Title

Review: The Effect of Wavelength Modulation on Microbunching Instability

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Review: The Effect of Wavelength Modulation on Microbunching Instability

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Abstract: A smaller wavelength value further decreases microbunching instability and the application of second harmonic generation will improve the performance of the free electron laser.

INTRODUCTION

This paper attempts to bridge further the findings in Tang et al's paper, "Laguerre-Gaussian Mode Laser Heater for Microbunching Instability Suppression in Free-Electron Lasers." In Tang's paper, the proposed idea of mitigating microbunching stability (MBI) is by introducing a Laguerre-Gaussian (LG_{01}) laser mode as a heater, demonstrating improved MBI suppression in contrast to the traditional Gaussian laser modes. This finding is crucial as it allows advanced free electron laser (FEL) operation modes such as soft X-ray seeding, where suppression of MBI is necessary. [1]

MBI is a phenomenon that leads to the degradation of electron beam quality, leading to a decrease in laser gain. This quality is particularly undesirable when using FEL, which requires relativistic electron beams with high brightness and high current due to it demanding high precision. [1] Introducing a laser heater helped resolve the microbunching instability phenomenon by increasing energy spread, which suppresses downstream MBI accumulation. With laser heating techniques, the intensity of FEL increases by a factor of three. [2] The desirable goal is the minimization of MBI, and the review will push further at the paper's attempt to propose a better method, built up by Tang et al., to mitigate MBI, especially by investigating the effect of wavelength modulation on the intensity of FEL.

METHODS

This review aims to build upon the foundation presented by Tang et al. Branching out from the foundation, the goal of the review is to determine a method of improving the laser heater beamline by changing a laser parameter and determining a state-of-the-art technology that would achieve this.

To determine the relationship of intensity with various parameters, the equation that relates the intensity with altering parameters has to be defined. Tang et al. mention that a transverse Laguerre-Gaussian 01 (LG_{01}) mode is an effective laser beam shape that reduces MBI exponentially. Using the Gaussian profile, Equation 1 presents the equation of the intensity profile of a beam:

$$I(r,z) = \frac{P}{\pi\omega(z)^2/2} exp(-\frac{2r^2}{\omega(z)^2}) \quad (1)$$

When using Equation 1, the beam radius as a function of z also has to be defined as illustrated in Equation 2:

$$\omega(z) = \omega_0\sqrt{1 + \left(\frac{\lambda z}{\pi\omega_0}\right)^2} \tag{2}$$

Using Equations 1 and 2, a relationship between a key laser parameter, wavelength, and the intensity of FEL can be determined. After determining the effect of wavelength on the intensity of FEL, a state-of-the-art technology that could be applied to the FEL to bring about this change will be analyzed.

RESULTS AND INTERPRETATION

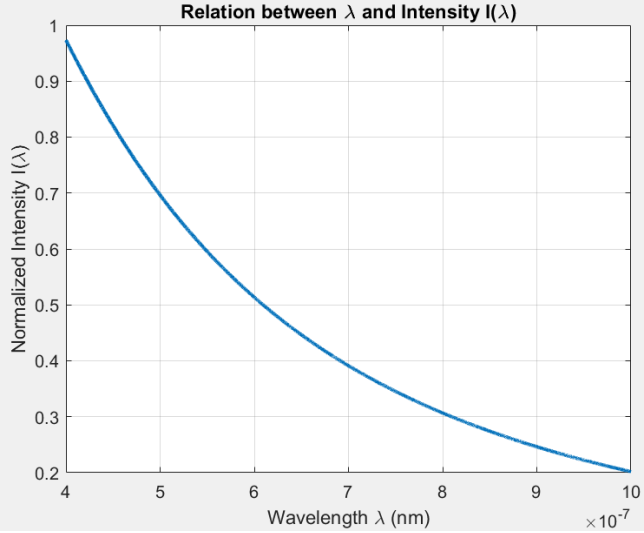

Fig. 1. Relationship between wavelength and intensity (Normalized to the maximum value of intensity in a given region of wavelength)

Figure 1 presents the effect of wavelength alteration on the intensity of the FEL. A simple trend that is visible is that the intensity of the laser decreases as the value of wavelength increases. This intuitively makes sense and is a result that was expected as a smaller wavelength would increase precision which would lead to a decrease in MBI.

The finding that smaller wavelength increases intensity, hence improving laser heater beamline, is crucial when determining the state-of-the-art technology that could be applied to the typical FEL to bring this change. A method that could bring this change is the application of second harmonic generation (SHG). SHG is a method where two photons from a single beam in a nonlinear crystal combine to produce a single photon with double the frequency, or the second harmonic. [3] With the application of SHG, the FEL will show increased intensity which will ensure a decrease in MBI.

CONCLUSIONS

The investigation builds up on the findings of Tang et al. and proposes a method that could decrease MBI in the FEL. A shorter wavelength leads to higher intensity, which in turn leads to a decrease in MBI. This is a crucial finding as a decrease in MBI for FEL means that it has

a more uniform FEL output. SHG was a state-of-the-art method proposed that could achieve this due to the characteristic of reduced wavelength that it presents.

This improvement will guarantee improved results in future experiments that use FEL due to reduced MBI, which allows higher precision results. Further steps that could be taken from this review are the verification of the theoretical idea into the practical world or a build-up from this idea to create a better FEL.

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