Tunable Narrowband Tm:YAP Laser Using a Transversally Chirped Volume Bragg Grating

Quentin Berthomé^{1,2}, Arnaud Grisard³, Basile Faure¹, Grégoire Souhaité¹, Eric Lallier³, Antoine Godard², Vadim Smirnov⁴, Ruslan Vasilyeu⁴

1. Teem Photonics, 61 Chemin du Vieux Chêne, Innovallée, 38240 Meylan, France

2. ONERA, DPHY, Université Paris Saclay, F-91123 Palaiseau, France

3. Thales Research & Technology, 1 Avenue Augustin Fresnel, 91767 Palaiseau, France

4. OptiGrate Corp (an IPG Photonics Company), 562 South Econ Circle, Oviedo, Florida 32765, USA

Tunable long wave infrared (LWIR) coherent sources emitting between 8 and 12 μm can be used for versatile remote gas sensing. In ref [1] we implemented a parametric oscillator 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 we also need a narrow band spectrum to control the spectral output of the optical parametric oscillator, which is based on Vernier spectral filtering in doubly-resonant cavities. Seger and his team exhibited single longitudinal mode operation in a microlaser tuned with transversally chirped volume Bragg grating (TC-VBG) near 1 μm [3]. We show how this concept can be applied to a different laser emitting at 2 μm .

We designed a Tm:YAP laser with a TC-VBG as output coupler. The cavity, shown in Fig. 1 (a), is composed of a high reflective dielectric concave mirror around 2 μm , a 4 mm long 4 %at. thulium doped a-cut YAP rod and a TC-VBG with 1940 to 1960 nm tuning range, 85 % reflectivity and 0.8 nm bandwidth. We pump the cavity with a 9 W laser diode emitting near 790 nm. Depending on the output wavelength, this laser has a threshold between 1.8 W and 2.1 W and 14 to 17 % of efficiency. With this cavity we obtained a continuous wave laser emitting up to five cavity modes which gives a 0.2 nm wide spectrum with up to 1.5 W laser output power at 1948 nm under 7 W pumping. Working at low power above the threshold reduces the laser spectral width below 0.1 nm but it quickly reaches 0.2 nm wide (see Fig 1 (b)). We plan to push on to obtain narrower linewidth.

Fig. 1 (a) Schematic of the laser cavity with the TCVBG (b) Laser spectrum at 1948.6 nm obtained with an optical spectrum analyser with 0.050 nm resolution for different output powers.

With transversal translation of the TC-VBG over its 20 mm length, the wavelength is tuned continuously from 1940 nm to 1960 nm. After parametric downconversion to the LWIR, this range would translate to ~ 500 nm near 10 μm , which would be enough to acquire the same spectrum as presented in ref [1]. This is to our knowledge, the widest tuning range near 2 μm obtained with this method. This leads to an efficient, simple, compact, tunable diode pumped solid state laser with narrow linewidth near 2 μm . There is no theoretical limitation to adapt this solution over the entire thulium gain band. However, practical limitations to TC-VBG chirp rate and size limit the total tuning range accessible with one TC-VBG. The next step will be to make the laser work in pulsed regime with either passive [4] or active Q-switching.

Example References

- [1] Q. Clément, J.-M. Melkonian, J.-B. Dherbecourt, M. Raybaut, A. Grisard, E. Lallier, B. Gérard, B. Faure, G. Souhaité, and A. Godard, "Longwave infrared, single-frequency, tunable, pulsed optical parametric oscillator based on orientation-patterned GaAs for gas sensing", *Opt. Lett.* **40**, 2676 (2015)
- [2] F. Gutty, A. Grisard, C. Larat, D. Papillon, M. Schwartz, B. Gérard, R. Ostendorf, M. Rattunde, J. Wagner, and E. Lallier, "140W Peak Power Laser System Tunable in the LWIR", *Opt. Expr.* **25**, 18897 (2017)
- [3] K. Seger, N. Meiser, C. Canalias, V. Pasiskevicius, and F. Laurell, "Tunable, passively Q-switched single-longitudinal-mode Nd:YVO₄ laser using a chirped volume Bragg grating", *Appl. Phys. B* **109**, 99-103 (2012)
- [4] A. Grisard, B. Faure, G. Souhaité and E. Lallier, "High energy single frequency passively Q-switched 2-micron microlaser in thulium-doped yttrium aluminium perovskite", paper ATu2A.39 in ASSL, OSA (2014)