Single-polarisation, single-frequency, 2 cm ytterbium-doped fibre laser

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A single-polarisation, single-frequency, ytterbium-doped silica fibre laser has been demonstrated in a 2 cm linear cavity. The output power reaches 35 mW with an optical signal-to-noise ratio greater than 65 dB. A polarisation-maintaining fibre Bragg grating is used as the polarisation-dependent reflector to generate the single-polarisation output with the polarisation extinction ratio greater than 20 dB. The laser works stably for 2 h under laboratory conditions.

Introduction: Fibre lasers show advantages of high reliability, fibre compatibility, high output power, narrow bandwidth, and low noise floor. These characteristics make them competitive alternatives to solid-state and semiconductor lasers. Single-frequency fibre lasers can be used for coherent communications, holographic imaging, optical data storage [1], laser ranging [2], and interferometers [3]. In 2004, a single-frequency, custom phosphate glass fibre laser was demonstrated with 200 mW output power [4]. Using custom photosensitive Er/Yb-doped fibre, single-polarisation, single-frequency output was generated in both distributed feedback (DFB) and distributed Bragg reflector configurations [5]. In another experiment, a Fabry-Perot cavity composed of Faraday-rotator mirrors is used to generate the single-polarisation, single-frequency fibre laser output [6]. In 1999, injection locking was used to make a DFB fibre laser work in a single polarisation [7]. In this Letter, we demonstrate, for the first time, a single-frequency, single-polarisation silica fibre laser with a polarisation-maintaining fibre Bragg grating (PM-FBG) in a short linear cavity. The fibre laser works with a single-frequency, single-polarisation output under all pump levels, and is made from commercially available fibre and components.

**Experimental setup:** The experimental setup of the single-polarisation, single-frequency laser is shown in Fig. 1. A wavelength division multiplexer (WDM) is used to couple the 976 nm pump light into the laser gain medium. The 1.5 cm active silica fibre is highly doped with ytterbium with an absorption rate of 1700 dB/cm at 976 nm. It is spliced between two FBGs. The singlemode (SM) FBG has a centre wavelength of 1029.5 nm and a peak reflectivity of 99%. The 3 dB bandwidth is 0.46 nm. The PM-FBG has different modal refractive index along the orthogonal fast and slow axes, which enable the two reflection wavelengths with 0.3 nm spacing. Both reflection bands have 3 dB bandwidths of 0.06 nm and show reflectivity of 55% at the corresponding wavelengths. The environment temperature is 22 °C and the thermal controller is set to 50 °C. The measured transmission spectra of the SM-FBG at 50 °C and the PM-FBG at 22 °C are shown in Fig. 2. An amplified spontaneous emission source was used as the broadband seed in the measurement. Overlapping of the spectrum of FBGs by temperature tuning is used to generate the single-frequency, single-polarisation output. With the thermal controller on the SM-FBG, its reflection band is tuned to overlap the wavelength peak of 1029.4 nm of the PM-FBG. The other peak of the PM-FBG lies outside the reflection band of the SM-FBG.

**Results and discussion:** The laser output power has been measured from the PM-FBG with a power meter. The laser pump threshold is 10 mW. With a commercial laser diode pump of 490 mW, the laser output power reaches 35 mW. Higher efficiency can be achieved by optimising the reflectivity of the PM-FBG. The optical signal-to-noise ratio (OSNR) of the laser output has been measured with an optical spectrum analyser to be greater than 65 dB, as shown in Fig. 3. There is only one lasing mode in the whole spectrum of the ytterbium gain band.

The singlemode behaviour of the fibre laser has been verified with a scanning Fabry-Perot (F-P) spectrometer. The FSR is 30 GHz and the finesse is ~150, giving a resolution of about 200 MHz. Since the mode spacing of the laser cavity is approximately 5 GHz, the lasing modes of the cavity can be well resolved by the F-P cavity. Fig. 4 shows the single-frequency laser spectrum from the scanning F-P cavity. Although three F-P modes can be supported in the 3 dB reflection band of the PM-FBG, the curvature of the PM-FBG reflection spectrum provides sufficient longitudinal-mode discrimination to enable only a singlemode to operate at each polarisation. In the measurement, no mode hopping is observed.

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The state of polarisation of the laser has been measured with a quarter-wave plate, a polariser, and a power meter. The quarter-wave plate is put between the laser output end and the polariser to turn the lasing light into linearly polarised light, since the WDM is not a polarisation-maintaining (PM) WDM. The single polarisation has been verified. The polarisation extinction ratio is measured to be greater than 20 dB under different pump levels. The laser operates stably in single frequency and single polarisation in terms of power variation and wavelength drift. Over a 2 h time period, the power rms deviation is < 0.9% and the peak-to-valley wavelength drift is < 0.02 nm.

**Conclusion:** A single-polarisation, single-frequency, ytterbium-doped silica fibre laser has been demonstrated in a 2 cm linear cavity. The output power reaches 35 mW with an OSNR greater than 65 dB. A PM-FBG is used as the polarisation-dependent reflector to generate the single-polarisation output with the polarisation excitation ratio greater than 20 dB. The laser works stably for 2 h under laboratory conditions.

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References