Intra-cavity frequency shifted laser pumps for non-degenerate and partially coherent Bragg-Scattering FWM in nonlinear fiber

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Nonlinear effects in fibers with partially coherent pumps have attracted a great interest in view of their potential for polarization insensitive wavelength conversion and the increased resilience to Stimulated Brillouin Scattering [1]. In this work we experimentally study the problem of non-degenerate four-wave-mixing (FWM) by using a pair of partially coherent pumps, and focus our attention on a specific type of FWM, which is generally called "Bragg-Scattering" (BS-FWM). This kind of FWM has attracted a renewed interest because of its intrinsically low-noise nature which makes it potentially applicable for light-by-light manipulation even for very faint signals such as quantum keys [2].

Instead of ASE spectrum-sliced sources [1], in our experiment we used two intra-cavity frequency-shifted feedback lasers (IFSL1, IFSL2), independently amplified by two separate erbium doped fiber amplifiers (EDFAs). In Fig.1 we present our experimental setup. The two pumps and a third laser working as signal source were injected in a sequence of two off-the-shelf segments of highly nonlinear fibers of lengths equal to 450 m (HNLF1) and 350 m (HNLF2), respectively. These two fibers slightly differ in their nominal zero dispersion wavelength (ZDW), which is equal to 1545 nm and 1546 nm for the HNLF1 and HNLF2. Each IFSL consists of an intra-cavity acousto-optic frequency shifter working at a frequency of 110 MHz and a blazed grating in a Littrow configuration to provide frequency dependent cavity losses. The inset in Fig.1 shows an example of radio-frequency spectrum measured for the IFSL1 with a free spectral range of 3.6 MHz. Each IFSL has 20 m of polarization maintaining erbium doped fiber pumped by a 1480 nm laser diode. When operating the two lasers in the continuous wave regime, we estimated the 3dB bandwidths of their optical spectra to be equal to 15 GHz and 20 GHz for IFSL1 and IFSL2, respectively.

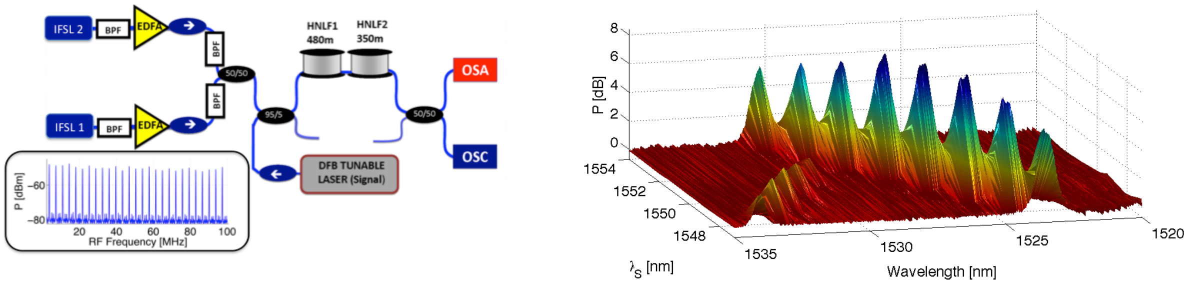

Fig. 1 Left: experimental setup; inset: details about radio frequency spectrum measured for IFSL1. Right: experimental ON-OFF spectral ratio of BS-FWM for 8 different signal wavelengths (λ_S). For all these measurements the average pump powers were of 51 mW and 73 mW.

In order to study frequency conversion by BS-FWM we used a 0.13 mW narrowband tunable laser to provide the signal wave. Let us remind that the BS-FWM may add to or subtract from the signal carrier frequency the beating frequency between the two laser pumps. In our implementation we varied the signal wavelength in the range 1547 nm-1554 nm, while keeping the pump wavelengths fixed to 1540.5 nm and 1564.5 nm, respectively. Thus, the BS-FWM idler is expected between 1520 nm and 1535 nm, with a peak of conversion efficiency at FWM phase-matching. We show on the right-hand side of Fig.1 the results of experimental measurements of converted idler power for various signal wavelengths. Although the conversion efficiency is lower than in the case of coherent pumps with direct phase modulation, the BS-FWM generated idler remains clearly observable despite the large bandwidth of the pumps and their complete statistical independence. In the figure, the vertical axis represents the ratio between the spectrum when the signal is ON and OFF, respectively. Hence, we obtain nearly 8dB of signal-to-noise ratio, where the noise comes from the ASE of EDFAs and IFSLs. We could partially reduce the ASE by a series of 3 inline 5 nm wide bandpass filters (BPFs) on each pump. Note that although the signal is narrowband, the converted idler is broadened by the wideband spectral contributions of the two pumps.

References

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