Adiabatic soliton laser

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Classical optical soliton theory is successfully exploited in lasers, governing generation of mode-locked transform-limited pulses with well-defined characteristics [1-3]. However, the output pulse characteristics of traditional optical soliton lasers are restricted by the generation of spectral side bands and multiple pulses [4]. After periodic (each round trip) amplification in a short section of active fiber, a soliton adjusts its width dynamically and sheds a part of its energy as dispersive waves, which could accumulate to a significant level and destroy the stable regime of single-pulse generation.

In this work we propose a new concept of laser based on the adiabatic amplification of soliton pulse in the cavity - adiabatic soliton laser. The adiabatic change of the soliton parameters during evolution in the resonator relaxes the restriction on the pulse energy inherent in traditional soliton lasers.

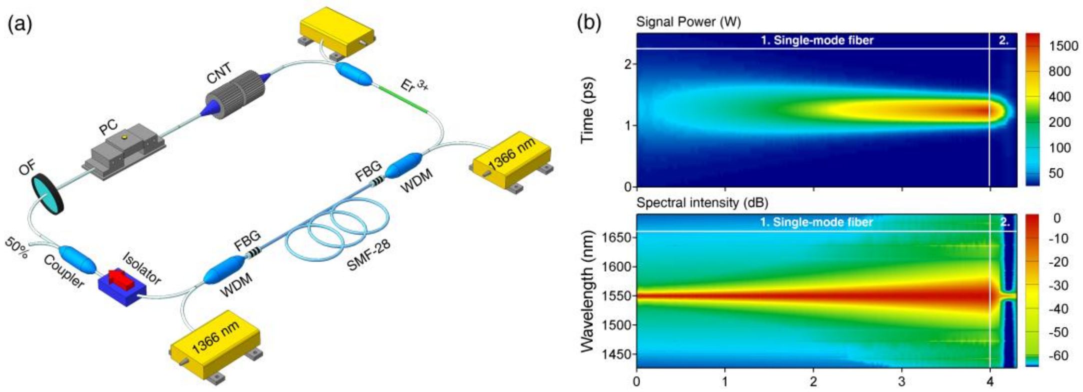

Fig. 1 (a) The experimental setup. (b) Adiabatic soliton temporal compression (upper picture) and simultaneous spectral broadening (bottom) along fiber sections. Shown are long SMF section (marked with "1") and short cavity section providing coupling, filtering, mode-locking and amplification of the optical pulse (marked with "2").

Figure 1a depicts the design of the proposed laser system. The ring laser cavity consists of a single-mode fiber (SMF), a 1.5 m long erbium-doped fiber with normal dispersion, an output coupler with 50% output ratio, an optical filter with ~2 nm spectral width centred at 1550 nm, and a saturable absorber element based on single-wall carbon nanotubes (SWCNTs) that provides stable mode-locking. Adiabatic amplification of soliton is implemented with the second-order Raman amplification scheme that was experimentally demonstrated in the different context of quasi-lossless optical transmission links [5,6]. The new feature in our scheme compared to [5,6] is that this span now produces a small residual gain that, when distributed over such a long span, acts as a distributed adiabatic amplifier. When the net-gain g satisfies the condition $gL_d \ll 1$, the soliton can be amplified adiabatically while maintaining $N \approx 1$, a feature that almost entirely eliminates dispersive waves.

Numerical modelling confirms a feasibility of the proposed concept. We used standard propagation model based on the nonlinear Schrödinger equation [1, 2] to analyze radiation building in resonator depicted in Fig 1a. Steady-state evolution along the fiber sections including 4-km-long SMF is shown in Fig.1b. A 60-W soliton with duration of 1 ps adiabatically compresses in the fiber [1]: its intensity is exponentially increased $P(z)=P_0 exp(2gz)$ to 1.9 kW and duration is decreased $T(z)=T_0 exp(-gz)$ to 190 fs at the point with coordinate z = 4 km. The pulse energy at z = 4 km is almost six times higher than the pulse energy at z = 0 km. We have shown that pulse energy in the adiabatic soliton lasers are higher than in corresponding conventional soliton lasers. The detailed analysis will be presented at the conference.

References

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[*] We acknowledge support of the Russian Science Foundation (Grant No. 14-21-00110).