

The Role of Laser Shaping in Microbunching Instability Suppression for Free Electron Lasers

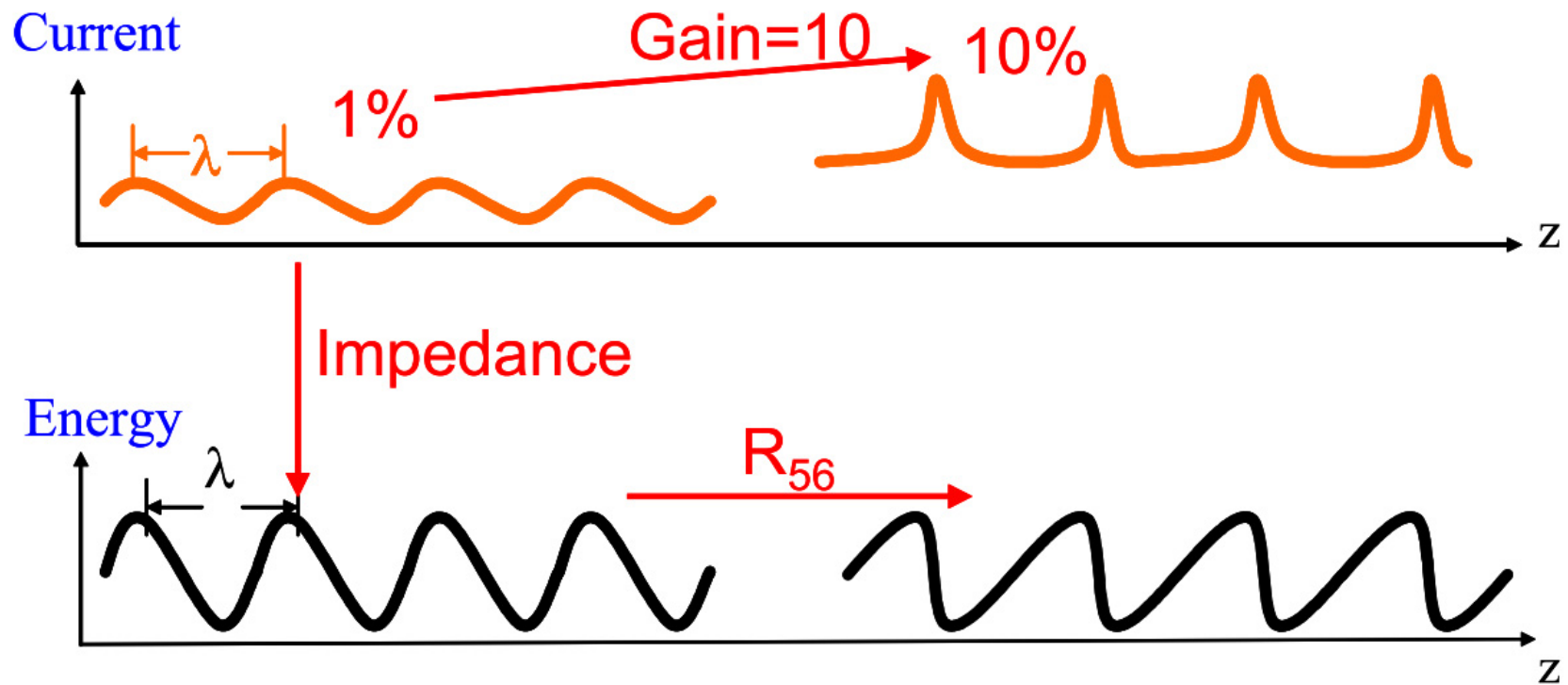
Jingyi Tang^{1,2}, Wei Liu¹, Randy Lemons^{3,1}, Sharon Vetter¹, Timothy Maxwell¹, Franz-Josef Decker¹, Alberto Lutman¹, Jacek Krzywinski¹, Gabriel Marcus¹, Stefan Moeller¹, Daniel Ratner¹, Zhirong Huang^{1,2}, Sergio Carbajo¹

1. SLAC National Accelerator Laboratory

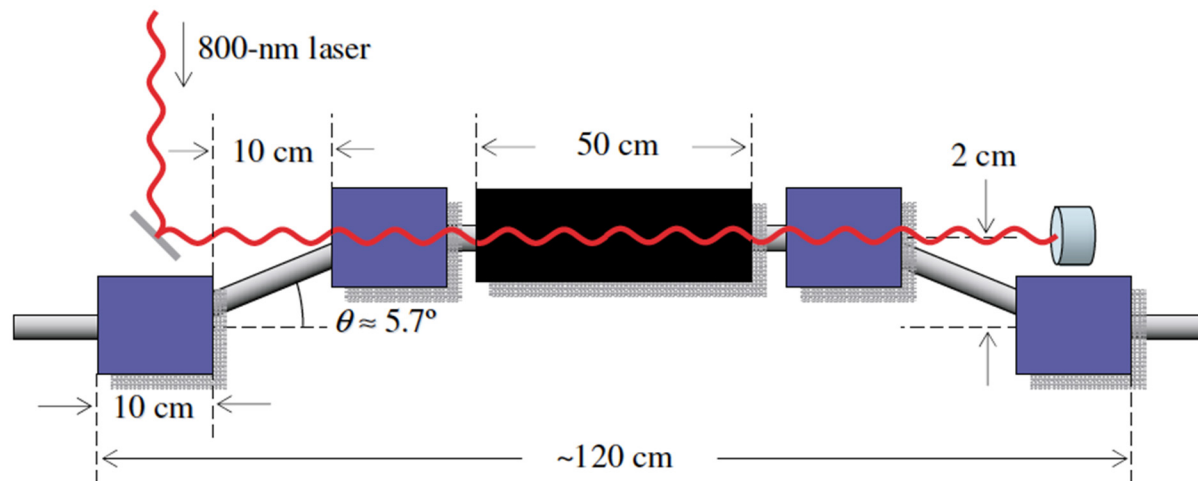
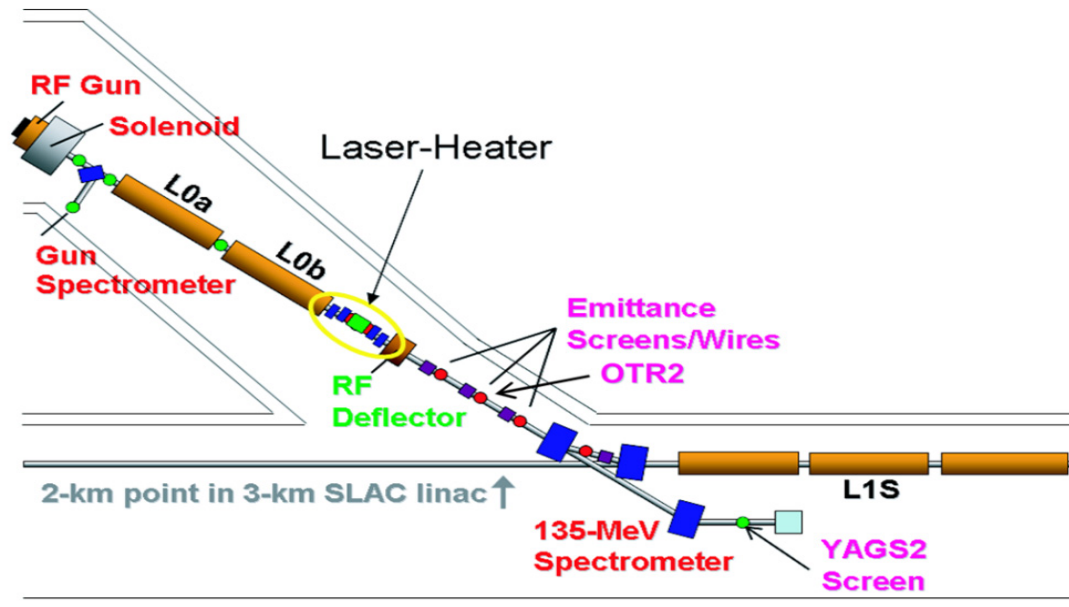
2. Stanford University

3. Colorado School of Mines

Microbunching Instability (MBI)



Laser Heater in LCLS



LH Laser Shaping for MBI suppression

Gain Suppression Factor

Metric to describe the performance of laser heater in suppressing microbunching Instability.

$$S_L \sim \left| \frac{b_f}{b_0} \right|$$

$$S_L(k) = \int \underbrace{e^{-\frac{r^2}{2\sigma_x^2}}}_{\text{e-beam}} \underbrace{J_0[k R_{56} A f(r)]}_{\text{laser transverse profile}} r dr$$

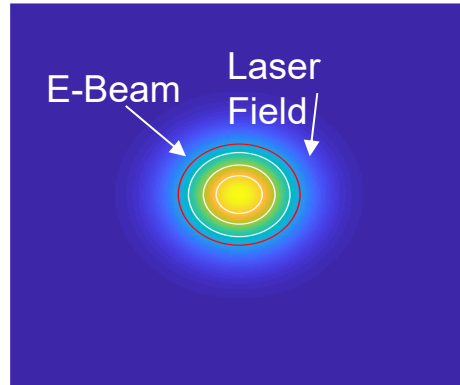
$$= \int \underbrace{V(\delta)}_{\text{e-beam energy distribution}} e^{-i k R_{56} \delta} d\delta$$

e-beam energy distribution

LH Laser Shaping for MBI suppression

Transverse Gaussian Mode

$$f(r) = A e^{-\frac{r^2}{2B_G^2}}$$

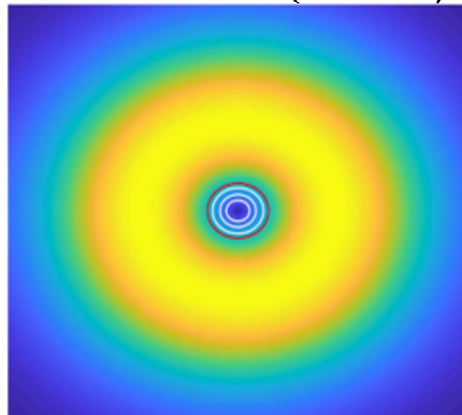


Transverse Laguerre-Gaussian Mode (LG01)

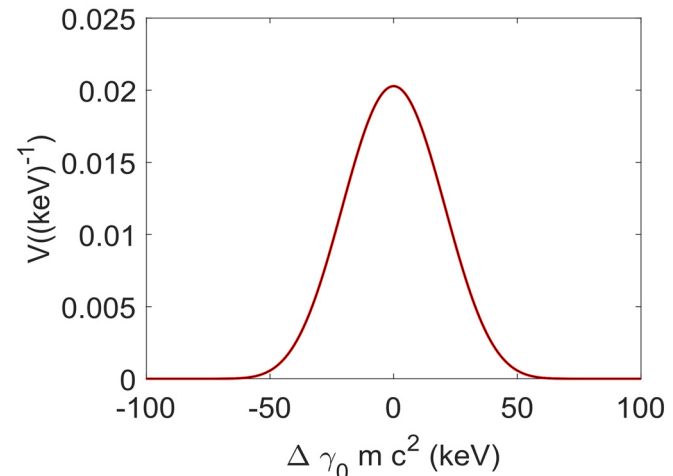
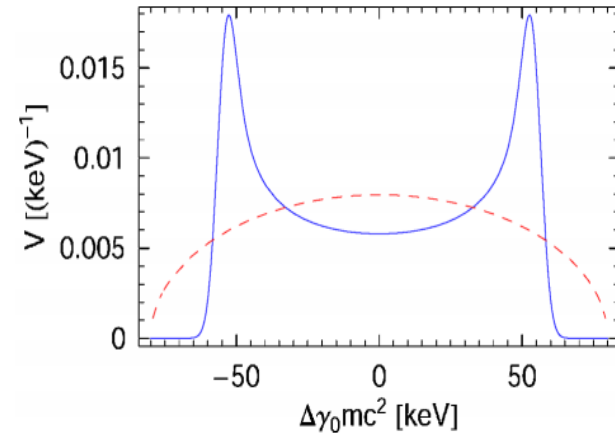
$$f(r) = A r e^{-\frac{r^2}{2B_{LG}^2}}$$

$$f(r) \sim A r$$

$$\text{for } r \ll B_{LG}$$



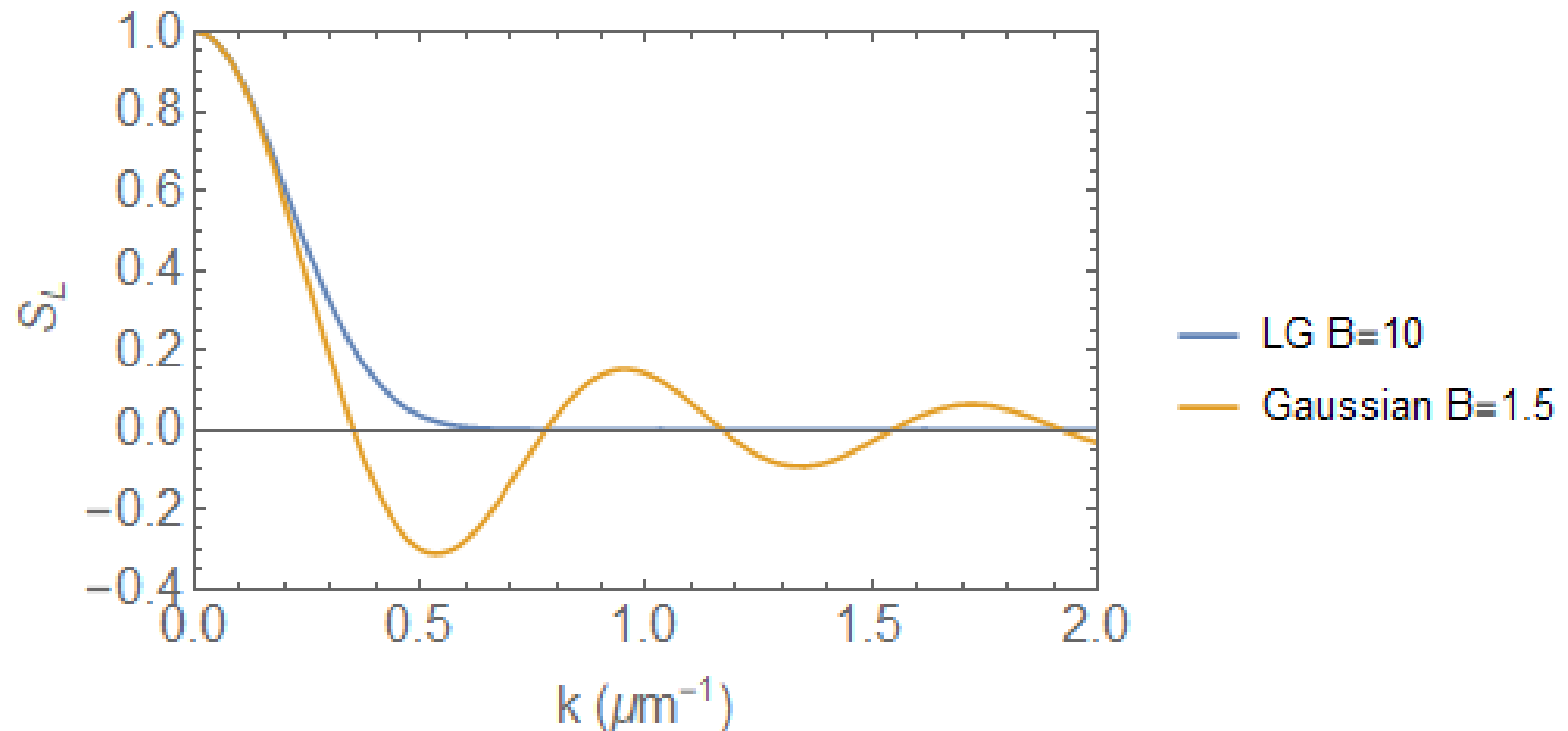
Energy Distribution of e-beam



LH Laser Shaping for MBI suppression

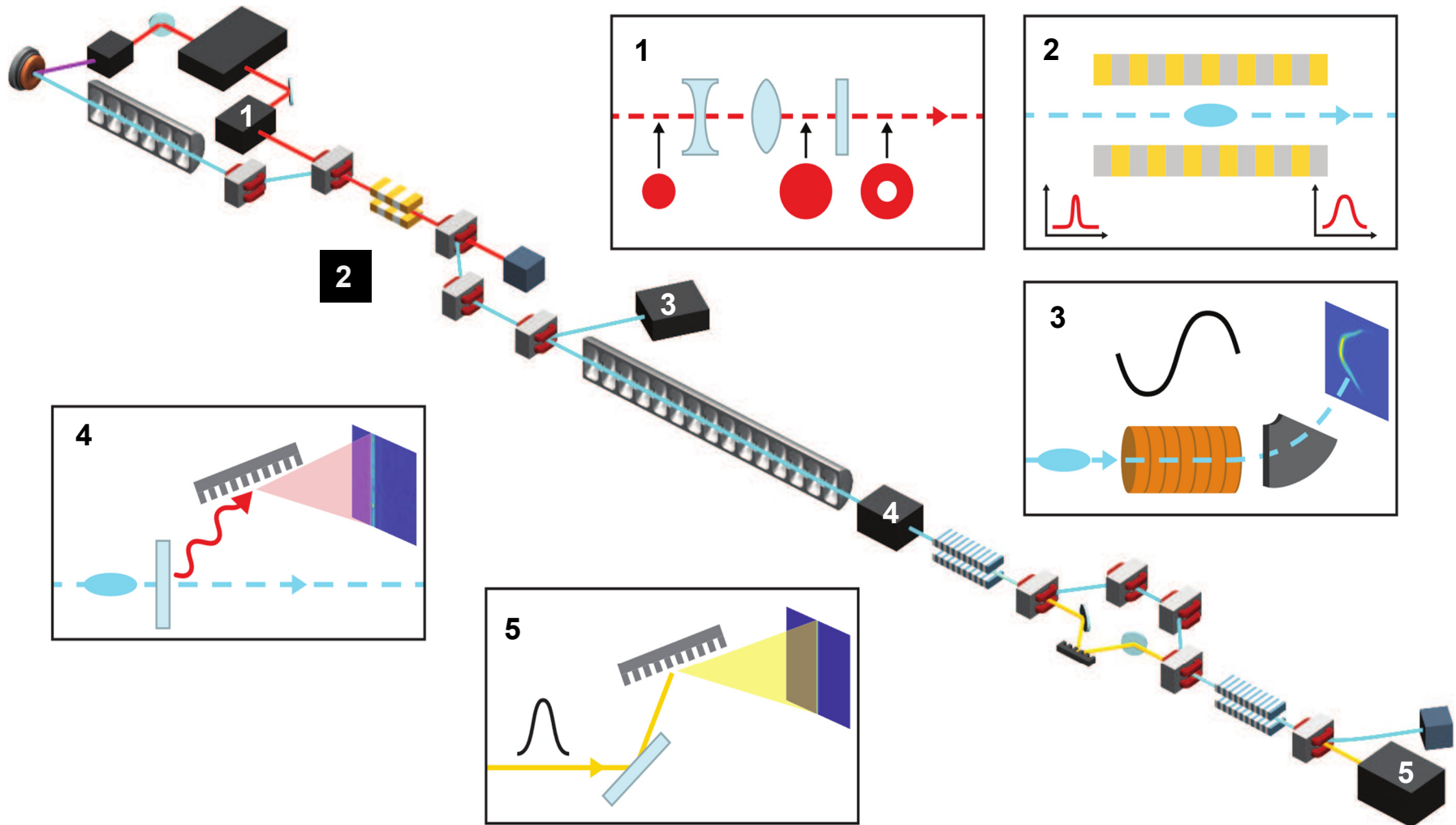
Gain Suppression Factor

Lower suppression factor for better microbunching suppression.



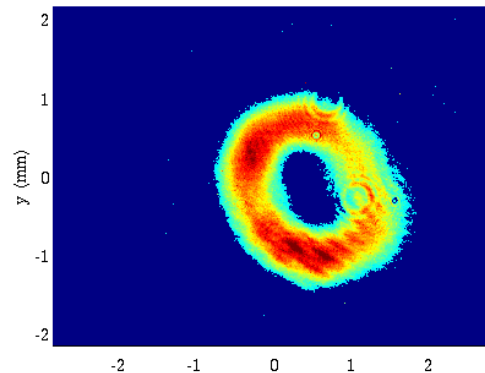
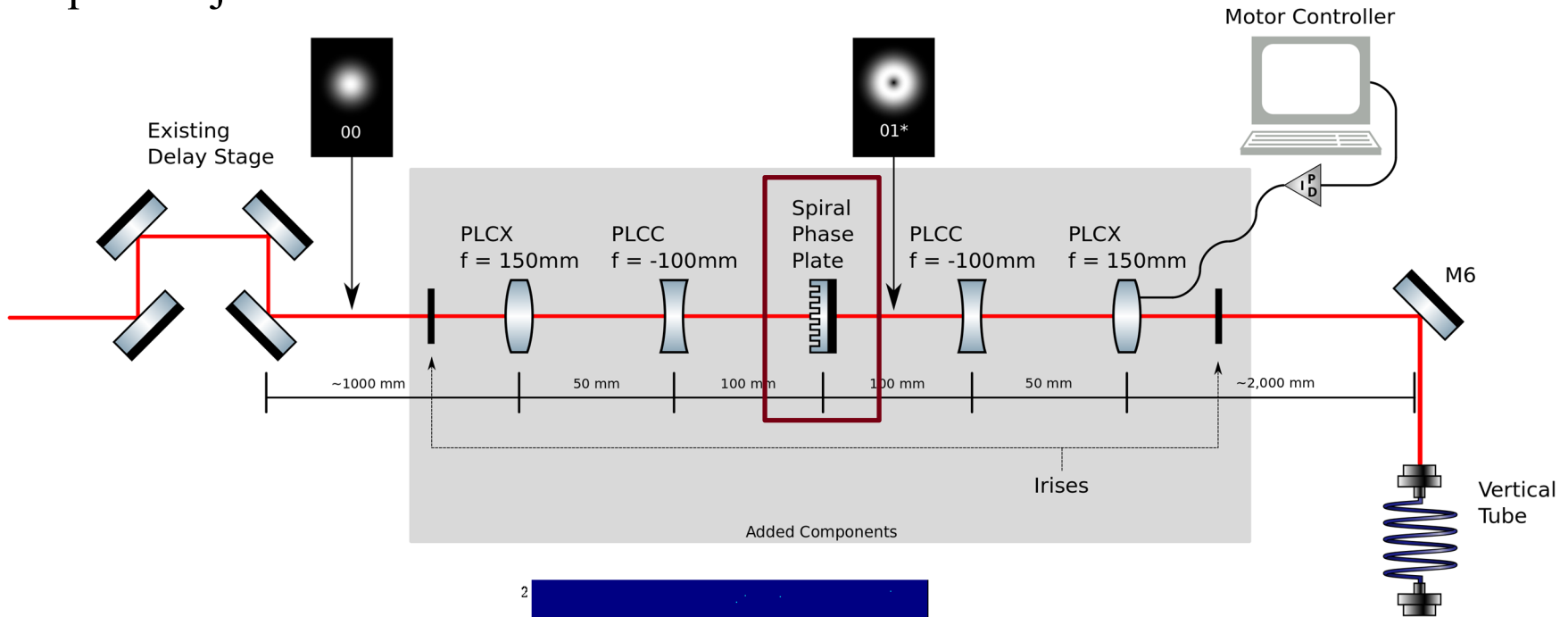
Experiment Layout

SLAC



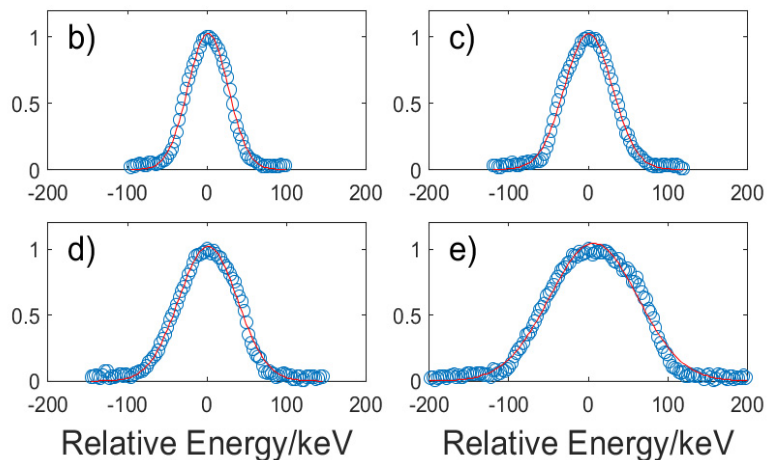
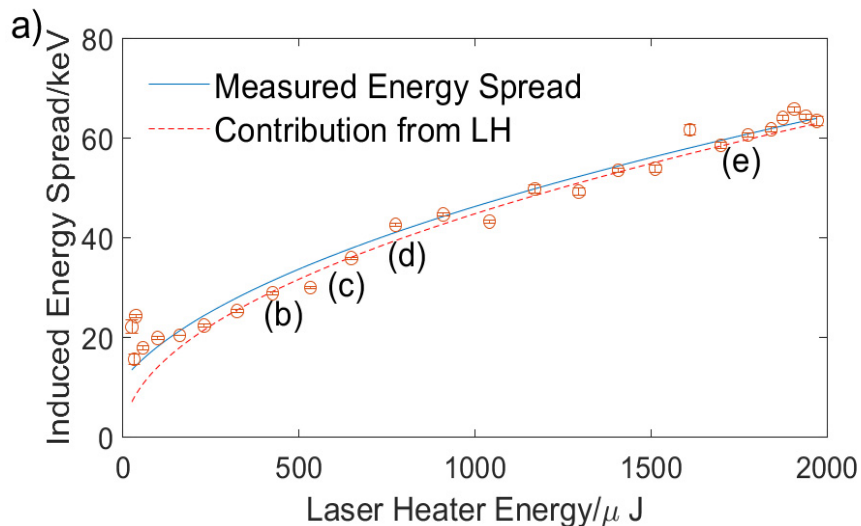
Optical Mode-conversion System

Optical mode-conversion and control systems schematic at LCLS photoinjector

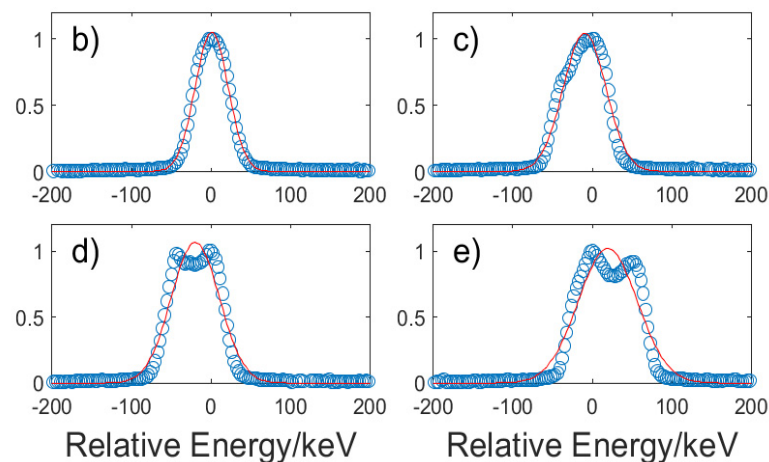
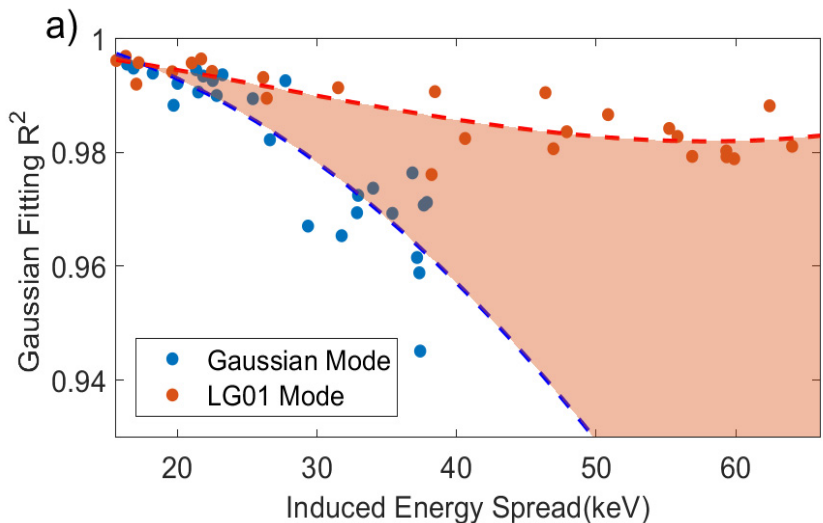


Measurements of LH-Induced Energy Distribution

SLAC



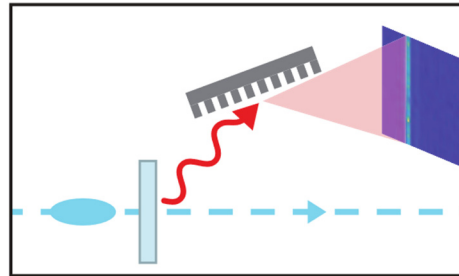
LG01



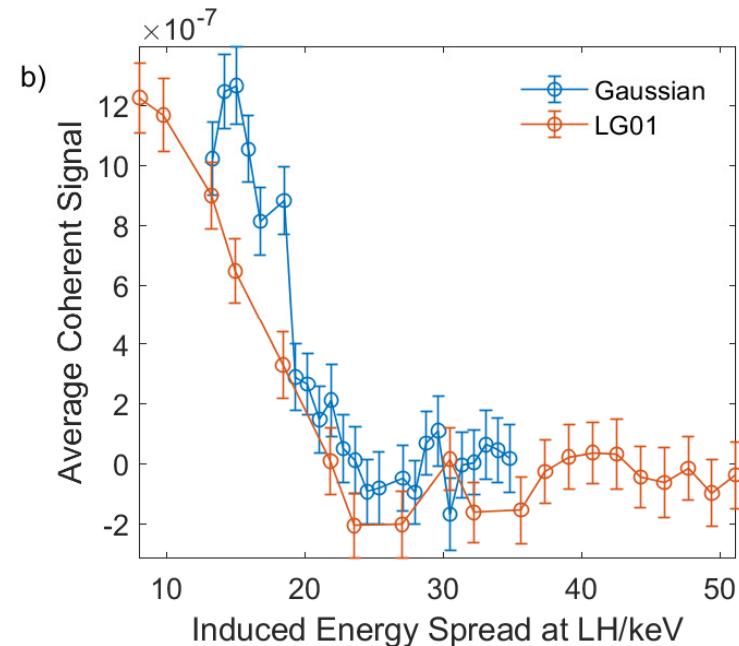
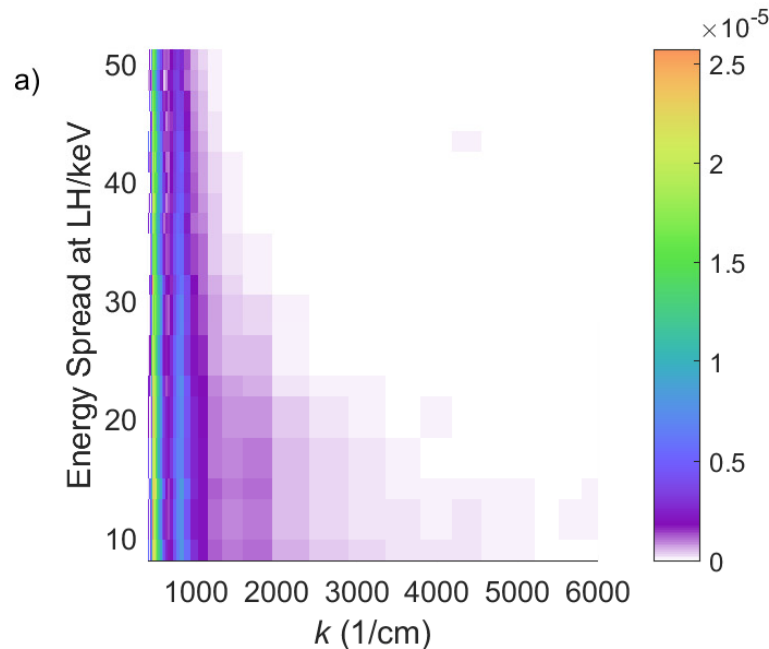
Gaussian

Downstream Measurements: IR Spectrometer

SLAC

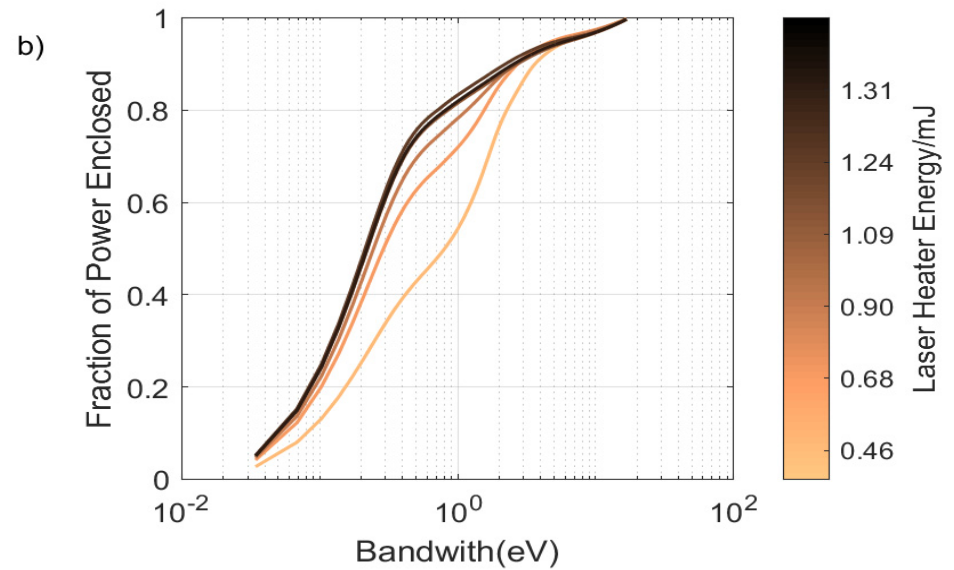
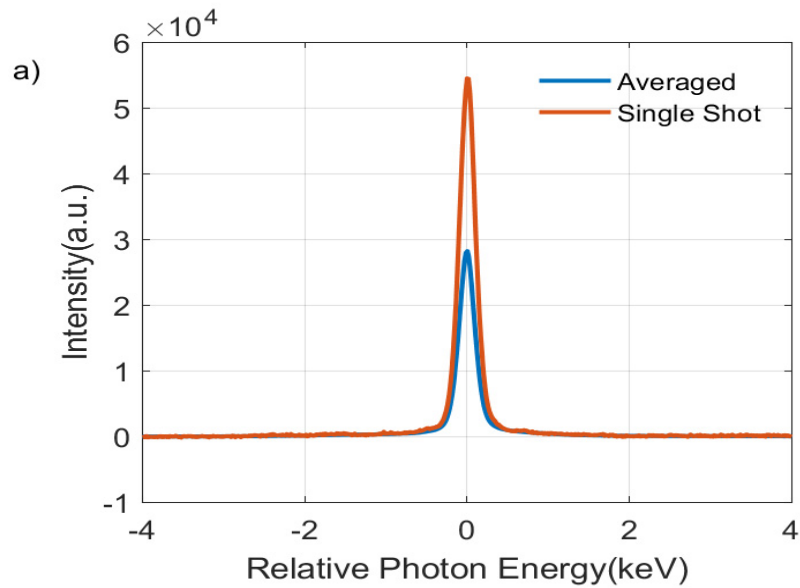


$$k \in (3000, 5000) \text{ cm}^{-1}$$



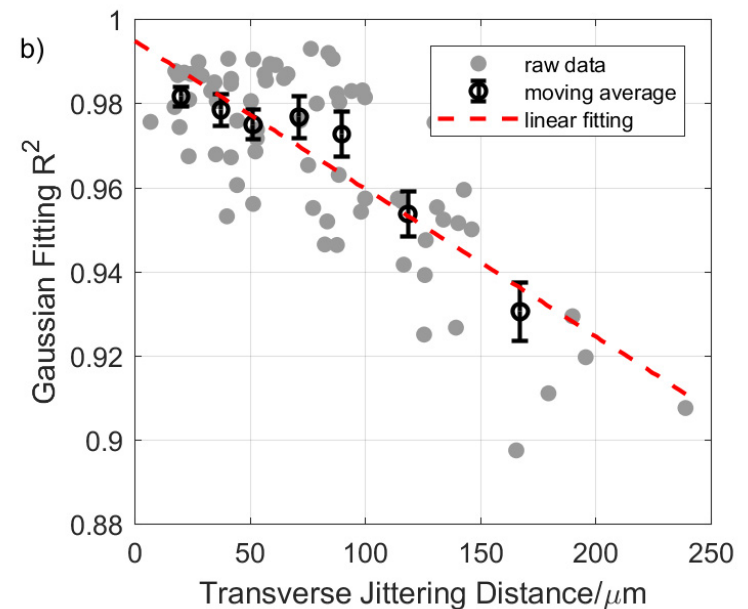
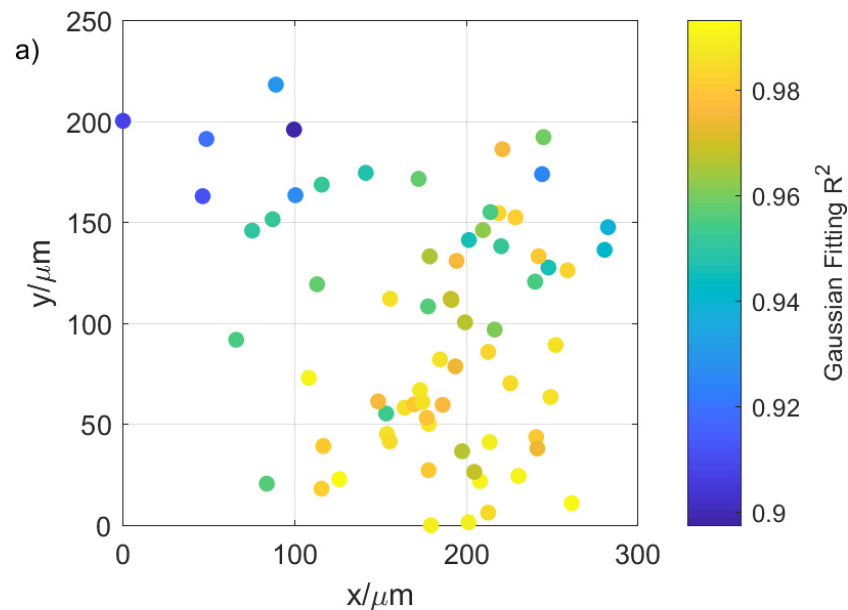
Downstream Measurements: Soft X-ray Self Seeding

SLAC



Effect of Laser Transverse Jitter

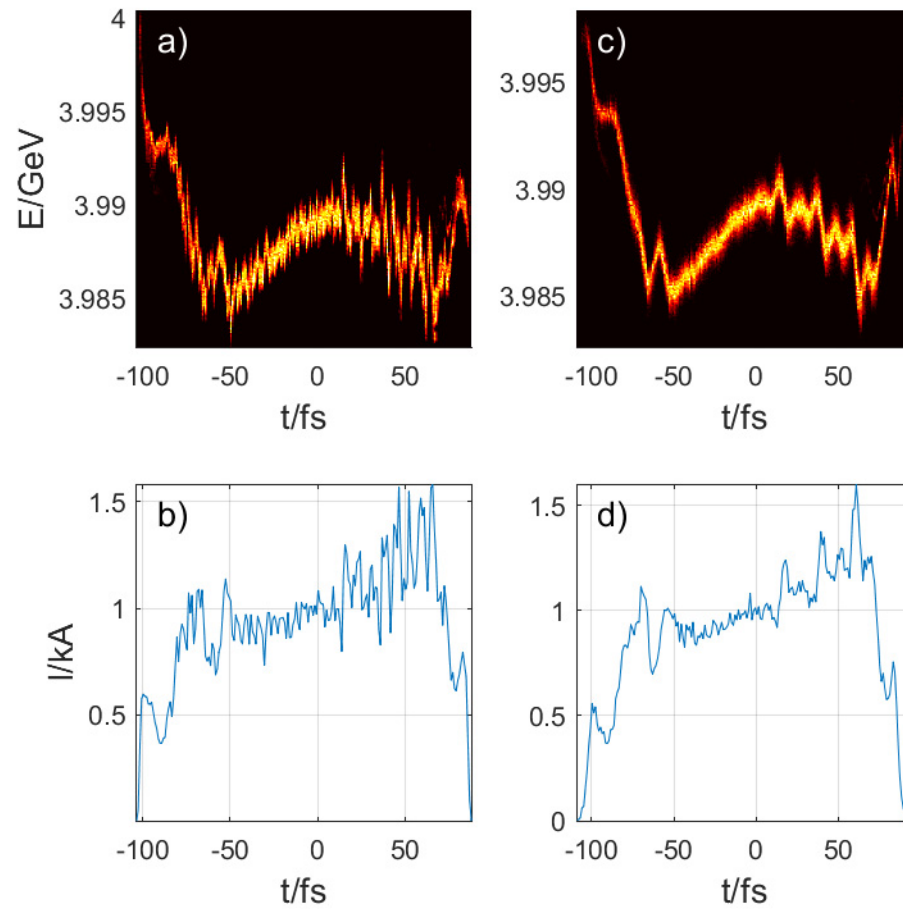
Laser beam Position at Virtual Heater Camera +
Energy distribution of e-beam at Spectrometer



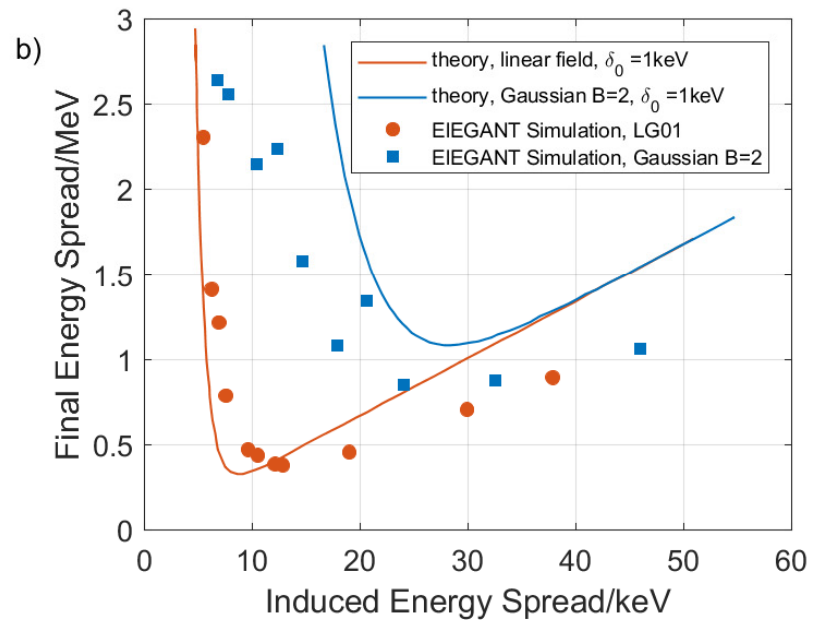
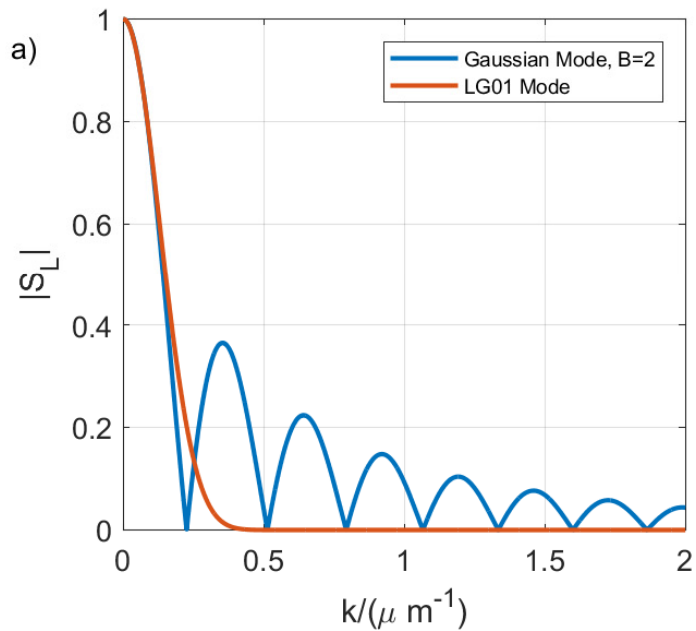
Conclusion

1. LG01 mode laser heater can introduce Gaussian energy distribution to e-beam and downstream measurements show signals of improvements in microbunching suppression.
2. Transverse jitter of laser can degrade LG01 mode LH performance.

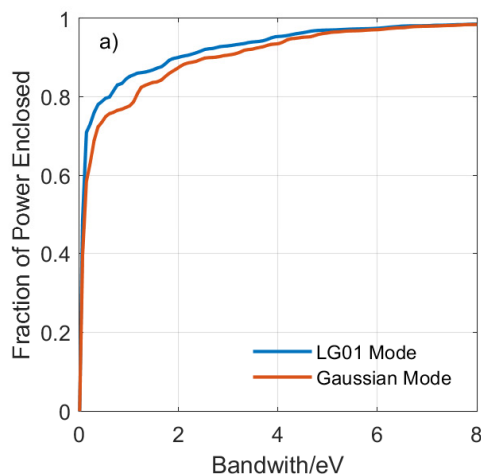
Simulation



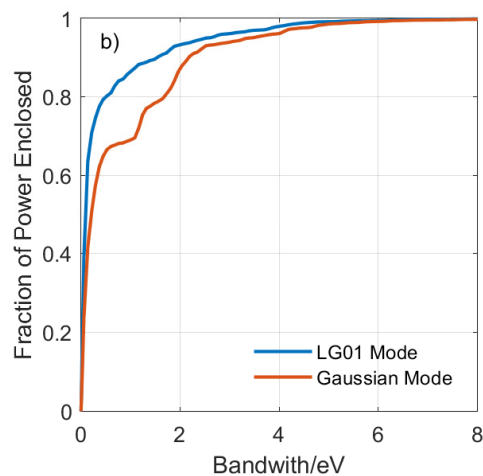
Simulation



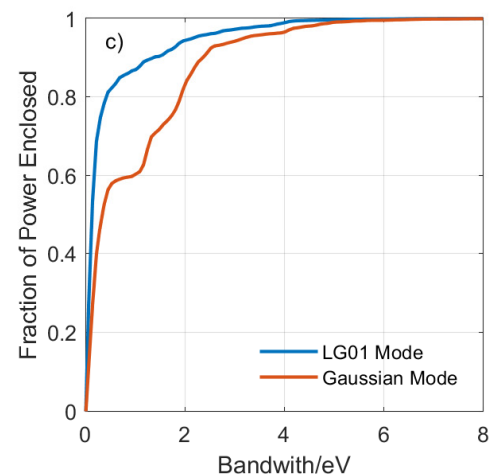
Simulation



10m



15m



20m