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Generation of Pulsed Fiber Laser: ns to fs domain

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Recently fiber lasers have become an indispensable tool in scientific endeavors as well as in multifarious industrial applications. While high power continues wave fiber lasers delivering hundreds of watts to killo-watts of average power are being used in manufacturing and strategic sectors for cutting, welding, additive manufacturing and directed energy applications, pulsed fiber lasers operating in the kHz repetition rate and nano-second pulse duration with pulse energies from micro-joule to mille-joule are being used for marking and engraving applications. These pulses are usually obtained from a Q-switched master oscillator power amplifier (MOPA) fiber laser or by amplifying a gain-switched laser diode to suitable pulse energy and power. Apart from this class of pulsed fiber lasers, mode-locked fiber lasers which now a days can deliver a very large variety of pulse duration ranging from femto-seconds to micro-seconds, are used for more precise and novel applications such as marking/ engraving on reflecting/ transmitting materials, nonlinear wavelength conversion, label free nonlinear microscopy, novel pump sources and also for study of various pulse dynamics [1, 2].

A Q-switched fiber MOPA consists of a seed cavity, loss modulated using an acousto-optic modulator to generate Gaussian shaped pulses which are further amplified using large mode area fibers to suitable pulse energy and average power. Temporal profile of an indigenous designed Q-switched pulsed MOPA at 20 W average power and 0.5 mJ pulse energy has been shown in figure 1(a). Like q-switching, mode-locking of a fiber laser can be achieved by either active loss modulation or by using a saturable absorber. The most popular method for ultra-fast pulse generation is using a semiconductor saturable absorber mirror (SESAM), either in a ring cavity configuration or using linear cavity configuration with a broadband reflector. By proper dispersion management and operating in conventional soliton or dissipative soliton regime, pico-second to femto-second pulses with different pulse energy have been reported from SESAM based mode-locked fiber lasers. Auto-correlation trace of a sub-picosecond duration dispersion managed dissipative soliton mode-locked pulse directly from a SESAM based Yb-fiber laser cavity having nJ pulse energy has been shown in figure 1(b). Mode-locked fiber lasers without physical saturable absorbers uses nonlinear polarization rotation (NPR) or nonlinear loop mirror (NLM) method which exhibits transfer functions depicting saturable absorption effect. Recently cavities based on these saturable absorbers are being heavily cultivated to observe novel pulse dynamics such as dissipative soliton resonance (DSR) and noise like pulse (NLP) which generate mode-locked pulses of wide features in terms of both temporal and spectral properties. In figure 1(c) a rectangular shaped dissipative soliton resonance mode-locked pulse of nano-second duration has been shown. Figure 1(d) and 1(e) shows a noise like pulse and corresponding auto-correlation trace showing a femto-second coherence peak. Both of these pulses have been obtained using NALM based mode-locked cavity with suitable design.

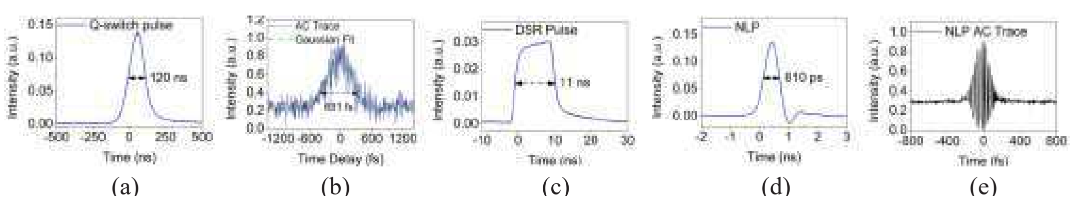

Figure:1. (a) Q-switch Pulse, (b) SESAM mode-locked femto-second pulse, (c) DSR pulse, (d) NLP, (e) NLP AC trace

1. David M. E. Fermann and I. Hartl, “Ultrafast fibre lasers,” Nat. Photonics, 7, 868–874, (2013).

2. Sourav Das Chowdhury, Atasi Pal, Sayan Chatterjee, Ranjan Sen, and Mrinmay Pal, "Diverse mode of operation of an all-normal-dispersion mode-locked fiber laser employing two nonlinear loop mirrors," Appl. Opt. 57, 1225-1230 (2018).