1.2MW-peak-power sub-picosecond optical pulse source based on a gain-switched laser diode

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INTRODUCTION Development of a compact high-peak-power ultrashort optical pulse source is in demand toward wide applications in multi-photon fluorescent microscopy and high-precision material processing. We have generated over 10kW-peak-power picosecond pulses from a light source composed of a gain-switched laser diode (GSLD) and multistage optical fiber amplifiers (OFAs) for two-photon microscopy applications.[1] In a simple mind, we expect to increase further the optical pulse peak-power by reducing the GSLD's repetition rate under saturation amplification condition of the main OFA. However, due to the low optical average power obtaining from a GSLD at low repetition rate, the amplified spontaneous emission (ASE) noise takes place a large ratio in the optical power after a chain of OFAs, and this reduces the optical pulse peak power significantly. We report that the ASE noise can be reduced by employing self-phase-modulation (SPM) in a passive fiber.[2] In contrast, we demonstrate that a simplified noise reduction scheme is also accomplished by employing SPM in an OFA. Combining with nonlinear pulse compression after the main OFA, our present method has enabled to increase the optical-pulse peak power to over 1 MW.

EXPERIMENTAL 1060nm-band optical pulses were generated from a gain-switched distributed-feedback laser diode (DFB-LD) at 1MHz repetition rate. The pulses were amplified by the first stage ytterbium-doped fiber amplifier (YDFA1) and then spectrally filtered by an optical bandpass filter (BPF1) to remove the ASE noise out of signal bandwidth. We amplified these pulses by the second stage YDFA (YDFA2) in which a spectral broadening occurred due to SPM. We used another BPF (BPF2) to extract the short wavelength components that were out of the bandwidth of BPF1, and this results in the pulse width reduction.[3] Intensity autocorrelation traces (IATs) for optical pulses evolved in the amplifier chain are shown in Fig. 1. The dot line represents the IAT for optical pulses after BPF1, having a temporal duration of 9 ps and an average optical power of 36 μW; the ASE noise ratio in this pulse train was evaluated to be about 30%, based on the oscilloscope pulse waveform measurement.[2] The dash line represents the IAT for optical pulses after BPF2, having a temporal duration of 2.9 ps and an average optical power of 2 mW. In this case, the ASE noise ratio in the pulse train was reduced to 8% due to the removal of YDFA1 ASE noise accumulation by BPF2. Although YDFA2 provided additional ASE noise also for the SPM-broadened optical pulses in this bandwidth range, the ASE noise accumulated in the amplifiers chain was mainly originated in the ASE noise of YDFA1, and further amplified by YDFA2. After the third stage YDFA (large-mode-area one), the average optical power was increased to 1.6 W, and the in-band ASE noise ratio was slightly increased to 11% level. Thereafter, with a grating-pair pulse compressor, we have compressed optical pulses to 0.6 ps duration (the IAT is also shown line in Fig. 1). The average optical power was 0.8 W after the compression, and thus the peak-power reached 1.2 MW.

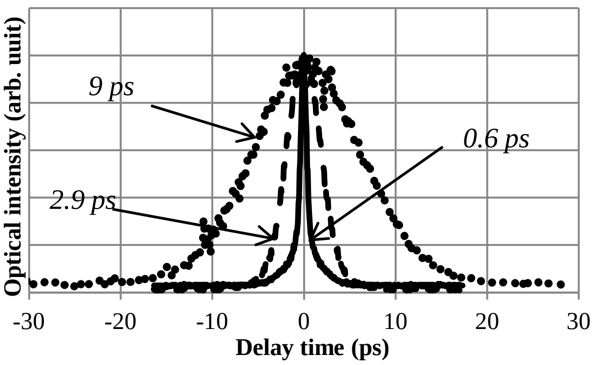

Fig. 1. IATs for optical pulses evolved in the amplifier chain; dot line: optical pulses after BPF1, dash line: optical pulses after BPF2, solid line: optical pulses after the final stage YDFA and the grating pair compressor. All the pulse widths are estimated based on $sech^2$ pulse shape fitting.

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