Thermal Lens Characterization Method of a Miniaturized Monolithic Side-Pumped DPSS High Power Laser

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Abstract

Compact sized and reliable high-power lasers for rough environment applications are increasingly demanded by industry. Optimizing such devices requires detailed knowledge of the underlying processes of laser beam creation. Thermal lens effects occurring during cavity pumping have main influence on laser forming and beam parameters. To monitor the thermal lens impact during pump light absorption in a miniaturized, monolithic and side pumped laser cavity, we developed a Hartmann-Shack based wavefront measurement method for even very small thermal lenses (radius > 10 m). These measurements improve the monolithic laser cavity development enabling designs with higher energy densities and better energy conversion.

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1. Introduction

Compact sized and reliable high-power lasers for rough environment applications are increasingly demanded by industry. CTR’s HiPoLas® DPSS laser (Fig. 1) combines the advantages of high energies per pulse (>40 mJ) and long lasting operation in a compact, temperature and vibration resistant housing [1]. Achieving and forming the according high energy densities requires in depth understanding of the processes occurring during pumping in the laser cavity especially in such a miniaturized layout. A Hartmann-Shack based thermal lens measurement based setup for miniaturized monolithic side-pumped laser now enables determining static and temporary occurring thermal lens in high energy laser rods.

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2. Experimental setup

A monolithic Nd:YAG/Cr:YAG laser rod (Fig. 2b) with high-power coatings on its highly parallel end faces is the key component of the setup. The coated end faces act also as resonator mirrors and thus the laser cavity is solely formed by the monolithic crystal [2]. The necessary optical pump energy for laser beam creation is delivered by high power laser diodes situated in the pump chamber around the laser rod. To measure even very small thermal lens effects (lens radius > 10 μm) on the cavity, an additional intensity-stabilized and widened 632.8 nm HeNe analysis laser beam with nearly flat wavefront is coaxially coupled through the laser crystal (Fig. 2a). The wavefront of the transmitted radiation is detected with a Hartmann Shack wavefront sensor [3].
In lasing operation the end mirrors have high and partially reflective high power coatings causing intensity modulation of the analysis beam [4]. This modulation causes higher wavefront changes than the thermal lens itself. Thus, the laser rod was replaced with an anti-reflective coated one instead (Fig. 2b) avoiding intensity modulation. Furthermore, an only Nd:YAG doped crystal was used for economic reasons.

3. Results

The absorbed pump light is converted into spontaneous emitted light and furthermore or directly into heat in non-lasing regime. The laser rod side face is surrounded by a cooling liquid held at constant temperature. Thus, primarily a radial temperature gradient occurs, causing a thermal lens, which can be determined by the wavefront distortions of the analysis beam. Fig. 3a shows the shape of the wavefront during 250 μs long pulsing at different points of time. The defocus term (3rd Zernike polynom) from the Zernike-polynoms calculation is extracted. Fig. 3b shows the resulting focal length with a maximum of 9.5 m.

Fig. 3: (a) Measured wavefronts of dynamically occurring thermal lens at several points of time. (b) Focal length calculated from the above presented measurements using the third Zernike-Polynom (Defocus) for a 250 μs long pump pulse.
Apart from this dynamic thermal lens occurring at every pulse we also recognized a stationary thermal lens depending on lasing frequency. Again, the pulse length was set to 250 μs. Fig. 4 shows the focal lengths of the stationary thermal lenses ranging from 4.5 to 0.5 m for 1 to 30 Hz. According LasCad simulations with the according absorption profile [5] correspond nicely with those results.

![Fig. 4: Stationary thermal lens at different frequencies (duty cycles) measured in non-lasing regime.](image)

4. Conclusions

The presented high resolution wavefront measurement method makes the detection of small wavefront changes inside monolithic laser cavities possible. The results give important insight into formation of temporally occurring thermal lenses in miniaturized monolithic laser rods. Furthermore, the results will be exploited to optimize the laser chamber gaining higher energy densities and better energy conversation.

References