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Spectral Dynamics of Soliton Explosion in a Passively Mode-Locked Yb Fiber Laser with Time Stretch Spectroscopy

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A soliton explosion is that during passively mode locking operation, a spectral structure of laser pulse disappear suddenly, the spectral structure, however, returns back its original shape after few roundtrips. This phenomena timescale is from nanoseconds to microseconds, and therefore this particular event of single-shot pulse spectrum cannot be detected by using a conventional spectrometer which consists on a grating and a linear array detector. Progress on a time-stretch dispersive Fourier transformation (TS-DFT) is enabling the single-shot spectral measurement in real-time. The TS-DFT technique brought a new opportunity for measuring the shot-to-shot spectral evolution such as soliton explosions and optical rogue wave.

Here, we report on experimental observation of soliton explosions in a stretched-pulse configuration via nonlinear polarization evolution (NPE) of a passively mode locked fiber laser with TS-DFT. In the past study, the observation of soliton explosion was previously limited to all normal dispersion (ANDi) configuration fiber laser that is operating in a transition regime between stable mode locking and noise-like pulse generation. In this study, the soliton explosion is appeared in a particular transitions varying from a narrowband to broadband mode locking operation. Interestingly, the feature of observed soliton explosion is composed of periodic cycle of soliton explosion, recovery and the stable mode locking. The frequency of soliton explosions can be easily controlled by changing the pump LD power or intra-cavity dispersion. In simultaneous measurement of single-shot spectrum and pulse energy, the soliton explosion would be caused by the accumulated residual third-order dispersion (TOD) that leads to the pulse energy variations which is not sustainable for a stable operation after a fixed number of roundtrips. Once the accumulated TOD is dissipated through soliton explosion, the laser recovers the stable mode locking operation. The experimental observations presented in this paper will be instrumental in understanding critical balance between mode locking and other cavity dynamics such as chirp accumulation in stable fiber laser oscillators.