Recent machine-learning applications in ultrafast nonlinear fibre photonics

Sonia Boscolo[1], Christophe Finot[2] and Junsong Peng[3]
[1]*Aston Institute of Photonic Technologies, Aston University, Birmingham B4 7ET, United Kingdom*
[2]*Laboratoire Interdisciplinaire Carnot de Bourgogne, Université de Bourgogne-Franche Comté, 21078 Dijon Cedex, France*
[3]*State Key Laboratory of Precision Spectroscopy, East China Normal University, Shanghai 200062, China*
e-mail: s.a.boscolo@aston.ac.uk

Recent years have seen the rapid growth and development of the field of smart photonics, where machine-learning algorithms are being matched to optical systems to add new functionalities and to enhance performance. Ultrafast photonics areas where the promise of machine learning is being realised include the design and operation of pulsed lasers, and the characterisation and control of ultrafast propagation dynamics [1].

Here, we review our recent results and advances in the field, by describing the use of a supervised feedforward neural network (NN) paradigm to solve the direct and inverse problems relating to nonlinear pulse shaping in optical fibres, bypassing the need for direct numerical solution of the governing propagation model [2]. Specifically, we show how the network accurately predicts the temporal and spectral intensity profiles of the pulses that form upon nonlinear propagation in fibres with both anomalous and normal dispersion. Further, we demonstrate the ability of the NN to determine the nonlinear propagation properties from the pulses observed at the fibre output, and to classify the output pulses according to the initial pulse shape. We also expand our analysis to the case of pulse propagation in the presence of distributed gain or loss, with a special focus on the generation of self-similar parabolic pulses [3]. The network can accommodate to and maintain high accuracy for a wide dynamic range of system parameters. Our results show that a properly trained network can greatly help the characterisation and inverse-engineering of fibre-based shaping systems by providing immediate and sufficiently accurate solutions.

Further, we demonstrate an evolutionary algorithm (EA) for the self-optimisation of the breathing-soliton regime in a mode-locked fibre laser, based on the optimal four-parameter tuning of the intracavity nonlinear transfer function through electronically driven polarisation control [4]. We define compound merit functions relying on the characteristic features of the radiofrequency spectrum of the laser output, which are capable to locate various self-starting breather regimes in the laser, including single breathers with controllable breathing ratio and period, and breather molecular complexes with a controllable number of elementary constituents. Contrary to the generation regimes of stationary pulses of ultrafast lasers that have been mainly addressed by previous works using EAs, breathing solitons exhibit a fast evolutionary behaviour [5]. In this respect, our work opens novel opportunities for the exploration of highly dynamic, non-stationary operating regimes of ultrafast lasers, such as soliton explosions, non-repetitive rare events and intermittent nonlinear regimes [6].

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