ABSTRACT

Impact of Transverse Mode Instability on the generation parameters of High Average Power Fiber Lasers

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The aim of this doctoral dissertation was to characterize a high-power laser beam for its applications in material damage and beam powering, as well as the numerical and experimental analysis of Transverse Mode Instability (TMI). The research was carried out on a fibre laser with an average output power of 10 kW.

The work includes the development of procedures and measurements of crucial transverse beam parameters of a high average power fibre laser. A review of methods for describing the TMI phenomenon was performed, and a perturbative model was applied to examine the influence of fibre design parameters and amplifier pumping methods on the output power at which this effect occurs on a large scale. In the experimental section related to TMI, threshold power measurements were performed. Because of the lack of a standardized measurement method, this parameter was measured using three different setups and five distinct methods. A universal threshold power definition was proposed, applicable across different measurement techniques. The analysis of the TMI mitigation efficiency was carried out using the pump current modulation method, which was caused by the limited access to the individual modules of the laser system under test. For this purpose, the pump current was modulated with a sinusoidal and rectangular function with different modulation frequencies.

The measurements showed that, the brightness has stopped growing, laser beam area increases and its transverse distribution becomes non-stationary at an average power close to 4 kW. Experimentally determined threshold power values for the TMI phenomenon ranged between 3.5 and 4 kW. The use of pump current modulation reduced the TMI threshold by over 1 kW, while simultaneously weakening the strength of transverse beam profile fluctuations even at higher average powers.

The research results presented in this dissertation may serve as a basis for standardization for the TMI threshold measurement procedures. It seems justified to require the characterization of modern high-power fibre lasers in terms of TMI, especially those intended for specialized applications.

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