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2 kW single-mode fiber laser employing bidirectional-pump scheme

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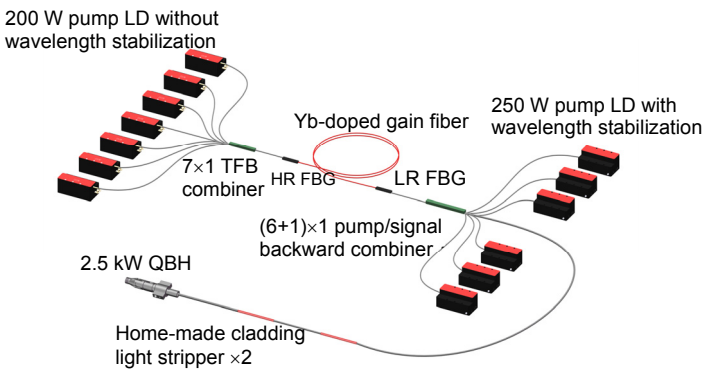

Setup of bidirectional-976 nm pumped all-fiber 2 kW laser.

Abstract: A high power single-mode fiber laser is an attractive laser source which has various application fields such as materials processing and long-distance laser energy transmission. In the last decades, the output powers of monolithic fiber lasers have increased remarkably. However, the power scaling of the single-mode fiber lasers is limited by the traditional fiber nonlinear effects and transverse mode instability (TMI). Among fiber nonlinear effects, the stimulated Raman scattering (SRS) is the main limiting factor for continuous-wave fiber lasers. SRS results in the output power instability of the fiber laser. Backward SRS is also damagingly raised by the reflected light from the optics or the work piece in a practical laser system. Therefore, a laser with high SRS suppression is desired for stable operation of a laser system. Besides, photodarkening is also found in Yb-doped high power fiber laser, which can cause the decrease of output power, long term stability and operation life of the fiber laser. Koponen has observed a seventh-order dependence of the PD rate on the excited-state Yb concentration for two different fibers. This result implies that PD of an Yb-doped fiber source fabricated using a particular fiber will be strongly dependent on the Yb inversion rate and lower inversion rate can be obtained by using 976 nm pump light as compared to 915 nm. A single-mode fiber laser employing bidirectional-976 nm pump scheme and high SRS suppression and high power stability are demonstrated without any TMI. We investigate the signal power vs. pump power (S-P) performances, beam distribution and quality, output spectrum and output power temporal characteristic of the fiber laser oscillator with bidirectional-pumping configuration. The forward-pumping is firstly utilized and then bidirectional-pumping is utilized to further scale the output laser. Besides, the performance of the homemade CLS used in the 2 kW system is described. By employing bidirectional-pumping, the TMI is remarkably mitigated and when the output power is further scaled to 2 kW with a slope efficiency of 76.6%, the Raman stokes light is ~47 dB below the signal power even with a 10-m delivery fiber with core/inner cladding diameter of 20 μm/400 μm. Nearly diffraction-limited beam quality is also confirmed with the measured M^2 below 1.2 and no residual pump and cladding light are observed. Beside, remarkable power stability is also demonstrated because of more uniform temperature distribution on Yb-doped gain fiber by a special thermal management. From the experimental results and theoretical evaluation, an output power of 3 kW is believed to be achieved by further increasing pump power.

Keywords: fiber laser; high power; stimulated Raman scattering; power stability

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