597
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OPERATING MODES OF A SELF-STARTING, PASSIVELY MODE-LOCKED FIBRE RING LASER EXPLOITING NON-LINEAR POLARISATION ROTATION

V.J.MATSAS, D.J.RICHARDSON, T.P.NEWSON and D.N.PAYNE

Optoelectronics Research Centre,
Southampton University,
U.K.

ABSTRACT:

We describe the various operating modes of an all-fibre soliton ring laser based on nonlinear polarisation evolution. Under certain conditions the laser exhibits output power bistability with abrupt changes in output power and operating wavelength with pump power variation.

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Passive mode-locking of erbium-doped fibre lasers (EDFL) has recently become of great interest as a source of solitons for communications with schemes based on Sagnac interferometers [1,2] and fast saturable absorbers [3] so far demonstrated. Passive mode-locking using Non-Linear Polarisation Evolution (NLPE) as a self-sustaining mechanism has also been proposed and demonstrated in a Fabry-Perot Nd^{3+} fibre laser employing intra-cavity dispersion compensation [4]. However, the system was incapable of self-starting. Self-starting, passive mode-locking of an Er^{3+} fibre ring laser has been briefly reported by Mollenauer [5], although a detailed description of the system behaviour was not presented. The mode-locking mechanism for similar systems has been theoretically attributed to NLPE [6,7], but experimental results confirming that this is the case have yet to be presented. In this paper we present for the first time experiments with a self-starting all-fibre ring laser which demonstrate the various regimes of system operation and present results which confirm that NLPE is indeed the mechanism behind the passive mode-locking of the system.

The experimental configuration is shown in Fig.1. The system comprised of 180m of Lo-Bi fibre (NA=0.1, λ_{co}=1230 nm, D=17 ps/nm/km, A_{mode}=124 $(\mu m)^2$ and beat length > 10 m) and a polarising isolator. Pumping was provided by a Ti:Sapphire laser operating at 980nm. The output coupling was 10%. Two polarisation controllers PC1 and PC2 were used to set the low intensity state of polarisation (SOP) entering and leaving the Lo-Bi fibre respectively, thereby controlling the loss of the system at low intensities. If the controllers are deliberately set to give a cavity loss at low intensity, NLPE at high intensities can alter the SOP of the light reaching the polariser, thus reducing the cavity loss and providing a mechanism for passive mode-locking. The pump power to the system could be smoothly and controllably varied whilst simultaneously monitoring the total output power, the output SOP, the optical spectrum and the full time domain behaviour.

Two distinct regimes of mode-locked operation were observed. At high pump powers (> 150 mW), long duration (>500ps) "square" pulses at the cavity round-trip frequency were observed, as also reported in the Figure-8 laser (F8L) [2]. The pulses were characterised by their broad optical bandwidth 30-40 nm. At low pump powers (< 150mW) the square pulses became less stable and the system operated entirely in the soliton regime. The soliton pulses were seemingly randomly spaced in the time domain, the pulse patterns repeating at the cavity round-trip frequency. Autocorrelation measurements showed the pulse durations to be between 2.0ps (for pump powers close to 150mW) and 1.55ps (for pump powers close to 30mW) with pulsewidth-bandwidth products at these pump powers of 0.38 and 0.32 respectively. Average repetition rates as high as 10GHz were observed.

In the soliton regime two distinct modes were observed, depending on the PC's setting. Their difference is most strikingly demonstrated by observing their spectral behaviour as a function of pump power (see Fig. 2). In mode #1, the central wavelength and spectral shape of the pulses remained constant as the pump power was varied. Note also the existence of symmetric, spectral side-lobes as observed in the F8L. In mode #2, discrete changes in the central wavelength and spectral shape were observed as the pump power was varied. The output power characteristic of the laser for the two soliton modes is shown in Fig.3. In mode #1 (dashed lines) the CW threshold was found to be 27 mW. Mode-locking was found to self-start at a second "threshold" of 70 mW (not shown). The SOP at the output remained constant during CW operation up until the onset of mode-locking, at which point an abrupt change in the SOP at the input to the polarising isolator was observed indicating that NLPE provides the mode-locking mechanism. Once mode-locking had been initiated, by gradually decreasing the pump power we observed discrete and abrupt jumps (downwards) in the laser output power, coinciding with the disappearance of individual pulses from the cavity. Mode-locking could be sustained to powers within a few mW of the CW threshold. A higher CW threshold of 30 mW was observed for the system operating in mode #2 (bold lines), however the second "threshold" had now been reduced to 47 mW. Once initiated, mode-locking could now be maintained at pump powers significantly lower than the CW threshold. Abrupt jumps -both upwards and downwards- in the output power were observed this time. Jumps downwards were associated with pulse disappearances and the smaller jumps upwards with discrete wavelength shifts.

We have briefly summarised and described the operating modes of a self-starting, passively mode-locked, soliton ring laser which we believe has great potential as a soliton generator for telecommunications and laboratory applications. Further results and a full discussion on the system and NLPE behaviour will be presented at the conference.

REFERENCES:

1. I. Duling III: *Electron. Lett.* 27, 544 (1991).
2. D.J.Richardson et al: *Electron.Lett.* **27** p.730 1991.
3. M.Zirngibl et al: *Electron.Lett.* **27** p.1734 1991.
4. M.Hofer et al: *Opt.Lett.* **16** p.502 (1991).
5. L. Mollenauer: Tutorial Session OFC (San Diego, 1991).
6. V.J.Matsas et al.: Submitted to *Opt. Commun.* (1991).
7. C.J. Chen et al.: *Opp. Lett.* **17**, p.417 (1992).

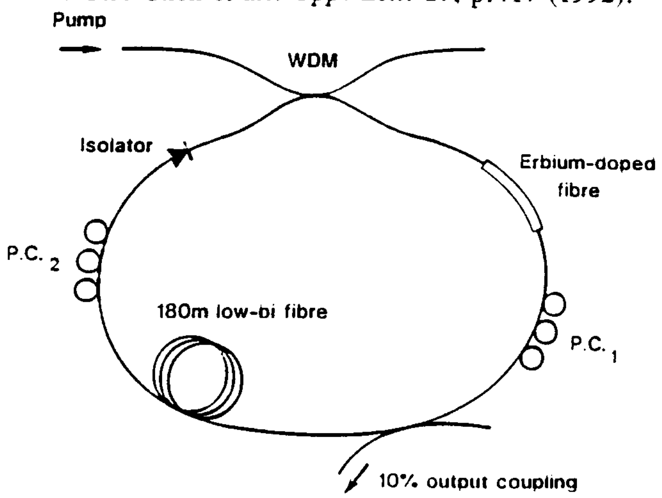

Fig.1: Experimental set-up

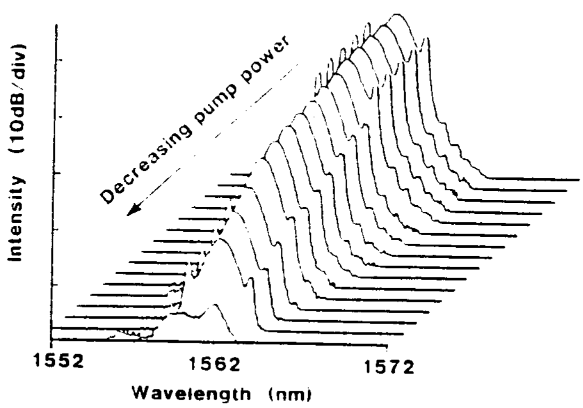

Figure 2(a): Optical spectrum variation for mode #1 with decreasing pump power

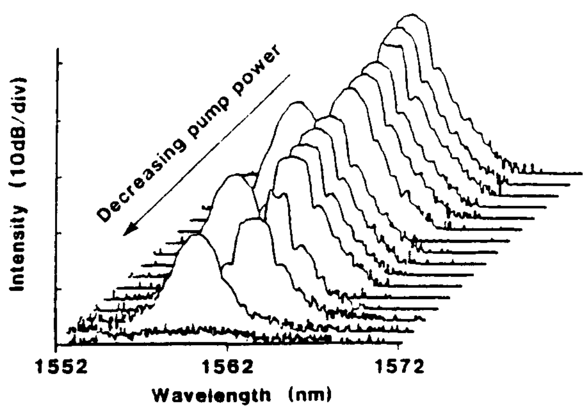

Figure 2(b): Optical spectrum of mode#2 with decreasing pump power

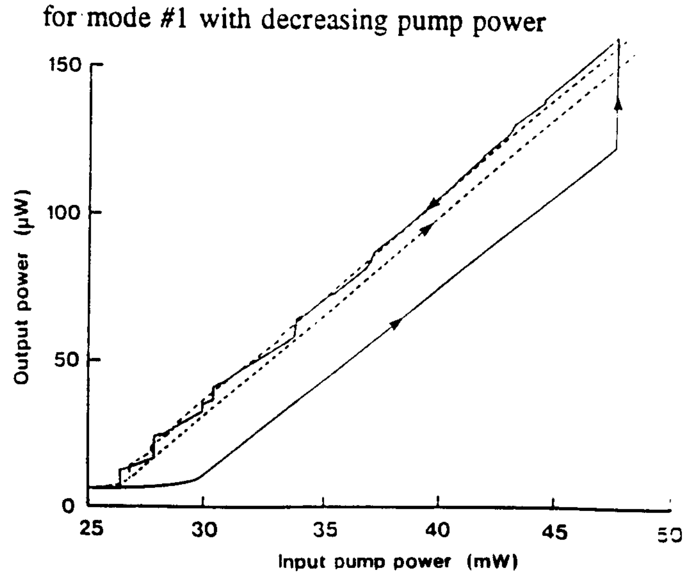

Figure 3: Power hysterisis curves for mode#1 (dashed) and mode#2 (bold)