1.8 µm Optical Parametric Oscillator Based on KTiOPO₄

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Abstract—A 1.8 µm optical parametric oscillator pumped by a diode end-pumped acousto-optically Q-switched Nd:YAG is demonstrated. A 30-mm-long KTiOPO₄ crystal cut with an angle of θ = 59.4°, φ = 0° is employed as the OPO crystal. 685 mW signal laser at 1.8 µm is obtained at the diode pump power of 13 W and the pulse repetition rate of 25 kHz. Simultaneously, 265 mW idler emission at 2.6 µm is obtained. The corresponded diode-to-OPO conversion efficiency is 7.3%. The pulse width of the signal and idler wave are measured to be 4.5 and 2.5 ns, respectively. This gives a peak power of 6.1 and 4.2 kW, respectively.

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1. INTRODUCTION

Diode-pumped solid-state lasers with different wavelengths are enjoying many practical applications including laser radar, optical microscopy, spectroscopy, medicine, remote sensing, communication, and so on. These applications have stimulated much interest in searching for coherent sources with novel wavelengths. Optical parametric oscillator (OPO) is efficient and reliable for emitting diverse radiations especially with wavelengths which are difficult or impossible to access with laser gain medium [1–15]. KTiOPO₄ (KTP) is one kind of the most used OPO crystal for its excellent optical and physical properties and the mature growth mechanism [16]. Starting with light from 1.06 µm Nd³⁺-doped solid-state laser, the type II phase matching curve of KTP can cover a range from 1.4 to 4.5 µm. Nowadays, many researches focus on KTP crystal cut with θ = 90°, φ = 0° satisfying non-critical phase matched (NCPM) scheme to generate 1.5 µm laser [4, 6, 9, 10]. Though NCPM can permit the largest nonlinear coefficient, KTP OPOs based on critically phase-matched (CPM) scheme, in which KTP crystals were cut around the retracing point of the phase matching curve, also have significant advantages. They can be flexibly designed to generate a fixed desirable wavelength by choosing appropriate cut angle. And theoretically, any wavelengths at the phase matching curve ranged from 1.4 to 4.5 µm could be expected. Here we demonstrated a CPM KTP OPO operating at dual wavelengths of 1.8 and 2.6 µm.

In 2007, Izzo et al. reports indicated that neural activity from motor and sensory systems in vivo can be evoked by pulsed 1.8-µm radiation [17]. Thus the 1.8-µm laser sources have promising applications in biomedicine such as cochlear implants and so on. However, owing to the lack of appropriate gain media, they are difficult to be accessed with conventional laser sources. Based on the above reasons, our CPM OPO technology supply us a feasible way to realize laser sources emitting in this band.

In addition, our device can simultaneously emit 2.6 µm radiation, which can serve as the pumping source of ZnGeP₂ OPO. It is noted that 2.6 µm radiation is superior to more usual 2.1 µm radiation for pumping ZGP. Due to high absorption and phase-matching properties, the ZGP OPO cannot be pumped by the 1.06-µm Nd³⁺ doped laser. Nowadays, there are two main solid-state pumping sources for ZGP OPO. One is laser diode directly pumping Tm-doped crystal or Tm, Ho doped laser crystal [18, 19]. The other is degenerate type II KTP OPO [3, 11, 12]. However, both these two sources operate at around 2.1 µm. Though 2.1 µm wavelength is far from the absorption edge of ZGP, it is also not enough for the use of intracavity scheme, in which the pump wave passes through the OPO crystal multiple round trips. The optical property analysis shows that the ZGP possesses transmittance of 70% at 2.1 µm, while of 83% at 2.6 µm. When applied to intracavity laser schemes, 2.6 µm radiation will process much less loss than 2.6 µm radiation thus reduce the threshold and increase the conversion efficiency. Therefore, to some extent, applying our 2.6 µm pump source has important advantage compared to more usual 2.1 µm pump source.

In this paper, we obtained 1.8 and 2.6 µm lasers simultaneously from a CPM OPO based on KTP crystal cut with an angle of θ = 59.4°, φ = 0°. To our knowledge, this is the first time to employ KTP oriented in this angle. We put the KTP crystal inside the pump laser cavity to take advantage of the high fundamental intensity inside the pump laser cavity. As a...
result, total output power of 950 mW, including 685 mW 1.8 μm signal power and 265 mW 2.6 μm idler power, was obtained at the diode pump power of 13 W and the pulse repetition rate of 25 kHz. The corresponding diode-to-OPO conversion efficiency was 7.3%. The results show that CPM OPO supply us a feasible and reliable way to generate novel laser lines that can be used for certain applications.

2. EXPERIMENTAL SETUP

The experimental configuration of the KTP optical parametric oscillator is shown in Fig. 1. The pump source was an 808-nm fiber-coupled CW diode laser with a core diameter of 600 μm and a numerical aperture of 0.22. All the mirrors used in our experiment were flat. The rear mirror (RM) was coated for anti-reflection (AR) at 808 nm (R < 0.2%) on its entrance face. The other face was coated for high-reflection (HR) at 1.06 μm (R > 99.8%) and high-transmission (HT) at 808 nm (T > 99%). The active medium was a 1.0-at % Nd³⁺, 8-mm-long Nd:YAG crystal. Both sides of the active medium were coated for AR at 1.06 μm (R < 0.2%). The 35-mm-long acousto-optically (AO) Q-switch (Gooch and Housego) had AR coatings (R < 0.2%) on both faces at 1.06 μm and was driven at 41 MHz center frequency with 15 W of rf power. The Q-switch was water cooled with the water temperature of 20°C. The OPO cavity consisted of M1 and the output coupler (OC). M1 was coated AR at 1.06 μm (R < 0.2%) and HR (R > 99.8%) at the signal wavelength of 1.81 μm. The output coupler was coated to be partial-reflection (PR) at the signal wavelength (R = 81%) to avoid extreme intracavity intensity that could damage the crystal. Serving as a fundamental cavity mirror simultaneously, the OC was also coated with a highly reflection of R > 99.8% at 1.06 μm. A type II critical phase-matching KTP (Crystech Inc.) crystal (θ = 59.4°, φ = 0°) with a size of 3 × 3 × 30 mm³ was employed as the OPO crystal in our experiment. Both faces of the KTP crystal were AR coated at both 1.81 and 1.06 μm (R < 0.2%). The Nd:YAG and KTP crystal were wrapped with indium foil and mounted in water-cooled copper blocks. The temperature was remaining at 20°C. These elements were all positioned close to each other to form a compact resonator. As a result, the cavity lengths of the fundamental and OPO cavities were 115 mm and 45 mm, respectively.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Considering that the coatings of all the elements were not specially considered at the idler wavelength, it was necessary to know whether the idler wave was coupled out from the OC at the very beginning. Here a Ge plate, an InGaAs photodiode detector and an HgCdZnTe photoconductive detector were used. The infrared transmission spectrum of this Ge plate is shown in Fig. 2. From this figure, we can see this Ge plate almost completely absorbed the signal wave at 1.81 μm, and had a transmission of about 20% at 2.6 μm. The InGaAs detector had a spectral response ranged from 0.8–1.8 μm and HgCdZnTe had a response extended to mid-infrared. We placed the Ge plate behind OC and let the output light incident on the Ge plate. Then these two detectors were used to detect the light that transmitted through the Ge plate.