Versatile GHz Burst-Mode Operation in High-Power Femtosecond Laser

Tadas Bartulevičius[1], Mykolas Lipnickas[1], Karolis Madeikis[1], Raimundas Burokas[1,2] and Andrejus Michailovas[1,2]

1. *Ekspla uab, Savanoriu ave. 237, LT-02300 Vilnius, Lithuania*
2. *Center for Physical Sciences and Technology, Savanoriu ave. 231, LT-02300, Vilnius, Lithuania*

Ultrashort pulse lasers are highly applicable in science, medicine, and industry. The recent development of new techniques which use gigahertz (GHz) bursts of ultrashort pulses attracted a lot of attention by demonstrating the superior performance of laser systems and the advantages in their applications [1]. Common methods for producing GHz bursts of pulses may be implemented in commercial lasers, however, only a few of them can provide significant improvements with a unique set of features and parameters. GHz burst formation by pulse repetition rate (PRR) multiplication techniques based on splitting and delaying ultrafast radiation from the MHz master oscillator are a convenient solution successfully demonstrated experimentally. Moreover, these techniques are of a high potential to be easily implemented in the all-in-fiber design, to provide compact, stable, and robust ultrafast lasers for the science and industry.

A new versatile patent-pending method to generate ultra-high (>2 GHz) repetition rate bursts of ultrashort laser pulses, overcoming many limitations encountered by other fiber-based techniques, is introduced in this work [2]. The developed method was based on the use of an all-in-fiber active fiber loop (Fig. 1 (left)) which contains the main parts responsible for burst formation (acousto-optic modulator (AOM)), pulse amplification (ytterbium-doped fiber (YDF) pump by a laser diode (LD)), and dispersion compensation (chirped fiber Bragg grating (CFBG)). The active fiber loop can form bursts of laser pulses with any desired PRR which does not depend on the initial PRR of a fiber oscillator. Moreover, the bursts of ultrashort laser pulses containing any number of pulses in a burst (from 2 pulses to thousands of pulses inside the burst) with identical intra-burst pulse separation were demonstrated (Fig. 1 (right)). Long bursts even up to a 1 µs width were formed using this method along with a temporal modulation of the initial pulse train. The amplitude of pulses within a burst was controlled by amplification conditions in the YDF amplifier providing a constant, decaying, or rising amplitude of the pulses within a burst as long as it was not limited by the effect of the gain saturation. The burst shape can be additionally modified using an AOM controlled by an arbitrary waveform generator outside the active fiber loop. The dispersion compensation mechanism using the CFBG element was successfully implemented in the active fiber loop which allowed to obtain ultrashort pulse durations within the GHz bursts.

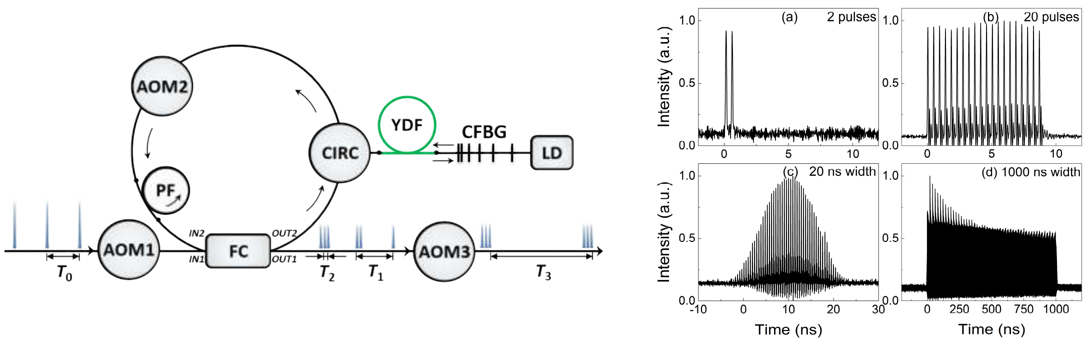

Fig. 1 Left: Schematic representation of an active fiber loop. Time delays: T_0 – between single input pulses, T_1 – between a delayed replica of an input pulse and an undelayed replica of the pulse, T_2 – intra-burst pulse separation of the formed bursts, and T_3 – between bursts of pulses. Right: Experimentally measured 2.2 GHz intra-burst PRR bursts containing from 2 (a) to about 2200 (d) ultrashort pulses.

The active fiber loop was installed into the constructed 30 W-level average power ultrashort (sub-1 ps) pulse laser system which operated in single-pulse and GHz-burst (2.2 GHz intra-burst PRR) operation regimes. A detailed description of a new pulse multiplication technique and the demonstration of its versatility in industrial-grade high-power laser will be provided at the conference.

References

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