Ultra-broadband Wavelength Swept Tm-doped Fibre Laser

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Wavelength-swept laser sources with broad wavelength tunability and narrow instantaneous linewidth in the two-micron band have potential applications in a number of areas, including spectroscopic characterisation and optical coherence tomography (OCT). The use of OCT for non-invasive investigation of paintings to provide the information necessary for effective restoration and to aid conservation is one example of an emerging application where operation in two-micron band brings the advantage of increased penetration depth due to lower loss in commonly used pigments compared to the situation at near-infrared wavelengths. Tm-doped silica fibre lasers provide an efficient way to access the relevant wavelength region due to the wide emission line that extends from ~1700 nm to ~2100 nm. Unfortunately, wavelength tuning across the entire emission band with a single fibre gain stage is extremely difficult due to the combination of varying quasi-three-level character as a function of wavelength and gain saturation due to short wavelength amplified spontaneous emission. In order to access the full emission bandwidth potential of Tm-doped fibres, a different approach must be employed with two or more fibre gain stages and with each gain stage tailored to provide emission in complementary bands.

Here, we apply this design strategy to demonstrate a wavelength-swept Tm fibre laser with a wavelength scanning range of 330 nm. The laser configuration (shown in Fig.1) comprised two Tm fibre gain stages. One of these employed a relatively short length (~94 cm) of a low Tm concentration (~0.2 wt%) single-mode fibre with a 10 μm diameter core and was core-pumped by an Er,Yb fibre laser at 1565 nm to provide emission towards shorter wavelength end of the Tm emission band. The second Tm fibre gain stage employed a longer length (~3m) of more highly-doped (~2 wt%) double-clad fibre with an 11 μm diameter core and a 125 μm diameter D-shaped pure silica inner-cladding. The latter was cladding-pumped at 793 nm providing access to the long wavelength end of the Tm emission band. Feedback for lasing was provided by the Fresnel reflection from perpendicularly-cleaved facets at the output end of the fibres and at the other end by external cavity arrangements containing replica diffraction gratings with 600 lines/mm for wavelength discrimination and a common rotating polygon mirror for sweeping the lasing wavelength [1]. The alignment of the external cavities was adjusted to yield a small spectral overlap in emission and to synchronise the wavelength scans from both lasers. The output beams from the two lasers were spectrally-combined with the aid of a dichroic mirror. Under the manual tuning, the core pumped laser had a tuning range from ~1730 nm to 2000 nm and cladding-pumped laser could be tuned from ~1940 nm to 2100 nm. In wavelength-scanning mode the source yielded a combined output power of over 500 mW and the wavelength could be swept from 1750 nm to 2080 nm at 300 Hz sweep rate (see Fig. 1). This is believed to be the widest wavelength tuning range reported to date for a Tm fibre laser and, with further optimisation, it should be possible to extend this to ~400 nm. During wavelength sweeping the Tm fibre laser is prone to self-pulsing due to temporal variation in cavity loss and gain leading to rather noisy behaviour. To remedy this problem, we have explored the use of an intracavity etalon in the external cavity. This leads to a stable pulse train with step-wise wavelength sweeping of one free-spectral-range per pulse and narrow instantaneous linewidth (<0.1 nm). The prospects for improvement in performance will be discussed.

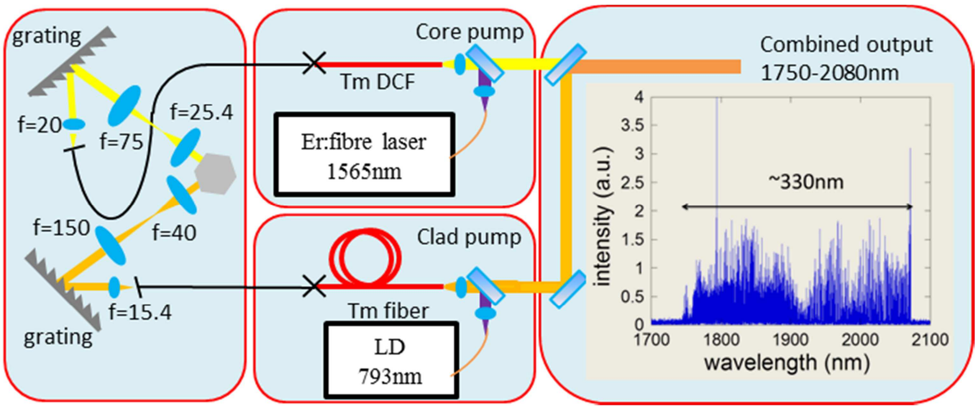

Fig. 1 Schematic diagram of wavelength-swept Tm fibre source with the corresponding time-averaged wavelength spectrum.

References

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