Power Scaling of Solid State Lasers

A. Tünnermann

Fraunhofer Institute for Applied Optics and Precision Engineering
Friedrich-Schiller University Jena, Institute of Applied Physics

Solid-state lasers are attractive sources of coherent radiation for various scientific and industrial applications. in the past 60 years different laser geometries have been developed to overcome challenges in power scaling conserving the beam quality. Rare-earth-doped fiber lasers have emerged as most attractive and power scalable solid-state laser concept due to the outstanding thermo-optical properties of an actively doped fiber. The large ratio of surface to active volume of such a fiber ensures excellent heat dissipation, furthermore the beam quality is defined by the refractive index profile of the active core and is therefore independent on the pump power. Fiber lasers and amplifiers offer a very high single-pass gain and therefore low laser thresholds and efficient diode-pumped operation. Using advanced fiber designs, in continuous-wave and pulse operation output powers exceeding the 10 kW-level with diffraction-limited beam quality have been demonstrated.

However, power and energy scaling of cw and pulsed single-mode fiber lasers and amplifiers is restricted due to nonlinear pulse distortions, which are enforced by the large product of intensity and interaction length inside the fiber core. In addition, transverse mode instabilities are observed which degrade the beam quality emitted by high-power fiber laser systems once that a certain average power threshold has been reached. This sudden degradation of the output beam quality is accompanied by temporal fluctuations of the beam profile. Most recently, strategies have been developed to mitigate or even, ideally, to overcome these limitations. Coherent combination of different fiber amplifier channels enables a further scaling of these parameters.

This contribution presents the physical and technical basics of solid-state lasers and their power scalability. The state of the art of science and technology and prospects for future developments in fiber lasers and amplifiers are reviewed.