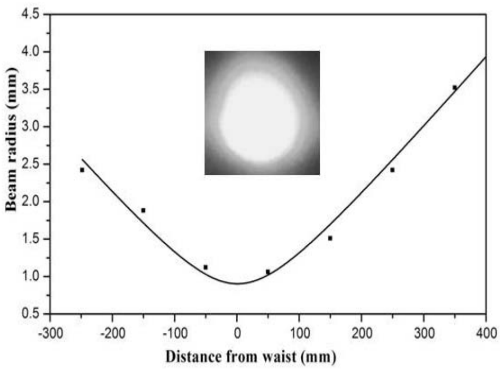

Fig. 4. Beam propagation behavior of OPO radiation.

We measured the M^2 values of 2 μm output by the knife-edge method, as shown in Fig. 4. The measured M^2 for 2 μm beam is about 10 for both transverse directions at maximum output power. This rather poor beam quality is due to the fact that thermal lensing effect in the Nd:YAG rod becomes large as the diode pumping power increase. The insets is a typical far-field photograph image of 2 μm profile on a screen, which is nearly circular symmetric at the maximum output power.

III. Conclusion

In conclusion, we have demonstrated a compact high power intracavity PPMgLN OPO with 12.5W output power and circularly symmetric beam profile. Future improvements will be focus on (1) spectral line narrowing use passive elements, and (2) a linearly polarized pumped scheme based on birefringence compensation or to use Nd:YVO4 as the inherently birefringent polarized laser source, to obtain better efficiency, beam quality and long-term operation stability.

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