

## Relative Intensity Noise in a Multi-Stokes Brillouin Laser

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We demonstrate that multi-Stokes operation is essential to get low intensity noise Brillouin fiber ring laser. 20 dB/Hz noise reduction compared to input pump laser is confirmed by a numerical modal replicating experimental observation.

Stimulated Brillouin Scattering (SBS) initiated in an optical cavity is an attractive phenomenon to generate narrow linewidth lasers. Multi-Stokes waves generated through cascade process allow to reach better coherence properties. We build a Brillouin multi-Stokes fiber laser with 20 meters Polarization Maintained fiber. This fiber ring cavity is resonantly pumped using a continuous wave laser. The circulating pump wave initiates Brillouin amplification in Stokes 1 (S1) wave traveling in the opposite direction. We show characteristics of cascade Brillouin laser on the Figure (left axis). S1 (blue), S2 (green), and S3 (yellow) output power are plotted as function of input pump power. When the power in S1 reaches the normalized output power needed to compensate linear losses of S2, coherent emission of S2 takes place; the cascaded process is on. In that regime, the S1 circulating power is clamped. Relative intensity noise (RIN) of individual Stokes are characterized and normalized by the pump RIN. RIN behavior of the three first individual Stokes lines as function of the input pump power are plotted on the Figure (right axis). Above, which corresponds to the S2 lasing threshold, the S1 experiences an abrupt RIN reduction up to 20 dB/Hz compared to the input pump RIN level. This reduction originates from the clamping effect of S1 line due to the appearance of the stimulated S2 emission. Dotted lines correspond to measured RIN and starred lines to numerical simulations based on a set of coupled-mode equations. Numerical results even predict 40 dB/Hz reduction. We assume that the discrepancy is due to experimental bench limitation. We finally show that Stokes RIN follows the noise distribution similar to a class B laser featuring relaxation of oscillations, originating from the coupling between phonons and photons. Our study gives inputs to design optimized Brillouin fiber laser in term of RIN reduction.

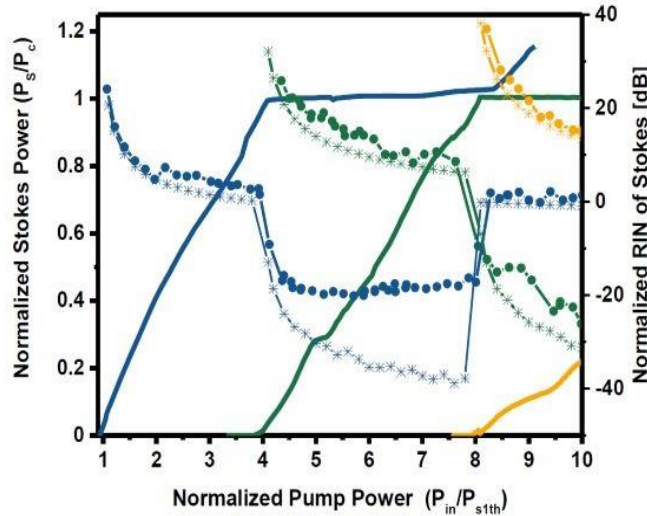


Figure 1 (left axis) Output Stokes power ( $P_s$ ) normalized to the circulating power ( $P_c$ ) versus input pump power ( $P_{in}$ ) normalized to the Stokes1 lasing threshold ( $P_{s1th}$ ). (right axis) RIN of Stokes lines normalized to the input pump RIN.