Compact 1.5-GHz Intra-burst Repetition Rate Yb-doped All-PM-Fiber Laser System for Ablation-cooled Material Removal

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Femtosecond (fs) laser pulse sources have become increasingly popular in the last decade as a result of their practical features, such as insensitivity to environmental variations, versatile designs, high power outputs. However, much of the progress is with non-integrated specialty fibers, which involve some compromise on these practical features. Monolithic fiber chirped pulse amplification (CPA) systems are very attractive for industrial and scientific applications due to the features such as compactness, reliability and robustness. Although fs fiber laser systems are powerful technologies for material and tissue processing, limited ablation rates and high energy are drawbacks. Recently, we identified a new regime of laser –material interaction, ablation cooled material removal [1], where the repetition rate has to be high enough so that the targeted spot size cannot cool down substantially by heat conduction which scales down ablation threshold by several orders of magnitude and reduces thermal effects to the bulk of the target. Here, we demonstrate a compact all-PM-fiber laser amplifier system with an intra-burst repetition rate of 1.5 GHz able to produce bursts ranging from 20-ns to 65-ns duration with 20 µJ to 80 µJ total energy, respectively, and pulses with up to 1 µJ individual energy at burst repetition rates ranging from 25 kHz to 200 kHz (Fig. 1(a)). The seed signal is generated by a home-built all-normal dispersion oscillator with a spectrum centered at 1035 nm and 20-nm (FWHM), 100 mW output and 385 MHz repetition rate (Fig. 1(b)). After the oscillator, rest of the system is built of polarization maintaining (PM) components and a single-mode pre-amplifier controls both dispersion and nonlinearity in the amplifier system. The pulses are stretched with a 110 m-long fiber after this pre-amplifier and raised to a repetition rate of 1.5 GHz by a multiplier. The signal is amplified again by a second single-mode pre-amplifier before converted into burst-mode via an acousto-optic modulator (AOM). Finally, a forward-pumped double-clad power amplifier, built of PM 10/125 Yb 1200 DC (nLight) fiber and pumped by a 18-W wavelength stabilized diode, boosts the optical power. To compress the pulses, a pair of 1200 line/mm transmission gratings is preferred to denser gratings to limit third order dispersion (TOD). Further, fiber lengths are shortened as much as possible to minimize nonlinear effects including Raman scattering and thus the power conversion efficiency is relatively low, around 20% for the power amplifier. The autocorrelation measurement for the compressed pulses indicates a width of ~250 fs (Fig. 1(d)). The amplified output spectrum of FWHM of 14 nm is shown in (Fig. 1(c)).

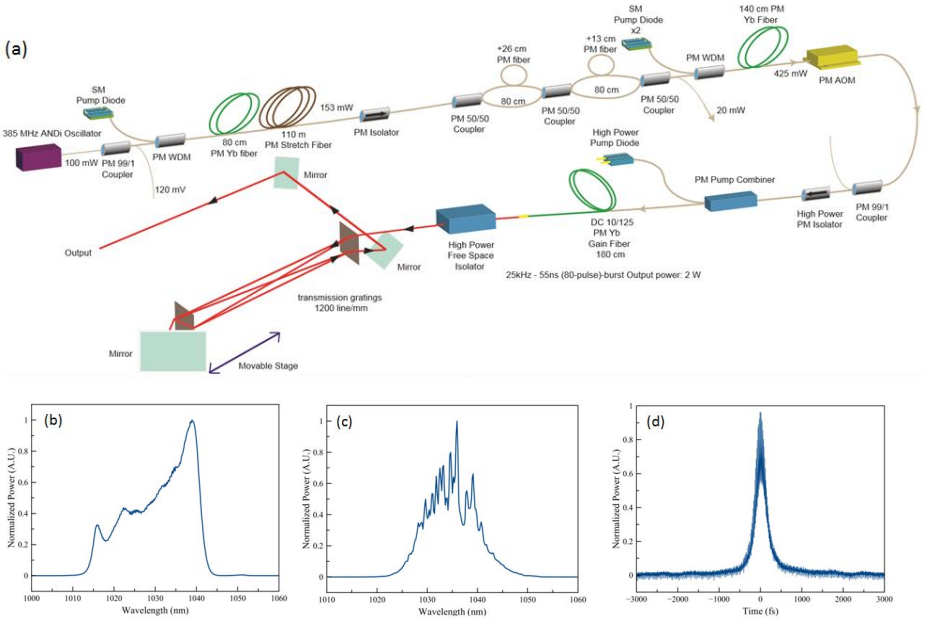

Fig. 1 (a) 1.5-GHz intra-burst repetition rate Yb-doped all-PM-fiber laser system setup. (b) The oscillator spectrum. Compressor output (c) spectrum and (d) pulse duration for 1µJ individual pulse energy, 80-pulse bursts at 25 kHz.

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