 https://doi.org/10.1051/epjconf/202226701012

Thermo-optical wavefront distortions in Nd:YVO_4 laser amplifiers

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Abstract: The power dependence of a Nd:YVO_4 laser amplifier beam wavefront was analyzed by Zernike polynomial decomposition. This analysis was performed experimentally and by simulations based on split-step Fourier propagation showing a good agreement. The simulations yield a base for the design of an aberration compensation system.

Nd:YVO_4 laser crystals are promising laser technology for future gravitational wave detectors (GWDs) [1] because of several reasons. Nd:YVO_4 features anisotropic emission cross-sections and inherent birefringence enabling stable output polarization and suppressing thermally induced depolarization. Furthermore, Nd:YVO_4 features a low saturation intensity. A major obstacle for the application of Nd:YVO_4 laser crystals, however, is vanadate's lower thermal conductivity and its higher brittleness compared to YAG [2]. Thus, detrimental thermal effects through thermo-optical coupling and the associated stress can exacerbate the power scaling process of Nd:YVO_4 laser crystals.
In this work, we established a numerical simulation tool to predict beam parameters of Nd:YVO_4 amplifiers including power slope, efficiency and the magnitude of thermal wavefront degradations to design a suitable aberration compensation system. The simulation tool is based on iterative computation of the complex field propagation via a split-step Fourier beam propagation model and a finite-difference thermal equation solver. The resulting wavefront was analysed by Zernike polynomial decomposition. The simulation input parameters are matched to an experimental amplifier with an a-cut Nd:YVO_4 crystal (3 mm x 3 mm x 12 mm, 0.15 at.%) which was seeded with 1.6 W single-frequency light at 1064 nm wavelength.

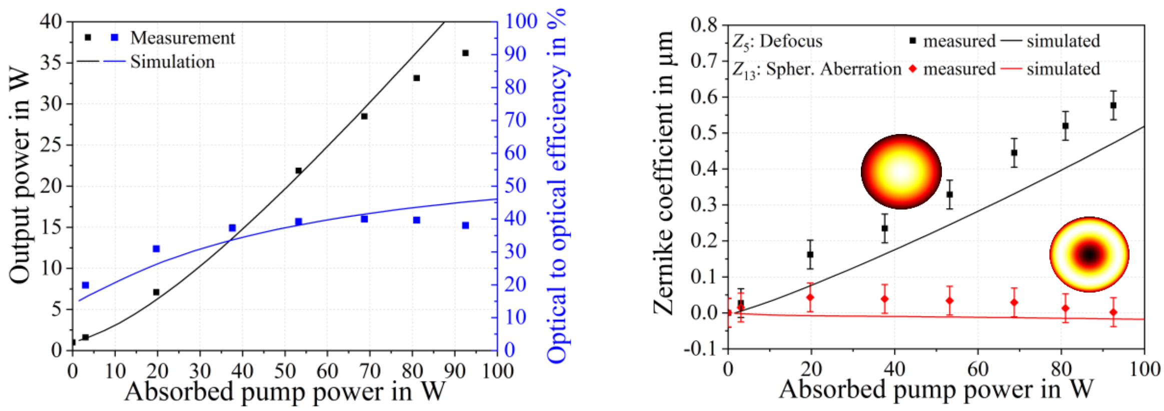

Fig. 1, left: power slope and optical-to-optical efficiency, right: symmetrical Zernike coefficients versus absorbed pump power

The simulated and measured output powers and efficiencies shown in Fig. 1, left are in good agreement. We obtained output powers up to more than 30 W (69 W absorbed pump power) in a single pass with around 45 % efficiency. The first symmetrical Zernike coefficients are depicted in Fig. 1, right; the corresponding Zernike polynomials are shown as the inset. The experimental and simulated values of Z_5, i.e. defocus, are in excellent agreement fortifying the validity of the simulated results. Furthermore, the next symmetrical term Z_{13}, i.e. spherical aberration, is close to zero in both experiment and simulation.

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