강한 입사광에 의한 2차조화파 발생의 준위상정합 조건변화

Disturbed quasi-phase matched second harmonic generation at high input power

유난이, 정창수, 고도경, 이종민 Oleg A. Louchev*, Sunao Kurimura*, and Kenji Kitamura*
레이저분광학연구실 고등광기술연구소 GIST,
* National Institute for Materials Science (NIMS), Japan
neyu@gist.ac.kr

Precise temperature control is required in almost all quasi phase matching (QPM) devices due to narrow temperature tolerance (2-3 °C on 10-15 mm long sample) during second harmonic generation (SHG) for green light. Thus a thermal load in QPM device become very important issue specially in compact configuration with high power pumping to maintain both high-beam quality and no efficiency roll-off. In this work, we investigated a disturbed and shifted QPM temperature curves in a PPMgSLT because of non-uniform temperature distribution along the crystal length during the frequency doubling at the high input power. To understand the non-uniform thermal distribution along the propagation and across direction of the light a coupled thermo-optical model was applied and clarified a strong thermal dephasing of SHG.

To measure temperature dependence of second harmonic (SH) intensity for various depending on input power a Nd:YAG laser at a repetition rate of 10 kHz with a pulse duration of 37 ns was operated. Using a lens the pump beam was focused to 90 um in radius at the beam waist. For better heat exchange between device and temperature controlled metal oven (accuracy ± 0.1°C) a compact square shape of sample holder was used so only input/output surfaces of laser light was opened and other surfaces were surrounded with metal holder.

Fig.1. shows QPM temperature curves at several input powers. In the (a) almost perfect *"sinc"* function was monitored at low power in temperature curve with the bandwidth of 3.2 °C which agrees well with the theoretical values of 3.26 °C but at the input power of 3 W (32 MW/cm^2) the curve is strong distorted. To enhance a thermal contact between the device and holder, we pasted thermal grease and measured again the temperature curves. Due to the better heat exchange the curves are recovered until input power level of 3W with SH out output of 1 W [Fig. (b)], however over than that the curves are distorted and the QPM temperatures are shifted to lower temperature (2-3 °C) then started fluctuation of SH power at each QPM temperature. Such temperature shift and disturbed phase matching condition are very harmful to practical application. To analysis the phenomena we employed a three-dimensional heat transfer model which contains an optical loss by linear absorptions at fundamental (α_1=0.002/cm) and SH harmonic (α_2=0.025/cm) waves and nonlinear two-photon absorption (β=2x10-11 m/W). For a pulse laser the quasi-state averaged heat source distribution is, $q(x, t) = \nu \int \alpha_1 I_1 + \alpha_2 I_2 + \beta I_2)^2 dt$, where ν is the laser frequency [1]. Fig. 2(a) shows temperature distribution along the crystal length. The used beam radius and laser parameters are

the same as experiment. In computation a QPM temperature of 30 °C was selected. At the input power of 10 W (100 MW/cm^2) temperature increased about 2 °C [Fig. 2(b)] with the non-uniform distribution. We also observed the non-uniform temperature distributions in the across beam direction of the laser beam. It can explain that the disturbed temperature curves in our experiment at higher input power. As a consistent report with our work, the QPM temperature was shifted about 0.3 °C in the Ref. 2 at the input peak intensity of 10 MW/cm^2 for an SH power of 7.05 W. Also in our previous work, we shifted the QPM temperature by 0.5 °C at an input peak intensity of 26 MW/cm^2 with 4.4 W SH power [3]. Fig. 2(c) shows initial (open)and final stabilized (closed squares) temperature inside a 10 mm-long QPM device as a function of laser frequency at fixed input power of 10W. According to our model and experimental results such QPM temperature shift strongly depends on not theaveraged power but peak power intensity. A uniform cooling of the device couldn't cancel the inhomogeneous thermal distribution that is additionally bringing the output power fluctuation. So an appropriate temperature gradient, heat conductance of the sample and holder and optimized device length that are important parameters for efficient high power generation depending on input peak intensity. In terms of thermal conductance of QPM device MgO-doped SLT crystal is a good candidate compare with $LiNbO_3$ or KTP crystal because of two times higher heat conductance [8.5 W/mK].

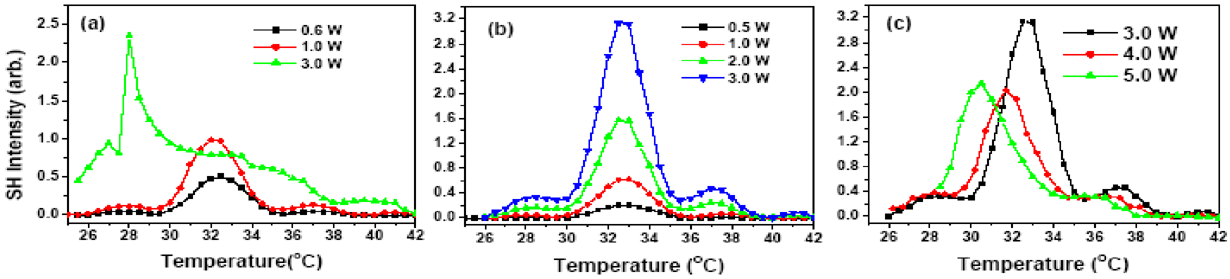

Fig.1. QPM temperature curves at several input powers with compact sample holder (a), and additionally varnished thermal grease (b) and (c).

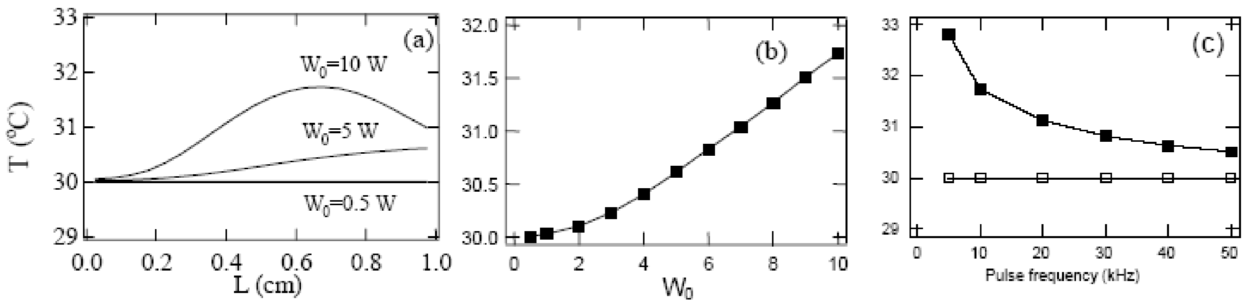

Fig.2. Temperature distribution along crystal length (a), depending on input power (b) and as a function of repetition rate of pump laser (c)

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