Overview of the Visible to Infrared SASE Amplifier (VISA) FEL

Aaron Tremaine

UCLA

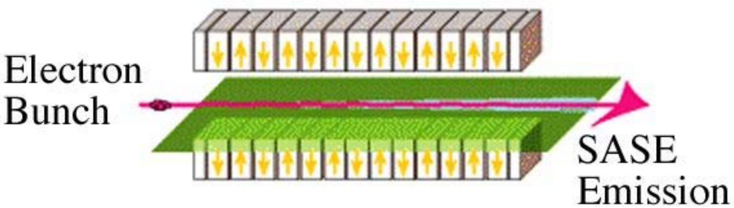
M. Babzien, I. Ben-Zvi, E. Johnson, R. Malone, G. Rakowsky, J. Skaritka, X.J. Wang, V. Yakimenko
BNL, Upton, NY, 11973
K.A. Van Bibber, L. Bertolini, J.M. Hill, G. P. Le Sage, M. Libkind, A. Toor
LLNL, Livermore, CA, 94551
R. Carr, M. Cornacchia, L. Klaisner, H.-D. Nuhn, R. Ruland
SLAC, Stanford, CA, 94309
P. Frigola, A. Murokh, C. Pellegrini, S. Reiche, J. Rosenzweig, A. Tremaine
UCLA, Los Angeles, CA, 90095

Aaron Tremaine, UCLA/BNL
tremaine@physics.ucla.edu

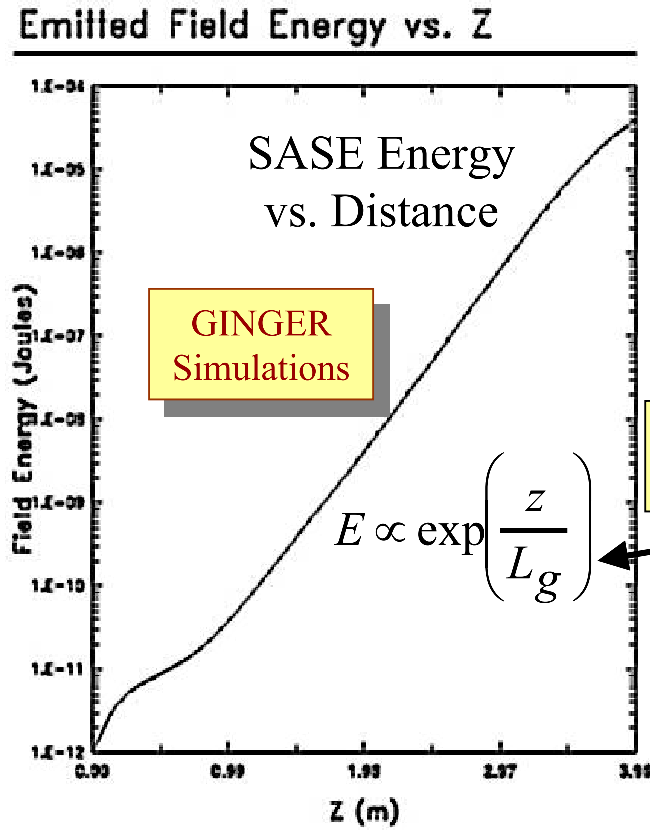
SASE FELs

SASE FEL theory well developed and verified by simulations

- *FEL radiation starts from noise in spontaneous radiation*



- *Transverse radiation electric field modulates the energy and bunches the electrons within an optical wavelength*
- *Exponential build-up of radiation along undulator*



Small Gain Length, L_g, desirable

Radiation Wavelength $$\lambda_{r,n} = \frac{\lambda_u}{2\gamma^2 n}\left(1 + \frac{K^2}{2}\right)$$

Courtesy of H.-D.Nuhn

Aaron Tremaine, UCLA/BNL
tremaine@physics.ucla.edu

Goals and Challenges for VISA

- Study Self-Amplified Spontaneous Emission (SASE) in the Collective instability regime
  - *Designed for Saturation*
  - *Needed for short wavelength FELs (LCLS)*
  - *Compare data with theory and code*
- Use a novel, strong focusing, 4m (4-1m sections), planar undulator
  - *30cm β-function*
  - *Alignment to $<30\mu m$*
- High quality electron beam
  - *Use the ATF at BNL*

Must have **both** conditions to saturate in only 3.6m.

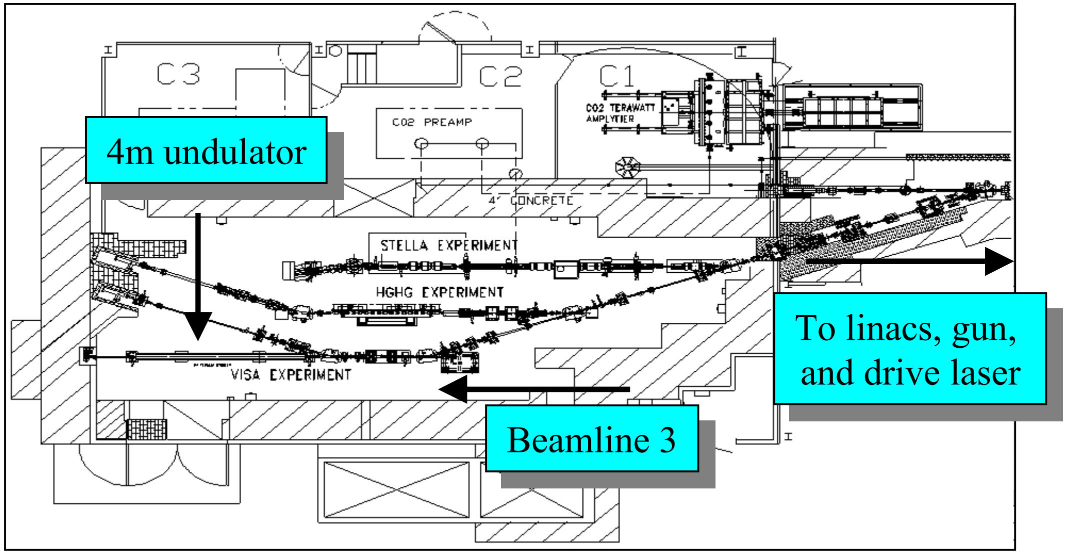
Aaron Tremaine, UCLA/BNL
tremaine@physics.ucla.edu

Parameters and Layout

VISA Design Parameters

- *System*

- 72MeV Electron Beam
- 200 Amps
- 2mm-mrad emittance
- 4-m undulator



- *Radiation*

- 800nm
- 18.5cm power gain length
- 10^7W
- <1mrad coherent angle
- 50µm photon beam radius

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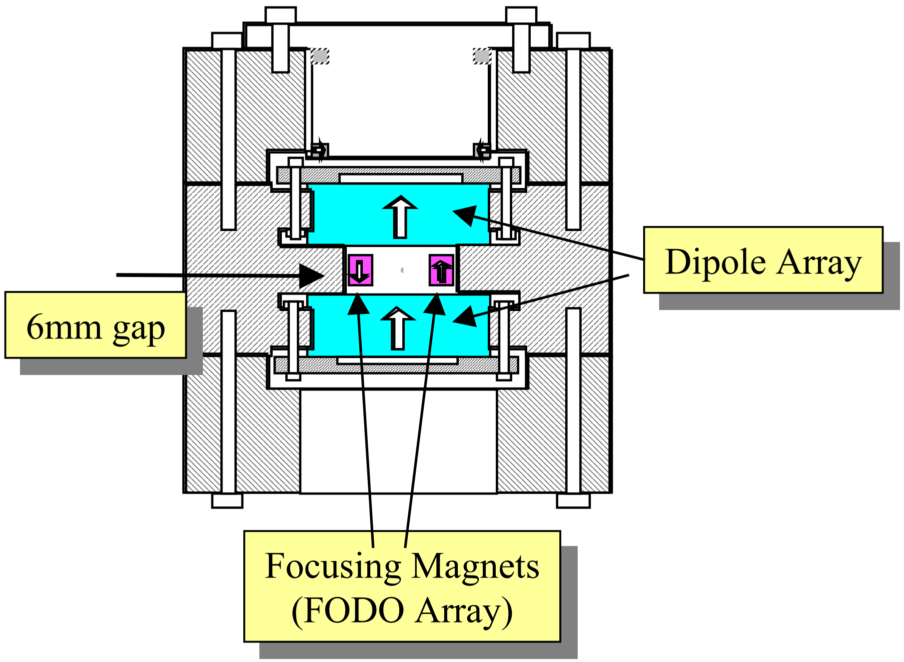
Undulator Endview



At SLAC
before full assembly

Undulator length	3.96m
Undulator period	18mm
Number of periods	220
Peak Field	.75T

FODO lattice period	24.75cm
Total FODO periods	16

← Reduces gain length by 40%

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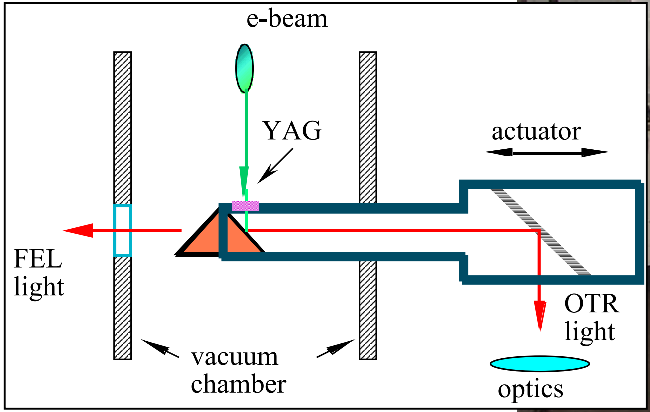
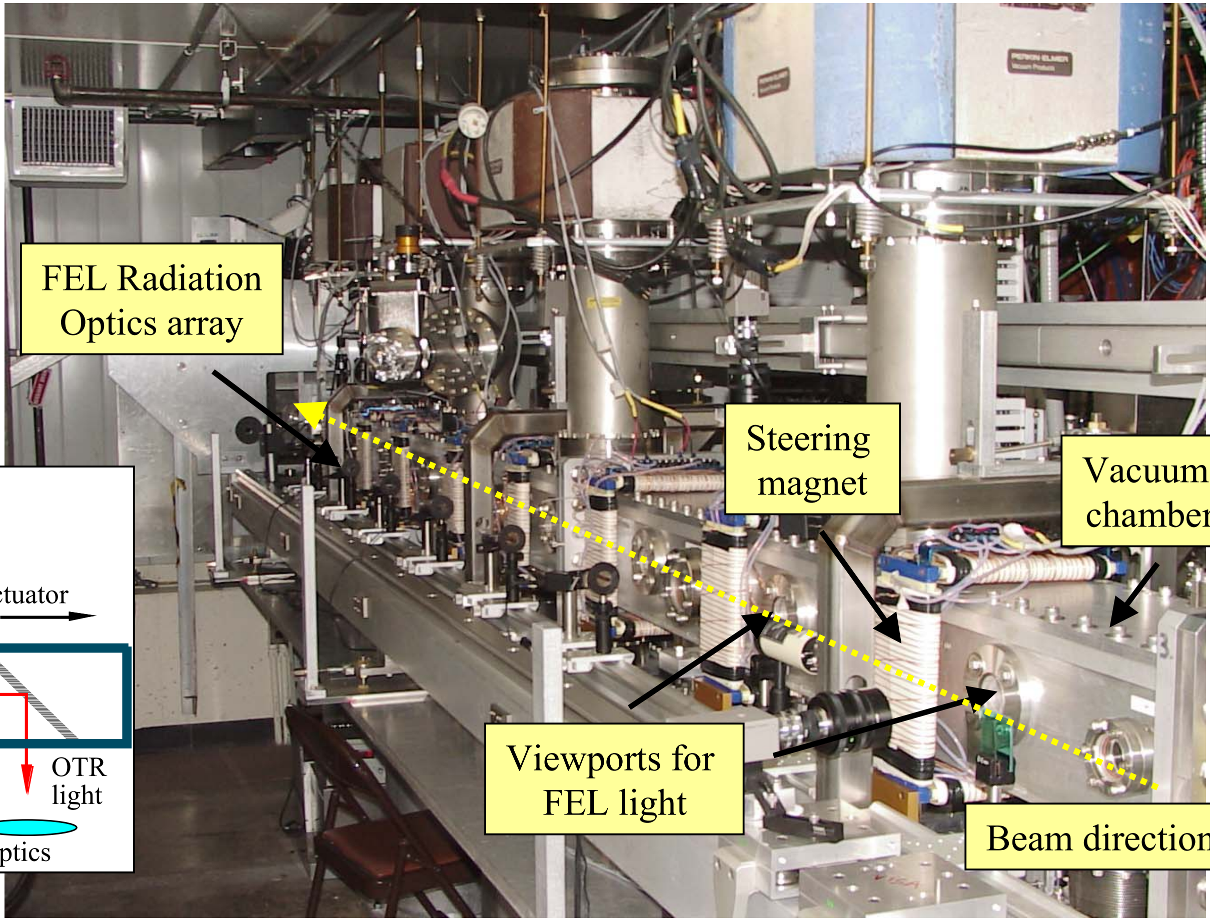
VISA at ATF - Beamline 3

Two functions for each port:
FEL radiation, BPM (using OTR)
Every 50cm along length of undulator
Height pop-in is < 4.5mm
-must be less than gap height, 6mm





Aaron Tremaine, UCLA/BNL
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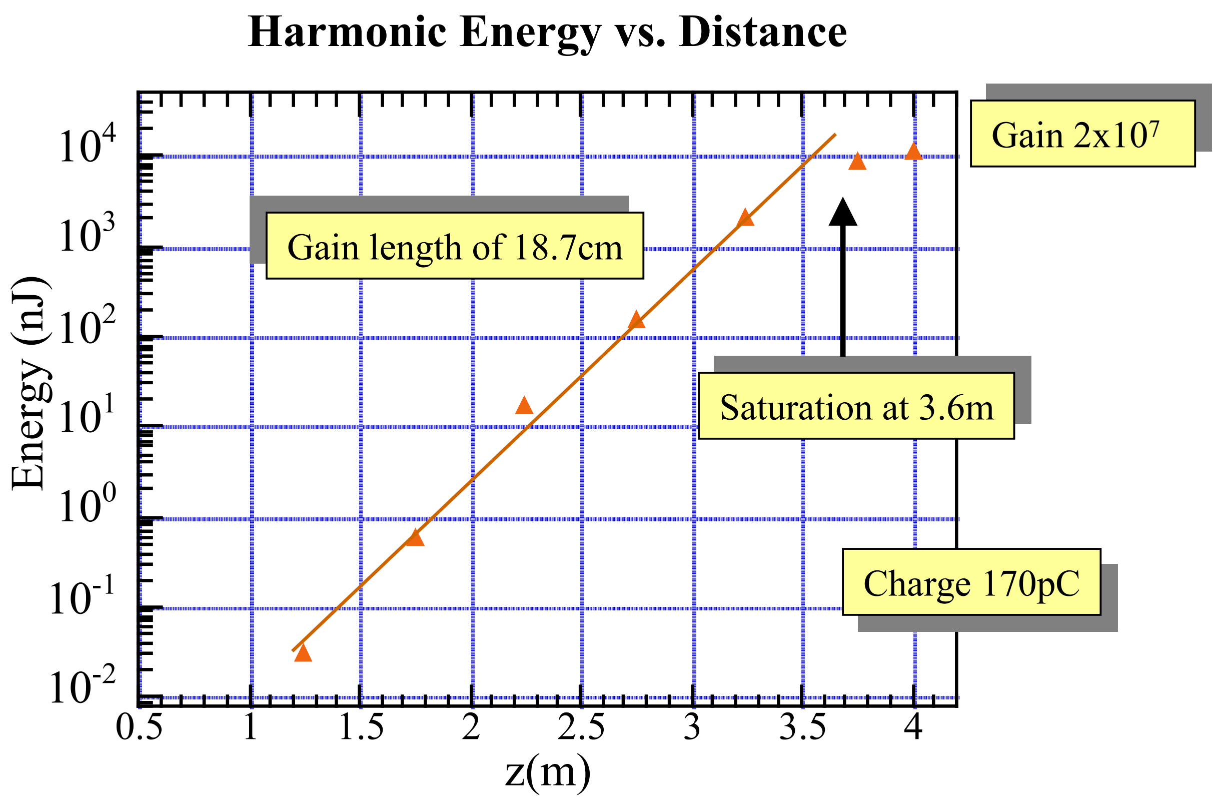
Energy vs. Distance



Define gain as $G=I/I_o$

I_o - Coherent fraction of spontaneous emission in first gain length

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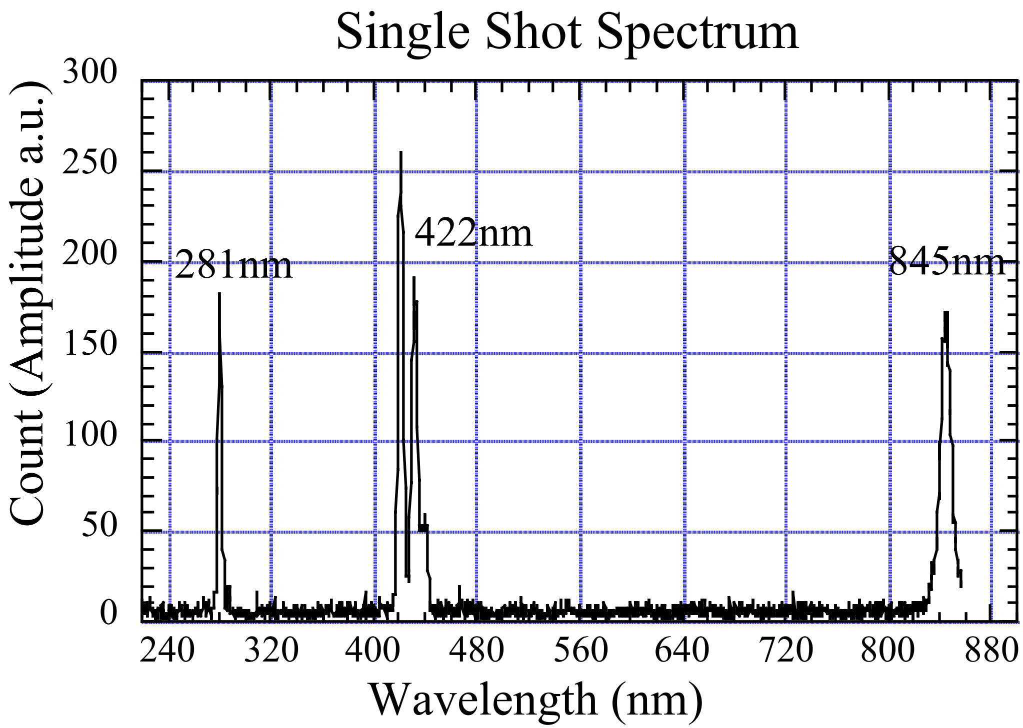
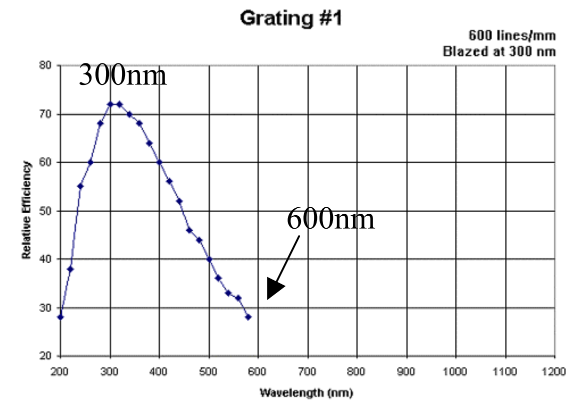
VISA Spectrum



Grating Efficiency



Alignment of radiation into spectrometer's 30µm slit is difficult. Resolution of spectrometer is 1.5nm

Harmonic Wavelengths confirmed: $\lambda_n = \lambda_r / n$

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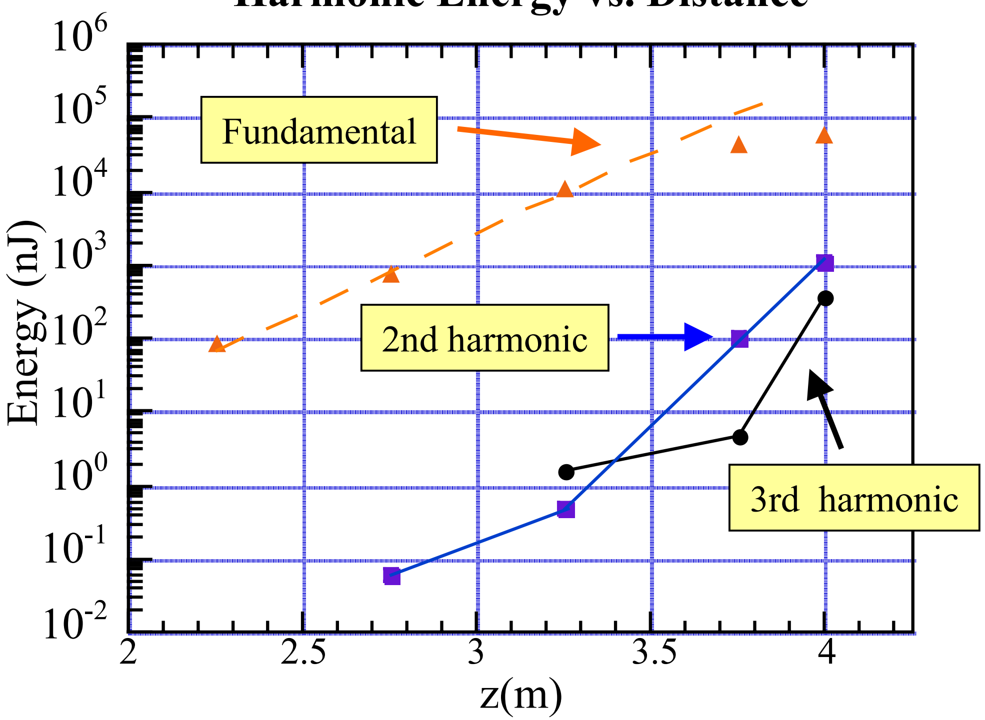
Harmonic Gain Lengths Measured



Energy Comparison

Mode (n)	Wavelength (nm)	Energy (μJ)	% of E_1
1	845	52	
2	421	.93	1.8
3	280	.40	.77

Using the relation of 2nd and 3rd harmonic energies as given by Z. Huang and K.J.Kim

$$E_2 = \left(\frac{K}{\gamma k_u \sigma_x}\right)^2 \left(\frac{K_2}{K_3}\right)^2 \left(\frac{b_2}{b_3}\right)^2 E_3$$

<u>Associated gain lengths</u>

$$L_f = 18.7cm$$
$$L_2 = 9.8cm \quad \Longrightarrow \quad L_n = L_g / n$$
$$L_3 = 6.0cm$$

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Measured Beam Parameters after 2nd Linac

Electron Beam Parameters Measured

Current I	55-65A
Emittance ε	1.1-1.6mm-mrad

To attain FEL performance measured, simulations would require 75A and .7mm-mrad

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Bunch Length Shorter than originally thought

One spike observed in frequency spectrum

$$L_b : 2\pi L_c$$

Bunch length measurements using CTR at Undulator confirm short bunch

Simulations PARMELA/ ELEGANT/ GENESIS demonstrate this compression and its results on SASE

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Conclusions

- Measured High Gain at 170pC
- Saturation in 3.7m
- Short Gain Length, 18.7cm
- Spectrum at 845nm
- Characterization of Harmonic radiation
  - $L_{g,n}$, λ_n, E_n
- Have good beam quality

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