Multiple continuous-wave and pulsed modes of a figure-eight fiber laser

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Fiber lasers are versatile low-cost sources that are attractive for a wide range of applications. In continuous-wave mode, tunable and multiwavelength laser sources are required for wavelength division multiplexing (WDM), fiber sensors and optical instrument calibration, for example. On the other hand, passively Q-switched and mode-locked fiber lasers, operating in pulsed mode, make it possible to reach values of peak power much higher than their continuous-wave counterparts, allowing the use of these sources for studying and exploiting nonlinear effects in fibers, a framework in which supercontinuum generation is now receiving particular attention.

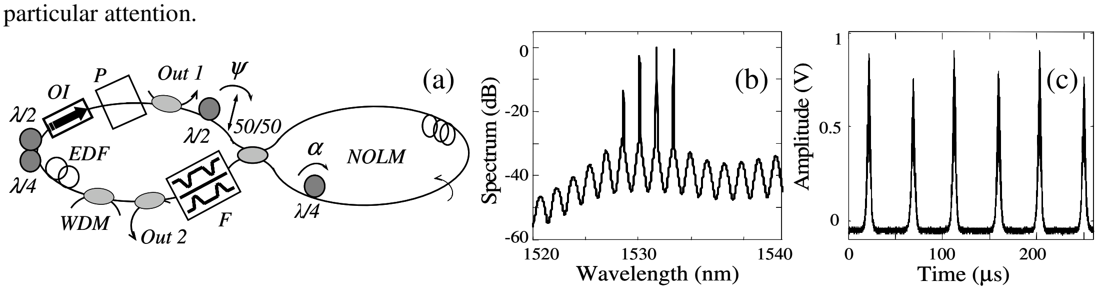

Fig. 1 (a) Figure-8 laser scheme; (b) optical spectrum for four-wavelength continuous-wave operation and (c) scope trace in the Q-switched pulsing mode. The filter spectral period = *1.65 nm*.

In this work we study different modes of operation of a figure-eight fiber laser [Fig. 1(a)]. The ring section of the laser (left) includes a 4-m Erbium-doped fiber (EDF) amplifier, an isolator (OI), two 90/10 output couplers, a polarizer (P), wave retarders and a periodic fiber-optic filter (F) based on two tapers in series. The filter was fabricated in a standard fiber using a Vytran glass processor. The principle of the device is that of a Mach-Zehnder interferometer: at the first taper the fundamental core mode partially couples to cladding modes, and a fraction of the light guided in the cladding modes couples back to the core mode at the second taper [1]. The transmission spectrum of the filter is thus a periodic pattern resulting from the interference between core and cladding modes of the fiber.

The Nonlinear Optical Loop Mirror [NOLM, right side of Fig. 1(a)] operates through nonlinear polarization rotation [2]. It includes a 50/50 coupler, a piece of *100 m* of twisted standard fiber and a quarter-wave retarder (QWR) inserted asymmetrically in the loop, whose angle α defines low-power NOLM transmission. Polarization at the NOLM input is made linear by the polarizer, the polarization angle ψ determining the NOLM switching power [3]. Hence, by controlling polarization in the NOLM, its transmission characteristic can be adjusted in different ways.

Depending on the adjustments of the wave retarders, different modes of operation of the laser are found. In continuous-wave, tunable single-wavelength operation as well as multi-wavelength lasing are observed [Fig. 1(b)]. For some adjustments, Q-switched pulsing takes place [Fig. 1(c)]. Finally, for some adjustments a mechanical stimulation (a kick) leads to the onset of passive mode locking. Measurements revealed that the mode-locked pulses actually are noise-like pulses. In this work, we analyze how simple wave plate adjustments can lead to such a variety of operational modes of the fiber laser.

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[1] D. Monzon-Hernandez, A. Martinez-Rios, I. Torres-Gomez, G. Salceda-Delgado, Opt. Lett. **36**, 4380 (2011).
[2] E. A. Kuzin, N. Korneev, J. W. Haus, B. Ibarra-Escamilla, J. Opt. Soc. Am. B **18**, 919 (2001).
[3] O. Pottiez, E. A. Kuzin, B. Ibarra-Escamilla, F. Mendez-Martinez, Opt. Commun. **254**, 152 (2005).