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Spectral broadening due to Modulation Instability (MI) during nonlinear propagation in fiber optics, can arise from noise amplification and involve incoherent and complex coupled processes, making their experimental control challenging. Over the years, MI control within both noise-driven and seeded regimes demonstrated different degrees of success [1-3]. In this experimental study, we propose a new approach of MI control by all-optical seeding, whose parameters are suitably adjusted via machine learning optimization techniques. In particular, we use Genetic Algorithms (GA) to tune the wavelength and phase parameters of two weak (yet coherent) optical seeds competing with spontaneous (noise-driven) MI dynamics. This all-optical control of noise-driven nonlinear dynamics is used to optimize the correlation between two specific wavelengths in the incoherent output spectrum. Experimentally, an 80 fs laser pulse, centered at 1560 nm, is filtered using a programmable spectral filter to reshape the broadband pulse into a picosecond pump and conjointly generate two seeds with controllable parameters (i.e., wavelength λ and phase Φ) - see Fig. 1(a). The three input signals are then amplified before entering a highly nonlinear fiber (HNLF), and the fluctuating output spectra detected in real-time using the dispersive Fourier transform (DFT) technique [4]. The corresponding spectral correlation maps can be extracted, as seen in Fig. 1(c-d), and the correlation between two selected wavelengths $\rho(\lambda_a, \lambda_b)$ can be optimized by iteratively adjusting the wavelength and phase of the input seeds, as shown in Fig. 1(b).

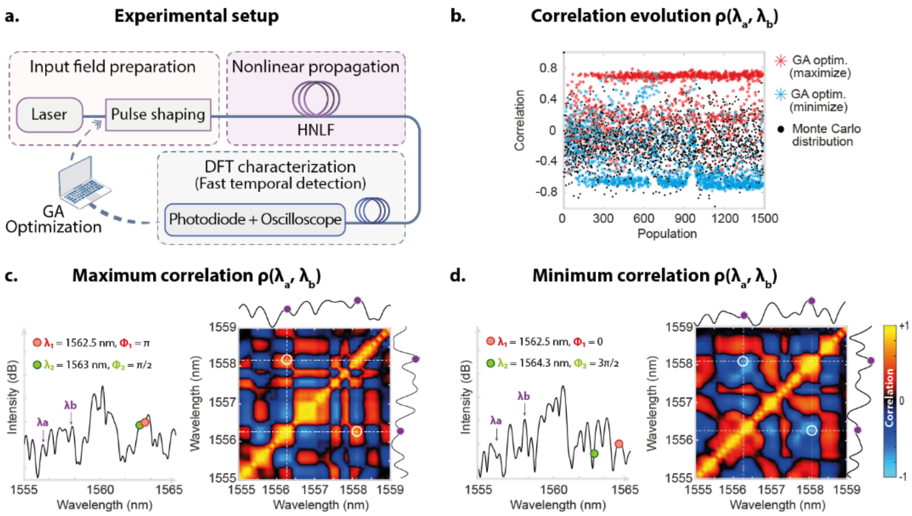

Fig. 1 a. Experimental setup. **b.** GA optimization results when maximizing (red) and minimizing (blue) the correlation between target wavelengths $\rho(\lambda_a, \lambda_b)$ compared with the correlation obtained from random seed parameters using Monte-Carlo method (black). **c.** GA-optimized spectrum (left) and correlation map (right) with the seed parameters (λ_1, Φ_1) and (λ_2, Φ_2), obtained for a maximal correlation $\rho(\lambda_a, \lambda_b)$. **d.** Same results for a minimal correlation $\rho(\lambda_a, \lambda_b)$.

The experimental results in Fig. 1(b) demonstrate that GA can efficiently optimize the correlation between different spectral components in the output spectrum, with a faster convergence than a Monte-Carlo method. For instance, the results of Fig. 1(c,d) show that the correlation between 1556.3 and 1558.1 nm can be adjusted from a maximal positive value of $\rho(\lambda_a, \lambda_b) = 0.78$, to a minimal negative value of $\rho(\lambda_a, \lambda_b) = -0.77$. This approach opens new paths towards tailoring incoherent nonlinear interactions and complex dynamics in guided optics. We expect this experimental control to be extended using deep-learning to mitigate time-consuming measurements [5].

References

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