Tera-Hz Radiation Source by Deference Frequency Generation (DFG) and TPO with All Solid State Lasers

Jianquan Yao[1], Xu Degang[2], Sun Bo[3] and Liu Huan[4]
[1]Institute of Laser & Opto-electronics, [2]College of Precision Instrument & Opto-electronic Engineering,
[3]Tianjin University,[4] Tianjin 300072, China
Tel: 86-22-27402416, Fax: 86-22-27406436,
Email: jqyao@tju.edu.cn

Abstract: The terahertz technique has attracted much attention from a variety of applications in fundamental and applied research field, such as physics, chemistry, life sciences, medical imaging, safety inspection, radio astronomy, modern communication, weapon guidance and so on. The technological progress of terahertz radiation source plays an important role in promoting the development of various terahertz technique and the related cross subjects. The generation of high-power, coherent, widely tunable, narrow-band terahertz wave, based on the process of the difference frequency generation [1] and the tera-parametric oscillation [2-5] in a polar crystal respectively, is expected to provide a promising terahertz radiation source with the obvious and exclusive advantages of compactness, simplicity for tuning, operation at room temperature and so on, which causes great research interest among the researchers all over the world. However, the research of this potential THz-wave generation technique is still in its infancy, and few relevant theoretical or experimental studies were reported in recent years.

Keywords: Terahertz，Terahertz radiation source

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1. Experimental Scheme

We presented a calculation, design and experiment by DFG and TPO with all solid state lasers. A high-power, narrow-linewidth, angle-tuned pulsed dual-wavelength KTP-OPO operating near the degenerate point is experimentally demonstrated. The theoretical investigation of the phase-matching properties for the tunable coherent terahertz wave generation in the isotropic semiconductor nonlinear materials is presented, based on the dual-wavelength KTP-OPO mentioned above in the process of the difference frequency generation (DFG). The cross-Reststrahlen band dispersion compensation phase-matching technique involved in this interaction is introduced theoretically. According to the perfectly phase-matched wavelength range of the ZnTe crystal, we successfully showed a high-power, narrow linewidth, widely tunable, dual-wavelength KTP-OPO with two KTP crystals for the first time, which can be used as one of the most potential pump sources for the THz-wave DFG.. Also we presented an experiment setup by laser diode pumped two wavelength operating (1319nm and 1338nm) Nd:YAG laser, it will expected near 3T radiation. The principle of operation of terahertz-wave parametric generation or oscillator (TPG / TPO) via the stimulated polariton scattering process is theoretically introduced in detail. The properties of THz-wave gain and absorption under different conditions in this process is presented. According to the investigation of the dispersion properties of the polariton in the polar crystal, a novel frequency tuning technique for TPO is reported for the first time. According to the experimental results of TPG using $LiNbO_3$, a high-power, coherent tunable Stokes light is obtained in the TPO experiments, which means that the tunable, coherent THz-wave radiation with high power is also generated. The phenomenon of the coherent tunable second-order Stokes light scattering is also observed.

DFG: depend different principle of two wavelengths witch will difference generation

a) Two wavelengths from a solid state laser such as Nd:YAG laser (wavelengths: 1319nm and 1338nm), it will expected near 3T radiation (Fig.1).

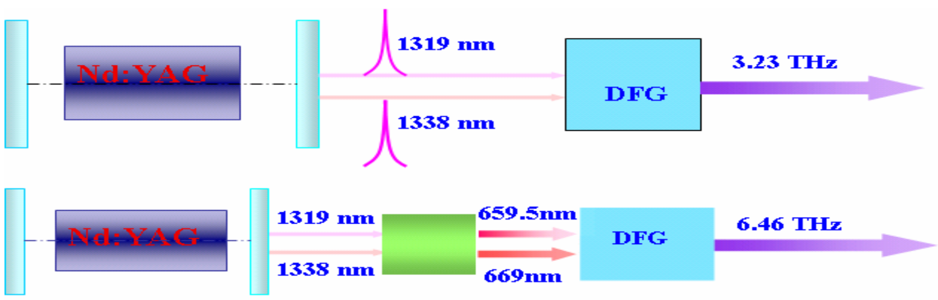

Fig.1 DFG by two wavelengths from Nd:YAG laser

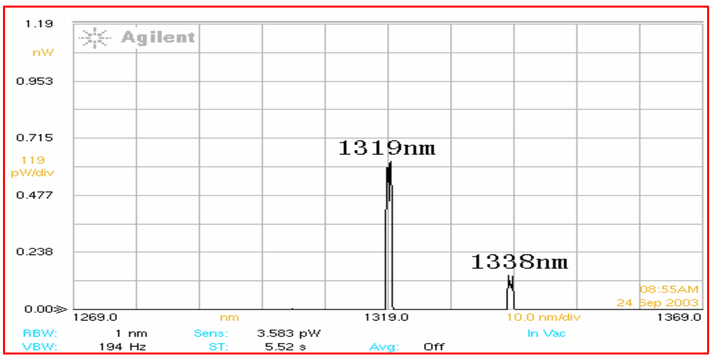

Fig.2   Spectrum of 1319 and 1338nm

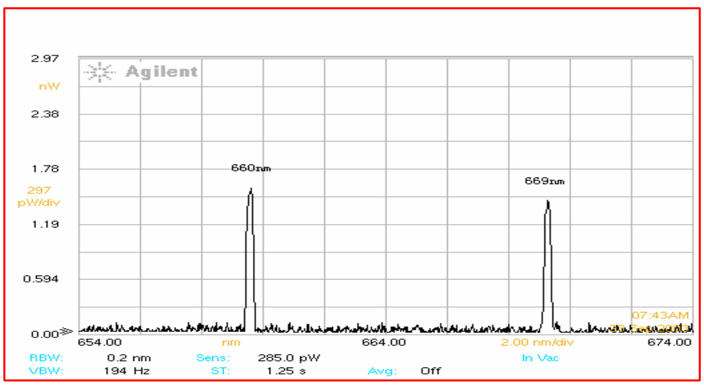

Fig. 3   Spectrum 660 and 669 nm

b) Two wavelengths from a tunable solid state laser such as Ti:sapphire laser (Fig4)

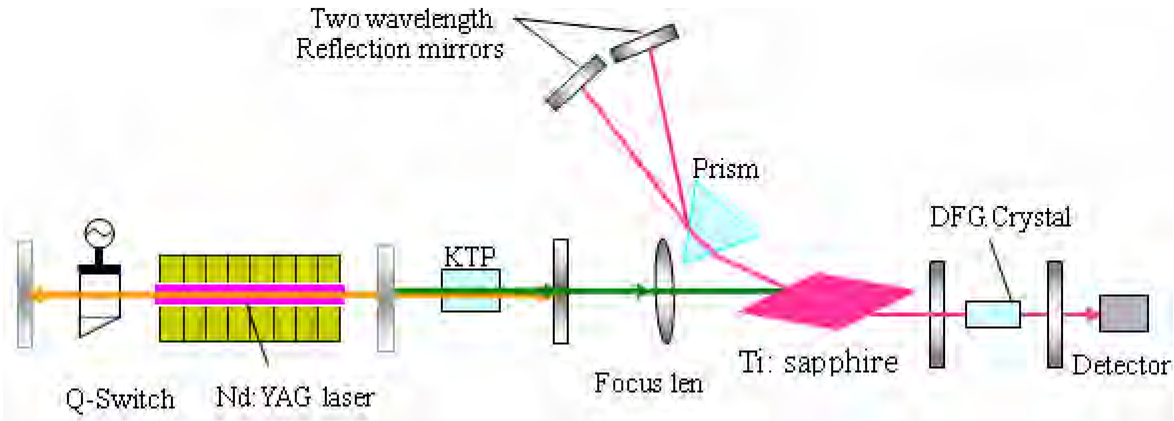

Fig. 4 DFG by two wavelengths from a tunable Ti:sapphire laser

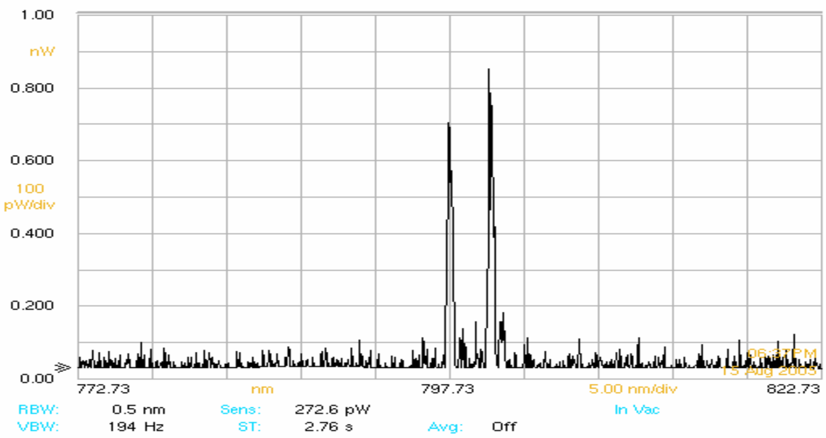

Fig. 5 Spectrum of 797.7nm and 801.0 nm from Ti:sapphire laser

c) Two wavelengths from a OPO device (Fig.6)

• From a near degenerate point OPO

• From a OPO with two nonlinear crystals such as KTP or period poled PPLN

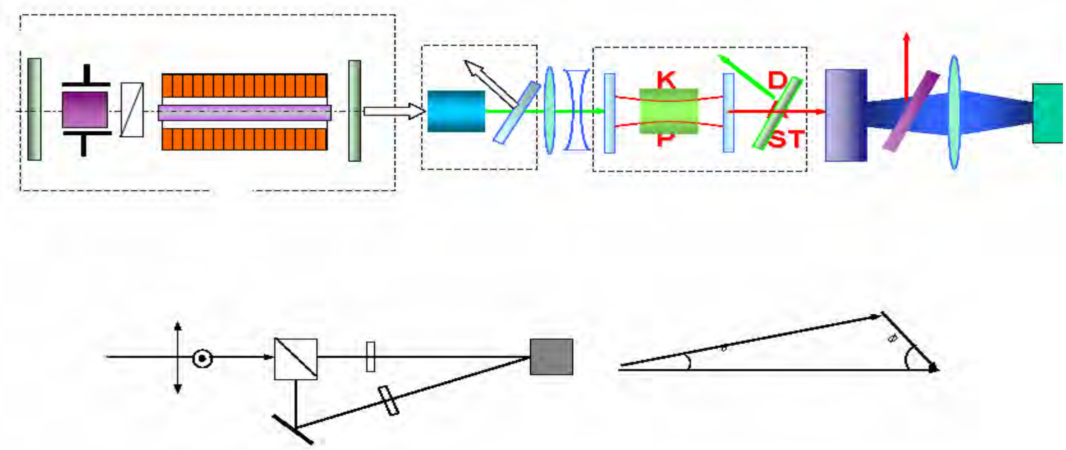

Fig. 6 Scheme of DFG by two wavelengths from KTP-OPO pumped by 532 nm laser

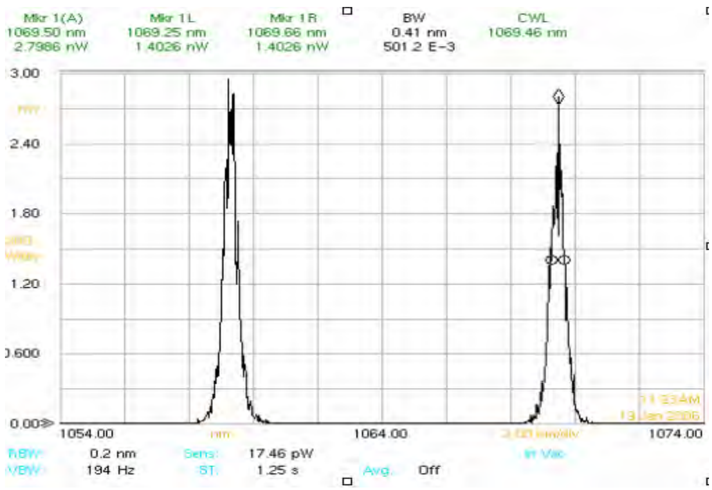

Fig. 7 Spectrum of two wavelengths from KTP-OPO pumped by 532 nm laser

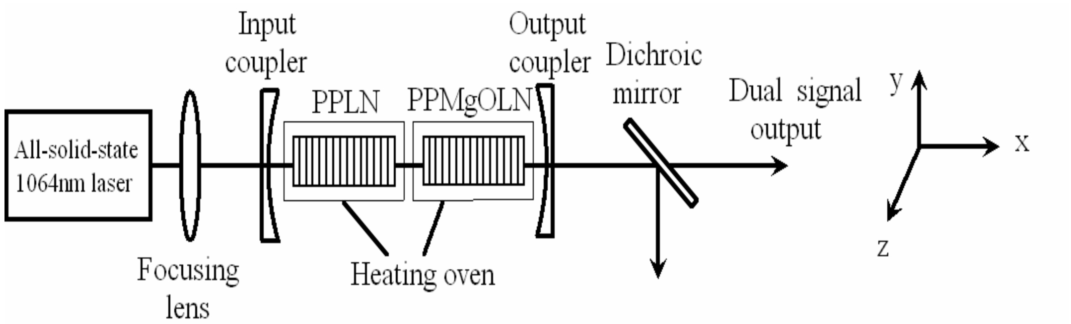

Fig. 8 Scheme of two wavelengths from dual PPLN-OPO pumped by 1064 nm laser

2. Experimental Results

A high-power, narrow-linewidth, angle-tuned pulsed dual-wavelength KTP-OPO operating is experimentally demonstrated. The theoretical investigation of the phase-matching properties for the tunable coherent terahertz wave generation in the isotropic semiconductor nonlinear materials is presented. The cross-Reststrahlen band dispersion compensation phase-matching technique involved in this interaction is introduced theoretically.

According to the perfectly phase-matched wavelength range of the ZnTe crystal, we successfully showed a high-power, narrow line width, widely tunable, dual-wavelength KTP-OPO with two KTP crystals for the first time, which can be used as one of the most potential pump sources for the THz-wave DFG.

The parametric oscillation of a widely tunable THz-wave by use of nonlinear optical characteristics of phonon polariton of $LiNbO_3$ has been researched extensively with a Q--switched Nd:YAG laser as the pump source[4, 5]. However, the effect of induce Raman scattering by polariton in LiNbO3 crystal to THz wave still is not researched entirely. In this paper, we research the properties of THz-wave gain and absorption under different conditions in crystal. According to the investigation of the dispersion properties of the polariton in the polar crystal, a novel frequency tuning technique for TPO is reported for the first time. According to the experimental results of terahertz parametric generation (TPG) using $LiNbO_3$, a high-power, coherent tunable Stokes light is obtained in the TPO experiments, which means that the tunable, coherent THz-wave radiation with high power is also generated. The phenomenon of the coherent tunable second-order Stokes light scattering is also observed.

Fig.9 indicated the experimental setup in witch including a Si-prism array for Thz wave coupler. In experimental we got the photo of Stokes light space distribution from TPG procession as shown of Fig.9.

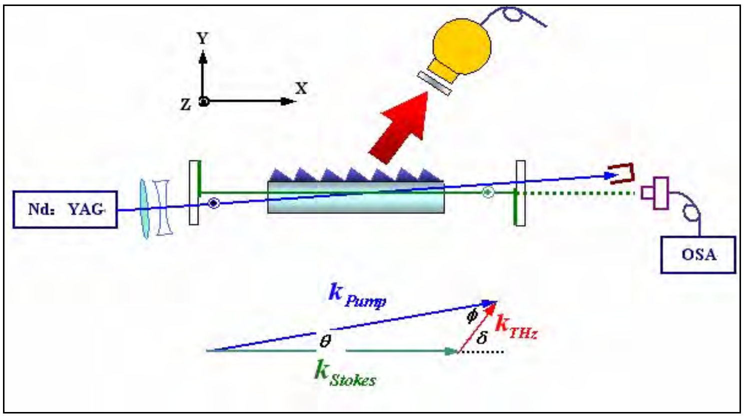

Fig.9 The experimental setup of the TPO

From Fig.10, it can be seen that two scattering Stokes of about 1071nm distributed in the side of pumping light symmetrically because of the symmetrical structure of crystal when the pumping light normal to incident the crystal. When the incident angle θ_{ext} of pumping light changes from 0.72° to 2.8°, which correspond to the angle of 0.33°～1.3° between pumping light and stokes oscillator light, the tunable stokes light of 1.067～1.075 nm and THz radiation of 104～378 μm (0.8～2.88 THz) were obtained simultaneously. Figure 10 depicted stokes-spectrum (a) and frequency shift spectrum (b) of TPG. From Fig. 11, the second-order stokes light was generated. The second-order stokes will increase with the pumping energy enhancing, leading to the one-order stokes light saturating and decreasing the output energy according to conservation of energy. Figure 12 gives the spectrum and frequency shift of one-order and second-order Stokes lights. When the frequency shift of one-order reduces, the second-order will decrease, even second-order and one-order will overlap.

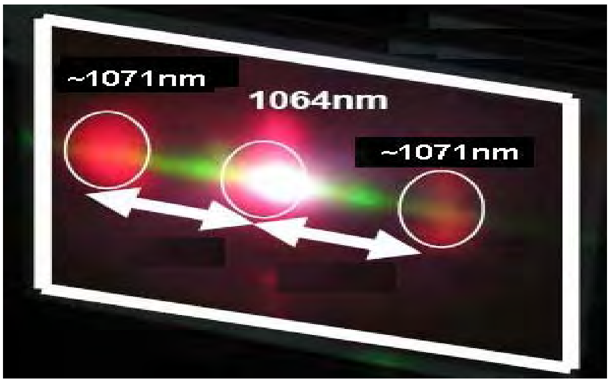

Fig.10 Stokes light space distribution from TPG procession

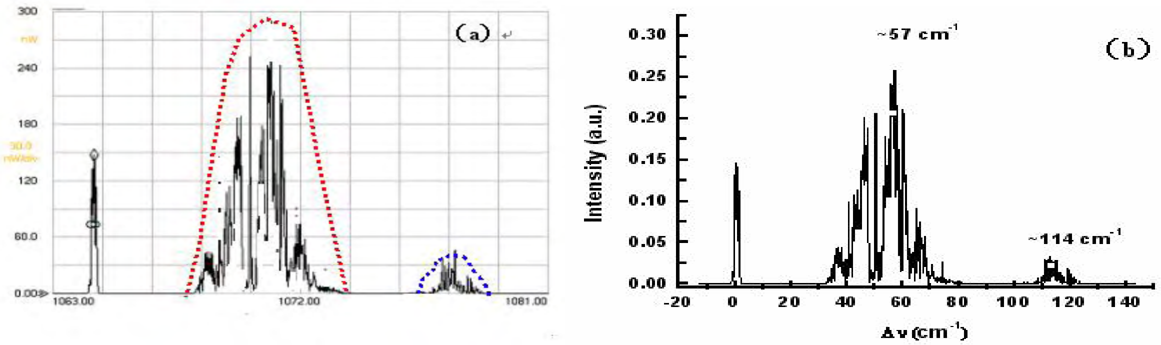

Fig.11 Stokes-spectrum (a) and frequency shift spectrum (b) of TPG

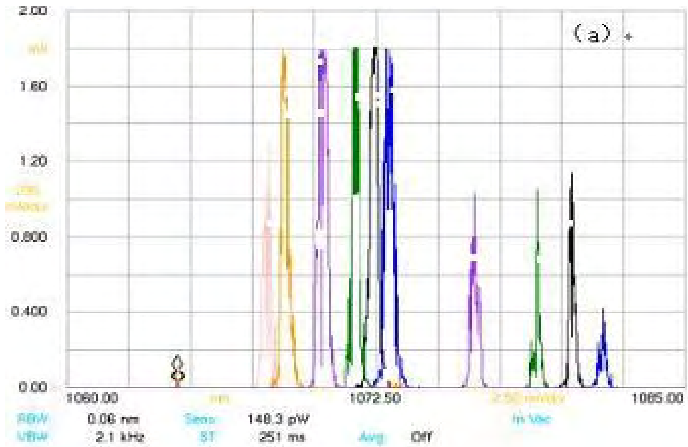

Fig.12 Spectrum and frequency shift of one-order and second-order Stokes lights

Fig.13 showed the output character as function of pumping energy at 1071.28nm stokes wave. When the pumping energy is 60mJ, Output energy of Stokes oscillation at 1071.28nm is 9 mJ with the oscillation threshold of 40 mJ and the optical-optical conversion efficiency of 15.4%。

A novel method for TPO tuning by change pumping laser wavelength is presented firstly. When angle between pumping light and axel of resonant cavity is fixed, if incident laser wavelength is changed，because refractive index of pumping light in nonlinear crystal at different wavelength is different, so that the in-collinear phase matching condition of three wave interaction will be changed, thus the cress point between phase matching curve and dispersion curve of electric -magnetic polariton， therefore Thz radiation will be continuously tuning. In experiment first and second order Stokes light were discovered.

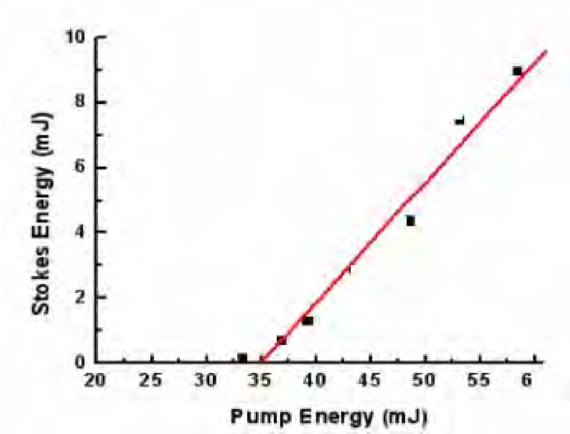

Fig.13 Stokes wave output character with pumping energy at 1071.28nm

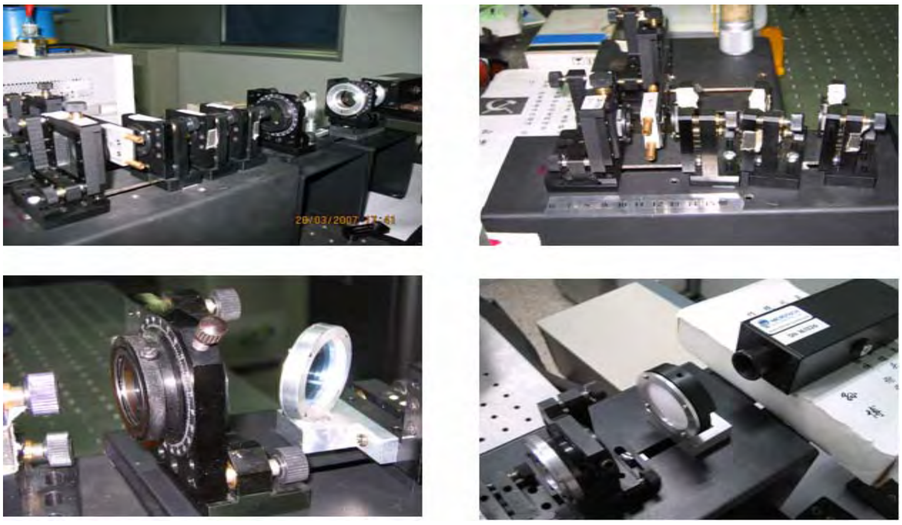

Fig. 14 Experimental setup

Experimental set up show in Fig. 14. We already got success results in those experiments; the results will publish in the other paper.

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