Title
EE170a Paper: Review on Using Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free Electron Lasers.

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Review on Using Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free Electron Lasers.

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Abstract: Using a laser heater (LH) can suppress instability via Microbunching (MBI) in an electron beam. This review discusses the effect an LG_{01} (Laguerre-Gaussian) LH has in MBI suppression in an FEL.

INTRODUCTION

FELs, at the most basic level, are sources of light. They have numerous applications in various fields including physics, medicine, and defense.

An FEL employs a high intensity, high current electron beam. MBI degrades the quality of the electron beam in an FEL by amplifying its energy and density modulation and increasing its energy spread.[1] This ultimately makes the beam less effective in practical use.

Identifying and suppressing the causes of MBI can improve FEL performance. Main causes of MBI include longitudinal space charge and coherent synchrotron radiation. Fortunately, use of a LH can combat these effects. A LH increases electron beam energy spread in an FEL by about one order of magnitude without exceeding the FEL's tolerance. Increasing the initial energy spread decreases MBI further "downstream." The relative effectiveness of this strategy for decreasing MBI depends on the amount of LH induced energy spread in the electron beam, and the energy distribution of the LH.[1]

The focus of the paper in review is to study the effect using an LG_{01} LH has on MBI suppression on the FEL at Linac Coherent Light Source. For context, the LH operates in the 01 Gaussian mode. Gaussian modes, similar to plane wave modes, describe the characteristics of a wave's propagation. Uniquely, Gaussian modes have a finite cross-section, defined by spot size. [2]

The current state-of-the-art technology can be found at LCLS. This field leading FEL uses a Gaussian laser with a matched transverse electron beam shape. The goal of this paper is to review the effect using a LG_{01} mode LH has on the FEL at LCLS.

METHODS

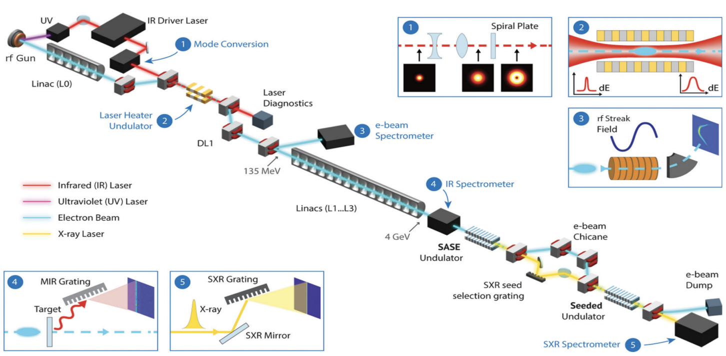

Figure 1 [1] (pictured left)

- Spiral phase plate (SPP) converts Gaussian LH to LG_{01} Mode (Fig. 1.1)

- 135 meV Spectrometer (Fig. 1.3) measures energy distribution

- Midanfrared (MIR) spectrometer (Fig. 1.4) measures MBI

The first spectrometer in the stream shown in Fig. 1.3 measures the cross-sectional energy distribution of the electron beam. The optimal distribution for the beam is Gaussian, and Figure 2 shows these results across different beam energy levels.

The MIR spectrometer shown in Figure 1.4 measures "coherent transient radiation from a thin film inserted into the electron beam."[1] Most importantly for analyzing results in this review, the profile of the radiation measured by this spectrometer is proportional to the amount of MBI. A lower magnitude of this value signifies lower MBI. Both of these measurements will show the effect the LG_{01} has on MBI.

RESULTS AND INTERPRETATION

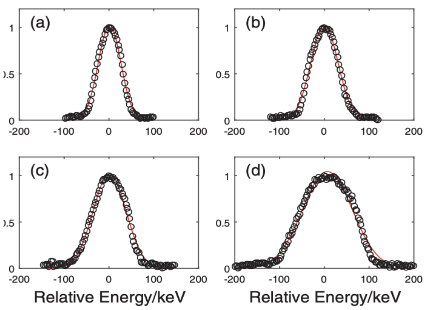

Figure 2 [1] (From 135 meV Spectrometer)

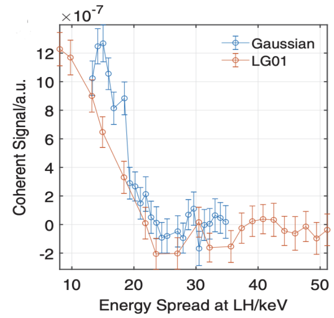

Figure 3 [1] (From MIR Spectrometer)

The readings from the 135 meV spectrometer (Fig. 2) show the energy distribution of the electron beam at different levels of induced energy spread. In order Figures 2.a-d are taken at 25.1, 30.3, 36.8, and 55.7 keV induced energy spread. For context, a higher induced energy spread is the result of higher LH energy. The figures and the red Gaussian fits behind the data visually show that the different energy distributions each are well-fitted to a Gaussian. When the electron beam's energy is at around 20-30 keV, a Gaussian energy distribution is a primary indicator of improved MBI suppression.[1] The LG_{01} consistently produced better Gaussian fit energy distributions than its Gaussian LH counterpart.

Figure 3 compares the radiation profiles of the electron beam with a LG_{01} LH, and a Gaussian LH. The LG_{01} LH at about 15-30 keV has consistently lower values in this metric than the Gaussian LH has, and the same is true at all measuring points higher than about 31 keV. It is notable that there is one significant outlier from this trend shown in the spot just right of 30 keV in Figure 3. There is a sudden and short lived simultaneous increase in effectiveness of the Gaussian LH, and decrease in the effectiveness of the LG_{01} LH. This wrinkle poses the need for further research into this niche.

Together, despite the outlier, these results show that the LG_{01} LH is generally a more effective tool for MBI suppression in a FEL

CONCLUSIONS

In this study, the LG_{01} mode LH is demonstrated to be an effective tool for MBI suppression in an FEL. It is also proven to be superior in MBI suppression to its predecessor, the Gaussian LH. It is feasible and effective to use a SPP to convert a LH from Gaussian to LG_{01} with a Gaussian energy distribution. There is discussion of soft x-ray self-seeded (SXRSS) FEL emission in the original paper. Perhaps there is more experimentation to follow in this field, or there is possible value in experimenting with LG LHs of different modes.

REFERENCES

[1] Tang, Jingyi, et al. "Laguerre-gaussian mode laser heater for microbunching instability suppression in free-electron lasers." Physical review letters 124.13 (2020): 134801

[2] Liu, Jia-Ming. Principles of Photonics.