COMPENSATION OF THERMALLY INDUCED BIREFRINGENCE AND
PHASE DISTORTIONS IN [100]-CUT Nd:YAG CRYSTALS

I. A. Gorbunov, A. K. Kotov, O. V. Kulagin,
Institute of Applied Physics, Nizhny Novgorod, Russia

Thermally induced birefringence in laser crystals limits the power and beam quality of high-power solid-state lasers and amplifiers. It is known, that 100-cut Nd:YAG crystals have less thermally induced depolarization that 111-cut ones [1]. Using a scheme with two rods, imaging telescope and a 90° rotator [2] allows to compensate for the depolarization. In contrast to 111-cut rod, pump heating of 100-cut rod causes a non circularly-symmetric refraction index change that leads to complex phase distortions in a laser beam [3]. We studied a possibility of depolarization compensation in 100-cut Nd:YAG rods using a scheme mentioned above.

A model of laser beam propagation considering azimuthal refraction induced in 100-cut rods was developed. The trajectory and optical path of rays for each of independent polarization modes was calculated by using a solution of eikonal equation. The amplitude and phase profiles for each mode were obtained at the output plane and then summed. The input beam polarization was linear and the input beam intensity profile was flat or Gaussian. The pump distribution assumed uniform in a rod. The result of depolarization calculation in a single Nd:YAG rod showed excellent agreement with the solution obtained by Shoji and Taira [4] for 100-cut rods, where the beam path assumed straight along the rod. In a scheme with two identical rods, imaging telescope and a 90° rotator [2] the depolarization was calculated for a range of heating powers up to 1000 W per rod. Within this range the depolarized fraction of output power didn't exceed 0.05% for 1320 nm wavelength probe beam, which was close to an actual accuracy of our simulation. This result was obtained for arbitrary input linear polarization orientation relatively to crystal axes.

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However, the quality of compensation was found to be sensitive to Nd:YAG crystal axes alignment with respect to each other. That result was obtained in the simulation and in an analytical estimation, that assumed the beam path straight in each rod. Calculation of the depolarization of a probe flat beam of 1320 nm wavelength radiation with linear polarization oriented at 45° to crystal axes, with 200 W absorbed power per rod is shown on Fig. 1. In the experiment we used two identical flashlamp-pumped amplifiers with 100-cut or 111-cut Nd:YAG crystals of 135 mm length and 8 mm diameter. The probe Gaussian beam diameter was 6.5 mm by 1/e² at 1320 nm wavelength. The measured depolarization dependence on the total electrical pump power for both rods in the scheme for 100-cut and 111-cut crystals is shown in Fig. 2. There 7 kW of total electrical power approximately corresponds to 200 W of absorbed power per rod. The depolarization level with 100-cut crystals was higher than with 111-cut ones. Following our theory this difference could be explained by misalignment between 100-cut rods axes. This misalignment was caused by the limited accuracy of axes orientation provided by the rods’ manufacturer. Also as it’s following from our calculation, the total thermal lens from both rods has substantial circularly non-symmetrical aberrations. That excludes a possibility of complete thermal lens compensation by spherical lenses.

References: