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Wavelength-switchable L-band fiber laser assisted by ultrafast laser fabricated random reflectors

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Abstract. A wavelength-switchable L-band erbium-doped fiber laser (EDFL) assisted by an artificially controlled backscattering (ACB) fiber reflector is here presented. This random reflector was inscribed by femtosecond (fs) laser direct writing on the axial axis of a multimode fiber with 50 µm core and 125 µm cladding with a length of 17 mm. This microstructure was placed inside a surgical syringe to be positioned in the center of a high-precision rotation mount to accurately control its angle of rotation. Only by rotating this mount, three different output spectra were obtained: a single wavelength lasing centered at 1574.75 nm, a dual wavelength lasing centered at 1574.75 nm and 1575.75 nm, and a single wavelength lasing centered at 1575.5 nm. All of them showed an optical signal-to-noise ratio (OSNR) of around 60 dB when pumped at 300 mW.

1 Introduction

Femtosecond (fs) laser writing has become an effective way to process any type of transparent optical material, such as silica optical fibers [1]. This technology enables the microfabrication of numerous fiber structures with excellent properties for a wide range of practical applications [2]. In particular, the development of fiber-optic microstructures based on refractive index (RI) modification under fs-laser irradiation has resulted in different implementations in the field of optical fiber sensors: surrounding refractive index sensors, strain sensors, curvature sensors, or multiparameter sensors [3]. These artificially controlled backscattering (ACB) fiber reflectors have been shown to have similar temperature sensitivity to traditional FBGs. However, the strain sensitivity can be improved by more than an order of magnitude when comparing these quasi-randomly distributed reflective microstructures with FBG-based sensors [4]. Here, an ACB fiber reflector inscribed by fs laser direct-write technique is used into an L-band erbium doped fiber laser (EDFL). This random reflector was inscribed on the axial axis of a 50/125 multimode fiber (MMF), with a length of 17 mm, and located into a high-precision rotation mount to control its angle of twist rotation. Only by rotating in a range of 8° the MMF sample where the RFG was inscribed, this wavelength-switchable EDFL can be switched among single and dual wavelength lasing.

2 Fabrication

The optical fiber inscription was carried out using a Cazadero fiber laser (Calmar Laser) that delivers 370 fs laser pulses at a central wavelength of 1030 nm. However, the light absorbed non-linearly by the fiber has a wavelength of 515 nm, due to the second harmonic generation (SHG) introduced in the setup, as shown in [5]. A pulse repetition rate of 150 Hz and a pulse energy of 0.75 µJ were used during the inscription. The laser pulses were tightly focused into the Ø50 µm core of a MMF using a 0.42 NA, 50× objective lens from Mitutoyo. The fiber was translated through the laser focus using a motorized nano-resolution XYZ stage from Aerotech.

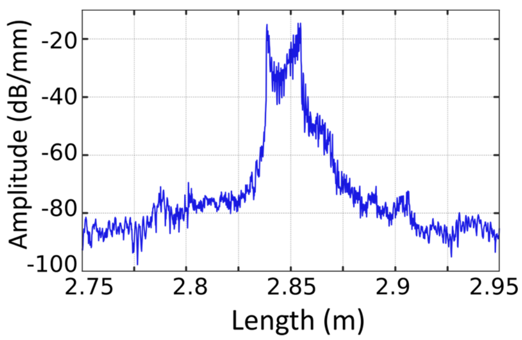

Fig. 1. Backscattered optical power as a function of fiber length for the MMF-RFG, located about 1.88 m from the connector of the OBR.

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This ACB-MMF reflector was written on the axial axis of the fiber with a random period between Λ_{min}=1.61085 µm and Λ_{max}=1.64230 µm and a total length of 17 mm. Although this is a random fiber grating (RFG) [6], the almost total periodicity of the optical structure gives rise to Bragg resonances which, in the third order (m=3), present reflection in the spectral band centered at around 1575.4 nm. Figure 1 presents the backscattered optical power as a function of fiber length for the inscribed ACB-MMF reflector characterized with an ultra-high resolution optical backscattered reflectometer (OBR).

3 Experimental setup

Figure 2 illustrates a schematic diagram of the L-band linear-cavity fiber laser experimental setup. A 976-nm pump power (Fig. 2(a)) was injected into the linear-cavity EDFL by means of a 980/1550 nm wavelength division multiplexer (WDM) (Fig. 2(b)). The gain medium was 5 meters of highly erbium-doped fiber (EDF) I25 (980/125, Fibercore Inc.) (Fig. 2(c)), with a peak core absorption ranges from 7.7 to 9.4 dB/m at 1531 nm [7]. This EDF was connected to the common port of the WDM and followed by a 3-ports optical circulator (Fig. 2(d)) in which ports 3 and 1 were connected to conform a fiber loop mirror (FLM), as in [7]. After passing through the highly EDF section again, the reflected signal from the FLM arrived to the 1550 nm-port of the WDM up to the optical coupler (Fig. 2(e)). Then, the signal is divided into two branches where 90% of the signal reached the MMF-RFG-based reflector and the other 10% was visualized with an OSA (Fig. 2(f)). The MMF-RFG was placed inside a surgical syringe so that it could be positioned in the center of the high-precision rotation mount (Fig. 2(g)) to accurately control its angle of rotation. A photograph of the RFG reflector inscribed by femtosecond laser writing is shown in Fig. 2(h).

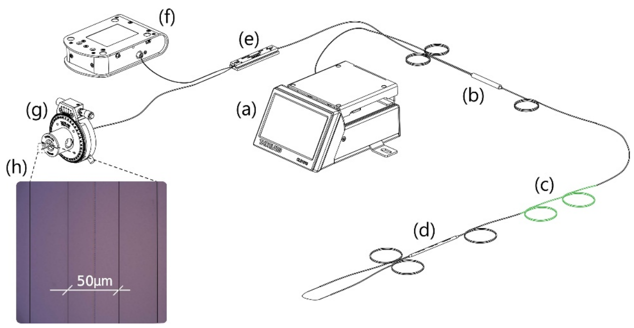

Fig. 2. Schematic diagram of the experimental L-band linear-cavity fiber laser setup

4 Results and discussion

Figure 3 shows the output spectra of the linear cavity EDF pumped at 300 mW when (a) single-wavelength laser emission centered at 1574.75 nm, (b) dual-wavelength laser emission centered at 1574.75 nm and 1575.53 nm, or (c) single-wavelength laser emission line at 1575.53 nm were obtained. By rotating the high-precision rotation mount where the multimode fiber-based reflector was located into a syringe, these three configurations can be easily reached. Output power levels of -1.02 dBm (Fig. 3(a)) and -1.85 dBm (Fig. 3(c)) were measured when single-wavelength laser emission was attained, both presenting an OSNR of 60 dB. On the other hand, when dual-wavelength laser emission was achieved, an output power level around -5 dBm and an OSNR of 58 dB was measured (Fig. 3(b)). As expected, by increasing the number of lasing wavelengths the output power values of the lasing emission lines decrease [8].

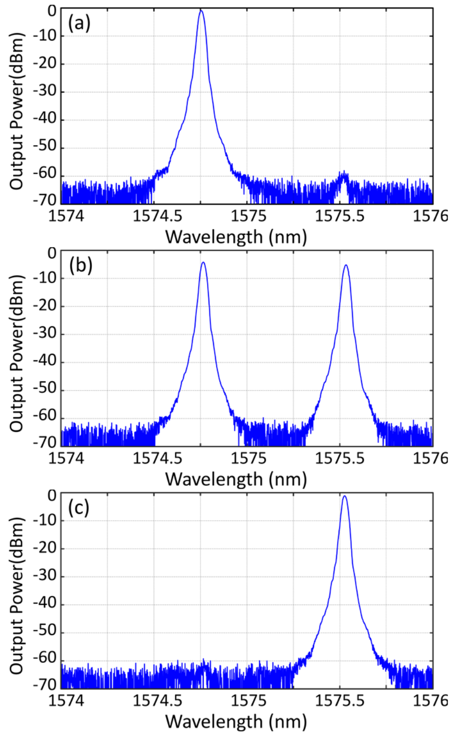

Fig. 3. Output spectra of the linear-cavity fiber laser when (a) single wavelength lasing centered at 1574.75 nm, (b) dual wavelength lasing centered at 1574.75 nm and 1575.75 nm, and (c) single wavelength lasing centered at 1575.5 nm are obtained.

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