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# Unexpected phase-locked Brillouin Kerr Frequency comb in fiber Fabry Perot resonators

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Stimulated Brillouin scattering (SBS) is the first nonlinear effect to be triggered when a powerful continuous wave laser interacts with a nonlinear waveguide. This effect is further exacerbated in resonators due to the multiple round trips in the cavity. SBS has proven to be extremely interesting for building ultra-stable microwave photonic synthesizers [1], to trigger broadband cavity solitons [2], or to balance thermo-optical effects to obtain ultra-stable sources [3]. Whatever the cavity architecture, the only requirement is to obtain a spectral overlap between the SBS gain ( $\nu_B = 10$  GHz,  $\Delta\nu = 50$  MHz), and the cavity resonances. This condition is automatically verified in fiber ring cavities, which have free spectral ranges (FSRs) typically between 1 and 100 MHz, or can be met by fine-tuning the cavity lengths in microresonators with FSRs in the GHz range [2-3]. In this paper we evidence an original mode-locking phenomena to generate a stable Brillouin Kerr frequency comb in fiber Fabry Perot resonators. The surprising feature of our work is illustrated in Fig. 1 (a). While there is a spectral overlap between the 8<sup>th</sup> cavity resonance (dashed lines) and the SBS gain curve (red curve) at 9.416 GHz, we observed a Brillouin Kerr frequency comb with a line-to-line spacing equals to 10.593 GHz (exactly 9 times the cavity FSR, blue line in Fig. 1 (a)) where there is no spectral overlap. The cavity is pumped by an ultra-narrow CW laser of 1.3 W. It is swept from

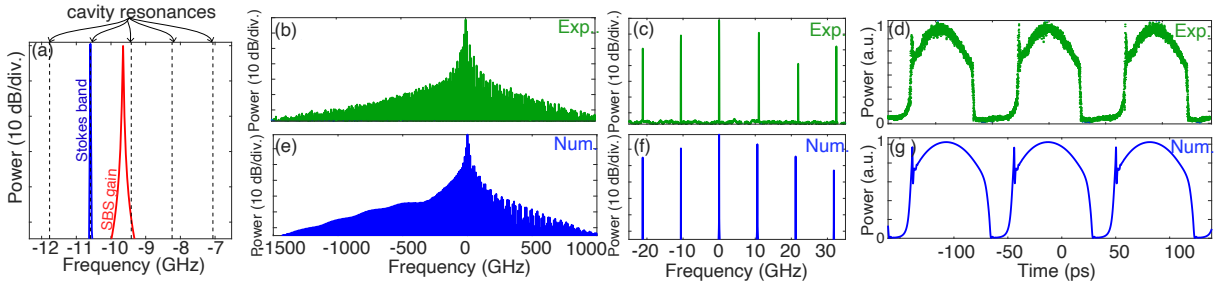


Figure 1 : (a) Scheme representing the SBS gain curve (red curve, SBS shift is 9.655 GHz), the cavity resonance positions (vertical dashed lines) and the first Stokes band (blue curve). (b) and (e) output spectra, (c) and (f) zoom on the central part, and (d) and (g) temporal traces. (b)-(d) Experiments and (e)-(g) numerics. Parameters : length 8.78 cm, FSR=1.177 GHz, cavity detuning  $\Delta = -0.0891$  rad, highly nonlinear fiber with group velocity dispersion  $\beta_2 = +0.38$  ps<sup>2</sup> km<sup>-1</sup> and nonlinearity  $\gamma = 10.8$  W<sup>-1</sup>.km<sup>-1</sup>, and a Q factor of 65 millions. Spectra had been recorded with a high resolution (20 MHz) optical spectrum analyser and time traces with a high bandpass (700 GHz) optical sampling oscilloscope.

blue to red to reach a cavity detuning of  $\Delta = -0.0891$  rad, in order to jump onto the upper branch of the cavity CW response. In the early steps of the process, a Stokes band at 10.593 GHz (9 times the cavity FSR) is generated, and many others through four-wave mixing processes cascade (Fig. 1 (c)). Finally, a broadband frequency comb of 2 THz (Fig. 1 (b) and (c)) is obtained corresponding to a stable pulse train (Fig. 1 (d)). Numerical simulations, including forward and backward fields [5], without any fitting parameters reproduce perfectly these experimental observations (Fig. 1 (e)-(g)). We explain this unexpected feature by performing a linear stability analysis of a mean-field reduction of the governing equations. We found a maximum of the parametric gain exactly at 10.593 GHz, revealing the parametric origin of the Stokes band at this unexpected position.

To conclude, we discovered and explained a new nonlinear mechanism in fiber Fabry Perot cavities. It enables the generation of phase-locked stable Brillouin Kerr frequency combs which could find great interest in microwave photonic synthesizers.

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