Passively Mode-Locked All-Fiber Ytterbium Oscillator with Integrated Hollow-Core Photonic Bandgap Fiber

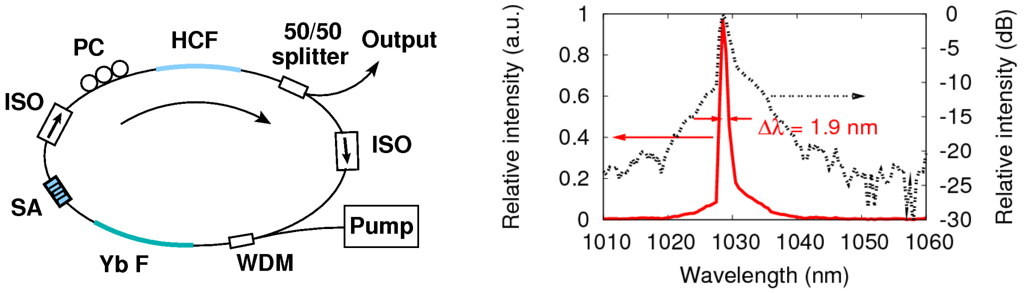
J. Fekete[1], A. Cserteg[2], R. Szipőcs[1]

1. Research Institute of Solid State Physics and Optics, Konkoly-Thege M. út 29-33., H-1121, Budapest, Hungary
2. Furukawa Electric Institute of Technology Ltd., Vasgolyó u. 2-4, H-1158, Budapest, Hungary

Passively mode-locked Yb based fiber oscillators were intensively investigated in the last decade, as they offer compact design and environmental stability. One of the main directions of research was to utilize fiber-integrated dispersion compensating elements in the cavity to ensure self-consistent solutions of the mode-locking mechanism, since conventional single-mode fibers (SMF) have normal dispersion below 1.3 µm. The application of hollow-core photonic bandgap fibers (HCF) for dispersion control is advantageous because in addition to their possibly anomalous group velocity dispersion (GVD) in the Yb wavelength range they have reduced nonlinearity compared to solid-core fibers. There have been experimental demonstrations of such lasers in the weakly stretched soliton [1] and in the similariton regimes [2]. These setups included free-space optics for coupling light into and out of the HCF and also for the alignment of the appropriate polarization states. However, for alignment-free operation and high stability an all-fiber setup is desired. Here we report a self-starting passively mode-locked fiber laser containing a HCF spliced into the cavity to provide anomalous GVD. The laser operates in the stretched-pulse regime, close to the zero cavity dispersion. To the best of our knowledge this is the first implementation of integrated HCF based intra-cavity dispersion control.

Fusion splicing of the HCF (HC-1060-02, Crystal Fibre) was carried out by a conventional electric-arc splicer and resulted in less than 3 dB loss of transmitted light after 2 splices. To reduce the effect of Fresnel reflections at the HCF-SMF junctions that would disturb mode-locking, the HCF was placed between two isolators. The oscillator (see Fig. 1 (a)) consists of a highly doped ytterbium gain fiber (Yb F) pumped through a WDM by a 976 nm fiber coupled laser diode providing maximally 600 mW power, SMF pieces (HI1060), a saturable absorber (SA), the isolators (ISO) and the HCF, a polarization controller (PC) to adjust the polarization state, and a 50/50 splitter used as the output coupler. The cumulative length of the SMFs is around 4.4 m and the length of the HCF is 3.3 m resulting in the net cavity dispersion to be close to zero at 1030 nm.

Starting from the normal dispersion regime, the resonator length was decreased by removing 10-20 cm segments of the SMFs. By measuring the second-order autocorrelation functions we tried to optimize the cavity length for the shortest pulse at the output after an extra ~2m of SMF piece. The shortest pulse duration was ~ 2 ps. The optical spectra (see Fig. 1 (b)) in the investigated region was relatively narrow, less than 2 nm in all cases, close to the resolution of our spectrometer. From this we assume that with even further optimization, the pulse duration would not reach the sub-picosecond regime. It is to be mentioned that the limited spectral bandwidth is in context with the application of the HCF as it is noticeable in the case of the ~1.4 nm similariton spectrum in [2]. The enshortened pulses after dispersion compensation obtain relatively high nonlinear spectral broadening due to the amplification and propagation in the Yb F and SMFs. This was observed on an additional output coupler after the Yb F. The nonlinear polarization evolution acting together with the birefringence of the HCF gives an explanation of the narrow bandwidth and the fact that without careful alignment of the polarization states the laser is likely to generate noise-like pulses or double pulses even at low pumping, close to the threshold.



(a) (b)

Fig. 1 (a) Setup of the fiber oscillator and (b) optical spectrum in linear and semi-logscale

References

[1] H. Lim, F. W. Wise, “Control of dispersion in a femtosecond ytterbium laser by use of hollow-core photonic bandgap fiber,” Opt. Express **12**, 2231(2004).

[2] A. Ruehl, O. Prochnow, M. Engelbrecht, D. Wandt, D. Kracht, “Similariton fiber laser with a hollow-core photonic bandgap fiber for dispersion control,” Opt. Letters **32**, 1084 (2007).

978-1-4244-4080-1/09/$25.00 ©2009 IEEE