Compact Diode-pumped Dispersion-managed SESAM-mode-locked Ho:fiber Laser

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Abstract: We demonstrate for the first time a compact mode-locked holmium fiber laser diode-pumped at 1150 nm. The laser operated in the dispersion-managed dissipative-soliton regime and provided 3.7 nJ pulse energy at 7.8 MHz PRF.
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1. Introduction

Mode-locked fiber lasers emitting in the wavelength range beyond 2 μm [1, 2] are promising for a number of applications including environmental sensing, material processing, medicine etc. Ho-doped fiber lasers, though usually exploiting more complicated pumping scheme in comparison with Tm/Ho-doped fiber lasers, allow laser emission to be red-shifted, namely up to 2.21 μm for the cw regime [3] and 2.11 μm for the mode-locked regime [4]. Holmium fiber lasers are usually being inband-pumped at 1.9 μm by the thulium fiber lasers [5] since laser diodes are not widely available at this wavelength range. However, the holmium ion has another absorption line at around 1150 nm., where Yb-fiber lasers emitting at the long-wavelength domain [6] and semiconductor disk laser emitting at 1160 nm [Chamorovskiy2012] could be used for pumping.

In this work we realize for the first time a compact directly diode pumped Ho-fiber mode-locked laser and demonstrate efficient high pulse energy self-starting operation at up to 4 nJ pulse energies.

2. Experimental setup

The experimental setup is shown in the Fig. 1. Two similar FBG-stabilized laser diodes LD (Innolume) provided 0.5W of polarized emission at 1150 nm each. The emission from both diodes was combined in the polarization beam combiner (PBC) and coupled into the fiber laser cavity. The cavity consisted of the 2-meter piece of holmium active fiber (Nufern SM-HDF-10/130), dispersion compensating fiber DCF (Nufern UHNA-4), and certain amount of passive fiber used in fiber couplers (Thorlabs SM2000). The mode-locking was initiated and supported by a semiconductor saturable absorber mirror (BATOP SAM2150-) with a modulation depth of about 5%. The SESAM was free-space coupled to the laser cavity using 6-mm focal length mid-IR aspheric lens (Thorlabs). Fiber loop was used as an output coupler with a reflectance of about 50% at the laser wavelength. The laser output was then separated from the residual pump power using another WDM fiber coupler. Two polarization controllers (PC) ensured the polarized laser output.

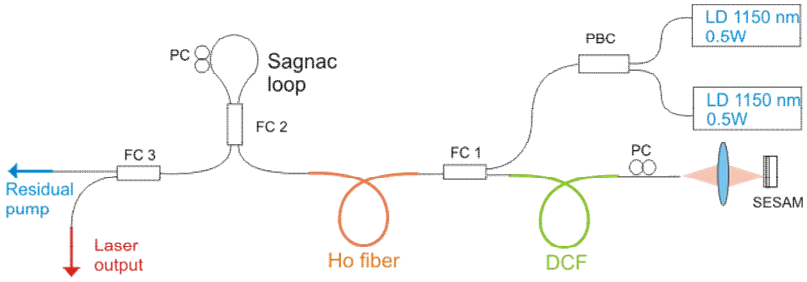

Fig. 1. The experimental setup for the holmium fiber laser: LD – laser diodes, PBC – polarization beam combiner, FC – fiber coupler, PC – polarization controller, DCF – dispersion compensating fiber, SESAM – semiconductor saturable absorber mirror.

3. Results and discussion

Stable self-started mode-locking has been obtained with DCF lengths of 7 to10 meters. Output powers of 25 to 30 mW have been typically obtained, depending on the adjustment of the polarization controllers. The fundamental cavity pulse repetition frequency of 7 to 8 MHz resulted in 3 to 4 nJ pulse energy. The laser emission was centered at around 2.1 μm and has >10 nm spectral bandwidth. Strongly chirped pulses with 2-2.5 ps pulse duration have been measured by the interferometric autocorrelator. According to the estimated cavity dispersion, laser emission spectral shape, and the chirped nature of the laser pulses, we can conclude that the laser has been operated in the dissipative soliton regime. Typical laser output characteristics for the output power of 28 mW are shown in the Fig. 2.

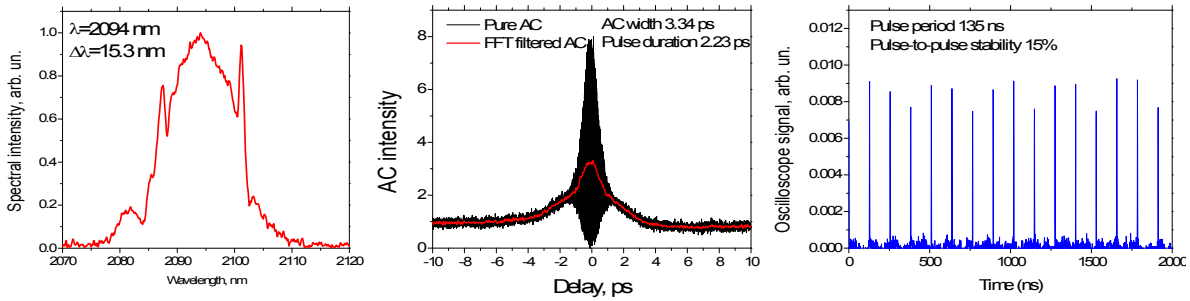

Fig. 2. Optical spectrum (a), interferometric autocorrelation trace (b) and pulse train (c) of a dispersion-managed mode-locked holmium fiber laser.

4. Conclusion

The reliable, highly efficient and self-starting mode-locked Ho-fiber laser emitting at 2.1 μm has been developed. The laser produces stable high energy (up to 4 nJ) pulses, which can be further amplified. The laser system is characterized by an extremely compact design due to the first realization in this type of laser of direct diode-pumping, which makes it particularly suitable for real life applications.

Acknowledgements

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