Fibre-tip microfabrication by ultrafast laser assisted etching

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Optical fibre technology is utilised for an abundance of applications in fields including telecommunications, built environment, remote sensing and medical instrumentation to name just a few. Optical fibres are inexpensive, flexible and narrow - offering access to otherwise inaccessible areas for sensing and diagnostics at a distance. Ever improving fibre design, manufacture, materials and photonic techniques continue to accelerate fibre optic adoption further still. One practical limitation of optical fibre implementation often arises at the fibre tip, where manipulation of the light for the intended application requires bulky optics and alignment mechanics, much larger than the fibre cross-section. Fibre tip components are typically fabricated using traditional manufacturing techniques and assembled manually by means of labour-intensive active alignment.

We propose that a laser-based glass microfabrication technology is ideally suited to manufacturing components for fibre tip instrumentation. The technique relies on ultrashort laser pulses to inscribe three-dimensional structures in fused silica glass, which are subsequently removed by selective chemical etching. Commonly referred to as ultrafast laser assisted etching (ULAE), when optimised, the laser modification can enhance the etching rate by 1000 times[1], enabling unrivalled fabrication design freedom and tolerance precision. Additionally, several features can be fabricated on a single substrate, offering a simple solution for aligning components passively.

To demonstrate this potential, we present fibre-coupled turning mirrors for gap-sensing[2] and tilt-detection for structural health monitoring with sensitivities of 5 nm and 0.014 mrad respectively, and passively aligned microlenses for fibre coupling applications ranging from astronomy to therapeutics. We further investigate the feasibility of fabricating optical components directly within the core and cladding of single and multicore optical fibres – demonstrating turning mirrors with an aperture of just 30 μm.

[1] C. A. Ross, D. G. MacLachlan, D. Choudhury R. R. Thomson, “Optimisation of ultrafast laser assisted etching in fused silica,” 2018, Opt. Express 26(19), 24343

[2] T. Y. Cosgun, A. Dzipalski, C. A. Ross, R. R. Thomson, M. Kingston, S. Brooks and W. N. MacPherson, "Sub-mm Gap Sensor Using Fibre Optic Fabry-Perot Interferometry for Long-Term Structural Health Monitoring," in 2020 IEEE Photonics Conference (IPC), Vancouver, Canada