MF2-2

Broadband Mid-IR Sources Based on Non-collinear Optical Parametric Generation with Periodically Poled $LiNbO_3$

Chih-Wei Hsu and C. C. Yang
Department of Electrical Engineering and Graduate Institute of Electro-Optical Engineering,
National Taiwan University, 1, Roosevelt Road, Sec. 4, Taipei, Taiwan, R.O.C.
(phone) 886-2-23657624 (fax) 886-2-23652637 (E-mail) ccy@cc.ee.ntu.edu.tw

Abstract

Broadband quasi-phase matched optical parametric generation with periodically poled $LiNbO_3$, based on a non-collinear configuration, is reported. The broadest signal spectrum covers from 1.734 to 1.962 μm when pumped with a Nd:YAG laser.

Recently, considerable research has been conducted to improve the performance of the optical $\chi^{(2)}$ parametric process. The retracing behaviors of phase matching curve for an optical parametric process had been studied with several birefringence phase-matched nonlinear optical crystals, either in collinear or non-collinear configuration [1]. These phenomena resulted to ultra-broad spectral width of phase-matching condition [2]. Although the quasi phase-matching (QPM) method can increase the interaction length without walk-off phenomena, based on the collinear configuration, reports have been made in demonstrating the advantages of angle-tuned optical parametric oscillator (OPO) with periodically poled $LiNbO_3$ (PPLN) [3] and KTP [4], based on non-collinear interaction. In this paper, we report that the non-collinear optical parametric generation (OPG) with PPLN can also lead to broadband signal and idler outputs.

In experiments, we used a single-longitudinal-mode, Q-switched Nd:YAG laser (Coherent Infinity 40-100) as the pumping source. Figure 1 schematically shows the experimental setup. We used a lens system to focus the pump beam to a waist of 95 μm inside the PPLN. The used PPLN contained 8 different QPM periods. The length of the PPLN was 1.9 cm. We placed the PPLN into an oven, whose temperature could be varied up to 250 °C. The pumping pulse was 3.5 ns in duration and had a top-hat spatial profile.

The phase-matched angles for signal and idler waves can be obtained considering the non-collinear interaction as shown in Fig. 1:

$$(K_i + K_g)\cos\gamma + K_s\cos\alpha = K_p, \qquad (1)$$

$$(K_i + K_g)\sin\gamma = K_s\sin\alpha, \qquad (2)$$

where K_p, K_s, K_i and K_g are the pump, signal, idler, and the QPM grating wave-vectors, respectively. The angles α and γ stand for those of the signal and idler directions with respect to the pump, respectively. The appropriate energy conservation law is $\omega_p = \omega_s + \omega_i$. Here, we assume that the idler propagation is along the normal direction of the QPM grating. The wavelength of the signal is shorter than that of the idler. Fig. 2 shows the theoretical phase-matching angle of the OPG based on 29.9-μm period PPLN with temperature varied from 160 to 200 °C. Here, we can see the retracing behavior of the phase-matching angle clearly, when the signal wavelength is near the degenerate point.

Experimentally, Fig. 3 shows the signal spectra of our OPG system with 29.9-μm period PPLN. The temperature was fixed at 160 °C. When we rotated the PPLN crystal to increase the angle γ, we could see that the signal spectrum varied from the λ_s = 1.594 μm with $\delta\lambda_s$ = 4 nm (the collinear case) to the broadest spectrum of signal wavelength from 1.734 to 1.962 μm (gray line). Further increase of the angle α led to the reduction of signal spectrum to the range between 1.815 and 1.884 μm (dashed line). These results are consistent with the theoretical predictions. In this configuration, the idler waves are propagated normal to the QPM grating, the corresponding signal waves diverge in space under the broadband operation. Meanwhile, we can observe efficient sum-frequency generation from pump and those signals in proper directions. According to our calculations, the SFG is also due to the non-collinear configuration interaction with the third-order QPM period.

In conclusion, based on non-collinear OPG with PPLN, we have experimentally demonstrated broadband signal generation due to the retracing behavior of the phase-matching curve. The broadest signal spectrum covered the wavelength rang from 1.734 through 1.962 μm. The corresponding idler wavelength varied from 2.325 to 2.754 μm. The bandwidth of signal and idler were 228 and 429 nm, respectively.

References:

1. S. D. Huang, C. W. Hsu, D. W. Huang and C. C. Yang, J. Opt. Soc. Am. B **15**, 1375 (1998).
2. C. W. Hsu, S. D. Huang, D. W. Huang and C. C. Yang, Elec. Lett. **34**, 212 (1998).
3. S. T. Yang, and S. P. Velsko, Opt. Lett. **24**, 133 (1999).
4. V. Smilgevicius, A. Stabinis, A. Piskarskas, V. Pasiskevicius, J. Hellstrom, S. Wang, and F. Laurell, Opt. Comm. **365** (2000)

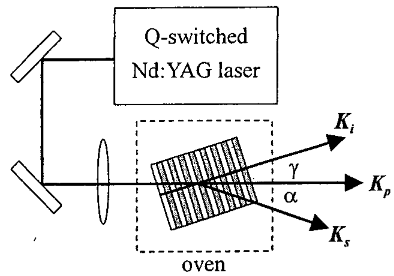

Fig. 1 Experimental setup.

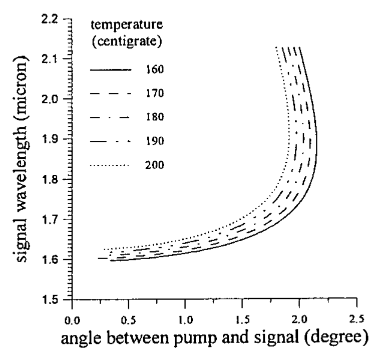

Fig. 2 Phase-matching angle.

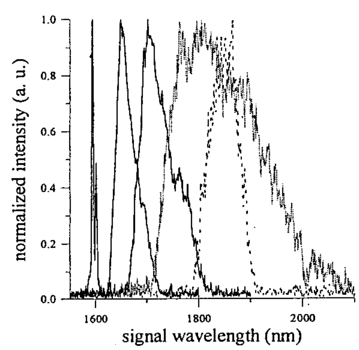

Fig. 3 Normalized signal spectrum.