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INCREASING THE STIMULATED BRILLOUIN SCATTERING THRESHOLD IN SINGLE-MODE PASSIVE FIBER WITH A FREQUENCY COMB

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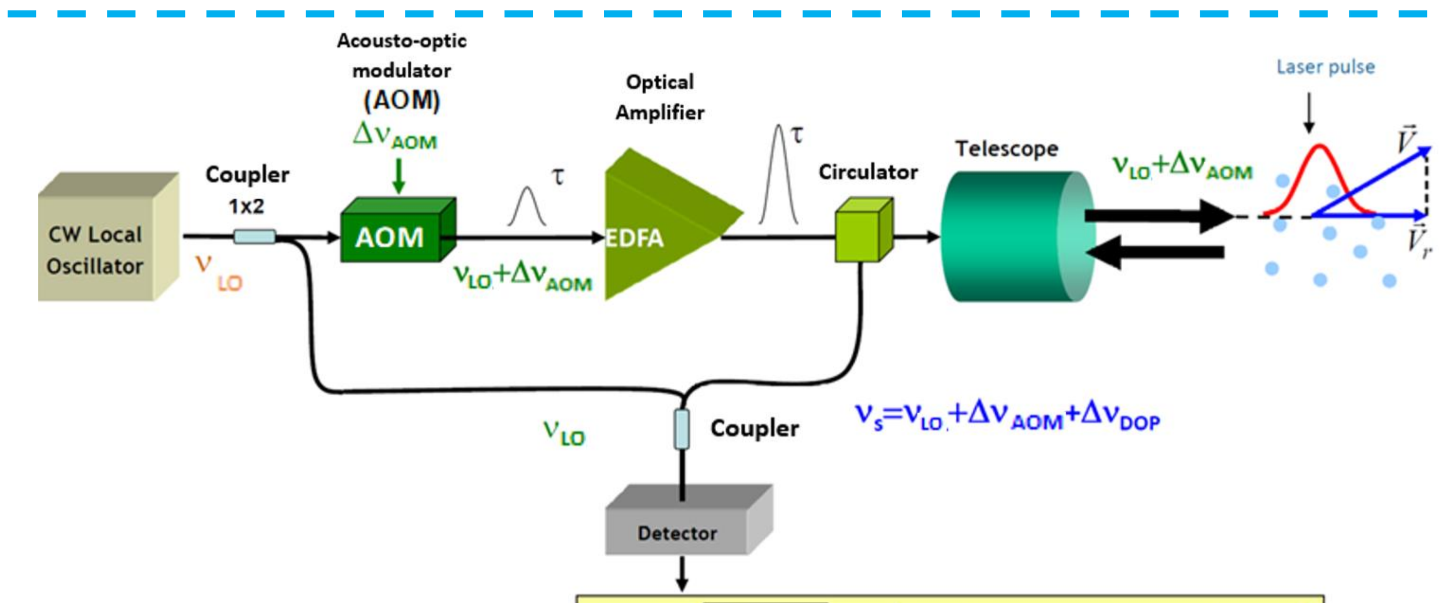
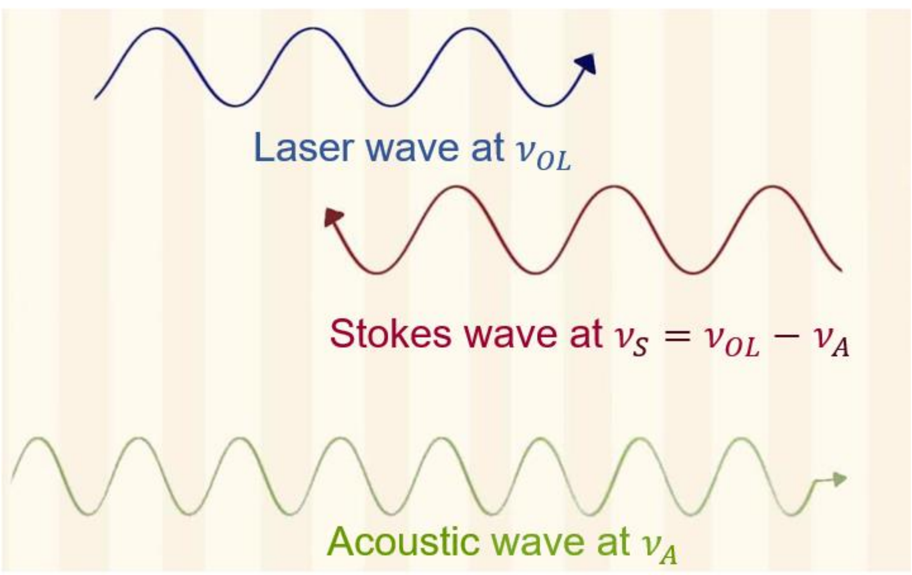
Context

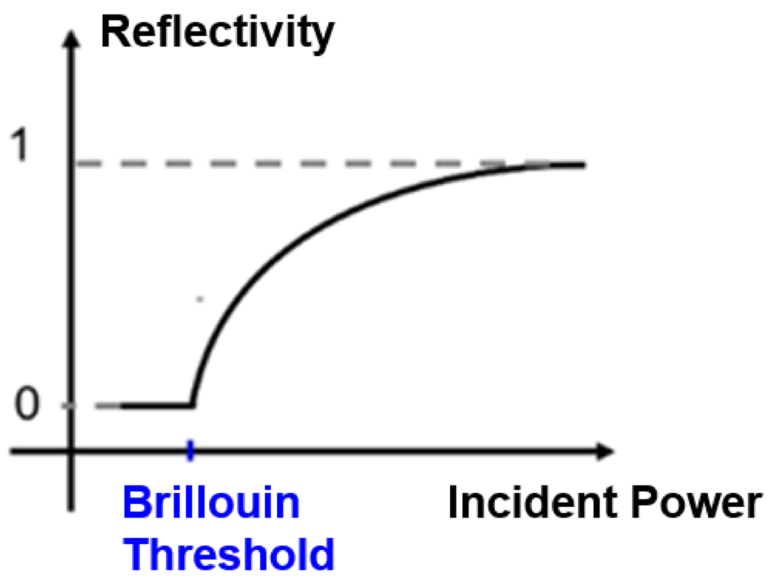
- **Lidar** to measure **wind speed** with **Doppler frequency shift** of the aerosol backscattered beam [1]
- **All-fiber lidar** for compactness, robustness and reduced cost
- **1545 nm** for eye safety, atmospherical transparency and maturity of telecom components
- **Applications :** Management of air farms and airports, in-flight turbulence control



- Heterodyne current $i_{het} = 2\sqrt{I_s I_{LO}}\gamma_{het}\cos\left(2\pi\cdot(\Delta\nu_{AOM}+\Delta\nu_{DOP})\cdot t+\phi\right)$

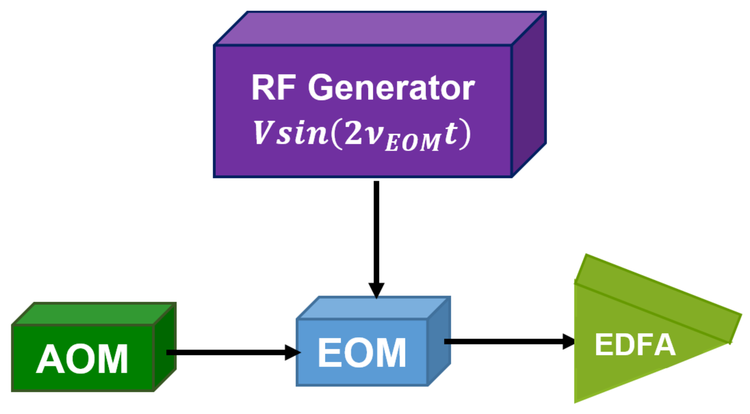
Principle of the Stimulated Brillouin Scattering (SBS)





- **Non-linear effect in the amplifier fiber**
- Power backscattered from a Brillouin threshold power P_{SBS} [2]
- Limit in peak power of the pulses, risk of damages

Frequency comb generation



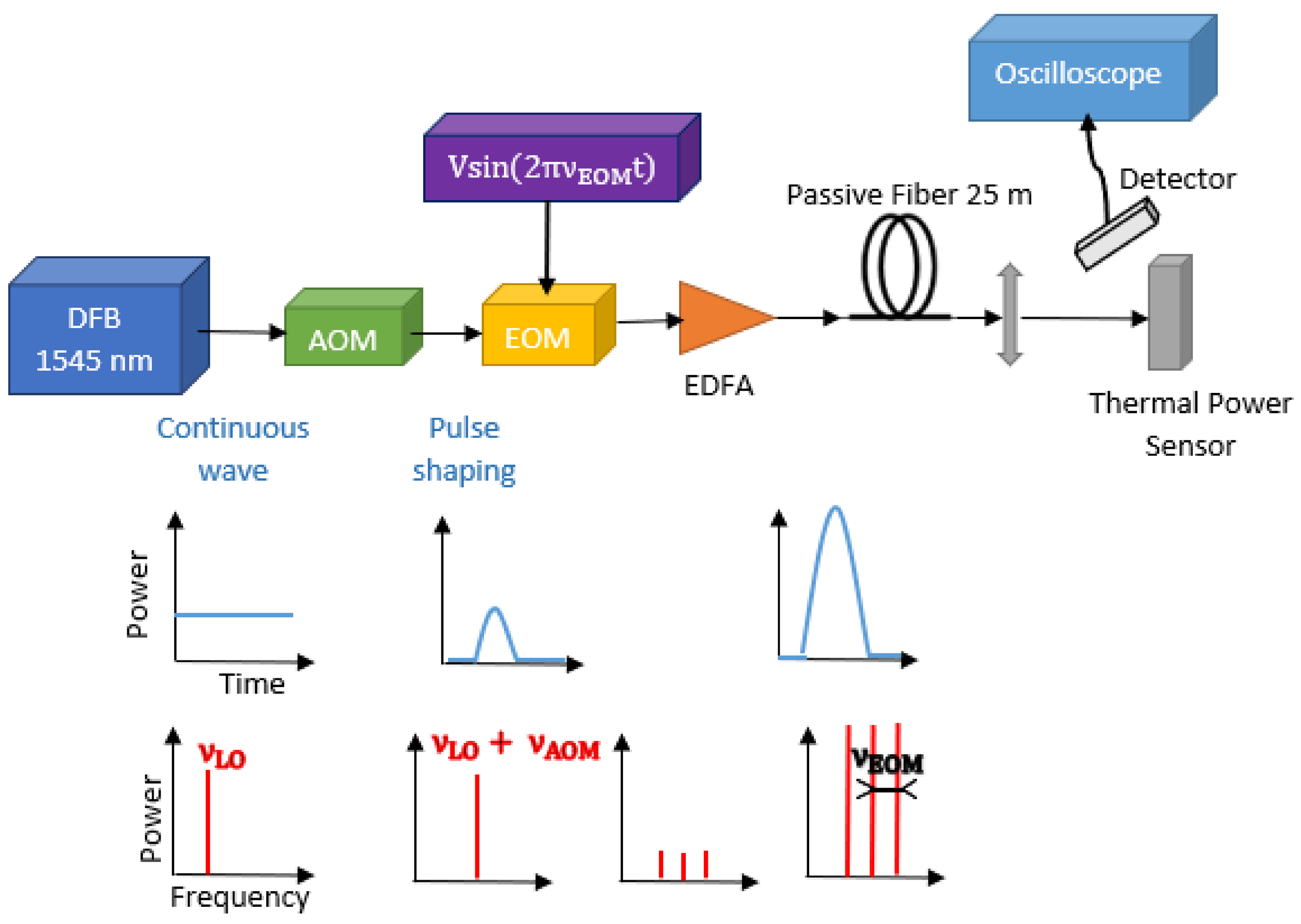
- **Phase modulation with an electro-optic modulator [3]**
- V_π: voltage to apply for a phase modulation of π
- Index of modulation : $\beta = V_\pi/\pi$
- $E(t) = E_0 e^{i(2\pi(\nu_{LO}+\nu_{AOM})t+\beta \sin(2\pi\nu_{EOM}t))}$
  $= E_0\sum_{n=-\infty}^{\infty} J_n(\beta)\, e^{i2\pi(\nu_{LO}+\nu_{AOM}+n\nu_{EOM})t}$
- Comb lines spaced of ν_{EOM}
- Amplitude of the lines on the power spectrum proportional to $J_n(\beta)^2$

SBS occurs when the power at a given frequency exceeds the threshold limit P_{SBS}. With a frequency comb, the power in each line is still limited by SBS, but the sum of the lines exceeds this limit.

Results

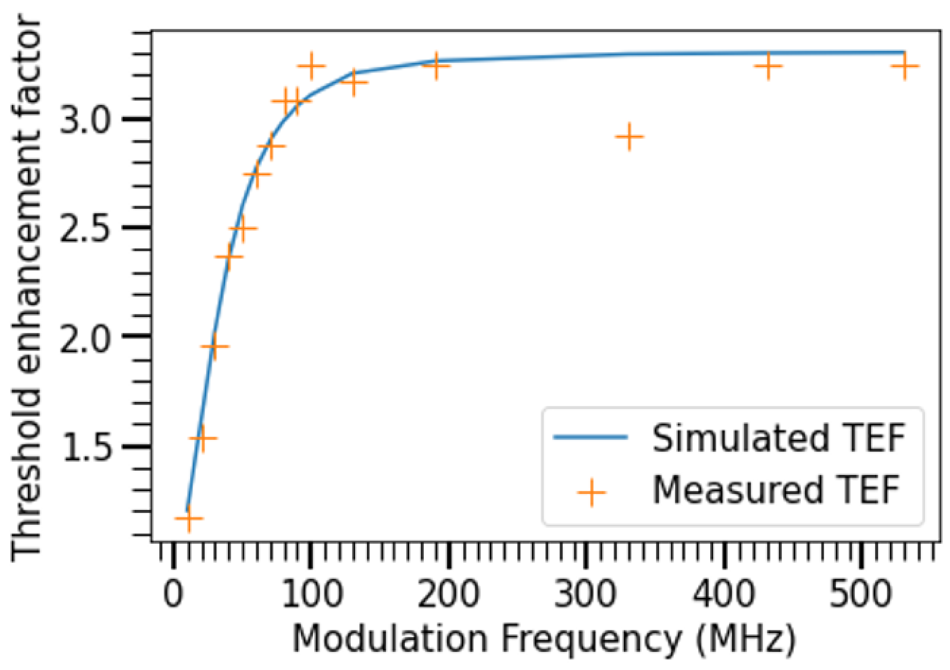
- TEF : Threshold Enhancement Factor
- $TEF = \dfrac{P_{SBS}\ \text{with the comb}}{P_{SBS}\ \text{without the comb}}$

Experimental set-up for measuring the TEF



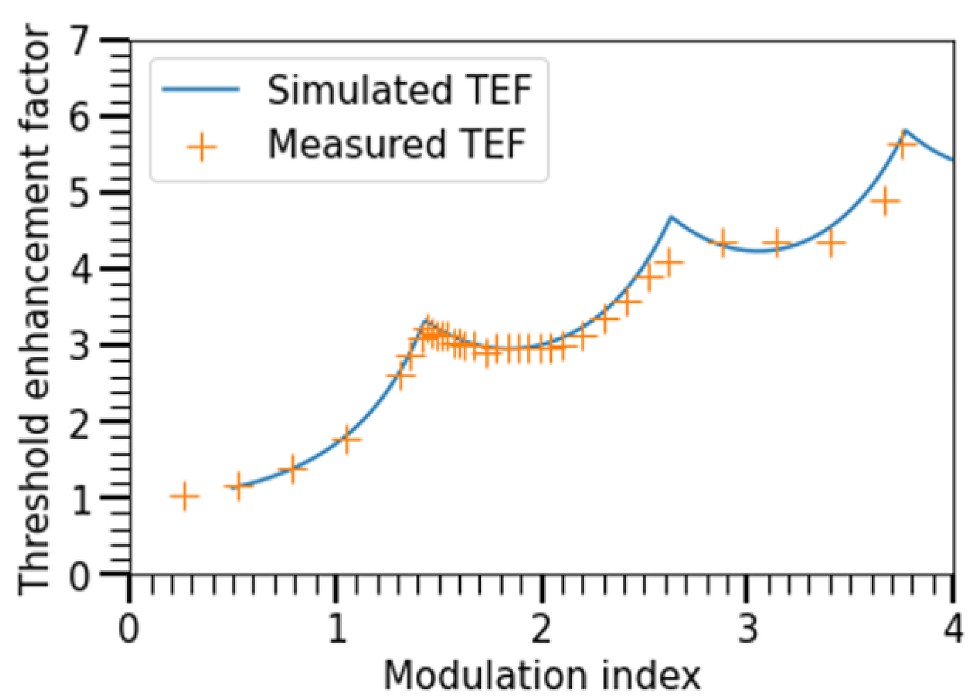
- Gaussian pulses with a duration of 330 ns at a repetition rate of 20 kHz
- Measure P_{SBS} at the fiber output by checking the shape of the pulse

Evolution of the TEF as a function of the modulation frequency



- $\beta = 1{,}44\ :\ J_0(\beta)^2 = J_1(\beta)^2$ Balanced three lines comb
- $Simulated\ TEF = \dfrac{\text{Power of the highest line of the Stokes spectrum modelized without comb}}{\text{Power of the highest line of the Stokes modelized with comb}}$
- Stokes spectrum model : convolution of the laser spectrum and a Lorentzian spectrul with a width of 40 MHz

Evolution of the TEF as a function of the modulation index



- $\nu_{EOM} = 130$ MHz
- $Simulated\ TEF = \dfrac{\text{Power of the highest line of the laser spectrum without comb}}{\text{Power of the highest line of the laser spectrum with comb}}$

Conclusion

For a frequency comb with N lines, the TEF is increased by a factor N, unless the lines are too close in frequency.

References

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[2] G. P. Agrawal, *Nonlinear Fiber Optics*, 3rd. ed., (Academic Press, Boston, 2001).
[3] T. Kobayashi, H. Yao, K. Amano, Y. Fukushima, A. Morimoto, and T. Sueta, "Optical pulse compression using high-frequency electrooptic phase modulation," IEEE J. Quantum Electron. **24**, 382-387 (1988)