Null-frequency-shift acousto-optic tunable filter for wavelength tuning of a Tm fibre laser

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Acousto-optic tunable filters (AOTFs) are used in many applications where fast agile tuning capabilities combined with conservation of spatial coherence are required; such as for selection of wavelength from a broadband source for applications in confocal microscopy, hyperspectral imaging and spectroscopy [1]. For generation of higher spectral intensity they can also be used inside a laser cavity in order to select the operating wavelength [2]. AOTF's utilise a travelling acoustic wave to diffract phase-matched wavelengths, with the diffracted wave frequency-shifted by the acoustic drive frequency. When used intracavity as a tuning element in a fibre laser, this continual wavelength shift on each pass through the AOTF has a number of undesirable consequences including, poor power stability and, in some situations, pulsing, which can lead to damage.

Here we report on a wavelength-tunable Tm-doped silica fibre laser employing a novel AOTF with no frequency shift as the tuning element. The fibre laser configuration, shown in Fig.1, comprises a 6-m length of double-clad Tm-doped silica fibre with a 10µm diameter core surrounded by a quasi-octagonal silica cladding with a flat-to-flat distance of 190µm. Feedback for lasing was provided by a perpendicularly-cleaved fibre facet at the output end of the fibre and at the opposite end by an external feedback cavity containing the null-frequency-shift AOTF. The latter comprises two TeO_2 AOTFs in series operating in opposite quadrants of the k-space diagram. Essentially the first provides a positive wavelength shift and the second a negative shift. This matching leads to true reciprocity and gives a zero net frequency shift whilst maintaining excellent pointing stability. Pump light was provided by a fibre-coupled 793nm laser diode free-spaced coupled into the end of the Tm fibre adjacent to the feedback cavity using a dichroic mirror. A relatively high Tm concentration of 4 wt% was used to promote the two-for-one cross-relaxation process to enhance the efficiency. The AOTF's were driven from by a common RF driver via a 3dB splitter to ensure matched frequency operation. The reflected wavelength was controlled by varying the RF drive frequency from 50.3MHz to 55.1MHz corresponding to a change in feedback wavelength from 2115nm to 1940nm respectively.

Using this arrangement, the fibre laser wavelength could be tuned from 1940nm to 2115nm with a spectral bandwidth of <0.5nm (FWHM)(see Fig.2). The laser yielded a maximum output power of 22W at 2030nm limited by pump power and has preliminarily shown >2x reduction in the power instability. The slope efficiency with respect to absorbed pump power was 55%, with an additional ~ 7% of the generated laser power lost into the rejected-non-diffracted beams of the AOTF pair. Further improvement in overall efficiency should be achievable via optimisation of the AOTF design to increase diffraction efficiency and through the use of a polarisation-maintaining Tm-doped fibre. The availability of high spectral brightness and wavelength versatile sources with high power stability in the 2µm region will benefit a range of applications in spectroscopy, remote sensing and processing of polymers.

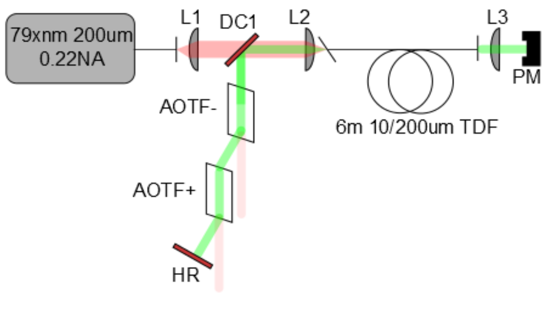

Fig 1. System schematic showing the Tm fibre laser with AOTF pair providing wavelength selective feedback.

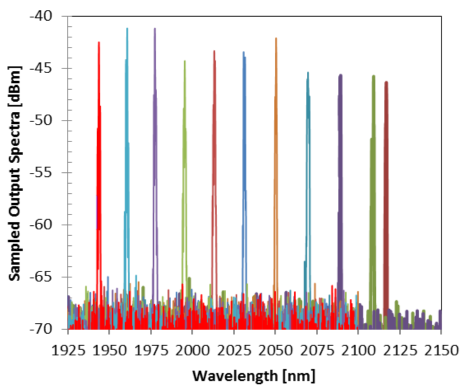

Fig 2. Example output spectra from the rapidly configurable wavelength tuning of the null-frequency shift AOTF

References

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