High-energy optical parametric oscillator by using 5mm-thick periodically poled $MgO:LiNbO_3$

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Abstract

Large aperture, periodically poled $MgO:LiNbO_3$ device enable us to realize high-energy and highly efficient optical parametric oscillation for mid-infrared generation. We achieved a maximum output energy of 52mJ with spectral bandwidth of < 2nm at degeneracy point of Nd:YAG laser by adopting an optical parametric oscillator / power amplifier system.

1.Introduction

High-energy, narrow-spectrum bandwidth mid-infrared coherent light sources are intensively required for many application such as molecular spectroscopy, air pollution monitoring. Optical parametric oscillation (OPO) based on $ZnGeP_2$ or quasi-phase-matched (QPM) GaAs are reported because of its wide-wavelength tunability and high efficiency[1,2]. High-power pump sources in 2μm-wavelength range are indispensable for efficient mid-infrared generation because of large absorption around 1μm range in $ZnGeP_2$ and GaAs. Narrow spectrum bandwidth is also needed for actual applications.

Recently, we succeeded in development of large aperture periodically poled $MgO:LiNbO_3$ (PPMgLN) device [3,4]. This large aperture PPMgLN device enables us to realize high-energy, highly efficient 2μm QPM OPO pumped with pulsed 1μm lasers. Actually, we have demonstrated a total output energy of 77mJ with slope efficiency of 72% around 2μm wavelength by using PPMgLN device with 5mm x 5mm aperture [4]. In this talk, we report on a widely tunable, high-energy OPO. Also, high-energy, narrow-bandwidth 2.128-μm degenerated master oscillator/power amplifier (MOPA) system based on large aperture PPMgLN devices are presented.

2.OPO by large aperture PPMgLN

As we reported previously[3,4], large aperture PPMgLN device enable us to realize a high-energy and high-efficieny OPO using flat cavity mirrors (Fig.1(a)) without severe cavity alignment. Wide wavelength tunability from 1.5μm to 3.4μm can be obtained by changing a QPM period and QPM device temperature shown in Fig.2. Since QPM technique enable us to use in a full range of material's transparent region, high energy OPO up to ~5μm can be expected using large aperture PPMgLN device by changing its QPM period. Moreover, if the PPMgLN device is uncoated, OPO without external cavity mirrors (that means an OPO only by Fresnel reflection) can be obtained with small decrease of efficiency because of high nonlinear gain of PPMgLN device.

3.High-energy, narrow-bandwidth 2μm light source by MOPA system

Although large-aperture PPMgLN device can produce highly efficient OPO system, its output light has a relatively wide spectrum without spectral narrowing elements because PPMgLN's wide spectral acceptance. Although a degenerate OPO from 1.064μm to 2.128μm can realize an effective power conversion, the spectral bandwidth of 2.128μm light should be essentially wide. Therefore, spectral narrowing of degenerate OPO is required for practical applications.

We constructed MOPA system by using large aperture PPMgLN devices as shown in Fig.1(b). L-shaped master OPO is consisted of plane cavity mirrors, 600 grooves/mm grating, 300 GHz etalon, and PPMgLN device. The PPMgLN device has 5mm x 5mm aperture and 36mm effective length with QPM period of 32.3μm. For power amplifier, we used the PPMgLN device with same size and QPM period as of the master OPO. The pump laser of Q-switched Nd:YAG laser (1.064μm, 30Hz rep. rate, 10ns duration) for MOPA system had nearly flat top shape of ~ 3.4 nm FWHM at the input face of the devices.

At first, we characterized an output spectrum of free-running large aperture PPMgLN degenerated OPO (i.e., without narrowing elements) as presented in Fig.3. The measured full width half maximum (FWHM) spectrum bandwidth was more than 100 nm. Next, we evaluated the output characteristics of the MOPA system. The typical output spectrum of the MOPA system at output energy of ~ 30mJ, is shown in

Fig.3. The spectral bandwidth was narrowed from 115nm at the case of free running degenerated OPO to less than 2 nm by using MOPA configuration. Because current spectrum-bandwidth evaluation is limited by our spectrometer (~2nm), further narrowed bandwidth can be expected in actual spectrum.

Fig. 4 shows the output performance of free running degenerated OPO and the MOPA system. Although there are small decrease in efficiency compared to that of free running OPO, narrow bandwidth, high energy amplified 2μm output of 52mJ at 86mJ pumping energy with conversion efficiency of 60% was obtained in the MOPA system at a seeding energy of 700μJ from master OPO. Increased efficiency of the MOPA system by increasing a seeding energy from 200μJ to 700μJ was also confirmed.

4.Summary

We demonstrated a high-energy, highly efficient quasi-phase-matched optical parametric oscillator based on large aperture PPMgLN. High-energy, narrow-bandwidth 2.128-μm degenerated MOPA system based on large aperture PPMgLN devices are also presented. These result shows that large aperture PPMgLN device is useful for the development of the high-energy, efficient, narrowband 2μm coherent light source. Further improvement of spectral narrowing and output energy scaling are under developing for efficient wide tunable, narrow-bandwidth mid-infrared generation.

Reference

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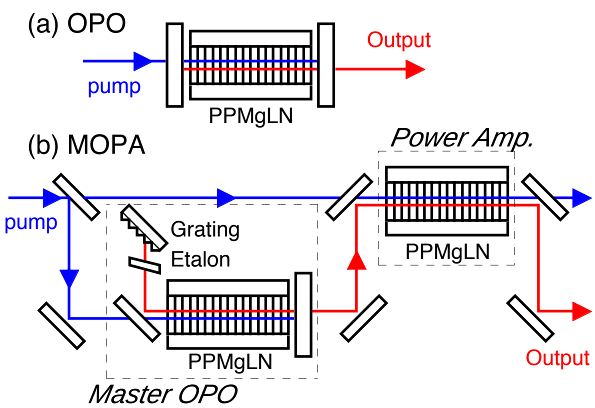

Fig. 1 Experimental setup for (a)OPO and (b)MOPA

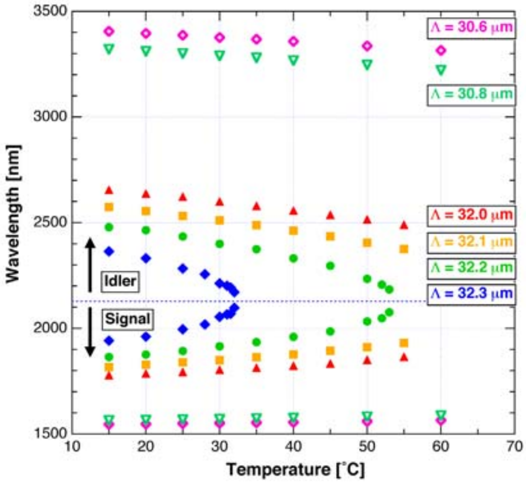

Fig. 2 Temperature dependences of OPO output wavelength for each QPM period.

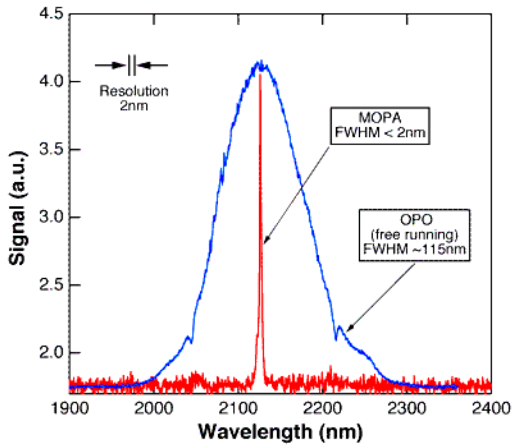

Fig. 3 Typical output spectra of OPO and MOPA at degeneracy wavelength of ~2.128μm.

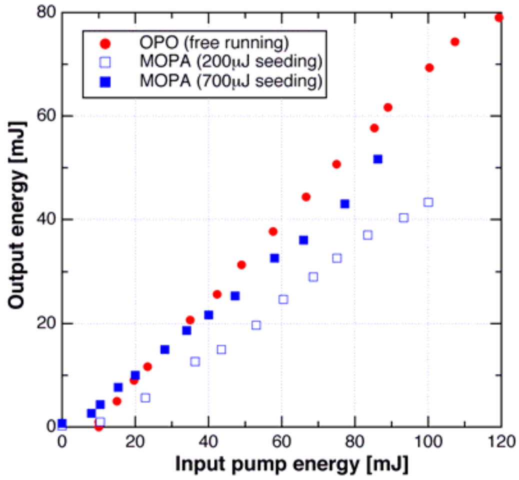

Fig. 4 Output-energy versus input pump energy of OPO and MOPA (seeding : 200μJ and 700μJ)