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Second Harmonic Generation of Short Pulse, High Peak-Power, Line-Narrowed TEA-CO_2 Laser Using a $AgGaSe_2$ Crystal

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Second harmonic generation of a short pulse, high peak-power, line-narrowed TEA-CO_2 laser has been demonstrated for the typical rotational transition lines of 10P,10R,9P branches by using a 15-mm long $AgGaSe_2$ crystal with a broad band AR coating . An effect of the longitudinal mode number on the conversion efficiency was also studied by changing the laser cavity length.

1 Introduction

9-10 μm band of the CO_2 laser and its frequency-doubled band correspond to "atmospheric optical windows". As these two bands also correspond to "eye-safe wavelength region", a second harmonic generation system with a TEA-CO_2 laser has been attracting considerable attention as a light source of the two-color laser radar[1].

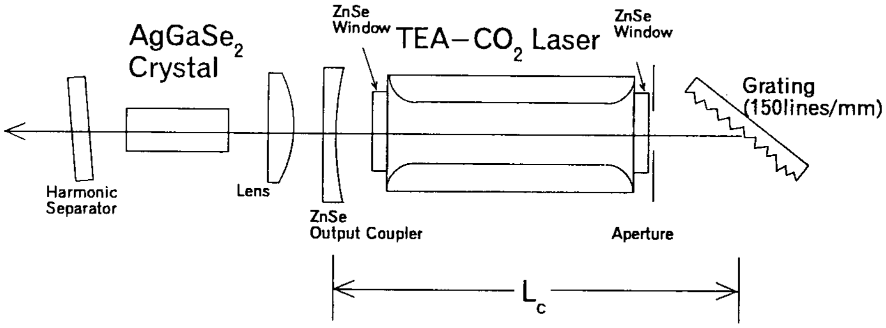


Fig.1 Schematic diagram of second harmonic generation experiment.

Until now, the crystal growth of a high quality, large size $AgGaSe_2$ has been achieved successfully for the frequency conversion of the CO_2 laser [2]. In addition, a compact, short pulse, high peak-power, high-repetition-rate TEA-CO_2 laser has been developed recently by Toshiba Corporation[3]. This short pulse, high peak-power TEA-CO_2 laser is very suitable for the efficient frequency doubling. This paper describes the second harmonic generation of this short pulse, high peak-power, line-narrowed TEA-CO_2 laser for the typical rotational transition lines of 10P,10R,9P branches by using a 15-mm long $AgGaSe_2$ crystal with a broad-band AR coating of 9-11 μm.

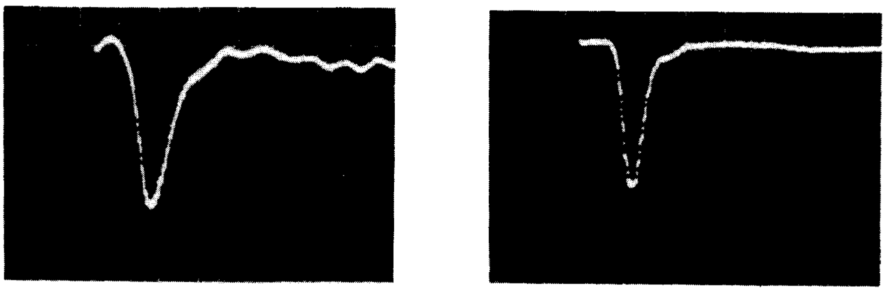
2 Experimental Setup

Fig.1 shows a schematic diagram of the experimental setup. The semi-sealed TEA-CO_2 laser was used for this experiment. For short pulse, high peak-power operation, the capacitor transfer circuit as the excitation circuit and the specified gas mixture were employed[3]. The main discharge electrodes consist of two copper electrodes having a 1 cm wide discharge width, spaced by 1 cm, defining a 30 cm long discharge length. The external optical cavity consists of a 150-lines/mm flat diffraction grating blazed at 10.6 μm with a Littrow configuration and a $ZnSe$ output coupler with a reflectivity of 75 % and a radius of curvature of 15 m. The cavity length L_c is about 60 cm for the single longitudinal mode operation and is 120 cm for the two mode operation. A polarization measurement showed that 97 % of the total pulse energy was P-polarized with no Brewster plate. An intracavity circular aperture with a 0.7 cm diameter was used to control a transverse mode and it was recognized as TEM_{00} by observing the burn pattern. The oscillation wavelength was measured by a spectrum analyzer through the experiment.

The laser beam was focused into the $AgGaSe_2$ crystal by using the $ZnSe$ lens with a long focal length of about 50 cm. The 15-mm long $AgGaSe_2$ crystal, grown by Cleveland Crystals, Inc., was cut for phase matching angle of 52.21 ° at λ = 9.97 μm. The crystal was antireflection coated with the double broad-bands of 9-11 μm and 4.5-5.5 μm for both sides. The transmittance measured was 90 % at 10P20 line (λ =10.59 μm). If the surface reflectivity of 3 % is assumed on one side, the optical loss of 4 % due to absorption and scattering is estimated.

The laser pulse shape was monitored with a 1-ns fast rise-time, room- temperature HgCdTe detector and a storage oscilloscope. The fundamental and second-harmonic laser energy was measured with Gentec model ED-200 and ED-500 joule meter. The MgF_2 harmonic separator was used to cut the fundamental wave.

3 Experimental Results and Discussion



(a) (b)

Fig.2 Temporal waveform of (a) fundamental TEA-CO_2 laser and (b) second harmonics.Time scale is 50 ns/div..

Fig.2 shows the typical temporal waveforms of (a) fundamental TEA-CO_2 laser when oscillating at the 10P24 line (10.63 μm) with a 60-cm short cavity and (b) its second harmonics. The fundamental temporal distribution of the laser pulse consisted of a 41-ns (FWHM) gain-switched spike, followed by a 200 ns tail. In this short cavity operation, the pulse shape exhibited an almost smooth pulse without clear mode beating, so the single longitudinal mode oscillation was obtained. In Fig.2(a), 56 % of the total pulse energy is contained in the gain-switched spike. As can be seen from Fig.2(b), the second harmonic pulse consisted of only a 27-ns (FWHM) short pulse. In this condition, 2 mJ of second-harmonic energy was generated with a pump energy of 35 mJ at a pump beam intensity of 4.4 MW/cm^2 (0.18 J/cm^2). Then the energy conversion efficiency of 5.6 % and the peak-power conversion efficiency of 11 % were obtained. As the surface damage threshold of this crystal is thought to be 1.0 J/cm^2 under the high-repetition-rate operation [1], more efficient operation could be achieved up to a maximum energy conversion efficiency of 30 %.

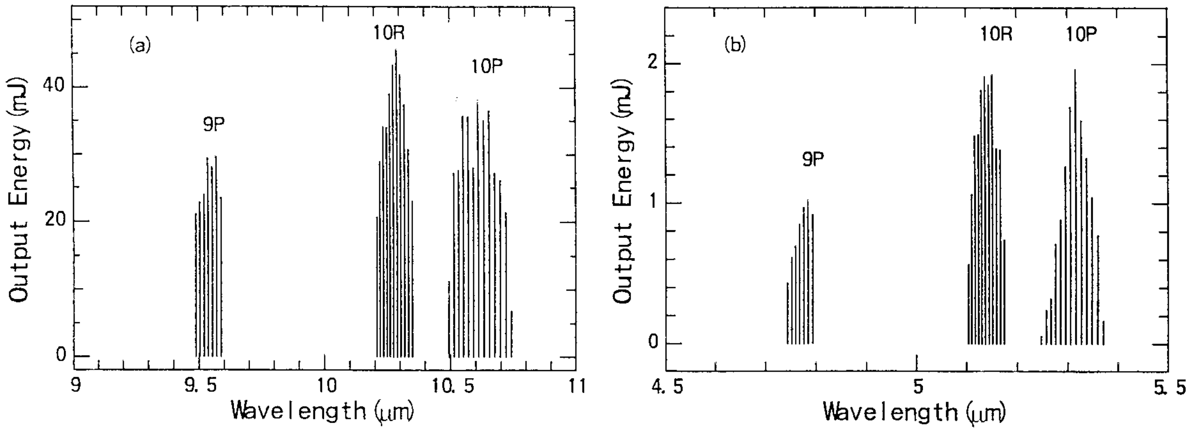


Fig.3 Laser output energy of (a) the rotational transition lines of 10P,10R,9P branches and of (b) its second-harmonics.

Fig.3 shows (a) the fundamental output energy and (b) second-harmonic energy versus the laser wavelength corresponding to the rotational transition lines of 10P,10R,9P branches. The data measured were averaged for ten shots. In this experiment, the cavity length was fixed at 60 cm. Because our crystal was cut for 9.97 μm, the maximum tilt angle was about 10 ° at 10P branch. As can be seen from Fig.3, the wavelength dependence on the second- harmonic energy exhibited a slight change to that for the fundamental output. This phenomena could be due to the different absorption characteristics on the each transition lines.

There were some reports that the multi-longitudinal mode laser gives the higher conversion efficiency. To verify this result, an effect of the longitudinal mode number on the conversion efficiency was studied experimentally. The longitudinal mode number was controlled by changing the cavity length. The preliminary experiment showed that the multi-longitudinal mode operation gives higher conversion efficiency as reported in reference [1]. The detailed characteristic is under experiment.

4 Conclusion

In Conclusion, the second harmonic generation of a short pulse, high peak-power, line-narrowed TEA-CO_2 laser has been demonstrated for the typical rotational transition lines of 10P,10R,9P branches, we believe for the first time, by using a 15-mm long $AgGaSe_2$ crystal with a broad band AR coating. An effect of the longitudinal mode number on the conversion efficiency was also studied by changing the laser cavity length. This study indicated that the short pulse, high peak-power, line-narrowed TEA-CO_2 laser developed could be very useful for the efficient second harmonic generation.

Acknowledgement

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