Hollow-core anti-resonant fibres for transmission of high peak power laser light: impact of coupling misalignment

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Various designs of hollow-core optical fibres have been in use for many years. In principle, they allow propagation with both ultra-low loss and ultra-low nonlinearity by guiding light in air rather than in a solid material. They also provide significantly higher laser-induced damage thresholds and can transmit at wavelengths at which the cladding material is opaque. In particular, the relatively new negative-curvature anti-resonant fibres (NC-ARFs) can have exceptionally high laser damage thresholds, thanks to a very small area of overlap between the propagating mode and glass cladding structure [1]. NC-ARFs are hence very promising for high-power laser beam delivery, and indeed ultra-short pulsed flexible delivery systems based on these fibres have been commercialised [2]. However, in order to obtain high damage threshold the laser-fibre coupling arrangement is vitally important.

We present a detailed study of the coupling efficiency of selected NC-ARFs as a function of lateral and angular misalignment. NC-ARFs with two different structures have been investigated, together with a standard single mode step-index fibre as a benchmark. We show that it is essential to control the lateral position to $\pm$x μm and angular alignment to $\pm$y μrad. This knowledge is necessary in order to design a suitably robust laser-fibre coupling system that can operate in a dynamic manufacturing environment. It is worth noting that both of the NC-ARFs analysed are less sensitive to input coupling misalignment than the single mode step-index fibre.

[1] J.D. Shephard, A. Urich, R. Carter, P. Jaworski, R.R.J. Maier, W. Belardi, F. Yu, W.J. Wadsworth, J.C. Knight, D.P. Hand (2015) Silica hollow core microstructured fibers for beam delivery in industrial and medical applications, Frontiers in Physics, Vol. 3 Art. 24

[2] Photonic Tools, https://www.photonic-tools.de/products/llk-ultrafast/