Femtosecond Laser-Inscribed Components for Mid-Infrared Fibre Lasers Systems

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The development of a worldwide optical telecommunications network was enabled by the availability of reliable and low-loss optical fibers as well as by the development of fiber-coupled (i.e. "pigtailed") integrated optical components that can provide additional functionalities. For operation in the telecommunications band at near-infrared (IR) wavelengths around 1550 nm, silica-based glasses offer unmatched performance and represent the backbone of modern photonics technology.

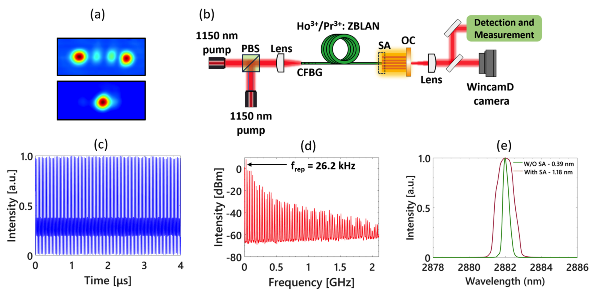

Figure 1: (a) Output beam profiles at low (top) and high (bottom) input peak power (b) the layout of the fiber laser cavity in which a 2D GLS waveguide array is used as a SA (c) pulse train (d) RF spectrum and (e) optical spectrum of the mode-locked laser

On the other hand, mid-IR photonics is regarded as an emerging and enabling technology as light at those longer wavelengths (≈3–20 µm) is absorbed by virtually all molecules, giving rise to fundamental (hence strong) and characteristic rotational/vibrational features that can be exploited in applications like environmental monitoring, chemical threat detection or material processing, to only name a few. While silica glasses are opaque in the mid-IR, optical fibers made of fluoride-glasses have recently reached a level of maturity that marks a transition from research to real-world applications. However, what is still needed is the development of integrated optical components that can be fiber-pigtailed to commercial fluoride fibers and that can provide additional functionalities that are needed for mid-infrared fiber laser systems, ranging from simple wavelength-dependent couplers and pump combiners to nonlinear saturable absorber chips for mode-locked lasers.

In this talk, we will present an overview of our work in utilising tightly focussed femtosecond laser beams to inscribe photonic structures into mid-infrared transparent glasses. We will demonstrate that a combination of advanced micro- and nano-analytical characterisation techniques can be utilised to unlock the physical mechanisms that underpin the induced change in refractive index in transparent dielectric materials upon femtosecond laser irradiation. Equipped with this knowledge, we show that a targeted compositional re-design of the glass composition of commercial fluoride glasses can enable the fabrication of optical waveguides with record-high numerical aperture (NA) and demonstrate how these waveguides can be used as the building blocks for advanced photonic circuits.

Further, we will present the design and experimental realisation of a saturable absorber for mode-locked mid-infrared fibre lasers. The device is based on an array of nonlinearly coupled waveguides that were femtosecond laser-inscribed into Gallium Lanthanum Sulphide (GLS) glass and inserted into a Ho^{3+}/ Pr^{3+} fibre laser cavity as shown in Fig. 1.

Finally, we will discuss the direct femtosecond laser-inscription of Fibre Bragg Gratings (FBGs) as well as Tilted Fibre Bragg Gratings (TFBGs) for in-fibre mirrors as well as for dispersion- and polarisation control in fibre lasers.