Title

Reviewing the Paper: Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Lasers

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Reviewing the Paper: Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Lasers

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ABSTRACT

Microbunching instability that is present in free-electron lasers(FELs) can cause excessive interruptions in the lasers. This paper is a review of attempting to use Laguerre-Gaussian Mode laser heating to solve this issue.

INTRODUCTION

The problem with microbunching instability is that it is not a simple noise or disturbance, but a collective effect that can develop and undergo amplification, which can cause degradation to and ruin the function of a laser beam[1,2]. Laser heating can be used in an attempt to suppress the microbunching instability for free electron lasers at low wavelengths(Angstrom level). The laser heater consists of a chicane with an undulator that propagates with a laser pulse that gives energy to the electron beam[1,2]. Most laser heaters use ordinary transverse gaussian beams in order to suppress microbunching instability, but there is room for improvement in its suppression through the use of other beam modes. One of these modes is the Laguerre-Gaussian mode with a radial order of 0 and an azimuthal order of 1(LG_{01}). The LG_{01} mode takes a characteristically “donut” shape[3]. In the following sections, the influence of the LG_{01} mode in comparison to the ordinary gaussian beams on microbunching instability will be shown.

METHODS

Both normal gaussian and LG_{01} wave shapes maintain a gaussian structured shape which is needed in order for a wave to be able to propagate over extended distances without deforming. The intensity of a standard gaussian wave and LG_{01} wave are shown respectively below with the LG_{01} wave having its phase as well.

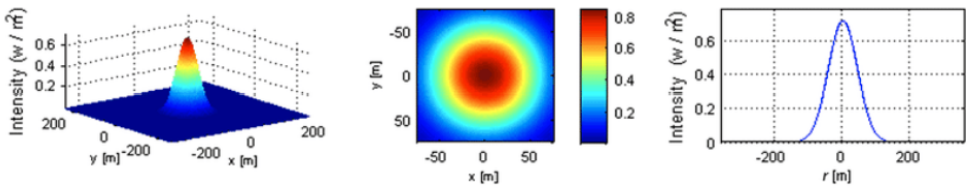

Fig. 1. (Ref. [4], Fig. 3).

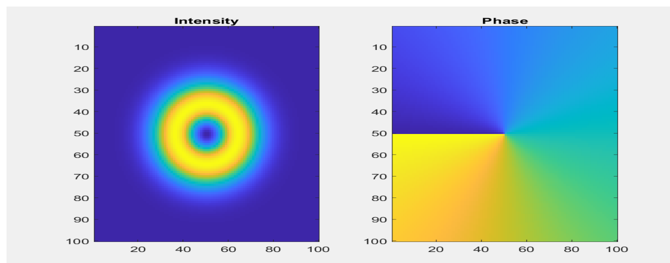

Fig. 2. (Ref. [3], Matlab Code).

The paper used a large configuration in order to find the effect of the laser heating, converting a gaussian wave to LG_{01} and sending that beam through the laser heating system. This beam induces the electron beam to be measured at the end by a spectrometer. In this way, the energies of both methods are able to be measured side by side as shown below[1].

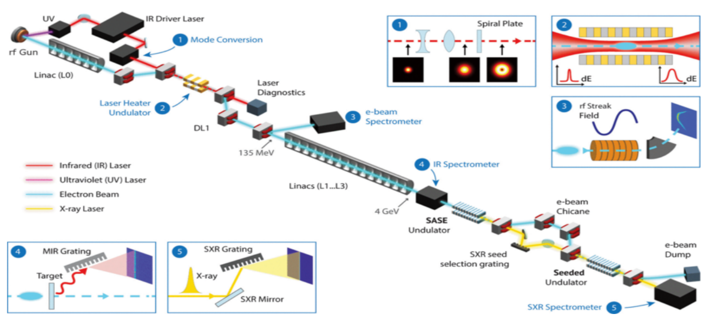

Fig. 3. (Ref. [1], Fig. 1).

RESULTS AND INTERPRETATION

The main results of this study show that using LG_{01} modes for laser heating maintain more of their energy when compared to the normal gaussian beams, for increasing induced energy. Figure 4 on the left shows the induced energy, while figure 5 on the right shows the corresponding gaussian curve fit of the normal gaussian mode and the LG_{01} mode. As demonstrated, the gaussian fitting of the energy propagated by the gaussian mode becomes erratic with increases in induced energy, while the gaussian fitting of the energy propagated by the LG_{01} mode tails off slowly with an increase in induced energy[1]. The tailing off of gaussian fitting is correlated to the increase in microbunching instability. Therefore, the LG_{01} mode causing less tailing off shows that it suppresses the microbunching instability more.

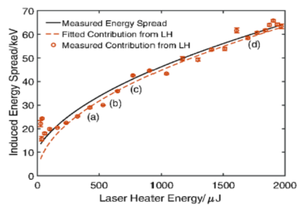

Fig. 4. (Ref. [1], Fig. 2).

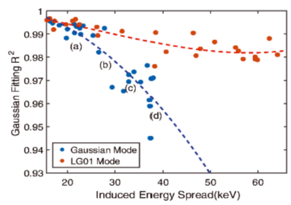

Fig. 5. (Ref. [1], Fig. 3).

One problem that occurs with this method is that there is a large energy cost to allow the LG_{01} beam to induce an energy spread to the electron beam. This cost is able to be covered for in the experiment by the spiral plate converting the beam at relatively high efficiencies(95%), but it could possibly cause problems in different utilizations[1].

CONCLUSIONS

In conclusion, using a LG_{01} mode laser heater truly does suppress microbunching instability more than the classic usage of the gaussian mode laser heaters.

Further work in this field could be to attempt to suppress microbunching instability not only in the propagation of the wave, but also at its source. One of the main things that can develop microbunching instability is shot noise[2]. The figure below shows the equation for shot noise. Therefore, we could attempt to reduce the microbunching instability by finding ways to reduce signal current, background photocurrent, and dark current as well.

$$\overline{i^2_{\mathrm{n,sh}}} = 2eB\bar{i} = 2eB\left(\bar{i}_{\mathrm{s}} + \bar{i}_{\mathrm{b}} + \bar{i}_{\mathrm{d}}\right), \qquad (11.35)$$

Fig. 6. (Ref. [5], Eq. 11.35).

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