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Extended Abstract

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Problems of high-power laser radiation measurement

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Conventional approaches to the high-power laser radiation measurement are thermal and photoelectric techniques. These methods require deflection of part of laser radiation power for its energy conversion into heat or electrical current, respectively. However, application of the beam splitters leads to significant distortion of laser beams. This limits the usability of these techniques for continuous measurement during the laser operation in industrial processes. In this study, a novel technique of fiber laser power measurement is presented. We have used a sensor representing a segment of single-mode optical fiber with copper coating. When laser radiation was transmitted through the copper-coated silica fiber sensor, its small part was scattered mainly due to Rayleigh scattering and therefore absorbed by the outer layer. This led to fiber heating and hence to the electrical resistance change of its metal layer, which was measured by milliohm meter. We have experimentally demonstrated fiber laser power measurement by splicing copper-coated fiber sensor to the output fiber of the laser. Dependence between sensor temperature and transmitting optical power was obtained. Total optical power loss was less than 0.03 % of transmitting power. We have demonstrated that this technique can be applied for continuous laser power measurements during the laser industrial operation without using beam splitters and without any significant optical power reduction or beam distortion. This technique can be applied not only for fiber laser power measurement. Using optically transparent silica rods, covered by metal coating will allow direct determination of high-intensity radiation power from any laser source.

The output energies of lasers have increased year-by-year since their invention. Compared to this increase of laser energies, the damage threshold of optical components has not strongly changed. Therefore, the size of optics in high-energy laser system increases. This situation could change dramatically if optics with higher damage threshold were developed. Here, we propose a high damage threshold optics using a neutral gas as an active medium. More than 95% diffraction efficiency has been achieved. The damage threshold for a 6 ns laser pulse is measured to be 1.6 kJ/cm2. The aperture size of the present system is about 60 mm2. Based on this result, we anticipate that control of a 1 kJ laser beam may be achievable using 1 cm sized optics, driven by a < 50 mJ ultraviolet laser, making this scheme promising in high power laser applications. Optical damage is a serious problem not only for energetic giant laser systems but also for high repetition rate lasers. Even well below the nominal optical damage threshold, the damage-risk is not zero. Recently, laser average power has increased significantly and laser pulse repetition rates have grown from 10 Hz to 10 kHz and more. Due to the probabilistic aspect of the optical damage, the actual useful fluence in the high repetition laser is much smaller than the singe-pulse damage limit. Once optical damage occurs in conventional solid optics, the damaged spot does not recover and it is not easy to replace the optics in a large-size optics laser system. High-intensity laser fields can produce unwanted damage to optical materials. As a point of reference, the threshold for laser damage to fused silica at a wavelength of 1.05 micrometers for a pulse of 30 ps duration corresponds to an intensity of 230 GW/cm2 or a fluence of 7 J/cm2. Over a wide range of pulselengths (approximately 1 ps to 1 μs), the threshold intensity for laser damage decreases with pulse length T as and correspondingly the threshold fluence for laser damage increases with pulse length In this range of pulse durations, the dominant mechanism of laser damage is avalanche breakdown. In this process, free electrons are accelerated by the laser field until they acquire sufficient energy to impact-ionize other atoms in the sample. These additional electrons are similarly accelerated and create still more free electrons. The combined action of the breaking of chemical bonds and the deposition of heat energy leads to the fracturing of the optical material. For pulses shorter than 1 ps, processes such as multiphoton absorption and multiphoton dissociation contribute to the mechanism of optical damage. For laser pulses longer than approximately 1 μs (including continuous wave laser beams), the dominant damage mechanism is direct heating of the optical material by linear absorption.

Bottom Note: *This work is partly presented at 5th International Conference on Theoretical and Applied Physics*