Er-Doped Fiber Laser with Regular and Random Distributed Feedback

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The cavity of distributed feedback (DFB) fiber lasers is usually based on a periodic structure such as pi-phase-shifted fiber Bragg grating (FBG), which is embedded into an active fiber, so that a stable single-frequency regime is provided [1]. In contrast, random DFB fiber lasers usually utilize Rayleigh scattering on natural or artificial random refractive index structures [2]. For example, random lasing in active fibers is possible either with the use of an FBG with multiple random phase shifts (in Er-doped fiber [3]) or an FBG with both randomly varying phase and amplitude (in Yb-doped fiber [4]). The development of point-by-point femtosecond (fs) inscription technology makes it possible for the formation of both regular and random refractive index structures of arbitrary shape, either inactive or passive fibers, thus offering new opportunities for the development of DFB fiber laser schemes.

Here we report on the development and characterization of a hybrid scheme based on a regular Er-doped DFB fiber laser at 1550 nm combined with random distributed feedback (RDFB) based on Rayleigh reflection. In this scheme, a 6-cm pi-shifted FBG inscribed in Er-doped fiber played a role of a regular DFB structure, and a 25-km SMF-28e+ fiber spool or a fiber section containing 5-cm fs-pulse-inscribed artificial random structure played a role of random reflectors. Fabricated Rayleigh reflector provided +50 dB/mm scattering power relative to the SMF-28e+ natural scattering level (Fig.1a).

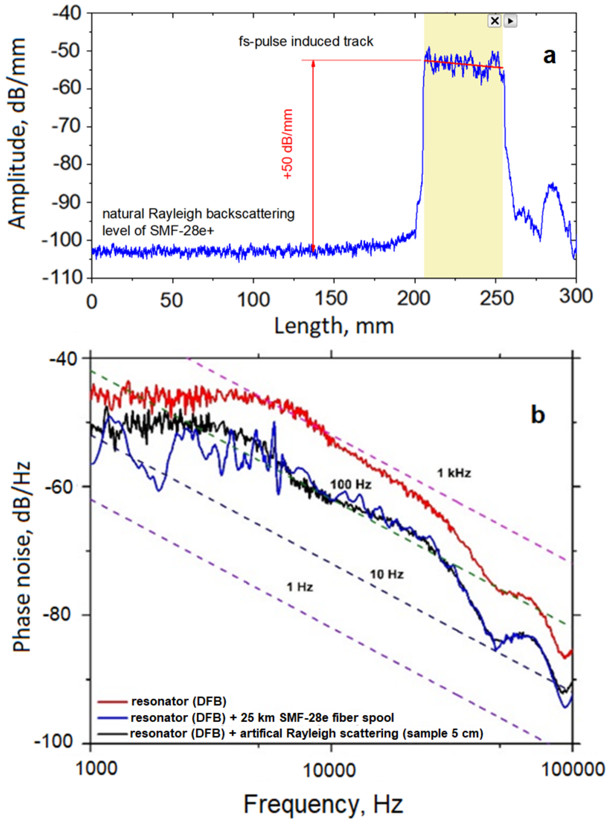

Figure 1: Reflectogram of a 5-cm-long fs-pulse-inscribed Rayleigh reflector (a), and comparison of the phase noise characteristics of an Er-doped DFB laser with a hybrid DFB+RDFB configuration where the RDFB is provided by either the 5-cm fs-pulse-inscribed Rayleigh reflector or a 25-km SMF-28e+ fiber spool (b).

Phase noise measurements were carried out for various laser configurations (Fig.1b). The spectral density of the phase noise only for the only 60-mm DFB laser is indicated by the red line, for the DFB laser combined with a 25-km SMF-28e+ fiber spool spliced to the resonator is indicated by the blue line, and the black line is the value for the DFB laser combined with fs-pulse inscribed Rayleigh reflector. The dotted lines correspond to the Lorentzian profile with different linewidths (from 1 Hz to 1 kHz). To measure the linewidth, we used a method based on recording the beating signals of the laser passing through a Mach-Zehnder interferometer with a delay line of 4.6 km [5]. As one can see, a hybrid DFB+RDFB cavity of relatively short length exhibits ultra-narrow (<100 Hz) linewidth coupled with unique phase noise characteristics, similar to those obtained when using the same DFB Er-doped fiber laser supplemented with 25-km SMF-28e+fiber spool. In the conference report, we will discuss the details of the laser fabrication and characterization, as well as potential applications of such laser sources.

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