Amplitude modulation filtering of FM-to-AM conversion due to the focusing grating of LMJ

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Abstract. FM-to-AM conversion is an important issue for high power lasers such as the Laser MegaJoule. Indeed temporal intensity modulation may prevent a good ignition of the target. FM is necessary to achieve optical smoothing: phase modulation broadens the spectrum and the different generated wavelengths will create different speckle patterns thanks to dispersion systems (gratings) that spatially average the focal spot on the target. We show in this paper that dispersion and focusing systems linearly filter intensity modulations by averaging due to time delay introduced by the gratings. For the LMJ configuration this filter is equivalent to a Gaussian low-pass filter with a 7GHz 3dB-bandwidth.

1. Introduction

To optimize the laser-target interaction, each of the laser beams of the Laser MegaJoule (LMJ) must have a very well controlled spatial and temporal shape. Control of the focal spot is realized by optical smoothing. There are different techniques of optical smoothing [1]. The one used on the LMJ needs a broadened spectrum realized with phase modulation (i.e.: frequency modulation, FM) and a dispersion system (plane or focusing grating). Ideally, a pure phase modulation does not change the beam intensity. But, the propagation through the different components of the chains is not perfect and filters the optical spectrum. Therefore, FM is partly converted in intensity modulations (i.e.: amplitude modulations, AM). This FM-to-AM conversion might prevent a good control of the temporal shape and so a good ignition of the target for different reasons: 1) parametric instabilities may be amplified with intensity modulations and 2) the radiative temperature of the hohlraum may change [2].

In this paper, we first mention the different systems of beam smoothing, then we explain how gratings average intensity of the beam and, whatever the system used, induce a linear temporal filtering that lowers most of the high-frequency intensity modulations. Finally, we present the results of a numerical model (confirmed by the Miró software [3]) on the LMJ configuration.

2. Influence of optical smoothing on the temporal pulse shape

On the National Ignition Facility (NIF), optical transverse smoothing by spectral dispersion (SSD) is achieved but on LMJ, longitudinal SSD is used. Differences between the two techniques are simply presented in figure 1. Transverse (resp. longitudinal) SSD is characterize by a variation of the focal spot in the transverse (resp. longitudinal) plane with wavelength. Both configurations use gratings (plane or focusing).
Gratings are interferential systems that privilege one direction for the equiphase surface which is different from the isointensity surface after the grating as shown in figure 2 for the NIF and figure 3 for the LMJ. Looking at figure 2, a temporal waveform distorted by FM-to-AM conversion is “tilted” after the grating by the time delay $\Delta T$. The lens acts in the focal plane as an integrator of the different parts of the waveform arriving on the lens and so on the focal plane at different times (a lens does not introduce significant time delay [4]). Thus, the intensity is averaged due to the time delay and AM is lowered by integration. Although more complex, the phenomenon is the same on LMJ: the focusing grating both generates the spatially varying time delay and integrates the intensity on the focal plane. Using this idea that has already been notified before for transverse SSD [5], we demonstrate that this summation can be seen as a linear filter and we determine the focusing transfer function for the LMJ configuration. We compare our models with simulations made with the Miró software.

3. Results on filtering of AM due to focusing in LMJ configuration

The filtering is due to the summation of the intensity depending on the time delay introduced by the grating but the geometry of the beams (as well as the gratings) determines how the intensity modulation is filtered on the focal plane. Analytical expression of the power in the focal place has been calculated in two particular configurations: focusing grating with round flat top beam and plane grating with spatially rectangular flat top beam where results are similar and linked to the number of color cycles $N_c = f_m \Delta T$ (where $f_m$ is the frequency of the phase modulation) and the surface $S$ of the grating. We consider an initial pulse with AM as followed $P_{\text{init}}(t) = S(1 + \sin(2\pi f_m t))$ so in the focal plane:

$$P_{\text{fin}}(t) = S\left(1 + \frac{\sin(\pi N_c)}{\pi N_c} \sin(2\pi f_m t - \pi N_c)\right)$$

(1)
The attenuation factor depends linearly of the frequency of AM by the function \( \frac{\sin(\pi N_c)}{\pi N_c} \) in those cases. In all the other cases we use numerical results (presented in Figure 4), they are confirmed by simulations made with the Miró software.

Equation (1) explains why for some specific frequencies, AM totally disappears in figure 4 for the round flat top beam on a focusing grating (blue-short-dashed curve). By changing the geometry of the beam to rectangular beams, the transfer function is modified: slow frequencies are less lowered and the filter is smoother.

This AM filter due to focalization on the LMJ configuration reduces the intensity modulation on the target and is equivalent to a Gaussian low pass-filter with a 7GHz 3dB-bandwidth (figure 5). We have previously shown [6] that part of the AM at low frequencies may be transferred to higher frequencies. Thus, the low-pass filtering function that we present in this paper filters out the highest frequencies reducing the overall AM on the target (figure 6).
4. Comparison of different filters for different ways of smoothing
As mentioned before, AM filtering is not a particularity of longitudinal SSD smoothing (figure 3.a and c). It also exists with transverse SSD smoothing and so for NIF configuration too [5]. In both cases it filters unwanted modulation due to FM-to-AM conversion but as well the temporal shape of pulses. This is not a problem for LMJ and NIF because no particular specification is given regarding frequencies above 5GHz. However it is possible to have only the beneficial effect and keep the original shape of the pulse by pre-compensation of the inhomogeneous wave before the phase modulation. Practically it is easier to realize on transverse SSD configuration as presented in figure 3.b.

![Figure 7. Different configurations of smoothing: filter may change.](image)

5. Conclusion
We have analytically and numerically calculated the linear filtering function of the intensity in the case of SSD. This reduces the total amount of temporal distortions in the focal plane.

6. References
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