Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression: Review

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Abstract: This review discusses the use of a laser heater with Laguerre-Gaussian shaped pulse to suppress microbunching instability which is undesirable in applications such as free-electron lasers [1].

INTRODUCTION

Free-electron lasers need high quality electron beams in order to meet the required gain and brightness [1]. Microbunching instability can decrease the quality of an electron beam causing the quality to be below that necessary for a free-electron laser [1]. Laser heaters can be used to suppress the effects of microbunching instability. A laser heater typically uses a simple Gaussian-shaped laser [1] which is not immune to microbunching instability. By modifying the shape of the laser used in the laser heater, it may be possible to reduce the undesired effects of microbunching.

METHODS

Reducing the microbunching instability depends on the energy spread and the distribution from the laser heater [1]. A Gaussian mode's spot size as well as its transverse field distribution change along the longitudinal axis (propagation direction) [3]. The distribution can be changed by modifying the shape of the laser pulse [1].

A Laguerre-Gaussian mode is TEM Gaussian modes defined in cylindrical coordinates which have circular and radial symmetry in the transverse plane [3]. Using a transverse Laguerre-Gaussian 01 mode should result in a Gaussian shaped energy distribution [1]. The spatial energy distribution of the simple, fundamental Gaussian mode (00), and the distribution of the Laguerre Gaussian 01 mode can be seen in figure 1 below.

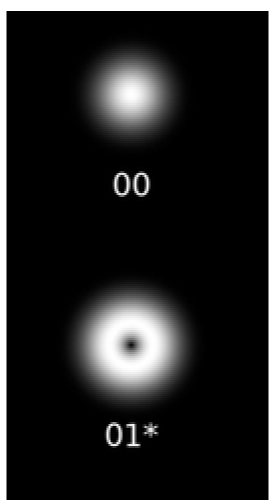

Fig. 1. Spatial energy distributions for Laguerre-Gaussian modes 00 and 01 (Ref. [2]).

In theory, we should have lower microbunching instability for the Laguerre-Gaussian 01 mode because the higher the order of the mode, the farther the spread of the transverse field distribution [3]. The farther the spread of the distribution, the greater the reduction in microbunching instability.

A laser heater using a Laguerre-Gaussian mode was implemented to determine if the mode would result in a Gaussian-shaped distribution and reduce microbunching instability, as expected from theory.

RESULTS AND INTERPRETATION

It was determined experimentally that the use of a Laguerre-Gaussian mode laser heater results in a Gaussian shaped energy distribution [1], as can be seen in figure 2 below, which shows the energy distributions at rms energy spreads of (a) 20.5 keV, (b) 26.7 keV, (c) 30.1 keV, and (d) 37.2 keV.

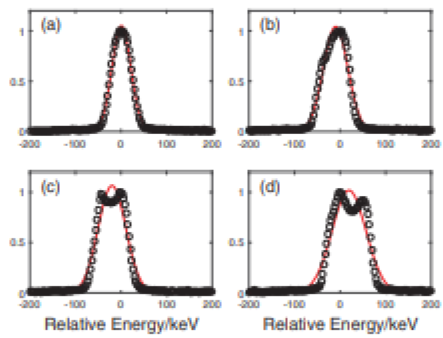

Fig. 2. Energy distributions from transverse Gaussian mode laser heater (Ref. [1], Fig. 3).

Figure 3 below shows that Gaussian fitting coefficient of the Laguerre-Gaussian mode compared to that of the fundamental Gaussian mode. The higher Gaussian fitting coefficient across energy spread tells us that a Laguerre-Gaussian mode laser heater is well-suited to reduce microbunching instability and does so much better than when using a simple Gaussian mode laser heater.

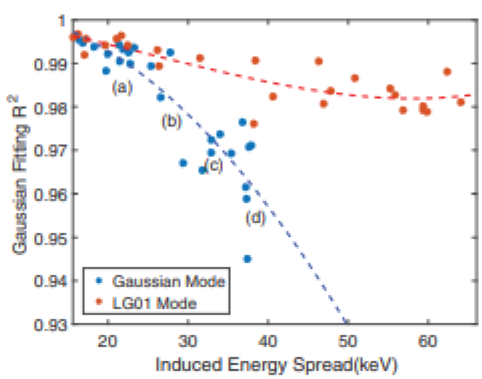

Fig. 3. Gaussian fitting coefficients for Gaussian mode and LG01 mode (Ref. [1], Fig. 3).

CONCLUSIONS

Theory suggests that a Laguerre-Gaussian 01 mode laser heater will result in a Gaussian-shaped energy distribution and reduce microbunching instability. When tested experimentally, it was found that results matched that theory, with the Laguerre-Gaussian 01 mode significantly outperforming the Gaussian mode in reducing microbunching instability.

REFERENCES

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