Two-stage linearly-polarized ytterbium-doped fibre superfluorescent source with 106 W output power

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High power and high brightness broadband superfluorescent sources have applications in a number of areas including sensing, spectroscopy, medical imaging and metrology. One attractive way to generate broadband output is via the process of amplified spontaneous emission (ASE) in a rare-earth doped fibre. Fibre-based superfluorescent sources offer high efficiency, a wide range of operating wavelengths by employing different rare earth dopants and, via cladding pumping, the prospect of high output power. For some applications, the requirement for high power is also accompanied by the need for a linearly-polarised single-spatial-mode output beam. This combination of operating characteristics is more difficult to achieve and places extra demands on the fibre design and overall system design.

Here, we report a 106 W single-mode, single-ended fibre superfluorescent source with a linearly-polarized output beam based on a simple two-stage configuration comprising a cladding-pumped Yb-doped fibre superfluorescent seed stage and a polarization-maintaining (PM) cladding-pumped Yb-doped fibre amplifier stage. The experimental set-up is shown in Figure 1. The seed-stage comprised a 7-m-long Yb-doped double-clad fibre and a 15 W diode pump source at 915nm. The fibre had a 20-μm-diameter Yb-doped alumino-silicate core with a numerical aperture (NA) of 0.06, and a pure silica inner-cladding of diameter, 400-μm. The fibre was prepared with a perpendicularly-cleaved end-facet at the pump in-coupling end of the fibre and with an angle-polished end-facet (at ~10˚) at the opposite end of the fibre to suppress parasitic lasing and achieve a predominately single-ended output. At the maximum launched pump power of ~ 14 W, the seed-stage produced ~ 3W of broadband (unpolarised) amplified spontaneous emission (ASE) output from the angle-polished fibre end in a single-spatial-mode beam with an M^2 parameter of ~1.1. The output from the seed was passed through two Faraday isolators with a combined isolation of ~ -60dB to strongly attenuate any feedback from the power amplifier stage. This reduced the ASE power to ~ 840 mW due mainly to the polarization-related loss of the isolators.

The fibre power amplifier stage employed ~7.2 m ytterbium-doped double-clad PM fibre (supplied by Nufern) and a high-power 976 nm diode-stack pump source yielding a maximum incident pump power of 208 W. The fibre had a 20-μm-diameter core, a core NA of 0.06, an inner-cladding diameter of 400μm and a nominal inner-cladding NA of 0.48. The core birefringence was ~ 2×10^{-4}. Both ends of the fibre were angle-polished at ~ 10˚ to eliminate backreflection from fibre end facets. The fibre was end-pumped through one end-facet and the seed was coupled into the core at the opposite end of the fibre. A half-wave plate at ~ 1μm was used to align the seed beam polarization to the fast (or slow) axis of the PM fibre. A dichroic mirror was used to extract ASE output from the pump in-coupling end of the fibre. Figure 2 shows the amplified ASE output power as a function of launched pump power for different launched seed powers of 530mW, 390mW, and 10mW. For a seed power of 530mW, the maximum output power was 106 W for a launched pump power of 187 W. The polarization extinction ratio was measured to be 13.5 dB. The slope efficiency with respect to launched pump power was ~ 67%. When the launched seed power was reduced to ~10mW, the maximum output power was only slightly lower at 100 W, corresponding to a single-pass gain of 40dB. In all cases, the maximum output power was limited by the available pump power, and there was no evidence of parasitic lasing. The core of the PM fibre was slightly multimode with a V-parameter of ~3.6, so we employed bend-induced suppression of higher order modes with a bending radius of ~ 8 cm to ensure fundamental mode operation. Under these operating conditions, the beam propagation factor (M^2) was measured to be less than 1.1. The ASE spectrum spanned the wavelength range of 1035-1100 nm and 3dB bandwidth was 21 nm (i.e. from 1056 nm to 1077nm). The prospects for further improvement in performance will be discussed.

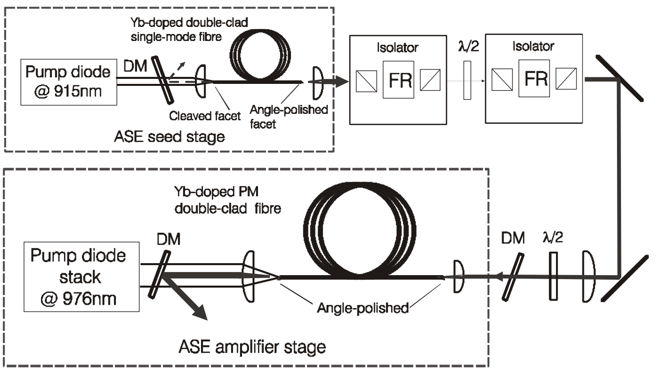

Fig. 1 Setup for the dual-stage fiber ASE source

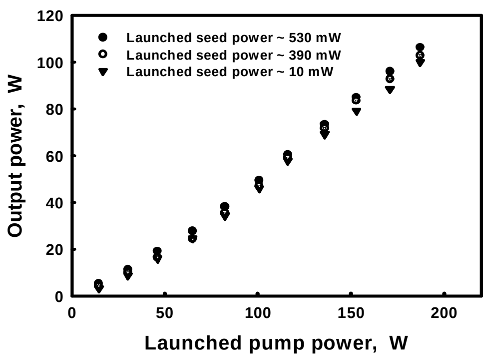

Fig. 2 ASE output power versus launched pump power