MASTER INTERNSHIP M2 PPN (5 months)

2023-2024

Title of the project: Topological localized structures in pocket-size fibre Kerr resonators

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Laboratory / Department / Team : ICB, team Safir

Collaborations: The University of Auckland, ULB Brussels, Max Planck for the Science of Light

Summary: Optical frequency combs (OFCs) are light sources which emit a broad and coherent spectrum made of discrete and evenly spaced frequency lines. They can act as “spectral optical rulers” that enable to measure unknown optical frequencies with extraordinarily high precision. Frequency comb systems commercially available mainly rely on bulky ultrashort-pulse lasers and supercontinuum technologies. However, a fundamentally different approach was demonstrated in 2007, when continuous laser light was shown to be transformed into an evenly-spaced comb when confined into a nonlinear Kerr microresonator. It is now well understood that such OFC generation in nonlinear Kerr resonators is mostly based on the emergence of robust, localized temporal structures, called dissipative cavity solitons (CSs), which are able to emerge through the dual-balance between chromatic dispersion & Kerr nonlinearity on the one hand and loss & coherent driving on the other hand. First observed in a macroscale optical fibre ring and demonstrated subsequently in a whispering-gallery-mode microresonators, CSs have attracted growing interest over the past decade and have led to major advances in numerous fields of science such as massively multiplexed optical communications, optical buffering, astrocombs, topology, spectroscopy or microwave generation. However, while CSs emerging from fibre loops support moderate spectral extent for OFCs applications, microcombs emerging from integrated ring platforms are mostly restricted to wavelength or materials with anomalous GVDs and are characterized by repetition rates ranging from tens of GHz to multiple THz, which could appear detrimental for specific applications such as high-resolution spectroscopy or GHz-microwave processing. Complementary to these ring architectures, Fabry–Perot (FP) Kerr mesoresonators made of few cms of optical fibre encapsulated in-between dispersive mirrors represent a promising and versatile approach for advanced OFCs generation. First, their native repetition rates range from hundreds of MHz to tens of GHz, thus bridging the gap between macroscale fibre loops and integrated microresonators. Furthermore, they combine the flexibility and stability of fibre-based systems as well as dispersion engineering of integrated platforms, whilst preserving interestingly high-Quality factors. First exploited in 2017 in pulse-driving regime for the generation of CSs, FP Kerr resonators have nowadays gained a boost of interest with a plethora of opportunities for dispersion engineering and system scalability. In this project, we will develop versatile and pocket-size GHz-FP Kerr resonators for advanced OFCs generation. In particular, we will investigate the vectorial nature of light in normal GVD FP resonators pumped in the 1.55 µm telecom band. We will show that the circulating light can spontaneously break its symmetry between the two polarization modes of the cavity and forms topological vectorial localized structures which can propagate endlessly in the resonator.

<u>References</u>

B. Garbin, J. Fatome *et al.* Phys. Rev. Lett. 126, 023904 (2021).
G. Xu, J. Fatome *et al.* Nature Communications 12, 4023 (2021).
N. Englebert, J. Fatome *et al.* Nature Physics, 19, 1014, (2023).
J. Fatome *et al.* arXiv:2106.07642 (2021).

Type of project (theory / experiment): Numerical and experimental

Required skills: Good knowledge in nonlinear fibre optics & Matlab