Title
Laguerre-Gaussian Mode Laser Heater

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Abstract:

This paper will discuss how a laser heater (LH) can positively improve instability control and the effect of Laguerre-Gaussian in Microbunching Instability (MBI) suppression for free-electron lasers.

Introduction:

Free-electron lasers produce a high-frequency and short pulse of radiation. It requires high-brightness electron beams and high current, and the radiation is generated by electrons passing through the magnetic compression accelerator.

It is fairly used in physics, chemistry, and biology. As radiation intensity grows, microbunching instability can damage the electron-beam quality and brightness. The authors suggested that a laser heater installed at the Linac Coherent light source (LCLS) can suppress the MBI. The laser heater consists of a short undulator with a chicane and an in-phase infrared laser that can increase the energy spread of the beam without exceeding the FEL tolerance.

MBI suppression is based on the amount of laser heater energy spread and distribution and is managed by shaping the laser heater pulse. The two edges of the laser do not have enough energy in a conventional shape beam, so recent studies use nonconventional beam shape to have better MBI suppression and gaussian-shaped energy distribution, like transverse Laguerre-Gaussian 01. (LG01)

The authors researched the application of LG01 mode laser at the Linac Coherent light source and the performance of free-electron lasers and their MBI suppression. They concluded that Gaussian-shaped energy distribution is induced by Laguerre- Gaussian mode light heater, and the final MBI is better suppressed.

Methods:

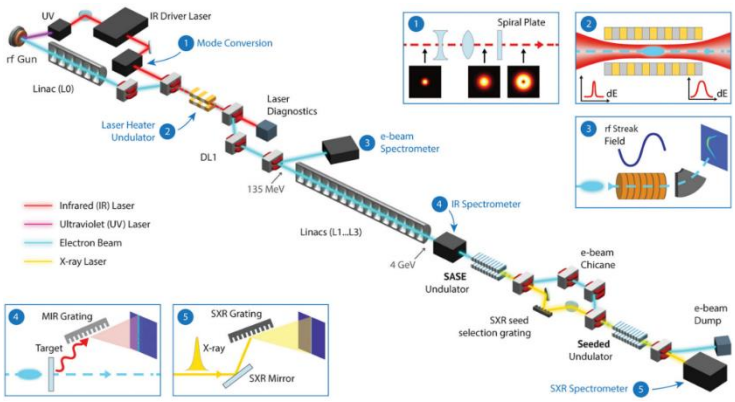

Figure 1 - Simplified schematic of start-to-end experimental configuration, from the photoinjector to the SXRSS diagnostic end station

This experiment aims to compare the improvement of MBI suppression from the LG01 mode to the original Gaussian mode. The FEL layout obtains the measurement result in the LCLS facility. Initially, a spiral phase plate (SPP) converts the Gaussian mode LH into LG01 mode, and the beam has a phase change of 2π after. To compare Gaussian and LG01, the researcher finds the Gaussian fitting coefficient for these two modes. It verifies that LG01 consistently induces more Gaussian energy distribution, which is one of the indicators for suppression performance. In the experiment, the SPP enables more than 95% transmission efficiency and achieves sufficient laser energy to induce the energy spread at optimal. The other performance indicator is a midinfrared (MIR) spectrometer placed on the linac after the beam reaches the final energy of 4 GeV. MBI suppression can be visualized since radiation is proportional to the MBI factor. The LG01 mode LH is simulated in ELEGANT, and GENESIS compares the result.

Results:

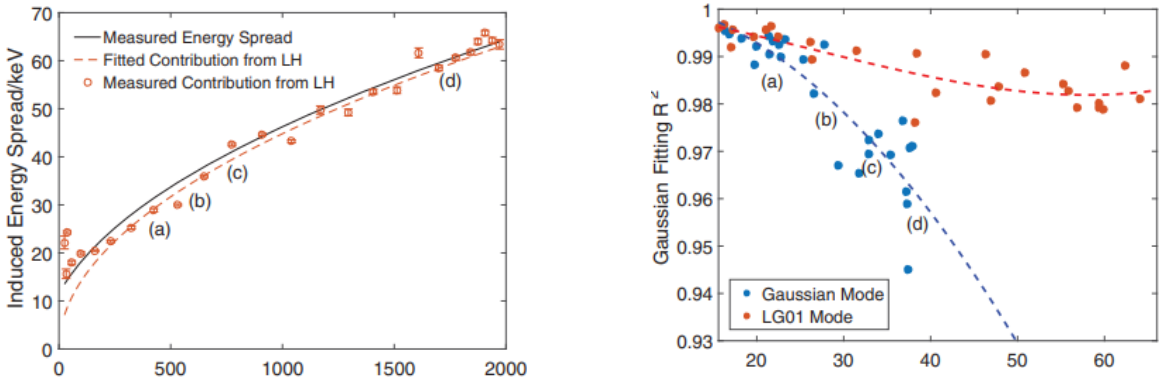

Figure 2 – Relationship between Laser heater energy, included energy spread, and Gaussian fitting

In comparison, the shape of the energy distribution between LG01 mode and Gaussian mode LH, LG01 mode fits the Gaussian shape better, energy spread increases, and has better energy distribution and less microbunching gain. Besides, the LG01 mode LH improves monochromaticity. Soft x-ray self-seeded (SXRSS) FEL emission has improved monochromaticity in ELEGANT simulation. The theory can also be proved by the comparison of the Gaussian fitting factor, which indicates that the LG01 mode has better suppression performance.

Conclusion:

By analyzing the midinfrared spectrometer reading and comparing the Gaussian fitting coefficient, the effect of microbunching instability in FEL is comparable between LG01 mode and Gaussian mode. The paper proved that the LG01 mode has better performance in suppression for free electron lasers.

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, J.M. (2016). Principles of Photonics.