Title

Critical Review of Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Methods

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Critical Review of *Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Methods* and a Proposed Alternative to the Gaussian Laser

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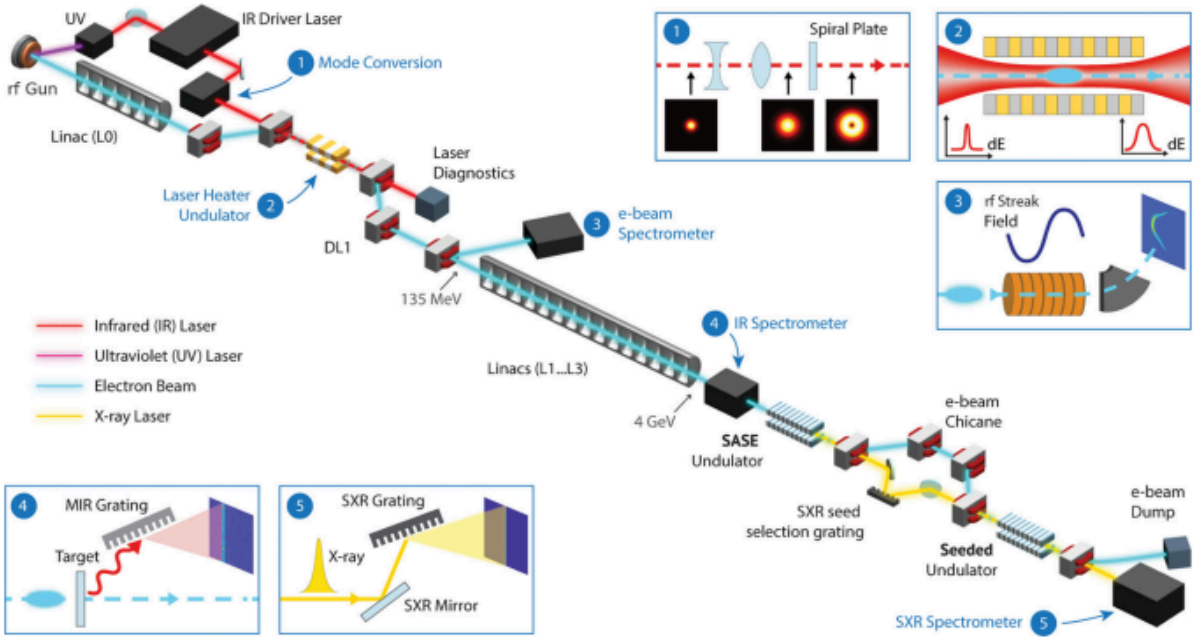
Abstract:

"Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Lasers" [1] proposes the usage of a Laguerre-Gaussian mode laser to minimize the impact of microbunching instability (MBIs) in free-electron lasers (FELs). This critical review serves to evaluate the effectiveness of the Laguerre-Gaussian mode laser heater and propose an alternative laser mode, a flat-top laser mode, which may also be useful in MBI suppression in FEL applications.

Introduction:

FELs are devices that generate massive, short pulses of radiation by sending electron beams through a magnetic structure called an undulator that, while inside, transversely oscillate and bunch together, emitting electromagnetic waves. The process in which these electrons bunch together is called microbunching, which is a cluster of electrons that all oscillate



A simplified model of the laser heater experiment, with a spectrometer at the end to measure the results [1]

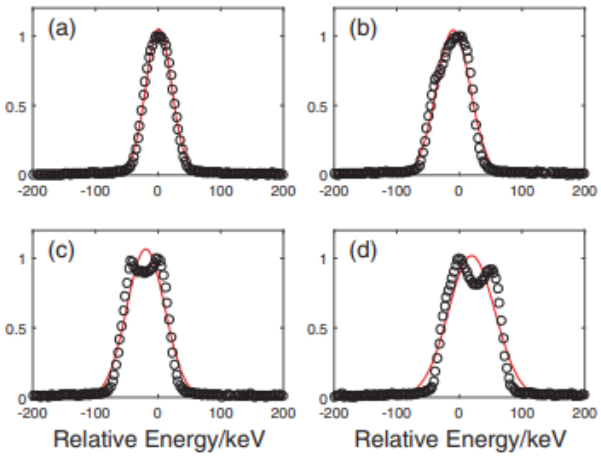
at a periodicity equivalent to the wavelength being emitted, coherently amplifying the radiation [2]. These microbunches are capable of reaching currents that exceed that of the threshold current, which distorts the bunches' charge distributions and energy spread, degrading the electron beam quality in FELs [3].

Laser heaters mitigate this effect by directing a laser pulse at the microbunches as they pass through an undulator centered in a chicane. This pulse modulates the energy of the electrons, and as they pass through the rest of the chicane, their overlapping longitudinal phase space increases uncorrelated energy spread, which suppresses the microbunching instability effect [4]. The distribution of the energy spread is influenced by the transverse profile of the laser heater, as the energy modulation of an electron is dependent on its position. By shaping the transverse laser profile, the effectiveness of suppressing the microbunching instability increases drastically [5].

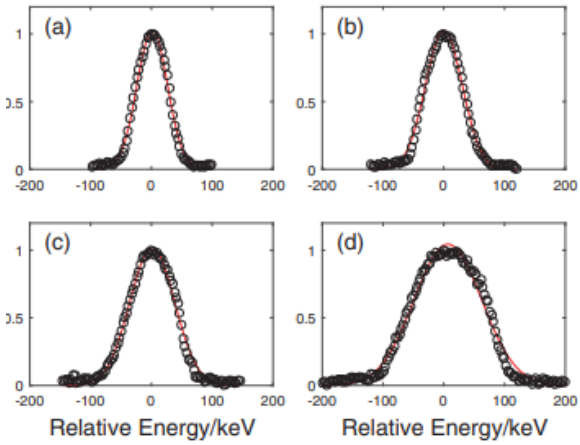
This review aims to analyze the outcome of the Laguerre-Gaussian mode laser heater for MBI suppression experiment and propose an alternative laser mode to suppress MBI.

Methods:

The paper suggests that cylindrically symmetrical lasers, i.e., Gaussian Lasers, provide enhanced suppression of microbunching. When the transverse size of the Gaussian laser matches the electron beam size, every electron will experience an energy modulation consistent with its position in the beam. While both the Gaussian mode and the Laguerre-Gaussian mode create symmetrical profiles, the Gaussian mode has “horn”-like distributions when energy spread is



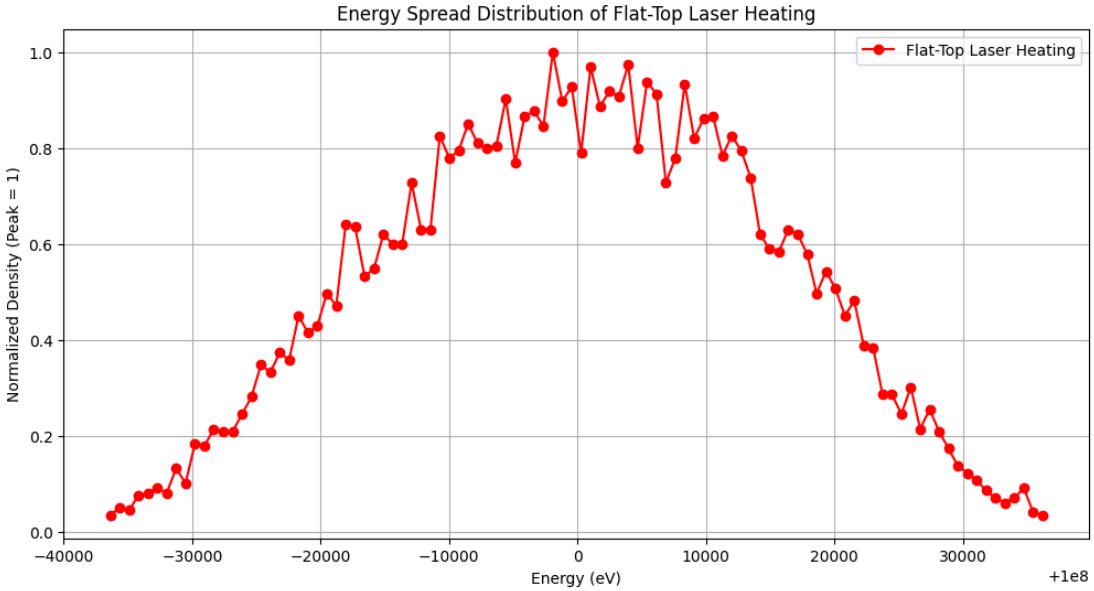
Gaussian LH with 20.5, 26.7, 30.1, and 37.2 keV rms energy spreads[1]



LG LH with 25.1, 30.3, 36.8, and 55.7 keV rms energy spreads[1]

high [1].

While Gaussian modes provide an even, donut-shaped intensity, an alternative to Gaussian beams would be to use a flat-top laser in the LH. Flat-top modes have an even intensity distribution, much like Gaussian and LG modes; however, it is a sharp, squarewave-like distribution as opposed to the smoothness found in the Gaussian beam. Due to this, electron energy modulation is not positionally determined, but all electrons will have a matched modulation. Using the same parameters as those in the paper, a simulated distribution using a flat-top mode yields the following:



Results:

In the paper, it was concluded that Laguerre-Gaussian mode laser heaters show promising results as they uniformly distribute energy spread, resulting in suppressed MBI. By using a flat-top laser heater, energy modulation is uniformly distributed. The energy distributions still yield a Gaussian distribution and show promising usefulness in being used as a laser heater mode to reduce MBI.

Conclusion:

This review evaluated the use of Gaussian mode laser heaters in suppressing MBI and compared the energy spreads resulting from using a standard Gaussian mode versus a Laguerre-Gaussian mode. The LG mode and standard Gaussian mode had similar energy distributions at low energies, but as energy spread increased, the LG mode stayed consistent in form while the standard mode created a “double horn” distribution, revealing its potential use in suppressing microbunching instability.

As an alternative to this, the flat-top mode was suggested as a potential mode for a laser heater as it maintains the uniform distribution found in the LG mode lasers. Future work in the field should implement the flat-top laser heater mode as an effective way to suppress MBI.

References

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