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High-accuracy measurement of refractive index difference for fiber laser applications

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Abstract: We report on a quantum-based measurement of index difference for fiber laser applications. Based on an interferometric setup, we demonstrate a state-of-the-art high-accurate measurement of $\Delta n = 5,0.10^{-4} \pm 1.10^{-5}$ thanks exploitation of peculiar properties of quantum photonics.

The development of fiber laser relies on the accurate knowledge of the refractive index difference [1]. Quantum metrology is one of the promising field enabled by quantum technologies. It allows to get precise results compare to classical methods when measuring physical properties. A very common approach is to inject non classical states of light in interferometers to increase accuracy as well as sensitivity. Recently, this scheme has been used for detecting gravitationnal waves for example [2]. Here, our goal is to take benefits of these capabilities to gather optical fiber photonic engineering with quantum optics to present high-accuracy and dispersion-free measurement of refractive index difference in original optical fibers. This knowledge is required in several fields of interest as in high- density energy transport in large mode area optical fibers. The conception of such fibers has become a very challenging technological issue based on a 10^{-5} precision knowledge of the used materials refractive index [1]. Our work is a step forward to break down the barriers of essential technologies for developping the next generation of fiber laser.

The principle of the method is based on quantum optical coherence tomography (QOCT). We perform a Hong-Ou-Mandel (HOM) measurement of the relative delay between broadband photon pairs. We generate entangled photon pairs in a periodically poled lithium niobate waveguide. The photons are directed to a Michelson interferometer in which one arm is the length-tunable free-space reference, and the other comprises the fibre under test. In our experimental arrangement, we observe quantum interference of two kinds. First, when indistinguishable photons return back to the beam-splitter (BS), they bunch together via Hong-Ou-Mandel (HOM) interference. In our case, this leads to the observation of a HOM peak. In order to measure refractive index differences, we use a dual-core FUT where each core was produced with slightly different parameters. By moving step-by-step the fibered arm using a nano-positionner, one can play on the photons indistinguishability, and by a simple coincidence measurement scheme describe the typical figure of merit showed in figure 1. Doing the same measurement one core after the other, it is possible to infer the index difference between the two materials that composed the two cores. We measured a test optical fiber to validate our approach and have found $\Delta n = 5,0.10^{-4} \pm 1.10^{-5}$.

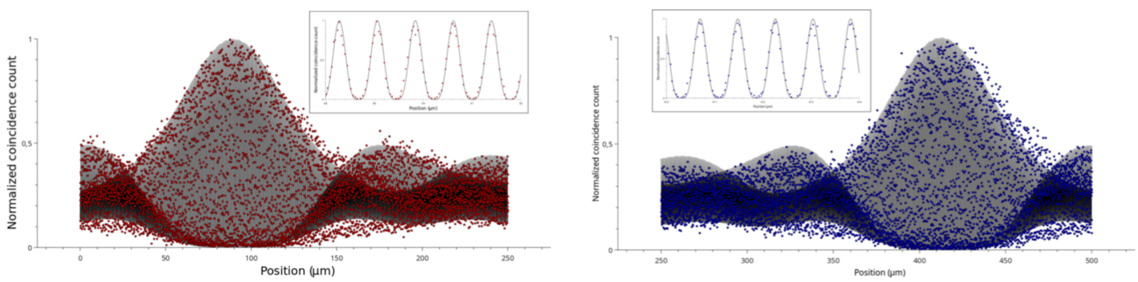

Fig. 1. HOM measurement showing coincidence counts versus the nano-positionner position.

1. R. Dauliat *et al.*, *Demonstration of a homogeneous Yb-doped core fully aperiodic large-pitch fiber laser*, Applied Optics **55** (2016).
2. B. P. Abbott *et. al.*, *Observation of Gravitational Waves from a Binary Black Hole Merger*, Phys. Rev. Lett. **116**, 061102 (2016).