Thesis summary

Candidate : Andreas IOANNOU
Title : "Femtosecond laser inscribed all-in-fiber components for sensing applications"

Cyprus University of Technology Supervisor: Prof. Kyriacos Kalli,
UMONS Supervisor : Prof. Christophe Caucheteur

Optical fibers are flexible waveguides, widely used in the telecommunications sector, where they allow transmission over longer distances and at higher bandwidths than conventional cables. Fibers are used instead of metal wires because of their low loss, light weight and small dimensions. Furthermore, they are also not affected by electromagnetic interference and can be used for sensing purposes.

In practice, different external effects may affect the fiber sensor and prevent a correct measurement to be taken (one that is independent of multiple effects, e.g. temperature or axial strain effects…). For that reason, it is of paramount importance to have the ability to demodulate cross-sensitivity issues and this is where the femtosecond laser implementation is highly relevant. With the femtosecond laser Plane-by-Plane technique, we create multiple, complex structures collocated in the same laser-processed region and enable the selective measurement of various, potential external perturbations. The flexibility and control of all the inscription parameters allows for the fabrication of customized all-in-fiber components that can provide reliable measurements on changes in the surrounding refractive index of the ambient medium, along with separate measurements for all the relevant physical parameters (temperature, strain, bending and torsion). Our ultimate goal is to combine the available sensing avenues that we will produce and if possible, eliminate the cross-sensitivity issues that may arise during practical implementations of specialized optical fiber sensing devices.

Through the inscription of higher order gratings, excitation of Leaky Mode Resonances (LMRs) was achieved. The femtosecond laser inscription triggers the interaction between the fiber's guided mode and backward coupling to the LMRs, a process that requires tight control of the grating period, reflection angle, order and the strength of the modified refractive index. The TFBG itself exhibits very low spectral polarization dependence, whereas the LMRs display strong polarization dependence in specific wavelength ranges, allowing for easy mode selection and opening avenues for various applications related to sensing and optical filtering. The tailored-for-LMR-generation optical filters were characterized for torsion, temperature and strain. When compared with the grating response, this led to an exceptionally large strain response and a remarkably well-behaved conversion matrix for the separation of strain and temperature in a single measurement. The nature of LMRs is considered and confirmed by measuring their radiation field using an infrared camera, simulating and computing their resonance wavelength using a finite element method and by experimentally observing their behaviour, while changing the ambient refractive index.

Finally, we have also considered the fabrication of Mach-Zehnder Interferometers that can support a fully functional FBGs. The devices exhibit responses to changes in temperature, strain, bend, surrounding refractive index and relative humidity. This hybrid configuration is capable of

measuring multiple parameters using the same demodulation equipment, with very high sensitivity, while minimizing cross-sensitivity issues.