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Efficient Second Harmonic Generation of Pulsed Nd-YAG Laser Radiation with Noncritically Phase-Matchable $LiNbO_3$ in Room-Temperature

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0.65 mol% MgO-doped $LiNbO_3$ single crystals were grown by CZ method. The obtained single crystals were colorless and transparent. Noncritically phase-matched second harmonic generation (SHG) of 532-nm radiation from 1064-nm in MgO-doped $LiNbO_3$ has been investigated by using pulsed Nd:YAG laser. The phase-matching temperature was room temperature. SHG conversion efficiencies were typically achieved higher than 50% at the phase-matching temperature with no photorefractive damage in the region of fundamental power density which was used in this experiment. The thermo-birefringence coefficient and the electro-birefringence coefficient of SHG were calculated from the temperature phase-matching profile with the electric field.

Key words: MgO-doped $LiNbO_3$, Second harmonic generation (SHG), Nd-YAG laser, Optical damage, Phase-matching temperature

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I. Introduction

Lithium niobate ($LiNbO_3$) is an important nonlinear optical crystal for applications to the second harmonic generation (SHG) of 1064-nm Nd : YAG laser output because of its large quadratic nonlinearity and capability of noncritical phase-matching.1-3) But the application to optical frequency doubling is hampered by the photo-refractive damage. MgO doping to LN crystals is one of solutions to this problem.2) Untill now, it has been reported that 4.5 mol% or more MgO doped LN have much larger resistance to the optical damage than pure LN. However, it is difficult to grow much MgO-doped good quality LN crystals.

II. SHG in $LiNbO_3$ Crystals

In case of the negligible pump depletion, the ideal intensity curve of SHG of LN crystal with length L can be written by4)

$$I_2(2\omega) \propto L^2 I(\omega)^2 \left[\frac{\sin\left(\frac{\Delta kL}{2}\right)}{\frac{\Delta kL}{2}}\right]^2 \tag{1}$$

where I(ϖ) is intensity of fundamental beam which frequency is ϖ, DkL/2 is phase change parameter which can be written by

$$\frac{\Delta kL}{2} \doteq \omega c L({n_2}^e - {n_1}^o) \tag{2}$$

$$(n_2^e - n_1^o)_T = (n_2^e - n_1^o)_{T_{pm}} + (T_{pm} - T)\frac{d(n_1^o - n_2^e)}{dT} + \frac{d(n_1^o - n_2^c)}{dE} \tag{3}$$

where E is the applied electric field density parallel to c-axis, and

$({n_2}^c - {n_1}^o)_{T_{pm}} \doteq 0$. $d({n_1}^o - {n_2}^e)/dT$ and $d({n_1}^o - {n_2}^e)/dE$ are the thermo-birefringence coefficient and the electro-birefringence coefficient of SHG. In case of point group 3 m crystals like $LiNbO_3$, the electro birefringence coefficient can be written with electrooptic coefficients r_{13} and r_{33}.5,6)

$$\frac{d(n_1^o - n_2^c)}{dE} = \frac{1}{2}[r_{13}({n_1}^o)^3 - r_{33}({n_2}^e)^3] \tag{4}$$

From equation (1), (2) and (3), it is possible to adjust the phase matching with the temperature or electric field which is applied to c-axis.

III. Experiments

0.65 mol% MgO doped $LiNbO_3$ crystals were grown with the Czochralski method from congruent composition (Li : Nb=48.6 : 51.4)7) The crystal samples were poled by DC 5 V/cm at 1200°C. Dimensions of crystals were 10×4×6 mm^3 for SHG efficiency measurement, 3.1×6×6.2 mm^3 for birefringence coefficient measurement.

The used laser sources were commercial 10 Hz Q-switched Nd : YAG laser(Lumonics, Model HY-750) and mode locked Nd : YAG laser. Pulse durations of lasers were 25 ns and 40 ps. To make Airy-like input beam profile, we used the 1-mm

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diameter circular aperture. The crystal temperature was adjusted in the small oven which was controlled with the programmable temperature controller.

The thermo-birefringence coefficient of SHG was calculated from the temperature phase-matching profile. The electro birefringence coefficient of SHG was calculated from the change of phase-matching temperature with the electric field which was applied to crystal c-axis. Applied electric field densities were 0, 3.22 and −3.22 kV/cm respectively.

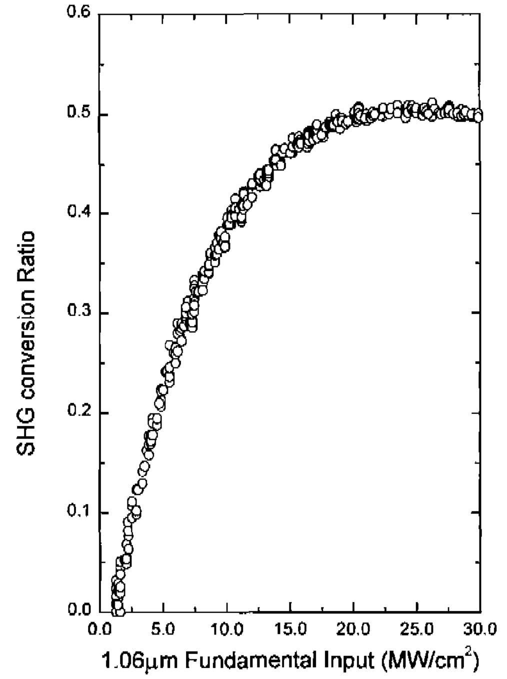

Fig. 1. SHG conversion efficiency of 0.65MgO : LN with the pulsed laser of 25ns pulse duration.

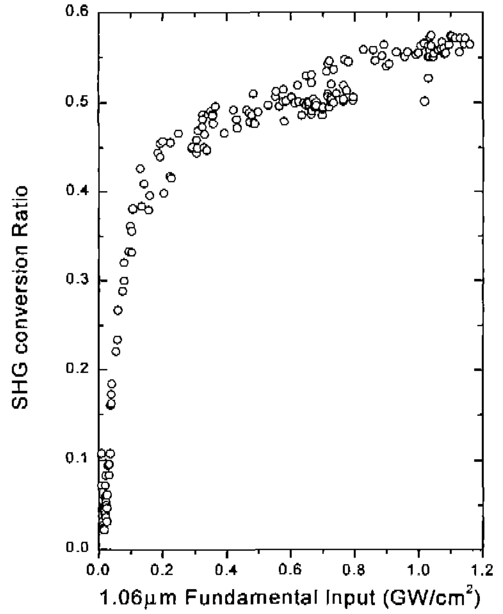

Fig. 2. SHG conversion efficiency of 0.65MgO : LN with the pulsed laser of 40ps pulse duration.

The SHG efficiency of crystals was measured over a certain range of input energy. The SHG conversion was calculated from the energy measured in the fundamental beam and the generated 532-nm beam.

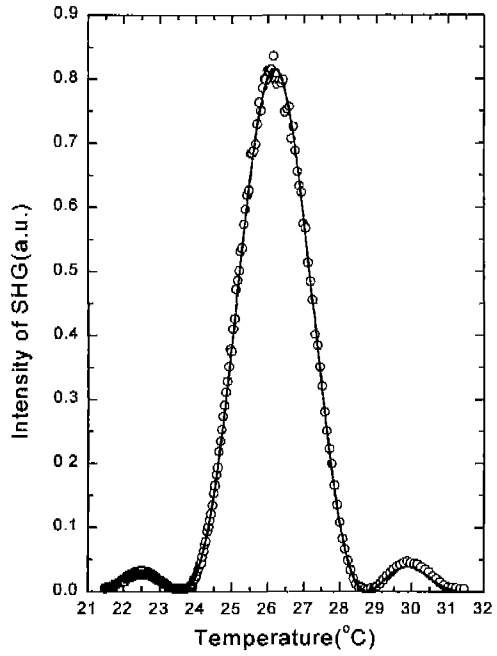

Fig. 3. Temperature phase-matching profile of 0.65MgO : LN (circle) and the best fitting(line).

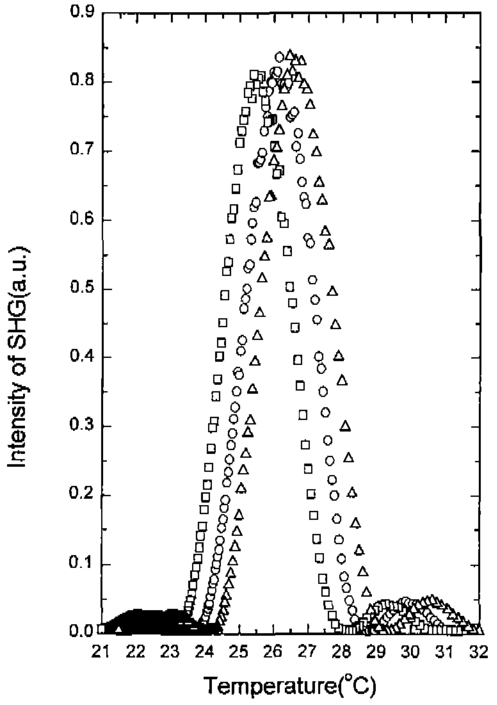

Fig. 4. Shift of phase-matching temperature of 0.65MgO : LN with electric field (0 kV/cm; circle, −3.22 kV/cm; triangle, 3.22 kV/cm; square).

IV. Results

With the room-temperature phase-matching, Conversion efficiencies which were higher than 50% were obtained at fundamental peak-power densities of 25 MW/cm^2 and 1 GW/cm^2 (Figs. 1 and 2). No photorefractive damage was induced during these experiments. This shows that laser induced refractive change is less effective for SHG with the shorter pulse laser.

Temperature phase-matching profile of this experiment was nearly same to the ideal profile (Fig. 3). The phase-matching temperature was shifted with electric field (Fig. 4).

The thermo-birefringence coefficient and the electro birefringence coefficient of SHG were $(6.61\pm12)\times10^{-5}{}^{\circ}C^{-1}$ cm/V.

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References

1. E. O. Ammann and S. Guch, Jr., *Appl. Phys. Lett.,* **52**(17), 1374 (1988).
2. J. Q. Yao, W. Q. Shi, J. E. Millerd, G. F. Xu, E. Garmire and M. Birnbaum, *Opt. Lett.,* **15**(23), 1339 (1990).
3. W. J. Kozlovsky, C. D. Nabors and R. L. Byer, *IEEE J. Quantum Electron.,* **24**(6), 91 (1988).
4. Y. R. Shen, The Principles of Nonlinear Optics, Chapter 7 (John Wiley & Sons, New York, 1984).
5. B. H. Soffer and I. M. Winer, *Phys. Lett.,* **24A**(5), 282 (1967).
6. M. Aillerie, M. D. Fontana, F. Abdi, C. Carabatos-Nedelec, N. Theofanous and G. Alexakis, *J. Appl. Phys.,* **65**(6), 2406 (1989).
7. G. T. Joo, C. D. Kim and J. S. Lee, KIST Report, June 30 (1995).