Graphene-mode-locked Holmium Fiber Laser Operating Beyond 2.1 μm

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Mode-locked fiber lasers emitting in the wavelength range beyond 2 μm are promising for a number of applications including environmental sensing, material processing, medicine etc. Ho-doped fiber lasers, though exploiting complicated pumping scheme in comparison with Tm/Ho-doped fiber lasers, allow laser emission at longer wavelength. Continuous-wave lasing at wavelengths up to 2.2 μm has been obtained in Ho-fiber lasers, but mode-locked operation has so far been only achieved at the wavelengths below 2.1μm [1] because of the lower gain and increasing optical losses in the fiber, making stable mode-locked laser action challenging.

We report the first mode-locked holmium fiber laser operating beyond 2.1 μm. The laser cavity setup is shown in Fig.1(a). For pump, we used a self-developed Tm-fiber laser, pumped by an commercial erbium fiber laser at 1.61 μm, providing about 60% slope efficiency at 1.85 μm. The cavity of the Ho-fiber laser was formed by a Sagnac fiber loop, 60-cm piece of a single-mode Ho-doped active fiber, and an open-air mode-locker block. Ho-doped fiber had 10 μm core diameter and 10^{19} cm^{-3} Ho^{3+} ion concentration. Mode-locker block consisted of a fiber collimator, Brewster plate, focusing mirror and a graphene-based saturable absorber mirror [2].

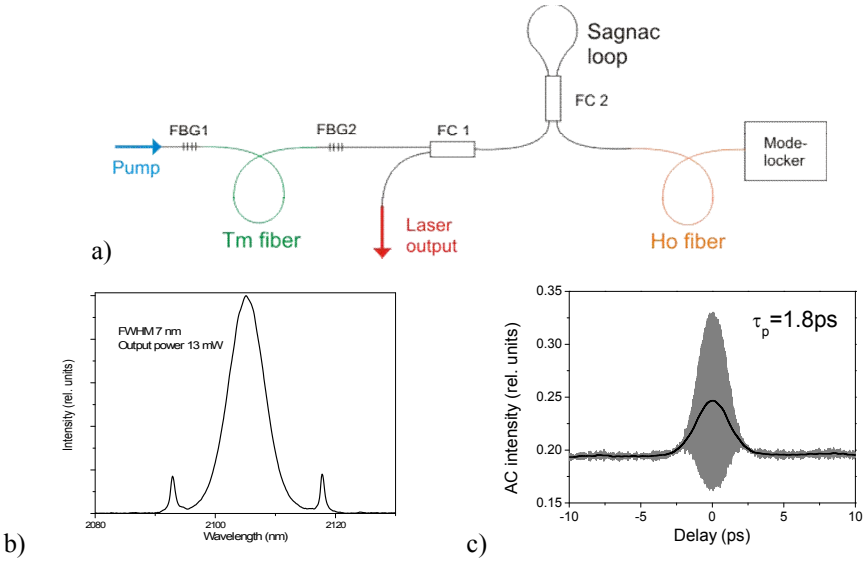

Fig. 1 The experimental setup of a holmium fiber laser (a); the optical spectrum (b) and autocorrelation trace (c) of a laser emission.

The stable mode-locking was achieved at a pump power of about 500 mW (about 1W of erbium fiber laser emission at 1.61 μm). The laser routinely produced pulses of 1.8 picosecond duration with the average output power of 13 mW at a central wavelength of 2107 nm. The spectral bandwidth of 7 nm FWHM (Fig. 1(b)) corresponds to 0.68 ps transform-limited pulse, so we believe that there is a possibility to produce femtosecond pulses in a similar scheme. The pulse repetition frequency of 60 MHz results in a laser peak power of about 100W. The important feature of a laser is that the output emission, unpolarized in the continuous-wave mode, became polarized as far as the mode-locking is achieved. We believe that in the mode-locked regime the cooperative action of a Brewster plate in an open-air mode-locker block and nonlinear polarization rotation in the fiber part of the cavity allows to stabilize the polarization state of the output emission. The polarization extinction ratio of a laser emission passed 1.5 m of SMF-28 fiber was measured as 1:16. This technique allows to produce polarized emission of stable mode-locked pulses from a fiber laser based on isotropic fibers.

The parameters of the laser output are sufficient for realization of the compact supercontinuum light source in frames of EU-FET grant GRAPHENICS, which we would like to acknowledge.

References

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