Highly Sensitive Dispersion Map Extraction from Highly Nonlinear Fibers Using BOTDA Probing of Parametric Amplification

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The performance of devices based on highly nonlinear fibers (HNLF) can be drastically impeded by even tiny fluctuations of the zero dispersion wavelength (ZDW) along the fiber. Being able to measure ZDW fluctuations along an HNLF is therefore essential for the design of efficient nonlinear optics based devices such as fiber optical parametric amplifiers (FOPA), regenerators and limiters. Different schemes using complex distributed sensing of localized nonlinear interactions have been used in order to derive the ZDW fluctuations along the fiber [1-2]. In [3], the distributed gain of a pulsed pump FOPA along an HNLF was measured using a Brillouin Optical-Time Domain Analysis (BOTDA) based technique. In this paper, by improving the experimental scheme, we have been able to measure the FOPA gain along the fiber with low noise, which enabled us to derive ZDW fluctuations as low as 0.02 nm along HNLFs with 2 meters longitudinal resolution.

The experimental setup is depicted in Fig. 1(a). Compared to [2], both the FOPA pump and signal are pulsed before being injected into the HNLF. The FOPA signal also acts as a BOTDA pump. Using an electro-optic modulator, two carrier-suppressed sidebands are symmetrically generated below and above the BOTDA pump (FOPA signal) frequency. The detuning between the sidebands and the BOTDA pump frequency is set to be equal to the Brillouin frequency shift of the fiber. The two sidebands are launched at opposite end of the fiber designated as cw probes 1 and 2. Thus the Brillouin interaction with the BOTDA pump will lead to a gain on the lower sideband and a loss on the higher sideband. Thanks to the presence of probes simultaneously experiencing similar gain and loss, the saturation of the BOTDA pump is avoided [2]. A tuneable 0.1 nm bandwidth filter before the oscilloscope makes it possible to acquire either the gain or the loss cw probe trace. Before injecting the cw probes into the HNLF, a polarization switch is also used to average out the polarization dependent Brillouin interaction.

Fig 1(b) shows the distributed FOPA gain along a 350-m long HNLF in the two directions of the fiber. The FOPA pump and signal peak powers were appropriately chosen to ensure that the FOPA pump is not depleted. The FOPA gain exhibits small fluctuations that can be attributed to the ZDW fluctuations. In order to map these fluctuations, we employed the WKB approximation [4] to obtain an analytic expression of the parametric gain in presence of fiber nonuniformity. Fig. 1(c) depicts the fluctuations of the ZDW retrieved from the measured FOPA gains. The determination of ZDW during the first few meters of propagation is however uncertain because the idler is yet to be generated. This problem can be easily overcome by using both directions to determine ZDW fluctuations at both ends of the fiber. An excellent agreement is observed between the left-to-right and right-to-left measurements. Compared to other techniques for ZDW distribution measurement, only 2 traces are required. This is a drastic gain in speed and simplicity.

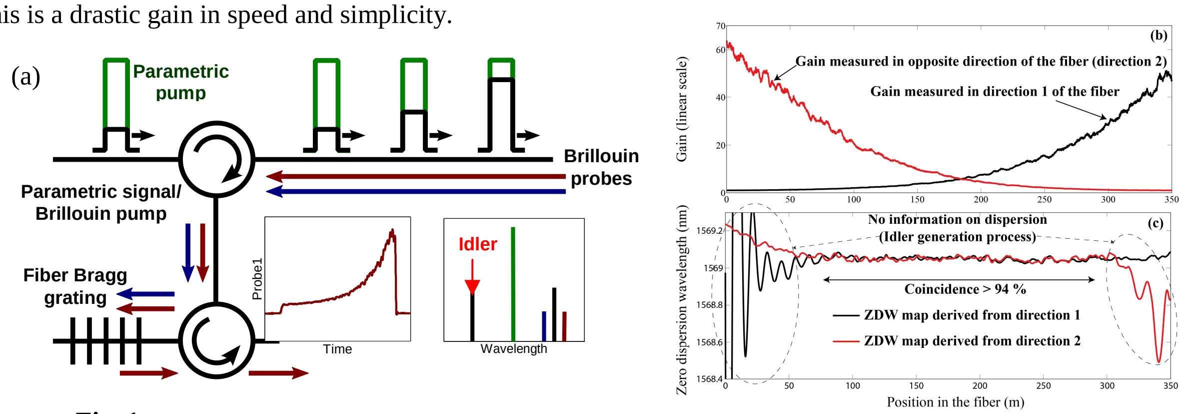

Fig. 1(a): Schematic of the setup, (b) FOPA gain measured along both directions of the HNLF, (c) Zero dispersion wavelength distribution extracted from FOPA gains in both directions.

In summary, an optimized scheme for the distributed measurement of parametric processes is developed which compared to other existing methods has the advantage of great simplicity and resolution. This scheme can also be used to study other nonlinear phenomena, such as FOPA pump depletion or supercontinuum generation.

References

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