9:15am-9:30am
WD4

Dynamics of passive modelocking with saturable Bragg reflector (SBR) in fiber lasers

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Compact gigabit sources of optical pulses near 1.5μm are a key enabling technology to high speed optical communication systems and interconnection networks. Er-doped modelocked fiber lasers, currently the subject of much research, provide a potentially attractive short pulse source [1]. Passive modelocking with semiconductor fast saturable absorbers have been successful in many solid state lasers [2]. A recently developed device incorporates an epitaxially grown pair of InGaAs quantum wells and a Bragg reflector structure to produce a saturable Bragg reflector (SBR). This essentially nonlinear mirror has been used to passively modelock Cr^{+4}:YAG and Er-doped fiber lasers near 1.5μm [3,4]. The advantage of SBR over other passive modelocking techniques such as Kerr lens (KLM) or APM is its extremely low saturation energy, enabling efficient femtosecond modelocking of low gain coefficient or short gain length lasers.

In this paper we present theoretical and numerical studies of the modelocked fiber cavity including a description of the pulse formation dynamics and its interaction with the SBR. Passive modelocking in solid state and fiber lasers has been studied and modeled by several groups [1]. The modelocking description equations have approximated the pulse changes per roundtrip as being small and linearized effects such as self phase modulation (SPM). However, in a fiber laser the SPM can be strong per roundtrip, equivalent to several π of nonlinear phase shift, and the linearized approach often fails to describe the correct and complicated pulse spectral evolution. We consider a Fabry-Perot fiber cavity consisting of gain, loss, group velocity dispersion (GVD), SPM, and and the SBR action. The pulse evolution equation in the fiber laser can be described by Haus' master modelocking equation [1],

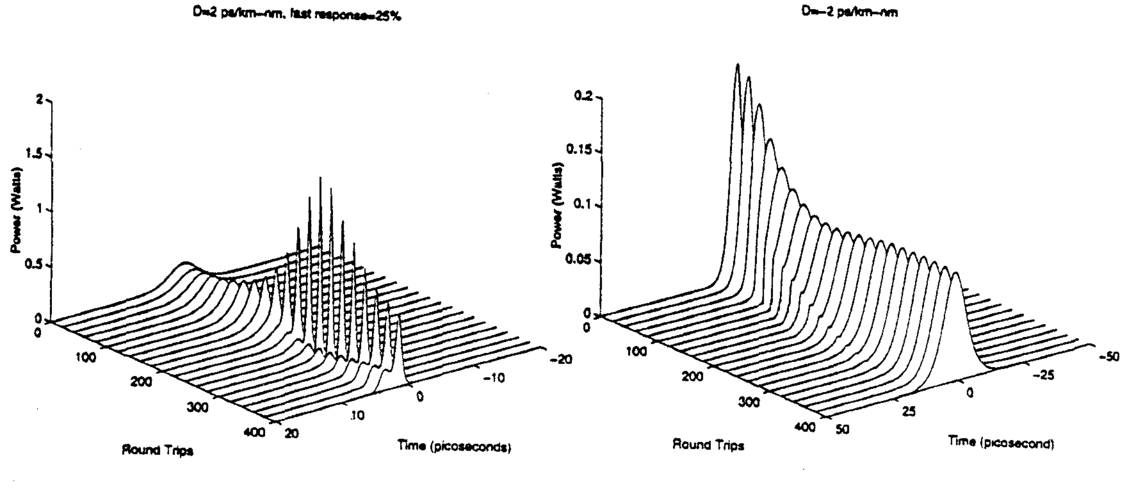
$$i\frac{\partial u}{\partial z} + \left(-\frac{k''}{2} - i\frac{g}{\Omega_g^2}\right)\frac{\partial^2 u}{\partial t^2} + \delta|u|^2 u + i(l-g)u = 0 \tag{1}$$

where u is the slowly varying pulse envelope, k'' the intracavity dispersion per roundtrip, g the gain coefficient, Ω_g the gain bandwidth, l the loss per roundtrip, and δ the nonlinear Kerr coefficient. The Kerr coefficient is given by: $\delta = (2\pi n_2)/(\lambda_o A_{eff})$, where n_2 is the nonlinear index, λ_o the carrier wavelength (1.5μm) and A_{eff} the effective area. We model both the fast and slow response components of the SBR, and the SBR action on the pulse envelope is described by:

$$u_r = \left[1 + \sigma_f\left(\frac{|u|^2}{|u_{max}|^2} - 1\right) + \sigma_s\left(\left(\int_{-\infty}^{t} |u|^2 dt\right)\Big/\left(\int_{-\infty}^{\infty} |u|^2 dt\right) - 1\right)\right]u_i \tag{2}$$

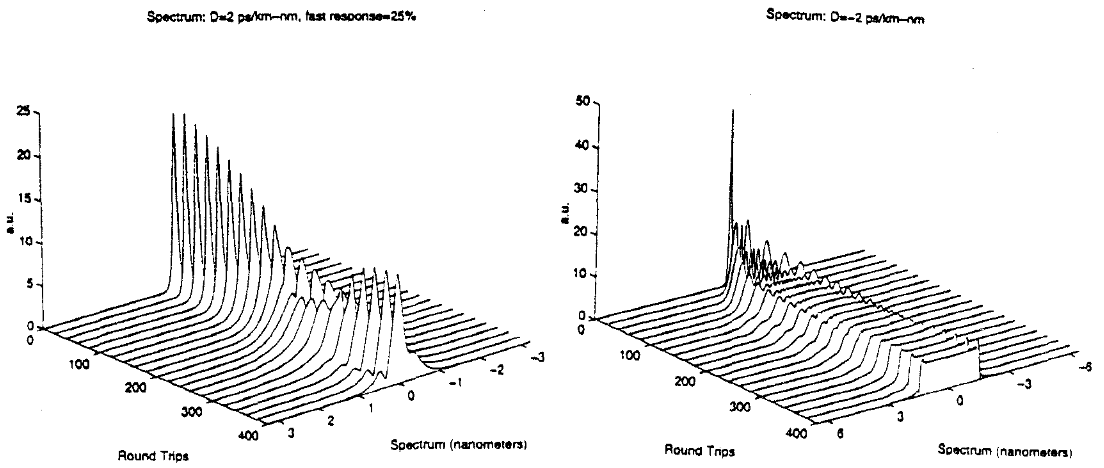
where u_i is the incident pulse at the SBR and u_r is the reflected pulse. The ratios of the fast and slow components of the SBR are given by the coefficients σ_f and σ_s respectively. We find that when the fast component coefficient σ_f is 0.25 (25%) or lower, the pulse shape will form a pedestal when the net dispersion in the cavity is in the anomalous dispersion regime (in our example D=2 ps/Km-nm). In the normal dispersion regime (D=-2 ps/Km-nm), the pulse will stabilize into a uniform secant hyperbolic pulse shape and no pedestal is formed. All other cavity parameters are kept the same. The evolution of the temporal pulse envelopes for the two cases are shown in Figure 1(a) for the anomalous and 1(b) for the normal dispersion case. Interesting differences are also observed in the spectral domain. In the anomalous dispersion case, shown in Figure 2(a), the spectrum evolves to a nonuniform shape, but in the normal dispersion regime (Figure 2(b)) a uniform square spectrum is observed. We will discuss further these numerical results as well as how they compare with experiments.

figure 1



(a) (b)

figure 2



(a) (b)

References

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2. S. Tsuda, W. H. Knox, E. A. de Souza, W. Y. Jan and J. E. Cunningham, Opt. Lett. 20, 1406 (1995); L. R. Brovelli, I. D. Jung, D. Kopf, M. Kamp, M. Moser, F. X. Kartner and U. Keller, Elec. Lett. 31, 287 (1995).
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