CW Nd : MgO : $LiNbO_3$ Self-Frequency-Doubling Laser at Room Temperature

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Abstract—**A CW Nd : MgO : $LiNbO_3$ self-frequency-doubling laser has been demonstrated at room temperature for the first time. The second-harmonic output at λ = 547 nm up to 18 mW was achieved in a simple resonator.**

I. Introduction

A simple CW self-frequency-doubling laser without any additional intracavity components operating at room temperature would be a favorable design for SHG. T. Y. Fan *et al.* achieved the first CW operation of a self-frequency-doubling laser with Nd : MgO : $LiNbO_3$ which was heated to a phase-matching temperature of about 152°C [1]. This laser generated 1.1 mW second-harmonic output. A diode laser-pumped Nd : MgO : $LiNbO_3$ laser has been demonstrated at room temperature but only the outputs of the fundamental wavelengths were obtained without self-frequency-doubling [2]. Recently, the pulse Nd : MgO : $LiNbO_3$ self-frequency-doubling laser pumped by a small Xe lamp was achieved at room temperature and net SHG green output of 400 μJ/shot was obtained [3]. In this paper, we report the first successful CW Nd : MgO : $LiNbO_3$ self-frequency-doubling operation at room temperature. Our self-frequency-doubling laser system pumped by λ = 598 nm dye laser radiation generated the second-harmonic output as high as 18 mW at room temperature. The construction of laser resonator is simple and reliable without any intracavity components except a Nd : MgO : $LiNbO_3$ crystal. The Nd : MgO : $LiNbO_3$ crystal was provided by South-West Institute of Technical Physics of P. R. China.

II. System Description

The dimension of Nd : MgO : $LiNbO_3$ crystal is 3 mm × 4 mm × 20 mm. The laser transmits along the edge of 20 mm-long. The y-axis of the crystal is parallel the edge of 4 mm-long. The crystal was cut according to the requirement of the phase-matching angle at room temperature. The phase-matching angle was calculated as 70°50′ and the practical phase-matching angle was designed as 72.5° with the consideration of pump heating effect [3]. The faces of crystal were coated to minimize the reflection of the fundamental wave. In this critically phase-matched crystal, the double refraction walk-off angle between π and σ polarization laser lines was about 1.18° and the walk-off width through the 20-mm-long crystal was about 410 μm. The intracavity TEM_{00} mode sizes of both π and σ polarized fundamental waves were about 100 μm, so that the crystal could be used as a polarization selector to suppress the relative strong π polarized transition. By means of adjusting the orientation of crystal, we could make the low-gain σ polarization laser oscillate preferentially to achieve the phase-matching for SHG; therefore; the Brewster angle window usually inserted in the cavity [1] [3] was not needed in this case. The σ polarization laser was adjusted to oscillate along the axis of cavity and the π polarization laser was completely suppressed. The crystal was doped with 0.21 Wt.% Nd_2O_3 and 1.8 Wt.% MgO. No photorefractive damage was observed during the experiments.

The experimental arrangement is illustrated in Fig. 1. The pump laser was a CW Rhodamine 6G ring dye laser turned to 598 nm absorption line of the crystal material. The crystal was placed on the center of the resonant cavity consisted of M_1 and M_2. The length of the cavity was about 46 mm. The radii of curvature and the transmissivities of the cavity mirrors M_1 and M_2 for the pump laser at λ = 589 nm, the fundamental wave at λ = 1.093 μm and the second-harmonic wave at λ = 547 nm were listed in Table I.

No attempt was made to oscillate the second-harmonic wave. The optical isolator I was inserted between the pump laser and lens L to reduce measurement errors owing to feedback. The lens L with focal distance f = 120 mm was used to focus the pump beam to the centre of Nd : MgO : $LiNbO_3$ crystal. The diameter of pump spot in the crystal was about 80 μm. The second-harmonic outputs from M_2 were received and measured by detector D with the filters F_1 and F_2 which prevented the residual fundamental waves and pump laser from entering into the detector.

Because the pump irradiance absorbed by the crystal inevitably resulted in the temperature rise, the crystal cut according to a calculated phase-matching angle can satisfy the optimum phase-matching condition only on certain pumping level at room temperature. The crystal was placed in an oven the temperature of which was controled and stabilized by a home-made electronic feedback system around room temperature to maintain the optimum phase-matching at different pump levels.

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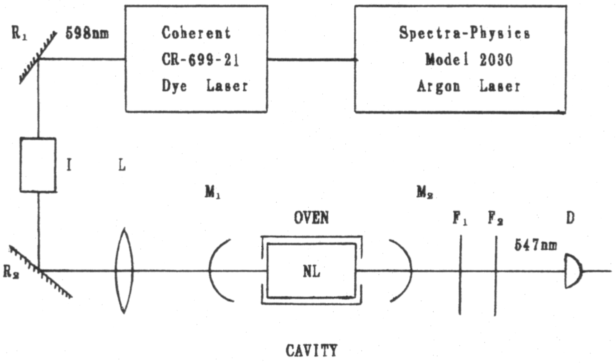

Fig. 1. Schematic of the Nd : MgO : $LiNbO_3$ self-frequency-doubling laser experimental arrangement.

TABLE I
THE RADII OF CURVATURE AND TRANSMISSIVITIES OF M_1 AND M_2

	M_1	M_2
R	20.6 mm	20.6 mm
$T_{598\text{ nm}}$	89.5%	95.5%
$T_{1.098\ \mu\text{m}}$	0.04%	0.20%
$T_{547\text{ nm}}$	51.6%	99.6%

III. EXPERIMENTAL RESULTS

The second-harmonic output from M_2 versus the absorbed pump power and the pump power incident on cavity curve was shown in Fig. 2. The solid curve is a least-squares fit to a parabola.

The maximum second-harmonic ($\lambda = 547$ nm) output power from M_2 and the conversion efficiency, defined as the ratio of total second-harmonic output to pump power absorbed above the threshold [1], were 18 mW and 6.4% per watt. The pump power corresponding to the maximum second-harmonic output of 18 mW was 850 mW. On this pump level the measured temperature of crystal was 43°C due to pump heating while the room temperature was 22°C. In this case, the optimum phase-matching was automatically reached without extra heating or cooling. If the pump power was higher or lower than this level (850 mW), we had to cool or heat the crystal to maintain the optimum phase-matching and obtain the highest second-harmonic output on the corresponding pump power.

Since the oven was designed to build a homogeneous temperature distribution in the crystal and a TEM_{00}-mode coherent beam was applied as the pump source, the appreciable distortion of the spatial profile of the second-harmonic output beam was not found even at higher input. Fig. 3 shows the spatial profile of the second-harmonic beam obtained by the pin-hole scanning technique at about 600 mW input power; obviously, it is a TEM_{00}-mode configuration with Gaussian profile. The laser operated at multiple longitudinal modes due to the absence of the intracavity mode selector.

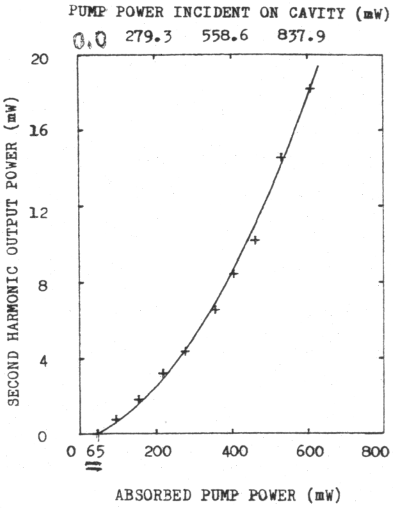

Fig. 2. The second-harmonic output from M_2 versus the absorbed input pump power and the pump power incident on cavity curve.

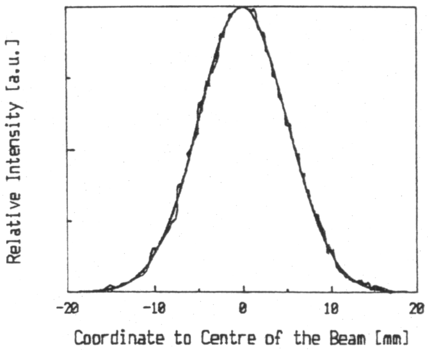

Fig. 3. The spatial profile of the second-harmonic beam. The output second-harmonic beam passed through a lens, its diameter spread to 20 mm.

IV. CONCLUSION

In conclusion, we have demonstrated the first CW self-frequency-doubling laser at room temperature and obtained the second-harmonic output as high as 18 mW. The simple configuration of the resonator and lower pump threshold (65 mW) provide a model for making commercial green CW compact laser systems with Nd : MgO : $LiNbO_3$ crystal as nonlinear material and laser medium and semiconductor diode laser as pump sources.

REFERENCES

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