Multiple noise-like pulsing of a figure-eight fiber laser

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Passively mode-locked fiber lasers are attractive low-cost sources of ultrashort pulses that have been extensively investigated in the past. Recently, as high-power pump diodes have become readily available, there has been a renewed interest in these fiber lasers for the generation of high-energy pulses, which are useful for applications like supercontinuum generation, sensing etc. Unfortunately, it was soon realized that the highest achievable pulse energy is limited by the onset of multiple pulsing. In the anomalous dispersion regime, the peak power limiting effect of the saturable absorber was found to be responsible for multiple soliton formation [1]. In the normal dispersion regime, although highly chirped pulses with durations of several tens of ps allow for much higher pulse energies, multiple pulsing still occurs [2].

Another category of pulses, the so-called noise-like pulses, were observed in both anomalous and normal dispersion regimes and are attracting a growing interest due to their high energy and wide spectrum, sometimes extending beyond 100 nm [3]. Noise-like pulses are ~ns collections of thousands of ultrashort (sub-ps) pulses with random amplitudes that are packed together. Although there is no consensus on the physical mechanisms involved in their formation, peak power clamping by the saturable absorber has been invoked [4]. Typically one noise-like pulse develops in the cavity, an increase in pump power translating into a seemingly unlimited increase in the number of sub-pulses, and thus of the energy of the bunch [5]. However a few cases of dual noise-like pulsing in passively mode-locked fiber lasers were reported [6,7].

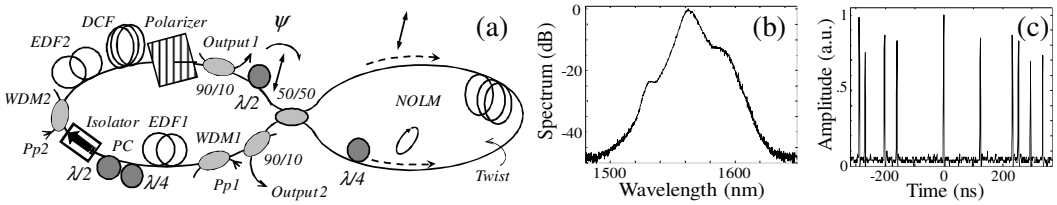

Fig. 1 (a) Figure-8 laser scheme; (b) optical spectrum and (c) scope trace of 10 noise-like pulses in one 1.6-μs round-trip. Pump powers at 980 nm Pp1 = 300 mW and Pp2 = 200 mW. DCF: dispersion-compensating fiber (D = -40 ps/nm/km, length = 200m).

In this work we report what we believe is the first experimental demonstration of multiple (>2) noise-like pulsing in a long (320 m) figure-eight laser with normal net dispersion [Fig. 1(a)] and show that this operation is related to the power limiting effect of the Nonlinear Optical Loop Mirror (NOLM) acting as saturable absorber. The NOLM consists of a 100-m piece of standard fiber, a 50/50 coupler and a quarter-wave retarder. It operates through nonlinear polarization rotation [8]. The important point is that adjusting the angle ψ of linear input polarization offers a way to control the NOLM switching power from a minimal value (~120 W) to infinity. For high switching power settings, a single ~5-ns pulse builds up in the cavity. Its noise-like nature is evidenced by a double-scaled autocorrelation trace (a sub-ps peak riding a wide pedestal) and a wide, smooth optical spectrum [Fig. 1(b)]. As the NOLM switching power is decreased, the pulse peak power diminishes and its duration increases beyond 15 ns, until it eventually breaks up into multiple ~2-ns pulses. Up to ~10 coexisting noise-like pulses are observed in the cavity [Fig. 1(c)]. This shows that overdriving of the mode locking mechanism sets a limit to single high-energy pulse generation in such lasers.

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