Towards Kerr optical frequency combs in a Brillouin fiber laser cavity

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Abstract: In this contribution, we investigate a simple and reconfigurable all-fiber ring cavity to generate tunable Kerr optical frequency combs in both 1.55- and 2-µm spectral bands. We demonstrate that coherent frequency combs can be obtained by finely exploiting both stimulated Brillouin backscattering and cascaded four-wave mixing in the nonlinear fiber cavity.

Broadband coherent light sources consisting of equally spaced discrete lines in the frequency domain, also called optical frequency combs (OFCs), constitute a very powerful tool in a vast number of applications such as optical frequency metrology, biology, and astronomical spectrograph calibration, wavelength division multiplexing, microwave generation and molecular spectroscopy [1–3]. Different optical technologies can be used for generating such OFCs, such as electro-optic modulation schemes, passive optical resonators, and mode-locked lasers. In this contribution, we investigate a novel reconfigurable all-fibered system based on a dual-wavelength Brillouin laser [4]. We have carried out extensive numerical and experimental studies of the nonlinear fiber cavity to reveal potential, robustness and limitations of such hybrid systems that take advantage of stimulated Brillouin backscattering (SBS) and multiple four-wave mixing (FWM) processes.

Figure 1(a) shows the typical experimental setup based on a nonlinear fiber cavity closed by an optical circulator. It allows the free propagation of the pump lasers, while the Brillouin Stokes waves can resonate and buildup in the opposite direction and undergoes cascaded FWM. This simple approach is simultaneously studied in the 1.55- and 2-µm bands. Distinct commercially available highly nonlinear fibers (HNLF) were tested to form the cavity, as well as various cavity length to check the impact of multimode lasing regime. Moreover, the bi-chromatic pumping configuration can be obtained the through combination of two continuous-wave lasers or by means of an electro-optic modulation, namely an intensity modulator driven at the null transmission point with carrier suppression. The key feature of this scheme is the ability to easily change and reconfigure the comb spacing, which is determined by the spacing between the two Brillouin pumps, which exceeds the native cavity FSR.

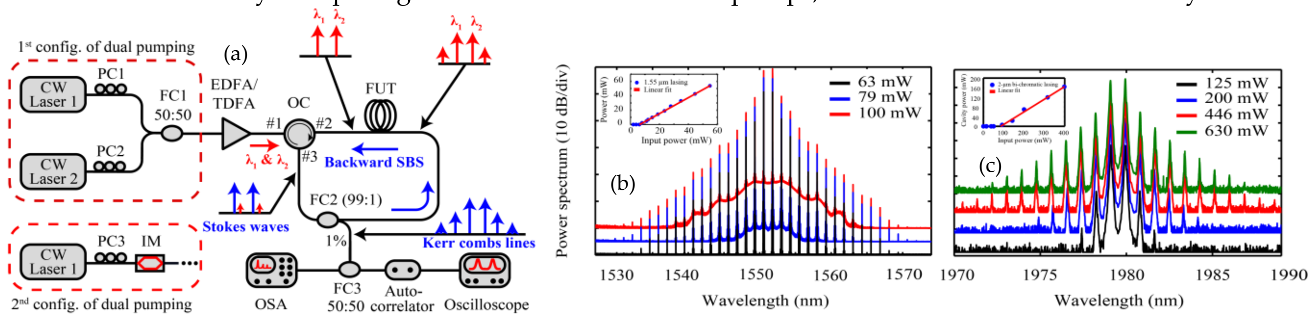

Fig. 1: (a) Experimental setup for generated Brillouin-Kerr combs. CW: continuous wave, PC: polarization controller, OC: optical circulator, FUT: fiber under test, FC: fiber coupler, IM: intensity modulator, OSA: optical spectrum analyzer, TDFA/EDFA: thulium/erbium doped fiber amplifier). (b, c) Examples of the spectral combs generated in both 1.55- and 2-µm bands, respectively, as a function on the injected pump power. Insets: Corresponding bi-chromatic Brillouin lasing thresholds.

In Figure 1(b), we show a typical example of the spectral combs generated beyond the SBS threshold in the 1.55-µm band, and this setup was easily extended to the 2-µm band, as shown in Figure 1(c). The impact of the net dispersion of the cavity was studied, in particular the detrimental effect of growing spontaneous modulation instability bands on spectral combs, occurring in the anomalous dispersion regime. Coherence and stability limitations of this dual-pump cavity, such as mode-hopping, will be revealed as well as their mitigation through various stabilization schemes such as phase-locking the pump-Stokes beatnote or the Pound–Drever–Hall (PDH) technique. Finally, we identify several scaling laws and guidelines to optimize the design of such systems to maximize the Kerr optical frequency comb coherence and bandwidth.

References

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