Title

Importance of Cylindrical Symmetry and Gaussian Energy Distribution in Laguerre-Gaussian Modes

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Importance of Cylindrical Symmetry and Gaussian Energy Distribution in Laguerre-Gaussian Modes

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Abstract: This paper will discuss the relative energy distribution and cylindrical symmetry of the Laguerre-Gaussian mode laser, namely the LG_{01} transverse laser mode as detailed by Tang et, al. and the importance of these on microbunching instability in free-electron lasers.

INTRODUCTION

At the basis of a Gaussian mode, traditional monochromatic optical waves are considered in a homogenous isotropic medium. The Gaussian mode is the set of modes of which the plane wave produces a finite cross-sectional distribution. The research paper written by Tang et, al. considers the energy spread and effects of an electron-beam when degraded by the LG_{01} mode laser heater (LH).[1] The heater prevents microbunching instability (MBI) and increases the free-electron laser (FEL) intensity. Due to the collective longitudinal space charge, the LG_{01} mode heater is used in this work due to the cylindrical transversal symmetry and the Gaussian-shaped energy distribution. Considering the theory of LG_{01}, the beam intensity equation is as shown below in Eq. 1.[2]

$$I(r,z) = I_0(z) exp\left[\frac{2r^2}{w^2(z)}\right] \tag{1}$$

From this equation, it is shown that the beam intensity follows a cylindrical symmetry pattern, essentially what the researchers were searching for in their Laser Heater.

METHODS

The methods used in this work consisted of using a Laser Heater Undulator with a spiral phase plate at the Linac Coherent Light Source inside the Stanford Linear Accelerator Center.[1] The spiral phase plate converted the basic Gaussian Heater already installed into an LG_{01} Heater. The shape of the plate allowed a large phase change in the original Gaussian beam, thus creating a zero at the center of the laser. Considering the cylindrical symmetry of a general LG beam, this lines up with the theoretical analysis of Gaussian modes. Because of this nullified amplitude at the center of the laser, this design allows incredibly high transmission efficiency of the original laser.

RESULTS AND INTERPRETATION

The main characteristic of diagnosis to be considered is the Gaussian energy distribution of the LG_{01} LH. The Gaussian energy distribution is important in this study as it's the first indicator of potential of better microbunching suppression. It is found that the LG_{01} LH conforms to the Gaussian distribution very well, as shown below in Fig. 1(a)-1(d) and Fig. 2(a)-2(d).[1] It's noted that the e beam performs at optimal performance distributions when heated to 20-30 keV, further reinforcing that the LG_{01} LH conforms to the Gaussian distribution that the researchers are searching for. The next diagnostic that the researchers were searching for was the midinfrared spectrometer (MIR) at the e-beam's final energy. This MIR would measure radiation of the e-beam and would have a radiation factor which is proportional to the MBI factor. In Eq. 2, we see relationship found. *I(k)* is the radiation profile of the MBI, and *f(k)* is the Fourier transform of the e-beam charge distribution.[1]

$$\mathrm{I}(\kappa) \propto |\mathrm{f}(\kappa)| \tag{2}$$

It was found from this relationship that the LG_{01} LH shows better MBI suppression than the Gaussian equivalent.

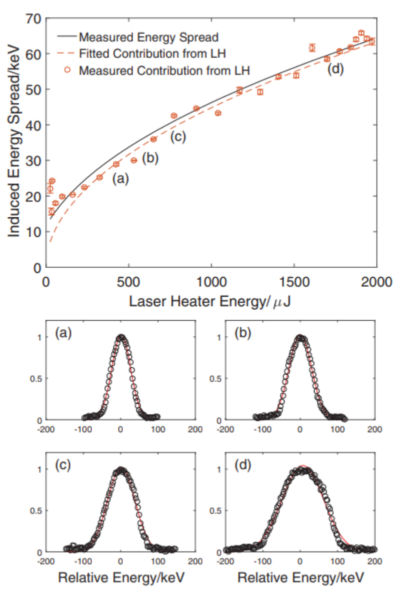

FIG 1. Energy Spreads of E beam after LH

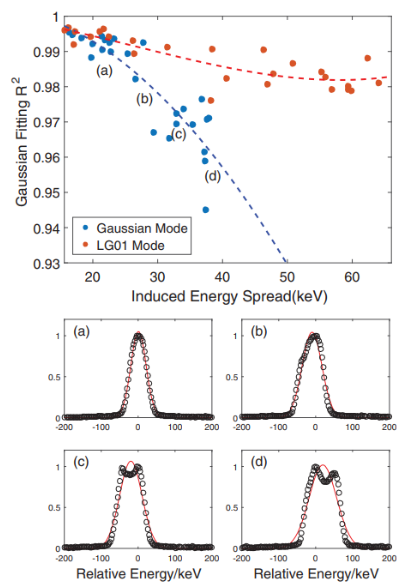

FIG 2. Gaussian fitting of induced energy spread

CONCLUSIONS

The main conclusions are as follows. The LG_{01} LH causes the e-beam's energy distribution to follow a Gaussian distribution, and as such reducing the microbunching instability. The cylindrical symmetry in the LG_{01} LH allows for a nullified amplitude at its center, hence improving the transmission efficiency of the original e-beam. In this particular study, the above is found to be true. In conclusion, the geometric properties of theLG_{01} Mode Laser Heater is extremely effective in reducing MBI and allows optimal greater e-beam transmission.

REFERENCES

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