Performance Comparison of Mode-Locked Erbium-Doped Fiber Laser with Nonlinear Polarization Rotation and Saturable Absorber Approaches *

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A mode-locked erbium-doped fiber laser (EDFL) is demonstrated using a highly concentrated erbium-doped fiber (EDF) as the gain medium in a ring configuration with and without a saturable absorber (SA). Without the SA, the proposed laser generates soliton pulses with a repetition rate of 12 MHz, pulse width of 1.11 ps and energy pulse of 1.6 pJ. By incorporating SA in the ring cavity, the optical output of the laser changes from soliton to stretched pulses due to the slight change in the group velocity dispersion. With the SA, a cleaner pulse is obtained with a repetition rate of 11.3 MHz, a pulse width of 0.58 ps and a pulse energy of 2.3 pJ.

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Fiber lasers are made possible by incorporating trivalent rare-earth ions such as neodymium, erbium and thulium into glass hosts. Since the 1980s, erbium-doped fiber lasers (EDFLs) have gained widespread interest because the lasing wavelength at 1.55 µm, falls within the low-loss window of optical fiber, which is suitable for optical fiber communications.[1,2] They have numerous advantages such as simple doping procedures, low loss, compact, high reliability and high-output power. We have also observed growing interest in mode-locked EDFLs due to their many applications in communication systems for time-division multiplexing (TDM),[3] code-division multiple access (CDMA)[4] and wavelength division-multiplexing (WDM).[5,6] They can also find applications in high-resolution spectroscopy, THz pulse generation, optical clockworks, absolute distance measurements and many others.[7−10]

Recently, a high concentration erbium-doped fiber (EDF), IsoGain$^{\rm TM}$, was commercially developed by FiberCore Co. Ltd. to provide the ultimate in cost-effectiveness for the EDF amplifier (EDFA), with typical C-band gain-lengths of only a few meters.[11] This fiber is actually more suited to reducing the exceptionally long doped fiber lengths required for effective L-band amplification. In this Letter, a mode-locked EDFL is demonstrated using a simple ring cavity structure with the IsoGain^{TM} EDF as the gain medium. The performance of the laser is investigated for two different mode-locking techniques; nonlinear polarization rotation (NPR) and saturable absorber (SA). Since the gain medium is only a piece of 2.5-m-long EDF, the cavity length of the EDFL is considered short and therefore stable clean pulses can be generated with a higher repetition frequency. The super-mode noise can also be suppressed effectively because the EDF has a very high nonlinearity.

Figure 1 shows the configuration of the proposed laser, which is an all-fiber setup using commercially available components. It consists of a piece of 2.5-m-long EDF, wavelength division multiplexers (WDMs), an isolator, a polarization controller (PC), a saturable absorber (SA) and a 3-dB output coupler. The total length of the cavity is about 14.5 m, which comprises a 2.5-m-long EDF and a 12-m-long single mode fiber (SMF) used in the other components. The EDF has an erbium ion concentration of 2000 ppm, cut-off wavelength of 910 nm, a pump absorption rate of 24 dB/m at 980 nm and a dispersion coefficient of -21.64 ps/nm·km at $\lambda = 1550$ nm. It is forward pumped using a 1480 nm laser diode via the WDM to provide amplification in the C-band region. The other part of the ring cavity uses a standard single mode fiber (SMF-28) with a dispersion coefficient of 17 ps/nm·km at $\lambda = 1545$ nm. A semiconductor SA is used for the initiation and stabilization of mode-locking at around the 1550 nm region. The SA is designed for transmission application and has a modulation depth ΔR of 15%, saturation fluence of 300 µJ/cm^2, nonsaturable loss of 10% and relaxation time constant of 2 ps. An isolator is used to ensure a unidirectional operation of the laser and acts as a polarizer. A PC is used to rotate the polarization state and allows continuous adjustment of the birefringence within the cavity to balance the gain and loss for laser pulse generation. The experiment is also repeated without the SA wherein the mode locking mechanism is based on the NPR technique.

Figure 2 shows the output spectrum of the mode locked EDFL with and without the SA in the ring

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