Machine learning approach for nonlinear pulse shaping in optical fibres

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Pulse shaping relying on nonlinear phenomena in optical fibres has become a remarkable tool to tailor the spectral and temporal content of light signals. Yet, due to the typically wide range of degrees of freedom involved, predicting the behaviour of nonlinear pulse shaping can be computationally demanding, especially when dealing with inverse problems.

Here, we use a supervised machine-learning approach to solve both the direct and inverse problems relating to pulse shaping. The data from numerical simulations of the nonlinear Schrödinger equation (NLSE) is used to train a feed-forward neural network (NN) relying on the Bayesian regularisation back-propagation algorithm and validate its predictions. The NN learns the NLSE model from an ensemble of several thousand simulation data (both temporal and spectral) corresponding to a mix of initial pulse shapes and randomly chosen combinations of input parameters: normalised propagation length and soliton-order number. After training, the NN is tested on a distinct ensemble of data. We find that the NN can accurately predict the temporal and spectral intensity profiles of the pulses that form upon propagation in fibres with both anomalous and normal second-order dispersion. We also demonstrate the ability of the NN to determine the parameters of the nonlinear propagation from the pulses observed at the fibre output and to classify the output pulses according to the initial pulse shape. Furthermore, our model can also handle the nonlinear shaping of initially chirped pulses, for which the chirp coefficient is accounted for as an additional input parameter.

Our results show that a properly trained network can greatly help the design and characterisation of fibre-based shaping systems by providing immediate and sufficiently accurate solutions. Although demonstrated here in a fibre optics context, the principle of using NN architectures to solve wave equation-based inverse problems is expected to apply to many physical systems.