Use of Laguerre-Gaussian Modes

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Abstract: The properties of Laguerre-Gaussian modes, such as symmetry, make them useful. Discussion on an experiment using Laguerre-Guassian mode laser heater for free-electron lasers to suppress microbunching instability.

INTRODUCTION

Laguerre-Gaussian (LG) modes refer to transverse electromagnetic (TEM) Gaussian modes for optical wave propagation [1]. In the transverse plane, these modes have radial and circular symmetry [1]. The symmetry of LG modes along with their connection to electrons' and photons' quantised orbital angular momentum (OAM) make them useful in various topics in physics like astronomy or quantum optics [2]. An investigated use for Laguerre-Gaussian Modes is through using a LG_{01} transverse laser mode, by way of a laser heater (LH), in order to address microbunching instability (MBI) that arises from the use of free-electron lasers (FELs) [3]. In order to judge the effectiveness of the LG_{01} mode LH, observations were made on the suppression of MBI and compared to a simple Gaussian-shaped laser-based LH [3].

METHODS

Fig. 1 shows the setup for the measurements performed in [3] to observe the effect of changing the laser heater configuration to that of an LG_{01} mode. A spiral phase plate is the point at which the transverse profile of the LH is transformed from Gaussian to LG_{01}. The measurements were taken at the Linac Coherent Light Source (LCLS).

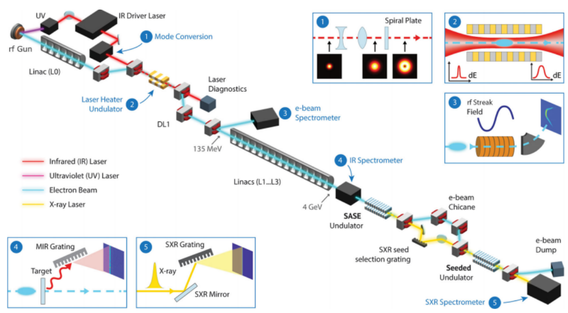

Fig. 1. Diagram showing the experimental setup for the suppression of MBI using LG mode laser heater (Ref. [3], Fig. 1).

RESULTS AND INTERPRETATION

The measurements performed in [3] showed the LG_{01} mode LH improved over the Gaussian mode LH, currently used at LCLS, in MBI suppression.

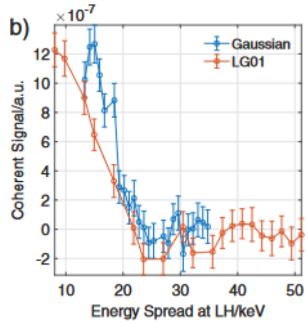

Fig. 2. Coherent spectral signal plotted across energy spread for both the Gaussian and LG_{01} LHs (Ref. [3], Fig. 4b).

Greater MBI suppression is directly related to lower spectral signal contribution. Thus, it can be seen on Fig. 2 at from 15 to 20 keV values for energy spread, the LG_{01} LH clearly outperforms the Gaussian LH.

The LH design has also been tested in the context of soft x-ray self-seeded (SXRSS) FEL emission. The presence of MBI negatively affects the resolution of some ultrafast x-ray spectroscopic methods [3]. From simulations, it was found that in a range of 1 eV around 750 eV, the center of the SXRSS spectra as seen in Fig. 3, using the LG_{01} LH could result in 20% improved monochromaticity. This implies the LG_{01} LH reduces unwanted effects that impact the performance of SXRSS [3].

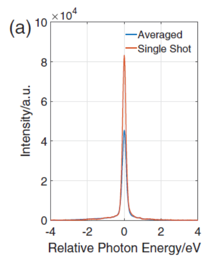

Fig. 2. SXRS spectra results with the LG_{01} LH, averaged and single shot (Ref. [3], Fig. 5a).

CONCLUSIONS

Improvement of LG_{01} mode LH over the Gaussian mode LH was seen in measurements of performance with respect to MBI suppression from [3]. Promising results were also seen from the evaluation of the LG_{01} LH with SXRSS. These results can be the impetus for improving upon the design of the currently used LH at the LCLS. Because MBI is harmful to the performance of FEL, identification of methods to reduce the influence of MBI improves upon the capabilities of such lasers and thus the quality of images that can be attained with them.

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