Nonlinear spectral compression in optical fiber.

Serguei Papernyi[1], Anastasia Bednyakova[2,3], Sergei Turitsyn[2,4], Wallace Clements[1], Mikhail Fedoruk[2,3]

1. MPB Communications Inc., 147 Hymus, Pointe-Claire, QC, H9R 1E9, Canada

2. Novosibirsk State University, 2 Pirogova str., Novosibirsk, 630090, Russia

3. Institute of Computational Technologies, 6 Ac. Lavrentjev ave., Novosibirsk, 630090, Russia

4. Aston Institute of Photonic Technologies, Aston University, Birmingham, B4 7ET, UK

Spectral broadening of a high power light wave in optical fiber due to four-wave mixing and/or self-phase modulation is a well studied nonlinear effect that has a number of practical applications [1]. The spectral broadening may be achieved both in anomalous and normal dispersion fiber. In this work, we have observed experimentally and confirmed through comprehensive numerical modeling that the spectral width of a powerful wave produced by a Raman fiber laser can experience spectral compression after propagation in a long enough normal dispersion fiber.

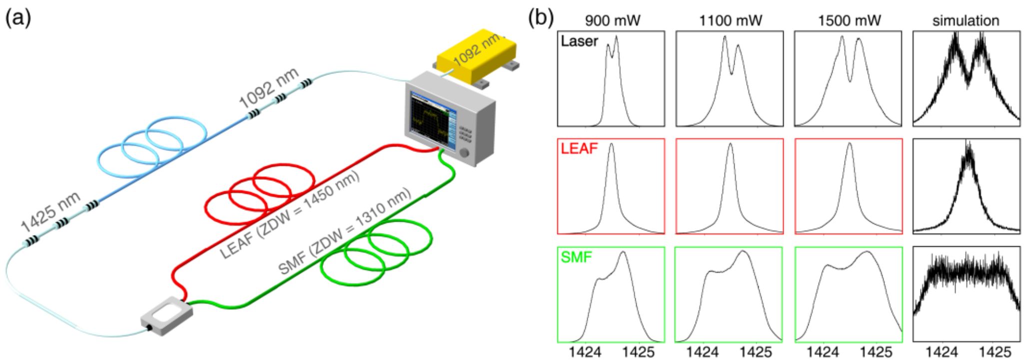

Fig. 1 (a)Experimental setup. (b) Spectrum shape after signal propagation in 100-km LEAF/SMF fiber, P_0=1.5 W.

The experimental set-up consisted of a CW pump source and two types of standard transmission fibers. A Raman fiber laser (RFL), pumped by an Yb-doped fiber laser, generated a CW signal at ~1425 nm with an output power up to 2W. The RFL spectra shown on the Fig. 1b consisted of two peaks characteristic of the intracavity four-wave mixing spectrum broadening in RFLs [3]. Then, the laser radiation at ~1425nm was launched into 100-km of LEAF or SMF-28 fiber with a zero-dispersion wavelength around 1500 nm for LEAF and 1310 nm for SMF. Thus, light propagates in the region of normal dispersion for LEAF and anomalous dispersion for SMF. The measured optical spectrum at the end of LEAF fiber shows significant narrowing (Fig. 1b - LEAF), in sharp contrast to the typical nonlinear spectral broadening in SMF (Fig. 1b - SMF) caused by four-wave mixing observed and studied in a number of experimental and theoretical publications [1-6].

We performed numerical modeling both of signal generation in the Raman fiber laser and its further propagation in telecom fibers. Evolution of the multimode partially coherent signal inside the laser cavity was modelled by the set of the coupled modified nonlinear Schrödinger equations [7], while signal evolution in LEAF and SMF fibers was computed using standard nonlinear Schrödinger equation [1]. The results of numerical simulations shown in Fig. 1b fully confirm the experimentally observed spectral behavior of nonlinear waves. We explain this unusual nonlinear spectral narrowing by an inverse four-wave-mixing leading to efficient energy re-distribution from the tails to the center of the nonlinear wave. A basic theory of the inverse four-wave-mixing will be presented at the conference.

References

[1] G. Agrawal, *Nonlinear Fiber Optics*, Chapter 4 (Academic Press, Orlando, Fla.2007).

[2] B. Barviau, S. Randoux, and P. Suret, "Spectral broadening of a multimode continuous-wave optical field propagating in the normal dispersion regime of a fiber," Opt. Lett. 31, 1696-1698 (2006).

[3] V.I.Karpov,W.R.L.Clements,E.M.Dianov and S.B.Papernyi, "High-power 1.48 ηm phosphoro-silicate-fiber-based laser pumped by laser diodes", Can. J. Phys, 78, 407-411 (2000)

[4] .S. Babin, D. Churkin, A. Ismagulov, S. Kablukov, and E. Podivilov, "Four-wave-mixing-induced turbulent spectral broadening in a long Raman fiber laser," J. Opt. Soc. Am. B 24, 1729-1738 (2007).

[5] S. Babin, V. Karalekas, E. Podivilov, V. Mezentsev, P. Harper, J. D. Ania-Castanon, and S. Turitsyn, "Turbulent broadening of optical spectra in ultralong Raman fiber lasers", Phys. Rev. A 77 033803 (2008)

[6] A. Picozzi, J. Garnier, T. Hansson, P. Suret, S. Randoux, G. Millot, and D.N. Christodoulides, "Optical wave turbulence: Toward a unified nonequilibrium thermodynamic formulation of statistical nonlinear optics", Phys. Rep. 542, 1-132 (2014).

[7] D. Churkin, S. Smirnov, and E. Podivilov, "Statistical properties of partially coherent cw fiber lasers," Opt. Lett. 35, 3288-3290 (2010).

[*] We acknowledge support of the Ministry of Education and Science of Russian Federation (grant 14.578.21.0029).

978-1-4673-7475-0/15/$31.00 ©2015 IEEE