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Wednesday AFTERNOON
May 5, 1993 JWB
Convention Center Room 317

2:00pm **Joint Symposium on Ultrafast Lasers 3**
H. M. van Driel, *University of Toronto, Presider*

2:00pm

JWB1 Self-starting, passively mode-locked Fabry-Perot fiber soliton laser using nonlinear polarization evolution

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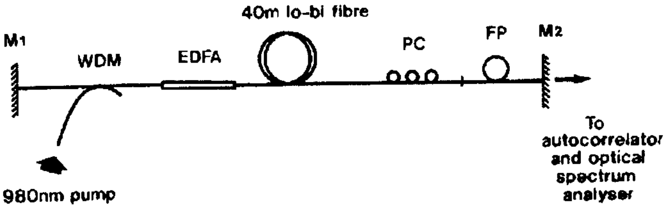
During the last three years the potential of mode-locked rare-earth-doped fiber lasers for ultrashort pulse generation has been explored and both passive and active mode-locking schemes have been demonstrated. Systems which use nonlinear polarization evolution in conjunction with an intracavity polarizer to provide the passive mode-locking mechanism have so far been demonstrated in ring[1] (self-starting) and Fabry-Perot[2] (self-sustaining) configurations, the latter of which employed an intracavity bulk polarizer and modulator. Following the work published by Davey *et al.*[2] we report a self-starting Fabry-Perot system capable of producing 1.6ps bandwidth-limited soliton pulses. We also show that the soliton pulsewidth in any of these configurations is ultimately limited by the dispersion-length product of the system, hence by careful choice of the fiber dispersion and fiber length the system should also be able to operate in the femtosecond regime.[3] The replacement of the two mirrors with fiber reflection gratings would make this configuration a truly all-fiber device.

The experimental configuration is depicted in Fig. 1. The system comprised 40 m of Lo-Bi spun fiber (NA = 0.12, λ_c = 1250 nm, D = 17 ps/nm/km, A_{mode} = 124 μm^2 and beat length > 10 m), 3 m of Er^{3+}-doped fiber (dopant concentration = 800 ppm, NA = 0.15, λ_c = 960 nm), a fiber polarizer (FP), and a polarization controller (PC) situated just before the fiber polarizer. Pumping was provided by a Ti:Sapphire laser operating at 980 nm. A 980/1550 nm fiber wavelength division multiplexer (WDM) was used to couple the pump light into the Er-doped fiber and the laser cavity was formed by butting the end of port #2 of the WDM against a 1550 nm 99% reflecting mirror (Ml) and the fiber polarizer end against an 85% reflecting output mirror (M2).



JWB1 Fig 1. Experimental configuration.

With the PC adjusted so as to minimize the intracavity loss, the laser had a CW threshold of 25 mW launched pump power. The onset of mode-locked operation was marked by an abrupt change in the optical spectrum and output power at a particular value of the launched pump power (450 mW). This is considerably higher than the pump power required for self-starting mode-locked operation in Fig-8 and ring configurations, but is in general agreement with the predictions of Zehetner *et al.*[4] Once initiated, however, mode-locked operation in our laser could be sustained to powers within a few mW of the CW threshold (25 mW).

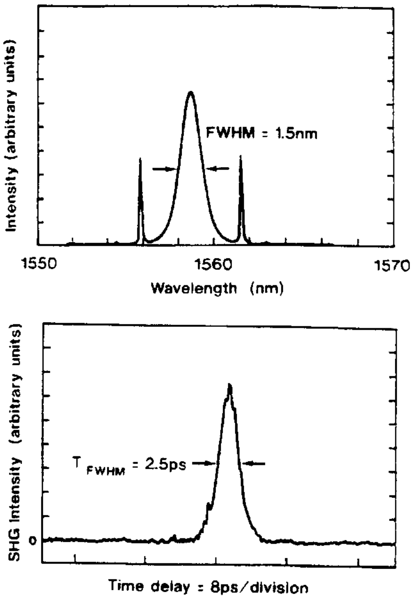
Soliton and square pulse regimes were observed as was also reported in Fig-8 and ring lasers. In the soliton regime, autocorrelation measurements showed a full width at half maximum of 2.5 ps, corresponding to a pulse duration of 1.6 ps. The spectral width was 1.5 nm, yielding a time-bandwidth product of 0.32, as expected for transform limited sech^2 pulses (see Fig. 2).

The two sidebands on either side of the central frequency in the optical spectrum of Fig. 2 is a well-known feature of soliton lasers. By making the assumption that for stable soliton propagation the first sideband should not fall inside the main soliton spectrum, i.e. $\Delta\nu_s \geq \Delta\nu_{FWHM}$ (or, equivalently, $L/Z_0 \leq 3.5$, a result borne out by computer simulations) we obtain the following limiting expression for the soliton pulsewidth τ[5]:

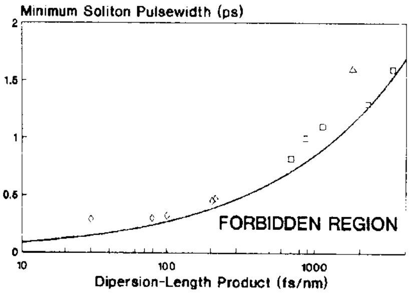
$$\tau = \lambda\sqrt{\frac{0.09DL}{c}} \qquad (1)$$

where $\Delta\nu_s$ is the frequency separation of the first sideband from the central frequency of the soliton, $\Delta\nu_{FWHM}$ is the full width at half maximum of the soliton spectrum, L is the length period of the perturbation ($L = L_c$ for Fig-8 and ring lasers, $L = 2L_c$ for Fabry-Perot), Z_0 is the soliton period, λ is the wavelength, c the speed of light, and D the fiber dispersion parameter. As Fig. 3 shows, the above expression is in good agreement with experimental results that have so far been obtained in Fig-8, ring and Fabry-Perot lasers by various research groups.

1. V. J. Matsas *et al.*, Electron. Lett. **28**, 1391–1393 (1992).
2. R. P. Davey *et al.*, Electron. Lett. **27**, 1257–1259 (1991).
3. M. E. Fermann *et al.*, postdeadline paper, Optical Society of America Annual Meeting, Albuquerque, NM, Sept. 21-25 (1992).
4. J. Zehetner *et al.*, Opt. Lett. **17**, 871–873 (1992).
5. A similar expression is found in a paper submitted to Appl. Phys. Lett. by I. N. Duling III (Personal communication).



JWB1 Fig 2. Optical spectrum and autocorrelation trace of pulses in the soliton regime.



JWB1 Fig 3. Soliton pulsewidth versus dispersion-length product (log scale); solid line, Eq. (1); boxes, experimental points from Figure-8 lasers; diamonds, experimental points from ring lasers; triangle, this work.