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# Experimental realization of a coherent Raman comb

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Transient stimulated Raman scattering (TSRS) in inhibited-coupling hollow core photonic band gap fiber (HCPCF) proved to be a promising means to generate several octave bandwidth coherent optical spectral comb [1-2]. This in turn could represent a powerful means for optical waveform synthesis [3] and attosecond optical pulse generation. While prior work indicates that the spectral component of this in-HCPCF TSRS generated comb are phase coherent with each other [1-2], uncertainty remains on the exact Stokes spatial-temporal coherent mode number that have been amplified, and hence on the residual phase noise of the generated Raman comb.

In this work, we demonstrate the amplification of a single spatio-temporal mode (STM) leading to a strong phase locking of the full Raman comb. The spectral generation is achieved using a single mode gas-filled HCPCF and pump pulse energy and duration space that ensures an extinction ratio of more than 30 dB between the fundamental STM and the other ones (see Fig. 1a). The interference is measured using an home-made sum frequency interferometer (SFI), allowing to make interfere two different lines of the generated comb. Our setup presents the interest to combine a high temporal resolution ( $\sim$ fs) with a large dynamical range ( $\sim$ 10 ps), which makes it ideal to characterize the coherence of two spectral lines on a wide temporal range.

By sending only the pump and 1<sup>st</sup> Stokes lines in our SFI, we take advantage of the interference to (i) demonstrate the phase locking between these two lines, and (ii) finely observe the temporal structuration of the pump and Stokes lines (see Fig. 2b, top). Fig. 2c (top) presents the pump and Stokes lines temporal profiles after deconvolution of auto-convolution traces. In order to demonstrate that the phase locking effect remains independently of the temporal structure of the Raman field, we performed the same measurement at higher pump power as shown Fig. 1b and 1c. In this situation, it is clear that despite the strong temporal structuration of the pulse, the phases of the two spectral lines are still locked. Similar results have been obtained injecting 1<sup>st</sup> and 2<sup>nd</sup> Stokes lines as well as 1<sup>st</sup> Stokes and 1<sup>st</sup> anti-Stokes lines in the interferometer demonstrating the coherence of the full Raman comb.

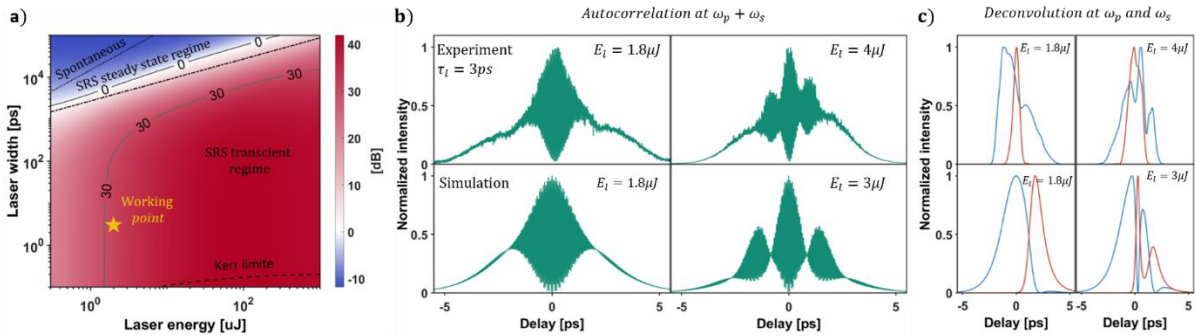


Fig. 1. (a) Ratio between the weight of the 1<sup>st</sup> STM compare to the weight of all the other ones [5], depending on the laser pulse energy and temporal width. (b) Comparison between the pump-Stokes interfering line (top) and the numerical resolution of the Maxwell-Bloch equations (bottom) for two different pumping powers. (c) Pump (blue) and Stokes (red) temporal profiles after deconvolution of the measured traces (top). The bottom corresponds to the results of the simulations.

These results are compared to the numerical resolution of the Maxwell-Bloch equations [4-5] (see Fig. 2bc, bottom) which are used to obtain the pump and Stokes fields at the output of the fiber as well as the quantum state of the Raman active medium along the fiber. We observe a very good agreement between the experimental and numerical results with no adjustable parameters highlighting the proper understanding of the situation.

In conclusion, we demonstrate here the full coherence of the generated Raman comb, independently of the complex temporal structure of the light. This work open the road to the experimental realization of a waveform synthesizer.

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## References

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