Actively Q-switched Tunable Narrowband 2 μm Tm:YAP Laser Using a Transversally Chirped Volume Bragg Grating

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Abstract: A pulsed, narrow-linewidth, wavelength-tunable Tm:YAP laser was realized. 1 kHz stable operation with 200 µJ, 50 ns pulses is reported. Spectrum was narrowed to 0.2 nm and tuned from 1940 to 1960 nm with a transversally chirped volume Bragg grating.
OCIS codes: 140.3070, 140.3540, 140.3580, 140.3600, 140.5680.

1. Context

Tunable long wave infrared coherent sources emitting between 8 and 12 µm can be used for versatile remote gas sensing thanks to atmospheric transmission at these wavelengths. In ref [1] we implemented a parametric oscillator, pumped by a 2 µm microlaser, in which wavelength tunability was achieved by temperature tuning of the crystal indices of refraction. It is well known that a similar wavelength range can be addressed by tuning the pump wavelength rather than the crystal temperature [2]. In addition, pump tuning can be significantly faster than temperature tuning. In this context, to control the spectral output of the optical parametric oscillator (OPO), which is based on Vernier spectral filtering in doubly resonant cavities [1], we also need a single longitudinal mode (SLM) pumping laser. Pulsed, tunable 2 µm sources laser have been developed [3,4] but they require complex alignment or do not have narrow line-width emission and they exhibit relatively long pulses. For this purpose we fisrt built a CW 2 µm Tm:YAP laser with a transversally chirped volume Bragg grating (TC-VBG) to narrow the spectrum and perform wavelength tuning [5]. To pump the OPO, ~250 µJ pulses of 10-100 ns are targeted. We first implemented passive Q-switching laser with a Cr:ZnSe saturable absorber [6]. In this work, we investigate active Q-switching with an acousto-optic modulator (AOM) to have a better control of the repetition rate and to increase it to a few kilohertz while preserving the single longitudinal mode behaviour.

2. Experimental set-up

We designed a Tm:YAP laser with a TC-VBG as output coupler and an AOM to perform active Q-switching of the laser with repetition rates of a few kilohertz. The cavity, shown in Fig. 1, is composed of a highly reflective dielectric concave mirror around 2 µm with a radius of curvature of 50 mm, a 4 mm long 4 %at. thulium-doped a-cut YAP rod, an AOM working at 2 µm, and a TC-VBG provided by OptiGrate with 1940 nm to 1960 nm tuning range, 85 % reflectivity and 0.8 nm bandwidth (FWHM). The AOM is used to switch the cavity losses and achieve pulsed operation. The cavity is about 50 mm long and is pumped with a continuous-wave 9 W laser diode emitting near 790 nm, which results in 7 W incident on the laser crystal due to Fresnel losses of VBG facets at 790 nm. The pumping laser is focused in the laser medium through the TC-VBG with a lens doublet to get a beam radius of 100 µm ($1/e^2$). A dichroic mirror is used to separate the 2 µm laser output from the input pump beam.

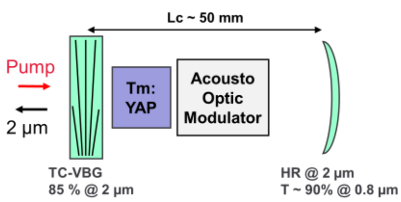

Fig. 1. Laser cavity

3. Results

With this cavity, we obtained 28 % slope efficiency with a 4 W pump threshold in continuous wave operation, see Fig 2. In pulsed operation the threshold was around 3.5 W and the slope efficiency was 31.6 % at a pulse repetition rate of 1 kHz. Repetition rates of 0.5, 1 and 2 kHz have been tested. Configurations with up to 200 µJ with 50 ns duration have been found. No stable operation with pulse energy higher than 200 µJ has been found.

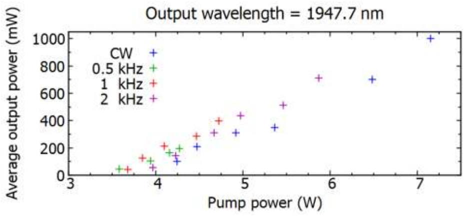

Fig. 2. Average output power at different repetition rates

The laser has a 20 nm tuning range between 1.94 µm and 1.96 µm when translating the volume Bragg grating, see Fig. 3. (a). The TC-VBG narrows the spectrum down to 0.2 nm with a continuous output power of 1 W obtained with 7 W incident pump power on the laser rod, Fig. 3.(b). The spectrum is slightly larger when the laser is pulsed but does not exceed 0.25 nm. Spectra shown in Fig. 3 were obtained with a slightly different but equivalent cavity.

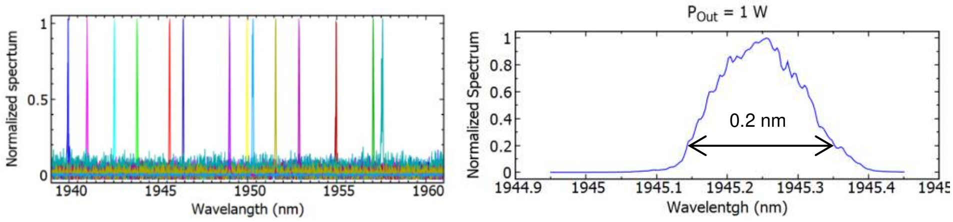

Fig. 3. (a) Output spectra for several longitudinal position of the TC-VBG (b) Output spectrum at maximum continuous output power for one longitudinal position of the TC-VBG

4. Comments

Stable pulsed operation is obtained close from the desired levels of 250 µJ and higher pulse energies were reached although they remained instable. As no damages were observed on the optics of the cavity and the laser stability recovered when the pumping power was lowered, thermal lensing effects are suspected to be the source of the instabilities at high energy operation. As expected, temperature rising was mainly observed in the laser rod. To reduce the impact of the thermal lens on the laser, the length of the cavity will be reduced to its minimum. In addition to this, better thermal management of the Tm:YAP rod will be implemented to make its thermal behaviour more repeatable and to help reduce high energy operation instabilities. Efforts will also be made to reduce residual wavelength drift of the pumping diode. Pulse duration and average output power are satisfying.

Although the output spectrum exhibits a good spectral purity, it still represents a few longitudinal modes of the cavity which is not a favourable to control the output spectral purity of the OPO. In order to reduce the output spectrum to a single longitudinal mode, filtering elements could be inserted in the cavity.

5. Conclusion

We demonstrated, for the first time to our knowledge, efficient actively Q-switched diode pumped Tm:YAP laser tunable from 1.94 µm to 1.96 µm with narrow spectrum, using a transversally chirped volume Bragg grating as output coupler and an acousto-optic modulator. The tunability on a 20 nm range obtained on the 2 µm laser translates to a 500 nm range tunability near 10 µm after down conversion which is enough to record some significant absorption spectra for gas sensing [1]. Moreover, using different TC-VBG it is possible to access any wavelength in the gain band of the Tm:YAP. Efforts will be made to stabilize its behaviour at high pulse energy and a Fabry-Perot etalon will be added to the cavity to filter the remaining modes and achieve SLM operation.

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