Auto-setting breather mode-locked fibre laser

Xiuqi Wu[1], Junsong Peng[1], Sonia Boscolo[2,*], Yu Zhang[1], Christophe Finot[3], and Heping Zeng[1]

[1] 1State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China

[2] Aston Institute of Photonic Technologies, Aston University, Birmingham B4 7ET, UK

[3] Laboratoire Interdisciplinaire Carnot de Bourgogne, Université de Bourgogne-Franche Comté, 21078 Dijon Cedex, France

[*] *s.a.boscolo@aston.ac.uk*

Abstract

In addition to their growing use as sources of ultrashort pulses for many applications, mode-locked fibre lasers constitute an ideal platform for the fundamental exploration of complex nonlinear wave dynamics. However, harnessing pulse generation from a fibre laser is a challenging task as reaching a specific mode-locked regime generally involves adjusting multiple control parameters, in connection with a wide range of accessible pulse dynamics. Machine-learning strategies and the use of evolutionary and genetic algorithms, which are well-suited to the global optimisation problem of complex functions, have recently shown promising for the design of smart lasers that can tune themselves to desired operating states [1, 2]. Yet, existing machine-learning tools are mostly designed to target laser generation regimes of parameter-invariant, stationary pulses, while the intelligent excitation of evolving pulse patterns in a laser remains largely unexplored.

Breathing solitons form an important part of many different classes of nonlinear wave systems, manifesting themselves as localised temporal/spatial structures that exhibit periodic oscillatory behaviour. Recently, they have also emerged as an ubiquitous mode-locked regime of ultrafast fibre lasers [3, 4]. These nonlinear waves are attracting considerable research interest by virtue of their connection with a range of important nonlinear dynamics, such as exceptional points, the Fermi-Pasta-Ulam paradox and rogue wave events [5]. In this talk, we demonstrate an evolutionary algorithm for the self-optimisation of the breather regime in a fibre laser cavity mode-locked through a four-parameter nonlinear polarisation evolution [6]. Depending on the specifications of the merit function used for the optimisation procedure, various breathing-soliton states are obtained, including single breathers with controllable oscillation period and breathing ratio, and breather molecular complexes with a controllable number of elementary constituents. Our work opens up a novel avenue for the exploration and optimisation of complex dynamics in nonlinear systems.

References

[1] Woodward RI, Kelleher EJR. Towards 'smart lasers': self-optimisation of an ultrafast pulse source using a genetic algorithm. *Scientific Reports* 2016, **6**(1): 1–9.

[2] Pu G, Yi L, Zhang L, Hu W. Intelligent programmable mode-locked fiber laser with a human-like algorithm. *Optica* 2019, **6**(3): 362–369.

[3] Peng J, Boscolo S, Zhao Z, Zeng H. Breathing dissipative solitons in mode-locked fiber lasers. *Science Advances* 2019, **5**(11): eaax1110.

[4] Peng J, Zhao Z, Boscolo S, Finot C, Sugavanam S, Churkin DV, Zeng H. Breather molecular complexes in a passively mode-locked fibre laser. *Laser & Photonics Reviews* 2021, Accepted for publication; arXiv:2103.16740 [physics.optics].

[5] Dudley JM, Dias F, Erkintalo M, Genty G. Instabilities, breathers and rogue waves in optics. *Nature Photonics* 2014, **8**(10): 755–764.

[6] Wu X, Peng J, Boscolo S, Zhang Y, Finot C, Zeng H. Intelligent breathing soliton generation in ultrafast fibre lasers. 2021, Submitted.