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Ananthu SEBASTIAN présentera ses travaux de thèse le 18 décembre prochain.
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Soutenance de thèse
Institut Foton – équipe Systèmes Photoniques
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Noise dynamics in multi-Stokes Brillouin laser

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Résumé

Stimulated Brillouin Scattering (SBS) is a coherent interaction process in which light is scattered from optically generated acoustic waves. It is a powerful tool for microwave and optical signal processing, distributed sensing and spectroscopy. Brillouin lasers are attracting a lot of interest for their ability to produce ultra coherent linewidths. This thesis is devoted to the understanding of the noise properties of Brillouin fiber ring lasers, operating with multiple Stokes orders. First, we present a technique based on the cavity ringdown method, which allows to characterize the Brillouin gain coefficient directly from porbing the laser cavity probe. Its advantages are to obtain parameters from a single experiment with low optical powers (some 10 milliwatts) for short cavities (a few meters long, or integrated cavities).

Secondly, it is shown that an intrinsic linewidth of a few tens of mHz can be easily obtained by cascading two non-resonant Brillouin lasers (for which the pump performs a single pass inside the cavity). In order to obtain these results, the long-term stability has been improved by using a Pound-Drever-Hall servo loop, which allows us to compare our analytical and experimental results. Unfortunately, we were unable to explore the fundamental limits of noise reduction due to the noise floor of our bench.

Thirdly, one of the major works of this thesis is the numerical and experimental study of the noise properties, including frequency noise and relative intensity noise, of a resonant Brillouin laser (for which pump and Stokes waves are resonant inside the cavity).

In particular, the impacts of the fiber-ring-cavity quality factor, Brillouin gain detuning, are evaluated very precisely on the laser RIN features such as amplitude noise reduction and relaxation frequency.

We emphasize the fact that many characteristics of the frequency noise are related to the RIN properties by a coupling between intensity and phase. We show that the cascade process modifies the dynamics of the Brillouin laser when compared to those of a single-mode Brillouin laser with a single first-order Stokes component. Our experimental results are in excellent agreement with our analytical calculations, obtained thanks to our non-linear system describing the operation of a multi-Stokes Brillouin laser. This good match is mainly due to our ability:

• to obtain very precise values of the cavity parameters and the Brillouin gain coefficient using the CRDM technique ;

• to achieve long-term stability (several tens of hours);

• to finely control the detuning between the laser Stokes resonance and the frequency of the Brillouin gain maximum.

We demonstrate experimentally for the first time that frequency noise is degraded in the presence of anti-Stokes Brillouin scattering. We also show that a gain detuning of the order of a few hundred kHz can degrade the intensity noise or also improve the linewidth by amplitude-phase coupling. All these very fine observations thus allow us to set the fundamental limits of such laser systems such as: the increase in noise due to anti-Stokes orders; the role of pump noise and its possible interrelation with cavity finesse; the effect of the detuning inherent to higher Stokes orders.

All these conclusions are key to the design and engineering of these Brillouin fiber lasers, which are currently attracting a great deal of interest as evidenced by the work in progress in the scientific community. This PhD thesis contributes to a better understanding of multi-Stokes Brillouin lasers.

***Mots-cles** : Nonlinear optics, Stimulated Brillouin Scattering, Brillouin laser, frequency noise, relative intensity noise, laser linewidth, optical resonator, cavity ring down spectroscopy, frequency stabilization*