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Photo-thermal Effects in High-Power QPM Wavelength Conversion

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1. Introduction

Thermally induced index change limits the high power operation of nonlinear wavelength converters. Thermal dephasing, longitudinal, reduces the efficiency and thermal lensing, radial, also deteriorates beam quality with instability. We demonstrated CW 19 W single-pass green SHG using a periodically poled Mg-doped stoichiometric lithium tantalate (PPMgSLT) module with a high heat-removal performance by reducing heat flow pass as short as 0.15 mm to metal [1]. In this work, we further examined the performance depending on focusing condition. The enhancement is demonstrated by choosing an appropriate focusing parameter, and thermal lensing in the module is investigated.

2. Heat capacity on focusing parameter

First, we examine the dependence of temperature increase in devices on the focusing parameter, ξ (=L/b). The quantitative analysis with effective heat capacity $C\alpha$ was proposed in [1]. The heat capacity is measured by fitting with shifted temperatures for different optimum SH powers. Because ΔT is relatively smaller than temperature acceptance bandwidth, we can determine one unique temperature for different SH powers, which was confirmed with the quadratic dependence of output power to the input power without any saturation. Higher $C\alpha$ represents higher heat disposal performance from devices. The $C\alpha$ increases in loosely focusing side although the normalized efficiency decreases, as shown in Fig. 1. The clarified functions allow us to choose the appropriate focusing parameter for required power and efficiency.

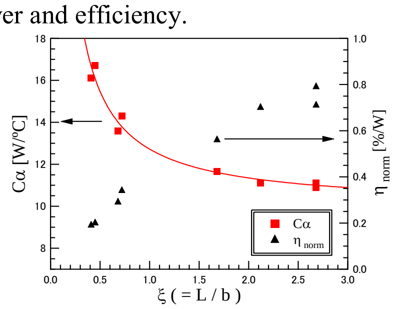

Fig. 1. Effective heat capacity, $C\alpha$ and normalized conversion efficiency, η_{norm} vs. focusing parameter, ξ.

3. Thermal lensing on focusing condition

Thermal lensing effect can be deduced by observing the size of fundamental (F) and SH beams at a screen. In experiment, we used a F beam with a waist of 30 μm in a PPMgSLT crystal. We statistically measured F and SH beam size with over 200 captured images at the same screen using a pick-up grating and CCD camera. The left of Fig. 2 plots the measured F and SH beam sizes for center focusing in length. F beam size for negligible SH power (< 4 mW) is increased as increasing F power, because the thermal lens in the front part more focuses the initial beam and makes a smaller beam waist, which result in the beam size increase at the screen. Owing to the thermal lensing by SH (green symbols), the F beam size is first decreased, and then increased by growing SH power, where the normalized conversion efficiency was 0.2%/W. This behavior can be explained by the positional change of the starting point of the SH thermal lens, which moves from rear part to the front part as growing SH power. In the case of rear focusing, the thermal lens goes through the focal plane at lower SH power, and the beam waist becomes smaller and moves to the input side. As increasing SH power, this phenomenon is accelerated and can result in the damage of crystals. Front focusing can delay the effect up to the higher SH power, which is shown in the right of Fig. 2. The thermal lensing effect can be managed in part by controlling the focusing conditions such as focusing level and position for stable high-power operation.

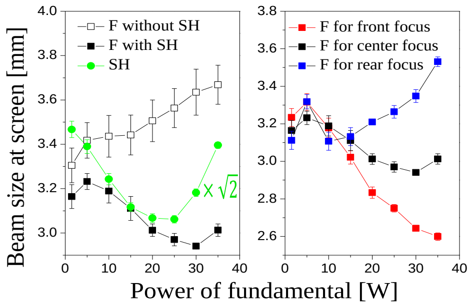

Fig. 2. Left: Beam size vs. F power. Right: F beam size for front, center, and rear focusing.

4. Conclusions

We investigated focusing parameter dependence of the effective heat capacity, showing trade-off relation between the heat capacity and the normalized conversion efficiency. Thermal lensing effect by positional changed SH thermal lens is also investigated. The knowledge will be of help to designing an SHG module and focusing optics.

Acknowledgements

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References

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