Bandwidth of a phase-modulated laser pulse

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High-power lasers for fusion like Laser Mégajoule (LMJ) require smoothing the focal spot in order to reduce parametric instabilities during laser-plasma interactions. One of the main smoothing schemes, called smoothing by spectral dispersion (SSD), is to broaden the spectrum through a phase modulation and to disperse the different frequencies with a grating [1].

The efficiency of SSD is mainly given by the coherence time given by the inverse of the spectral bandwidth. One may for instance consider the RMS value of the bandwidth but usually for a sinusoidal phase-modulated signal the bandwidth is given by $2.m.f_m$ where f_m is the frequency of the phase modulation and m its amplitude (or depth) in radians.

Indeed, Carson [2] demonstrated that 98% of the energy of a sinusoidally phase-modulated signal is contained within $2.(m+1).f_m$. However, the definition of the bandwidth should depend on the phenomenon to be considered. As a matter of fact, SSD has a drawback known as FM-AM conversion. Because of propagation phenomena, part of the phase modulation is converted into unwanted intensity modulation and only a small fraction of the energy may be responsible of significant FM-AM conversion. Indeed, filtering a phase modulated considering the Carson criterion induces around 20% overshoots because of FM-AM conversion (Figure 1).

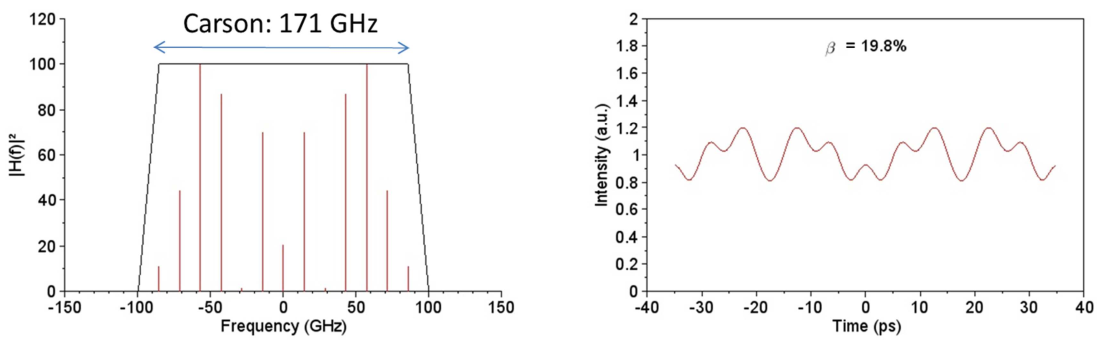

Figure 1: spectrum of a phase-modulated (f_m=14,25GHz, m=5) pulse (left) and induced FM-AM conversion when filtered by a 171 GHz flat-top filter (right).

In the presentation we will explain why and show that a much wider bandwidth, including up to 99.9999% of the energy, has to be considered when one wants for instance compensate for FM-AM conversion with high accuracy (i.e. below 1%).

References

[1] L. Videau, PhD Thesis, Ecole Polytechnique, 1998.

[2] R. Carson, "Notes on the theory of modulation", Proc. IRE, Vol. 10, pp. 57-64, 1922