Simple scheme for active mode selection in a multimode fibre oscillator

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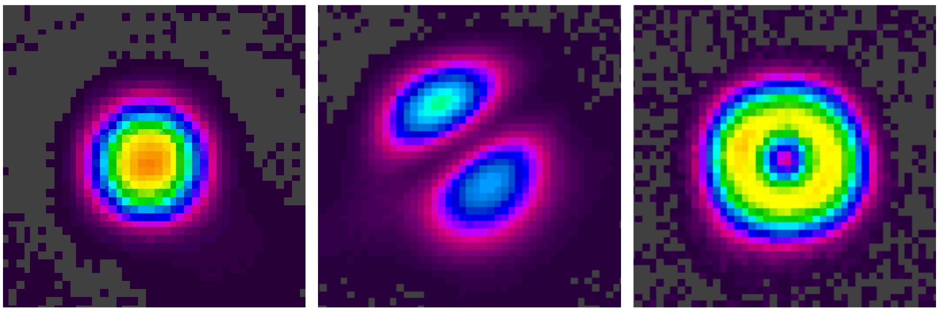
Operation of fibre lasers on individual higher order transverse modes has many attractions from a power scaling perspective. These include a higher threshold for unwanted nonlinear loss processes, reduced sensitivity to mode skew [1], as well as the prospect of improved energy extraction in pulsed systems. Moreover, it has also been shown that in some laser processing applications the use of doughnut-shaped beams [2] or beams with a dynamically adaptable transverse profile can yield substantially higher processing speeds. However techniques for selecting individual higher order modes in multimode fibre oscillators are often quite difficult to implement and lack the flexibility to switch between modes to suit the application.

Here we present a simple technique for mode selection in a multimode fibre laser that allows electronically controllable selection of individual transverse modes and relatively fast switching between modes. Our approach exploits the different spectral responses of in-fibre Bragg gratings (FBGs) in a multimode core and an acousto-optical tunable-filter (AOTF) to simultaneously achieve wavelength selection and spatial mode selection in a simple fibre laser with an external feedback cavity. This approach has been applied to a core-pumped Tm-doped silica fibre laser with a multimode core to selectively excite the fundamental mode (LP01) or the next higher order mode (LP11) or the doughnut-shaped hybrid LP11 mode at power levels in excess of 3 W by simply adjusting the RF drive frequency to the AOTF. Fast switching between LP01 and LP11 mode at ~kHz repetition rates was also realised.

The experimental layout consisted of a ~35cm long Tm,Ge co-doped fibre with an effective core diameter and numerical aperture of 18 µm and 0.22 respectively. The calculated V-number of this fibre was 6.3 and hence the fiber could support a number of modes. A FBG was written directly into the core of the active fibre to provide feedback. The estimated reflectivity and bandwidth of the FBG was 20% and 0.1 nm respectively with a Bragg resonance for the fundamental mode at 1926.3 nm. Feedback for lasing at the opposite end of the fibre was provided by an external cavity consisting of an AOTF and a high reflectivity mirror arrangement. The laser output was derived from the zero-order beam from the AOTF. The Tm fibre was core-pumped by a commercial 1565nm Er,Yb fibre laser with a maximum of 11.5W launched pump power.

By tuning the AOTF across the band corresponding to the wavelength range for the Bragg resonance conditions for various transverse modes in the FBG, lasing on the fundamental or higher order modes could be achieved. Figure 2 shows the output beam profiles for selective lasing on the LP01 (fig 2.a), LP11 (fig 2.b) and hybrid LP11 (fig 2.c) all with output powers above 3W. By switching the RF drive frequency and hence the AOTF wavelength from λ_{LP01} to λ_{LP11} we were able to switch between the LP_{01} and LP_{11} modes with a switching speed only limited by the AOTF acoustic-wave build-up time of ~20µs. Repetition rates ranging from DC to the kHz regime were realised.



(a) **(b)** **(c)**

Fig. 1 Output beam profile for AOTF tuned to (a) $LP0_{01}$, (b) LP_{11} and (c) hybrid LP_{11} doughnut mode

In summary, we have demonstrated a novel electronically controllable multimode fibre laser with modal content that can be controlled and modulated at rates up to the kHz level without moving parts. This technique allows flexibility in transverse mode output from a multimode fiber laser allowing dynamic control of modal content to suit advanced laser processing applications. The prospect of further increase in output power and extension to even higher order modes will be discussed.

References

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[2] M. Meier, V. Romano, and T. Feurer, "Material processing with pulsed radially and azimuthally polarized laser radiation," Applied Physics A **86**, 329-334 (2006).