Optical Turbulence and Polarization Rogue Waves in Experiments and Ginzburg-Landau Model of Quasi-CW Fiber Laser

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Fiber lasers operating via Raman gain or based on rare-earth doped active fibers are widely used as sources of CW radiation. However these lasers are only quasi-CW: their intensity fluctuates strongly on short time-scales and they are usually described within the NLSE model [1]. On the contrary, mode-locked pulsed lasers could be well modelled in terms of the complex Ginzburg-Landau equation (GLE). By replacing cubic nonlinear gain with a nonlinear loss term, one may obtain a variety of mode-locked regimes, including those of very irregular time dynamics which could be referred to as turbulent emission [2]. Here we show that CW Raman fiber lasers could be surprisingly described within the framework of the complex Ginzburg-Landau equation.

In our experiments, we use a linear cavity Raman fiber laser, nominally operating in the CW regime. We experimentally characterize its radiation by a technique of spatio-temporal intensity dynamics measurements [3] and found intermittent turbulent like behaviour, Fig. 1a.

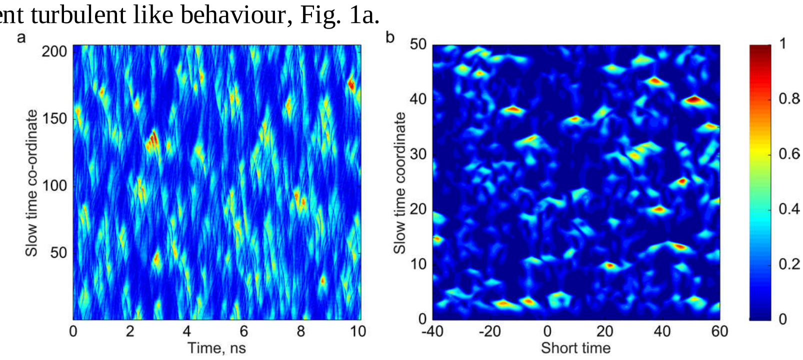

Fig. 1 Spatio-temporal turbulent dynamics of quasi-CW Raman fiber laser in (a) experiment and (b) modelling.

In spite of the fact that the laser operates in the quasi-CW regime, we use the Ginzburg-Landau equation model to describe its light emission. We found a good qualitative agreement with between the experimentally measured spatio-temporal dynamics of the quasi-CW fiber laser and the numerically calculated dynamics within the developed vector phenomenological model based on the coupled GLEs, Fig. 1. This clearly shows that the *quasi-CW* fiber laser can be effectively described by a phenomenological model that is widely used for the modelling of *mode-locked* lasers.

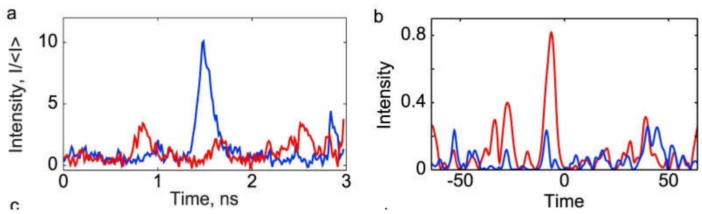

Fig. 2 Polarization rogue waves in CW Raman fiber laser in (a) experiments and (b) modelling.

Further on, the developed vector model of quasi-CW lasers provides the possibility to analyze the intensity dynamics in two orthogonally polarized modes. We found both in experiments and in modelling that most of extreme events occur in a single polarization, Fig.2 (red and blue – intensities in orthogonal polarizations).

To conclude, the framework of the complex Ginzburg-Landau equations, that are well known as an efficient model of mode-locked fiber lasers, is applied for the description of quasi-CW fiber lasers. The first ever vector model of a Raman fiber laser describes the experimentally observed turbulent-like intensity dynamics, as well as polarization rogue waves. Our results open debates about the common underlying physics of operation of very different laser types - quasi-CW lasers and passively mode-locked lasers**.**

References

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