Multi-parameter optimisation of dual-pump NALM fibre laser using machine-learning approaches

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Recently, a new design of a model-locked all-fibre Figure-8 laser employing a nonlinear amplifying loop mirror (NALM) with two active fibre segments and two independently controlled pump-power modules has been proposed and experimentally demonstrated. This laser layout combines the reliability and robustness of conventional Figure-8 lasers with the flexibility of nonlinear-polarisation-evolution (NPE) lasers, providing access to a variety of generation regimes with a relatively wide adjustment range of the pulse parameters. Moreover, it enables reliable and reproducible live electronic adjustment of the lasing regimes, which is practically impossible to do by adjusting fibre-based polarisation controllers in NPE lasers.

The general issue of reaching a target mode-locked laser regime with a setup featuring many adjustable parameters can be intelligently addressed by using machine-learning techniques. Here, we apply predictive regression to find optimum operating regimes in the NALM laser that are accessible through independent control of the pump powers in the gain segments, *Pp*,1, *Pp*,2, and the laser output coupling ratio *β*. We use a piece-wise propagation model for generating data that characterises the laser. In the fibres, propagation follows a standard modified nonlinear-Schrödinger equation including gain saturation and spectral response for the active segments. The gain coefficient amplitude is dependent on the average signal and pump powers, the average power dynamics being described by standard rate equations. We have trained a gradient boosted tree algorithm on our dataset to identify high-energy, stable mode-locked solutions across the full variation range of the total pump level delivered to the active fibres, *Pp*,tot, the ratio *Pp*1/*Pp*,tot, and *β* (tens of thousands of points). The algorithm has quickly handled the whole parameter space. Our approach paves the way for alternative approaches to the optimisation of nonlinear cavity dynamics, and can be generalised to other complex systems and higher degrees of freedom.