A periodically poled $LiNbO_3$ optical parametric generator in wavelength conversion from 2 to 3.88—4.34 μm

Xingbao Zhang (张兴宝)[1,2], Youlun Ju (鞠有伦)[1], Yuezhu Wang (王月珠)[1], Baoquan Yao (姚宝权)[1], and Yunjun Zhang (张云军)[1]

[1]*Institute of Opto-Electronics, Harbin Institute of Technology, Harbin 150001*

[2]*Microelectronic Center, Harbin Institute of Technology at Weihai, WeiHai 264209*

Received June 13, 2007

A periodically poled lithium niobate (PPLN) optical parametric generator (OPG) pumped by a laser diode (LD)-pumped Q-switched Tm,Ho:$GdVO_4$ laser operated at 2.048 μm with pump pulse of 25 ns and repetition rate of 10 kHz is reported. A continuous tunable middle-infrared (mid-IR) spectrum of $3.88 - 4.34$ μm is obtained by changing the crystal temperature from 50 to 124°C. When the incident pump power is 3 W, the total OPG output power is 95 mW, corresponding to optical conversion efficiency of 3.2%.

OCIS codes: 190.4970, 140.3600, 140.3070.

Tunable middle-infrared (mid-IR) coherent sources have obtained a variety of applications, such as remote sensing, spectroscopy, and laser radar. Optical parametric generator (OPG) is an efficient way to obtain such a laser source in mid-IR regions. In recent years, there has been increasing interest in the use of a periodically poled $LiNbO_3$ (PPLN) with the largest nonlinear coefficient and quasi-phase-matching (QPM) capability. Thus, PPLN OPGs are important devices for achieving widely tunable mid-IR optical sources. High efficient OPGs in 1-μm pumped PPLN have been demonstrated[1−3]. A 1-μm pumped OPG with 4-μm idler achieves quantum efficiency of 27% as the result of the large quantum defect. Compared with 4-μm idler of 1-μm pumped OPG, the quantum efficiency of 2-μm pumped OPG with signal is increased two times. Whereas, the presence of strong idler absorption in 2-μm pumped OPG results in high idler loss, while it reduces the effect of pump backconversion on the signal and leads to higher signal efficiency. Recently, improvement in commercially available 2-μm Tm,Ho laser and development of bulk PPLN materials have generated new possibilities for high efficient operation of 2-μm pumped PPLN OPGs. Hansson *et al.*[4] reported an OPG pumped by a low-repetition rate Tm,Ho:YLF laser at 2.051 μm with output optical range from 3.4 to 5.2 μm.

In this paper, a 2.048-μm Tm,Ho:$GdVO_4$laser pumped OPG is achieved by using a laser-diode (LD) pumped high-repetition-rate short-pulse Tm,Ho:$GdVO_4$ laser and a 5-cm-long PPLN. Hence a $3.88 - 4.34$ μm high-repetition-rate tunable mid-IR laser is realized.

Figure 1 shows a schematic of the experimental setup for a high-repetition-rate PPLN OPG. A 2.048-μm acousto-optically (AO) Q-switched diode-end-pumped Tm,Ho:$GdVO_4$ laser with TEM_{00} and a maximum average power of 7 W is built as a pump source. In the experiments, to avoid possible damage in the PPLN crystals, the average pump power is set at 3 W. The repetition rate of the pump laser is adjusted in the range of $10 - 100$ kHz and set at 10 kHz. An approximate 25-ns full-width at half-maximum (FWHM) pulse with an energy of 0.3 mJ and a peak power of approximately 12 kW are achieved. The pump light is focused to a beam with a waist radius of 50 μm by using a 50-mm focal-length lens. The focal point locates at the centre of the PPLN crystal. A broadband filter (M_1) with 3-μm cutoff wavelength is used to block residual pump light.

The multi-grating PPLN crystal (from Crystal Technology Inc.), which is 50 mm in length, 10 mm in width, and 1 mm in thickness with 10 grating periods from 28.2 to 31 μm in 0.2-μm increment, is used in the experiments. The crystals are mounted in heating ovens to avoid the photorefractive effect in the PPLN, which makes it possible to adjust the temperature of the crystals over a range of $25 - 250$ °C with a precision of ±0.1 °C.

The generated wavelengths are measured with a 300-mm focal length WDM1-3 monochromator (0.8-nm nominal resolution) and an InS detector. Temperature tuning for the 2-μm pump is achieved at the grating period of 28.2 μm. The continuous tuning idler range of $4.1 - 4.34$ μm and signal range of $3.88 - 4.1$ μm are obtained, respectively, for the temperature range from 50 to 124 °C. Figure 2 shows the theoretical results from the Sellmeier equation by the black dots[5] and experimental results by the solid line, respectively, which are in good agreement with each other.

Figure 3 shows the measured characteristics of total OPG output power with a 28.2-μm grating at the crystal

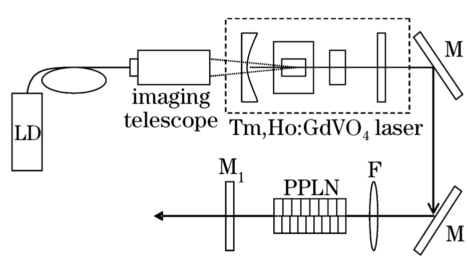

Fig. 1. Schematic diagram of a high-repetition-rate PPLN OPG.

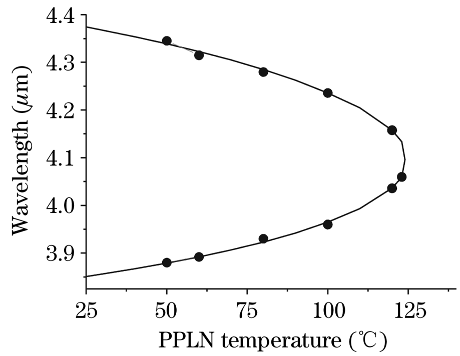

Fig. 2. Signal and idler wavelengths versus temperature at grating period of 28.2 μm.

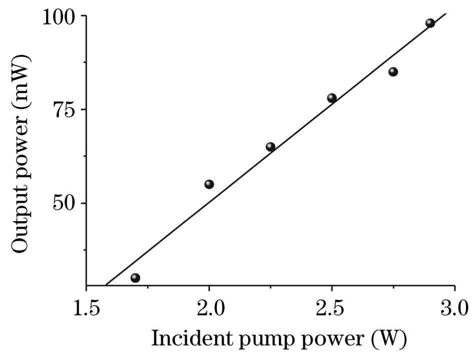

Fig. 3. Total OPG output powers versus incident pump power.

temperature of 50 °C. The OPG generates wavelengths of 3.88 μm for signal and 4.34 μm for the idler. The maximum OPG output power of 95 mW is achieved at pump power of 3 W, corresponding to total optical conversion efficiency of 3.2%. Such efficiency is lower than optical parametric oscillator (OPO)[6] due to the low gain in single pass through crystal.

In summary, we have demonstrated a PPLN OPG pumped by a 2-μm Tm,Ho:$GdVO_4$ solid-state laser. Using 5-cm-long PPLN with single-pass pumping configuration, the maximum OPG output power up to 95 mW has been produced with the frequency of 10 kHz. The maximum optical conversion efficiency reaches 3.2% in the presence of absorption. By changing the temperature of the crystal, a continuous tunable mid-IR spectrum of 3.88 − 4.34 μm is obtained. The PPLN OPG is a useful and simple way to generate broadband mid-IR radiations. The results are an initially discuss for the realization of mid-IR in a 2-μm pumped PPLN OPG.

This work was supported by the Scientific Research Foundation of Harbin Institute of Technology. X. Zhang's e-mail address is zxbljh@yahoo.com.cn.

References

1. V. D. Mark, J. Missey, P. E. Powers, and K. L. Schepler, Opt. Lett. **24,** 1227 (1999).
2. B. Zhang, J. Yao, X. Ding, H. Zhang, P. Wang, D. Xu, G. Yu, and F. Zhang, Chin. Phys. **13,** 364 (2004).
3. P. Zhao, B. Zhang, E. Li, R. Zhou, D. Xu, Y. Lu, T. Zhang, F. Ji, X. Zhu, P. Wang, and J. Yao, Opt. Express **14,** 7224 (2006).
4. G. Hansson and D. D. Smith, Opt. Lett. **25,** 1783 (2000).
5. D. H. Jundt, Opt. Lett. **22,** 1553 (1997).
6. X. Zhang, B. Yao, Y. Ju, and Y. Wang, Chin. Phys. Lett. **24,** 1953 (2007).