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The interplay among the effects of dispersion, nonlinearity and gain/loss in optical fibers is a powerful tool to generate a broad range of pulse shapes with tunable properties. Here we propose a method to optimize the systems parameters for a given pulse target. By reducing the system complexity and applying machine-learning strategies, we show that it is possible to efficiently identify the sets of parameters of interest. Two configurations are numerically investigated: pulse shaping in a passive normally dispersive fiber and pulse generation in a dual-pump nonlinear-amplifying-loop-mirror mode-locked fiber laser.

In recent years, there has been a growing interest from the photonics community in the generation of non-conventional optical waveforms because of their applications in all-optical signal processing and microwave signal manipulation. While sinusoidal, Gaussian and hyperbolic secant intensity profiles are now routinely produced by modulators or mode-locked lasers, other signal waveforms such as parabolic, triangular or flat-top pulse shapes remain rather hard to synthesize. Several approaches to the generation of specialized waveforms have been explored, including linear spectral shaping, the use of special Mach-Zehnder modulator architectures, and coherent Fourier synthesis. The interplay among the effects of dispersion, nonlinearity and gain/loss in optical fiber systems can be efficiently used to shape the pulses and manipulate and control the light dynamics and, hence, lead to different pulse-shaping regimes. In particular, it has been demonstrated that the temporal and spectral properties of a pulse can be tailored by use of such a nonlinear shaping approach to generate ultra-short parabolic or triangular pulses [1, 2]. However, achieving a precise waveform with various prescribed characteristics is a complex issue that requires careful choice of the initial pulse conditions and system parameters. The general problem of optimization towards a target operational regime in a complex multi-parameter space can be intelligently addressed by implementing machine-learning strategies. In this paper, we discuss a novel approach to the characterization and optimization of nonlinear shaping in fiber systems, in which first we perform numerical simulations of the basic propagation model to identify the relevant parameters, and then we use the machine-learning method of neural networks (NNs) to make predictions across a large range of the data domain.

Firstly, we tackle the general problem of determining the parameters of nonlinear pulse shaping systems based on pulse propagation in a passive normally dispersive fiber that are required to achieve the generation of pulses with different, simultaneously optimized temporal features. Within our approach, the nonlinear shaping process is reduced to a numerical optimization problem over the three-dimensional space of normalized fiber length (accounting for fiber dispersion and input pulse duration), normalized input power (accounting for fiber Kerr nonlinearity and input pulse peak power) and normalized level of the initial pulse chirp. The intersections of different surfaces provide the means to quickly identify the sets of parameters of interest. We also show that this optimization problem can be efficiently addressed by application of a regression model based on a NN algorithm [3].

Secondly, we discuss a new design of a model-locked all-fiber Figure-8 laser employing a nonlinear amplifying loop mirror (NALM) with two active fiber segments and two independently controlled pump-power modules [4]. This laser layout combines the reliability and robustness of conventional Figure-8 lasers with the flexibility of nonlinear-polarisation-evolution lasers, providing access to a variety of generation regimes with a relatively wide adjustment range of the pulse parameters. In this work, we numerically explore the broad range of operating states of the laser that can be accessed through independent control of the pump powers in the two gain segments and the laser output coupling ratio. We show that the application of an NN-based regression model provides a rapid identification of the output pulse features that are attainable through variation of the adjustable system parameters, by handling almost instantly the whole parameter space.

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