Influence of Bragg-gratings-induced third-order dispersion on the optical power spectrum of Raman fiber lasers

Pierre Suret, Nicolas Dalloz, & Stephane Randoux

Laboratoire Phlam / Universite de Lille 1 / bat. P5 / 59655 Villeneuve d'Ascq cedex
pierre.suret@univ-lille1.fr

Raman fiber lasers (RFLs) are light sources made with long cavities in which a very large number of modes (up to 10^6) interact through linear (dispersive) and nonlinear effects. They are good candidate to observe turbulent-like behaviors [1]. The generation of the multiple cavity modes in RFLs is now commonly described from a complex Ginzburg-Landau equation which has been analyzed from the weak-turbulence theory [1].

In particular, it is now admitted that the interplay between second-order dispersion and nonlinear optical Kerr effect inside the laser cavity leads to the generation of an optical spectrum with a *symetric* hyperbolic secant shape [1]. Recent works have been devoted to the study of the influence of the sign of the second-order dispersion [2] and of the mirrors reflectivity spectra on the optical spectrum of RFLs [3].

Here, we show from experiments that the third order dispersion cannot be neglected even when the RFL is operated in a strongly normal dispersion regime. In particular, in our experiments, the optical spectrum of a RFL oscillating near threshold is shown to be asymmetric. From a mean-field model (generalized Ginzburg-Landau equation), we use numerical simulations to show that the observed behaviors arises from higher-order dispersive effects (third-order dispersion) breaking the symmetry of the laser spectra.

We show precisely that third-order dispersion effects arise from reflexions at the fiber Bragg gratings (FBGs) mirrors used to close the laser cavity. Our experimental setup is a very common configuration and the dispersion of the FBGs is always high on the side of the reflectivity spectra. This means that the phenomena presented here will arise in most of the experimental setups because the optical spectrum of RFLs is generally broader than the FBGs spectral width.

From the theoretical point of view, we explore how third order dispersion influences the optical spectrum of RFLs. Simple phase-matching arguments explain the origin of the asymetry in the optical spectrum. We show that these results may have connection with anomalous thermalization recently described in nonlinear wave systems [4].

[1] S. A. Babin *et al.* J. Opt. Soc. Am. B (**24**), 8, (Aug 2007)
[2] E.G. Turitsyna *et al.* Phys. Rev. A. (**80**), 031804(R) (2009)
[3] E. G. Turitsyna *et al.* Opt. Express. (**18**), 5, p. 4469 (2010)
[4] P. Suret *et al.* Phys. Rev. Lett. (**104**), 054101 (2010)