Full Vectorial Finite Element Beam Propagation Method for Simulation of Depolarization in Laser Amplifiers

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We developed a complex physical model for simulating laser amplifiers to numerically analyze birefringence effects. This model will be useful in designing and optimizing solid-state, high power, continuous wave laser amplifier. Our analysis includes pump configuration, thermal lensing effects, birefringence, and beam propagation in the laser amplifier. In particular, temperature, deformation, and stress inside the laser crystal were calculated using a three-dimensional finite element analysis (FEA). The pump configuration for the active medium is simulated using a three-dimensional ray tracing. The process of amplification takes into account beam propagation, gain saturation, and depolarization. The thermal input to the active medium induces thermal lensing, deformation, and birefringence. The effects of thermal lensing and deformation on beam propagation can be well approximated using ray transfer matrix approximations. However, including the effects of depolarization requires a more accurate simulation tool. Depolarization is mainly influenced by the anisotropic stress induced change of the refractive index. The beam propagation method (BPM) has also been extended to be applicable to simulate the propagation of light in general anisotropic materials. Our simulations show the depolarization of a linearly polarized electromagnetic wave in a cylindrical laser crystal. These simulations were performed using a three-dimensional full vectorial BPM. The laser crystal uses a block structured finite element discretization for the transverse plane based on quadrangles. The beam is propagated in direction z using the Crank-Nicolson method that is coupled with an explicit stepping for the laser rate equations. Reflections of outgoing waves are omitted by a perfect matching layer. The two-dimensional propagation operator of the BPM requires small mesh sizes in order to accurately model the phase shift of the electromagnetic field. Therefore, we implemented a third order spline interpolation for the refinement of the refractive index that was obtained from the three-dimensional structural analysis.

References:

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