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A Compact Electron Spectrometer for an LWFA and Other Challenges

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**Guest Scientist at Fermilab*

U.S. Department of Energy

UChicago Argonne LLC

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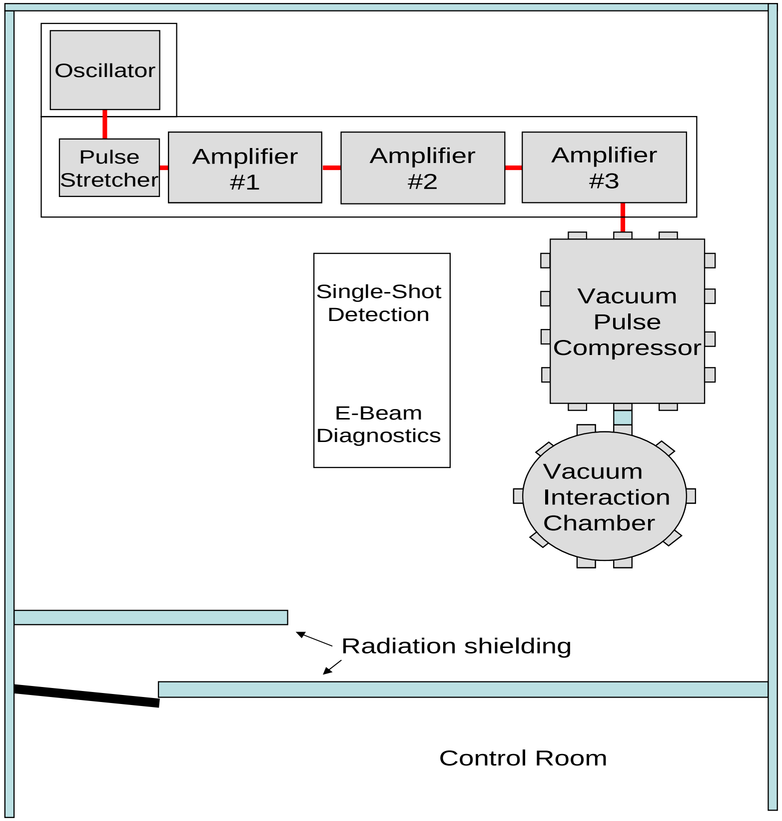
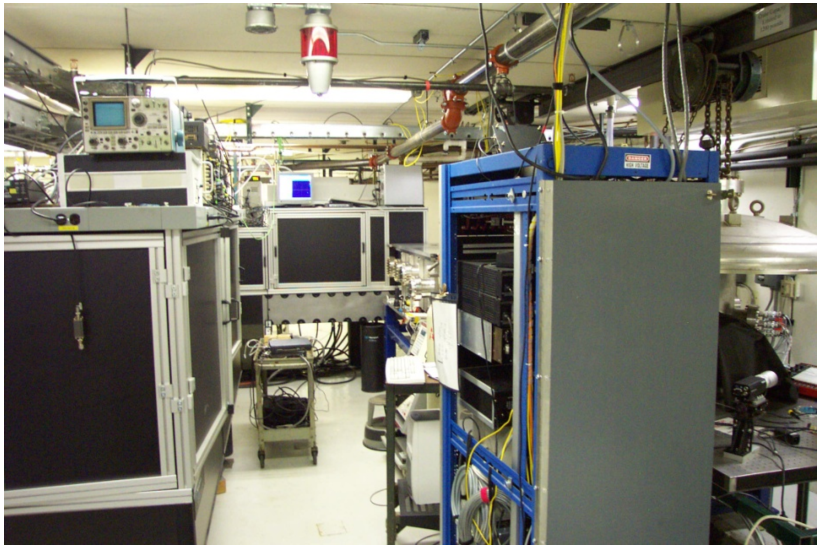
OUTLINE

- **Introduction**
- **Laser Wakefield Accelerator (LWFA) background**
- **Compact Electron Spectrometer Design**
- **Experimental and Analytical Results**
- **Challenges of FELS for the LWFA**
- **Summary**

Terawatt Ultrafast High Field Facility (TUHFF)

- Ti:Sapphire oscillator with three amplifiers used.





<u>TUHFF Laser Output</u>

30fs, 0.6 J (20 TW) @ 10 Hz

Acknowledgments

Radiation Chemistry Group

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Rui Lian – Coherent
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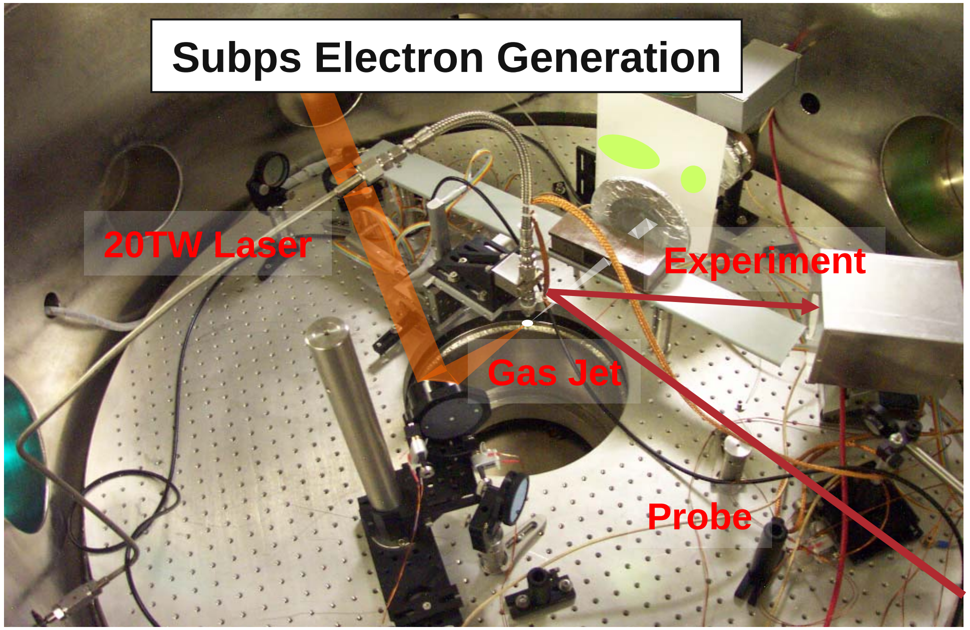

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*Compact Electron Spectrometer Components Evaluated**

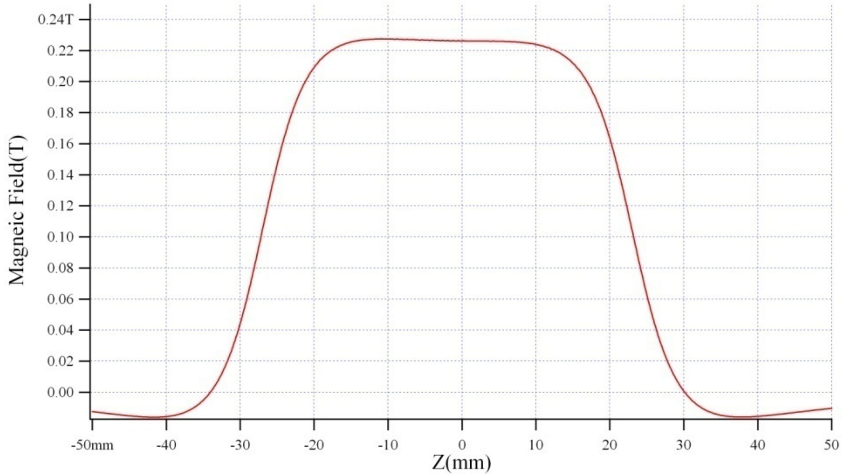
- Two NdFeB magnets
- Lanex converter screen (LOA)
- Roper 16-bit ICCD camera
- Bergoz ICT

- APS Magnet lab
- previous studies LOA
- S35 Optics lab
- Electronics lab

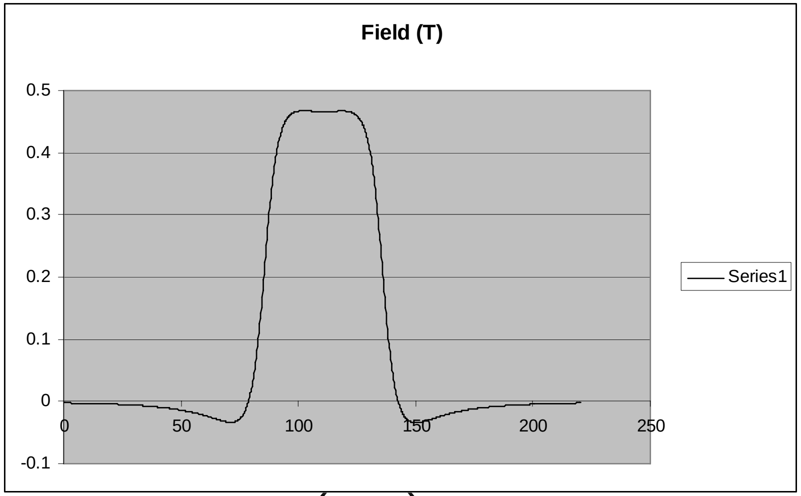
*Based On Y. Glinec et al. Design, LOA

Permanent Magnets Used in Compact Spectrometer Characterized in APS Magnet Measurement Lab

- NdFeB magnets are 5 x 2.5 x 1.2 cm^3



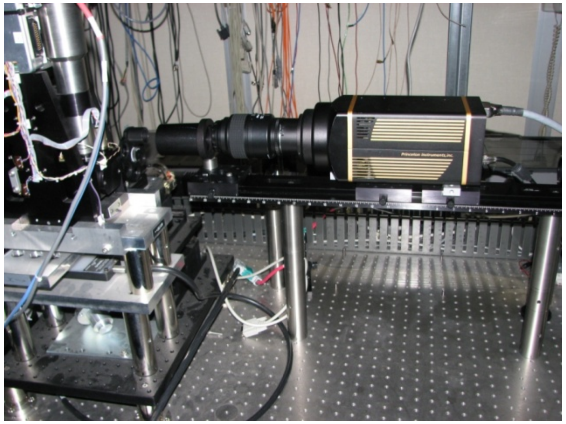
- Assembly with 12-mm gap measured



z (mm)

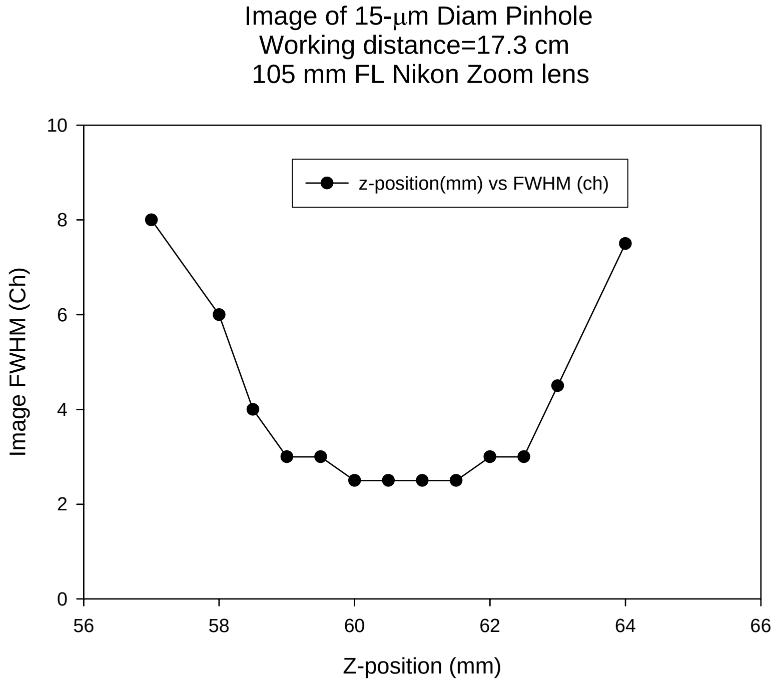
16-bit Camera Characterized in APS S35 Optics Lab

- Roper Scientific Camera tested

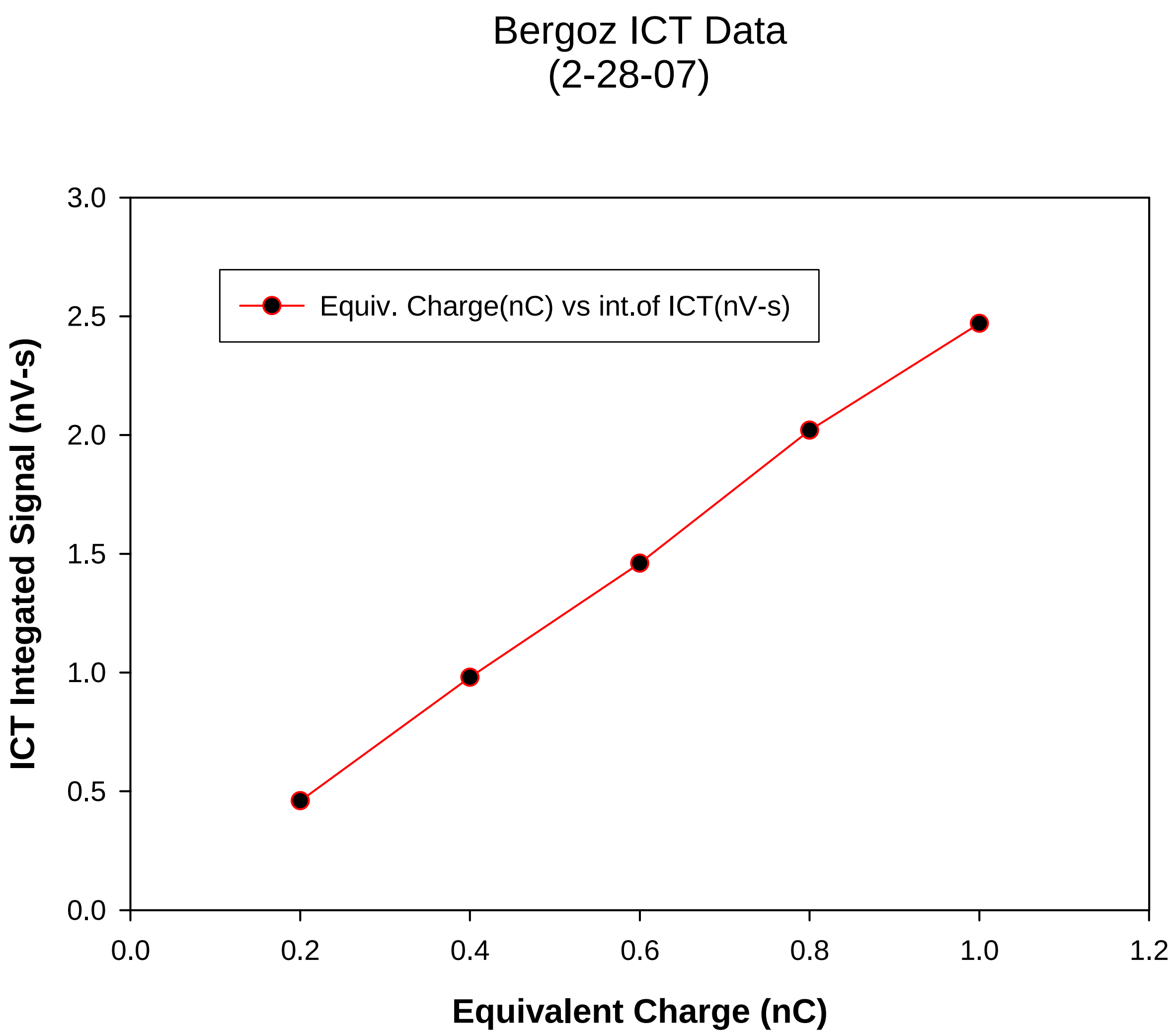


Working Distance (cm)	Calibration factor (um/pixel)	FOV (cm)
14	13.7	1.4
17.3	19.6	2.0
29	36.9	3.8
40	50.0	5.1
50	62.5	6.3
60	74	7.6
70	89.3	9.1

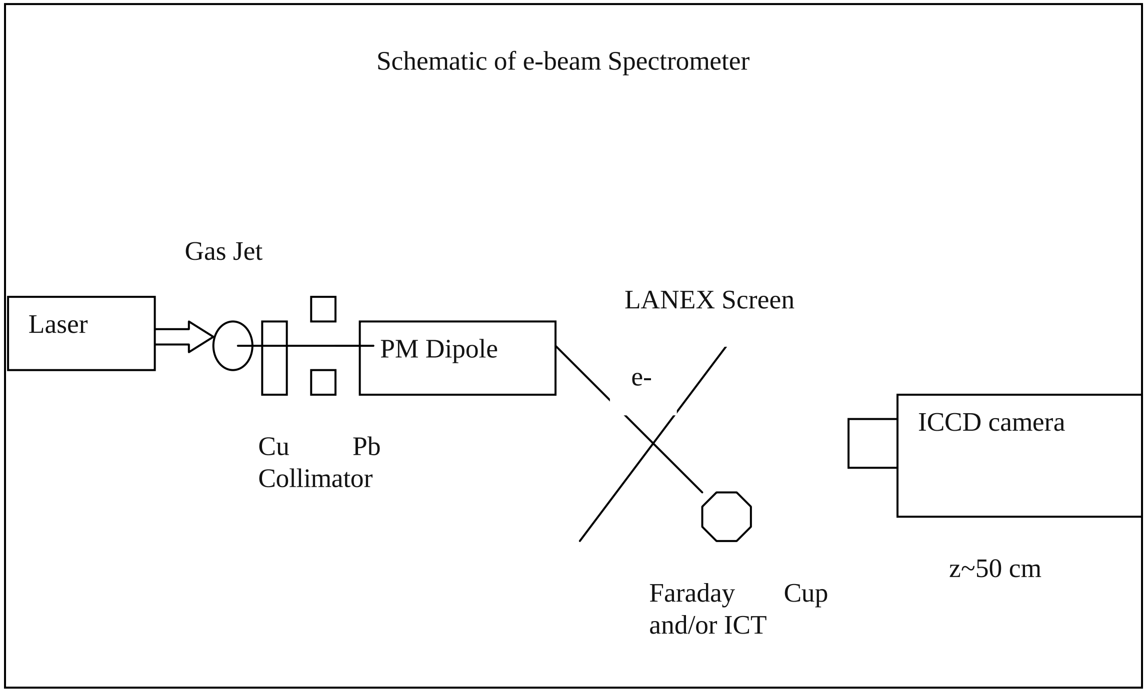
- 15-um Diam pinhole used for test source.



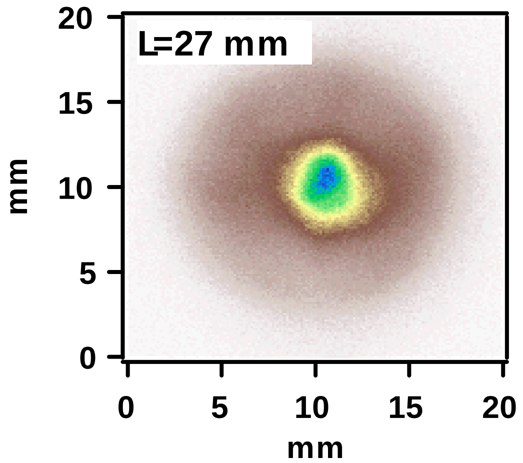
ICT Tested in Lab with Calibration Loop

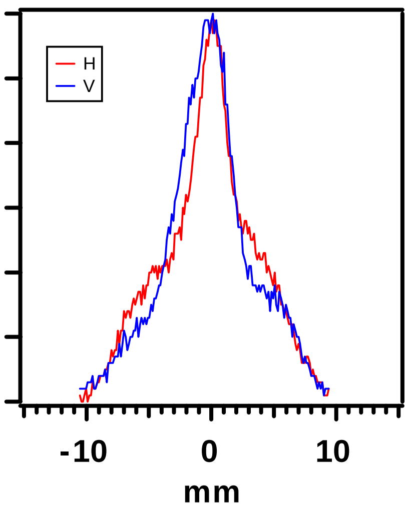


Schematic of the Compact Spectrometer Setup



Electron Beam Parameters:

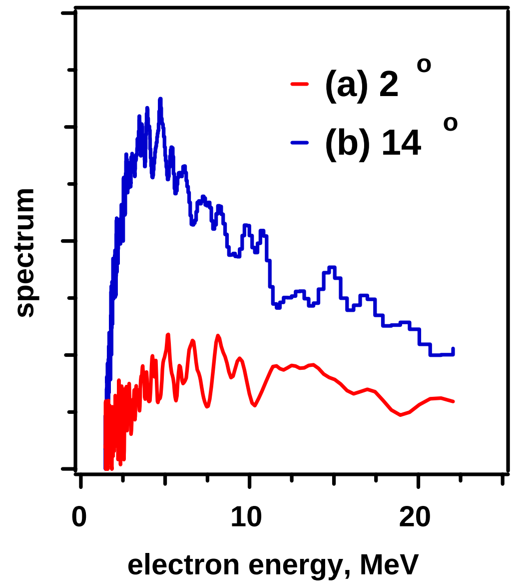




Electron beam spectrum

F(E) ~ exp(-E/<E>)

<E>=2.3±0.3 MeV



Electron pulse charge:

2-3 nC ± 15-30%

Transverse e- beam profile measured at 27 mm after the jet average of 100 shots, single shot much better

Electron pulse duration:

~1-2 ps at the sample?

Will be measured by EOS

Simulation of laser plasma interaction and the bubble regime

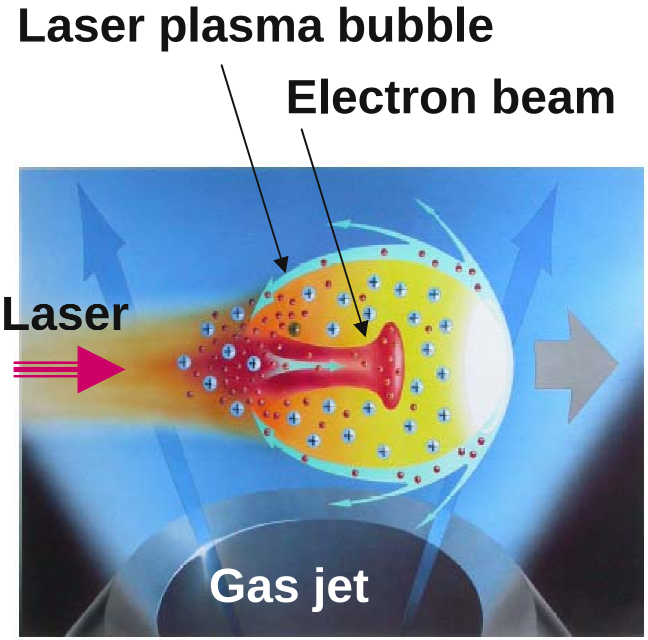
Goal and means

- Support the femto chemistry experiment by mapping the laser and plasma condition for optimum beam generation
- Support advanced accelerator research by investigating the laser plasma accelerator physics
- Using 3-D PIC code VORPAL with several computer clusters at ANL

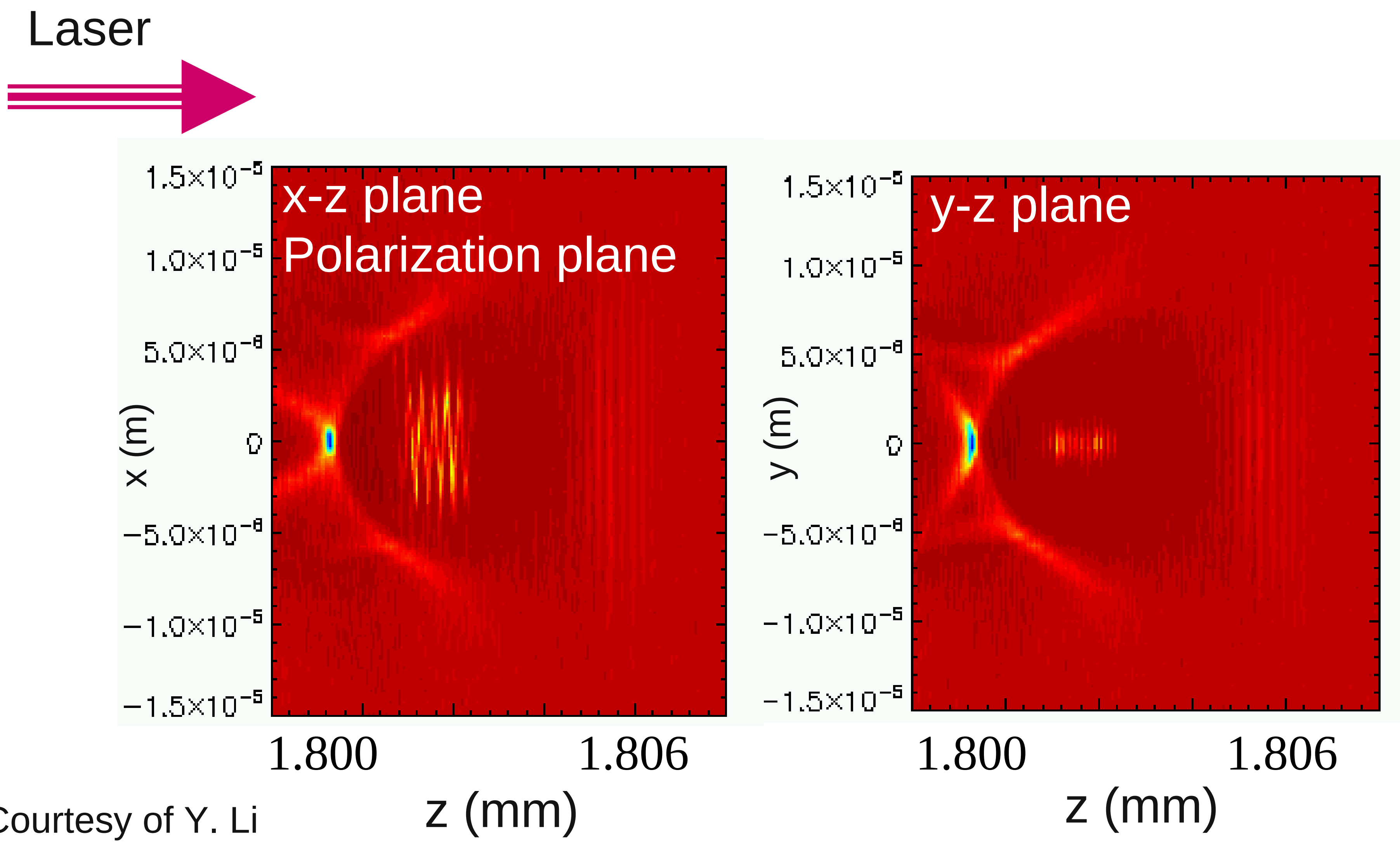
Topics

- Plasma and laser condition for femto chemistry
- Bubble regime laser plasma physics
- Injection of electron in the bubble regime: laser injection and nano wire trigger of wave breaking
- Beam properties: structure, propagation, and radiation
- Data visualization

VORPAL
Y. Li ANL
J. Cary, U. Colorado



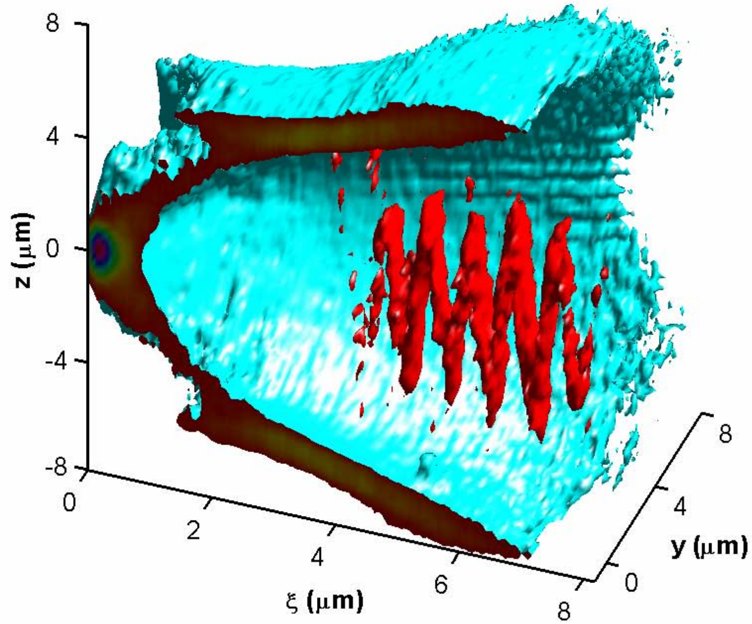
Laser Modulation of the Beam Structure in the Bubble

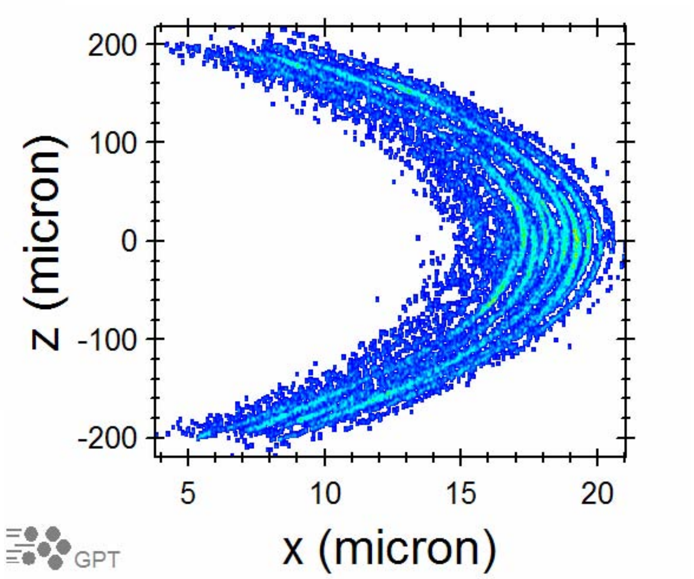


Courtesy of Y. Li

Laser modulation of the beam structure in the bubble

Beam modulation in the bubble



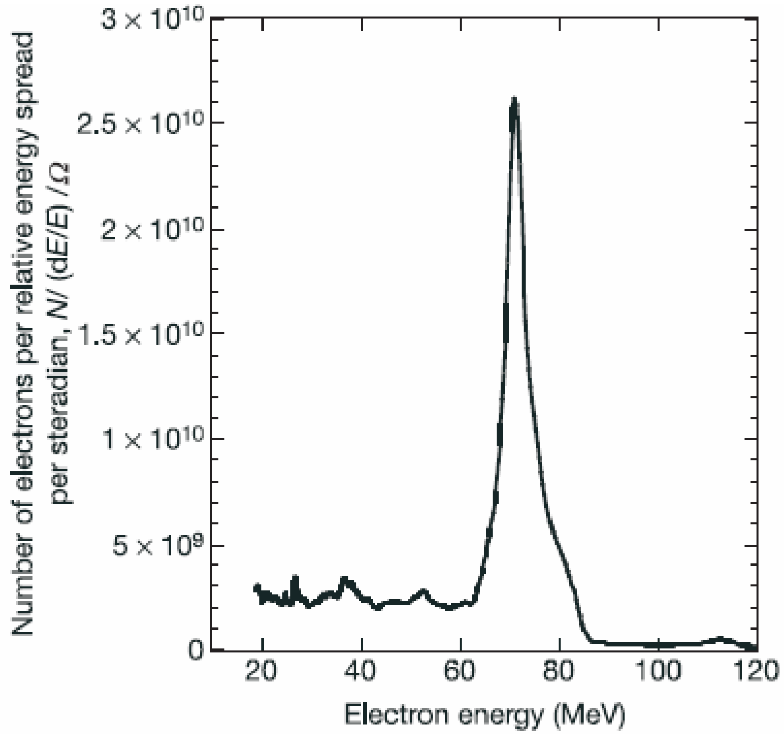


Courtesy of Yuelin Li

Micro bunching of the output beam

Towards sub-ps Electron Beams

Nature 431, Sept. 2004

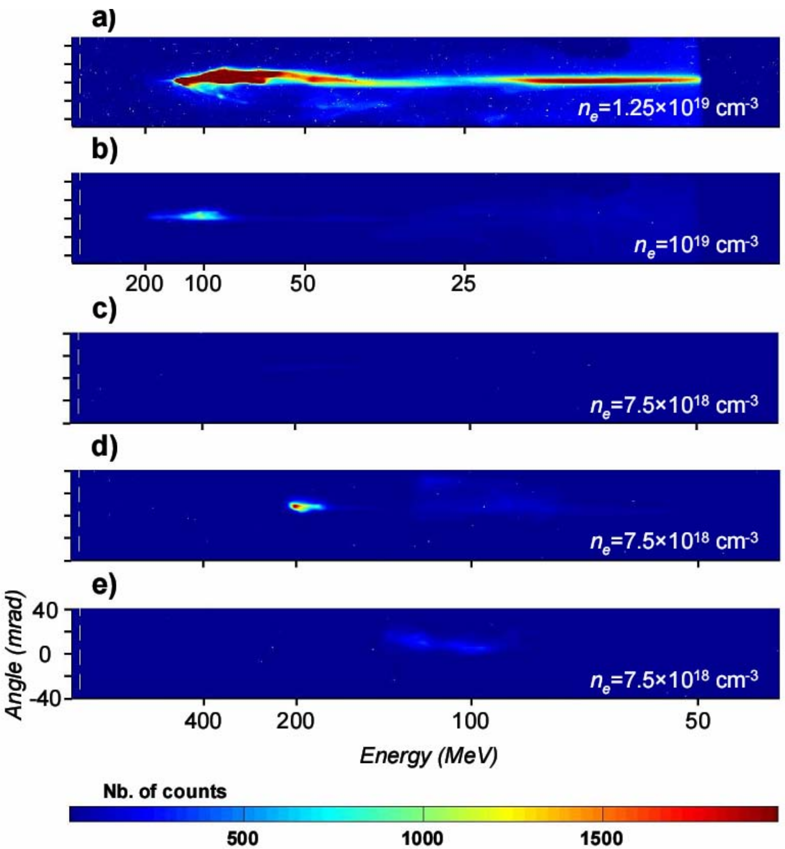


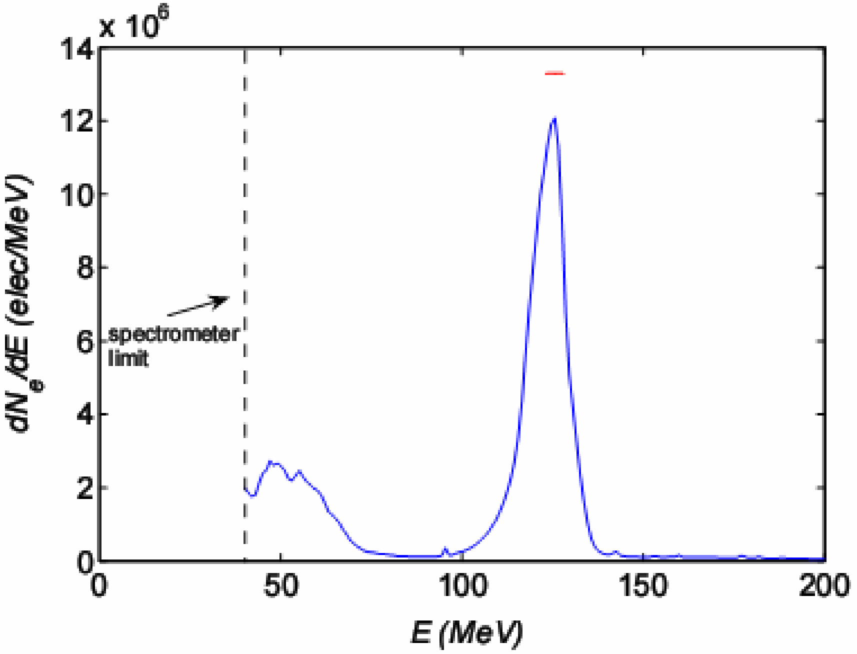
S.P.D. Mangles et al. Nature 431, 535 (2004) RAL
C.G.R. Geddes et al. Nature 431, 538 (2004) LBNL
J. Faure et al. Nature 431, 541 (2004) LOA

Estimated τ~ 10 fs
Low divergence

Physics is very complicated and must be understood to optimize LWFA For reliable quasi-monochromatic electron beam generation

LOA Experiments Show Quasi-monoenergetic Beams with Beat-Wave Injection Technique





J.Faure et al., Nature, 2006

Injection Technique Provides More Reproducible Performance and Energy Tuning

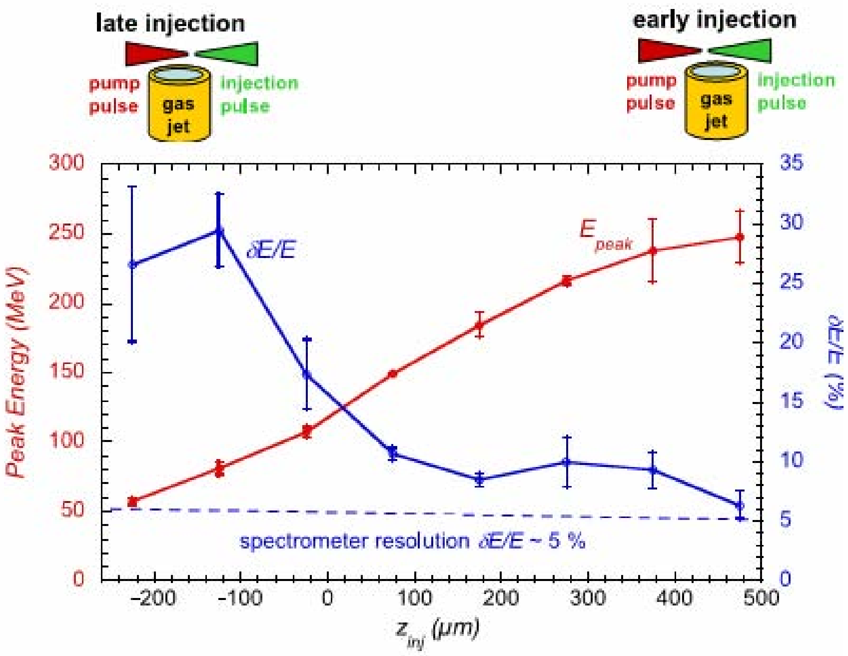
- 20-shot statistics tabulated.

Table 1: Statistics of the electron beam parameters over 20 shots.

<Peak energy>*	$\sigma_{Peak energy}$	<Energy spread>	$\sigma_{Energy spread}$
117 MeV	7 MeV	11 % (FWHM)	2 %
<Charge>	σ_{Charge}	<Divergence FWHM>	$\sigma_{Beam pointing}$
19 pC	6.8 pC	5.8 mrad	1.8 mrad

*<X> refers to the mean value of X and σ_X to the standard deviation of X.

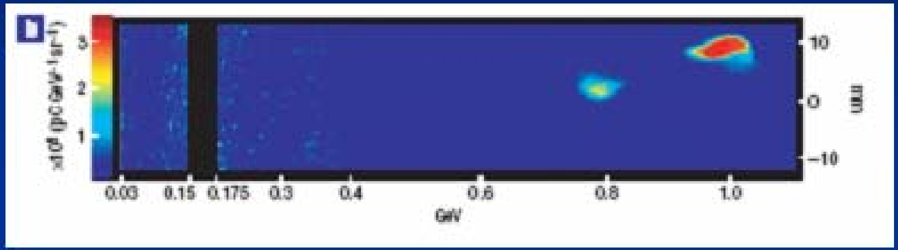
- Energy tuning by adjustment of injection timing.

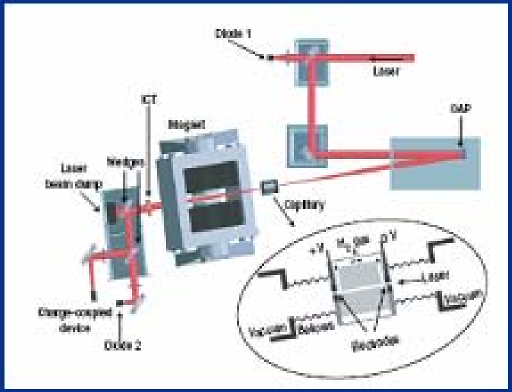


J.Faure et al., Nature, 2006

LBNL LOASIS Experiments Attain 1 GeV

GeV electron beams from a « centimetre-scale » accelerator





310-µm-diameter channel capillary

P = 40 TW

density 4.3×10^{18} cm^{-3}.

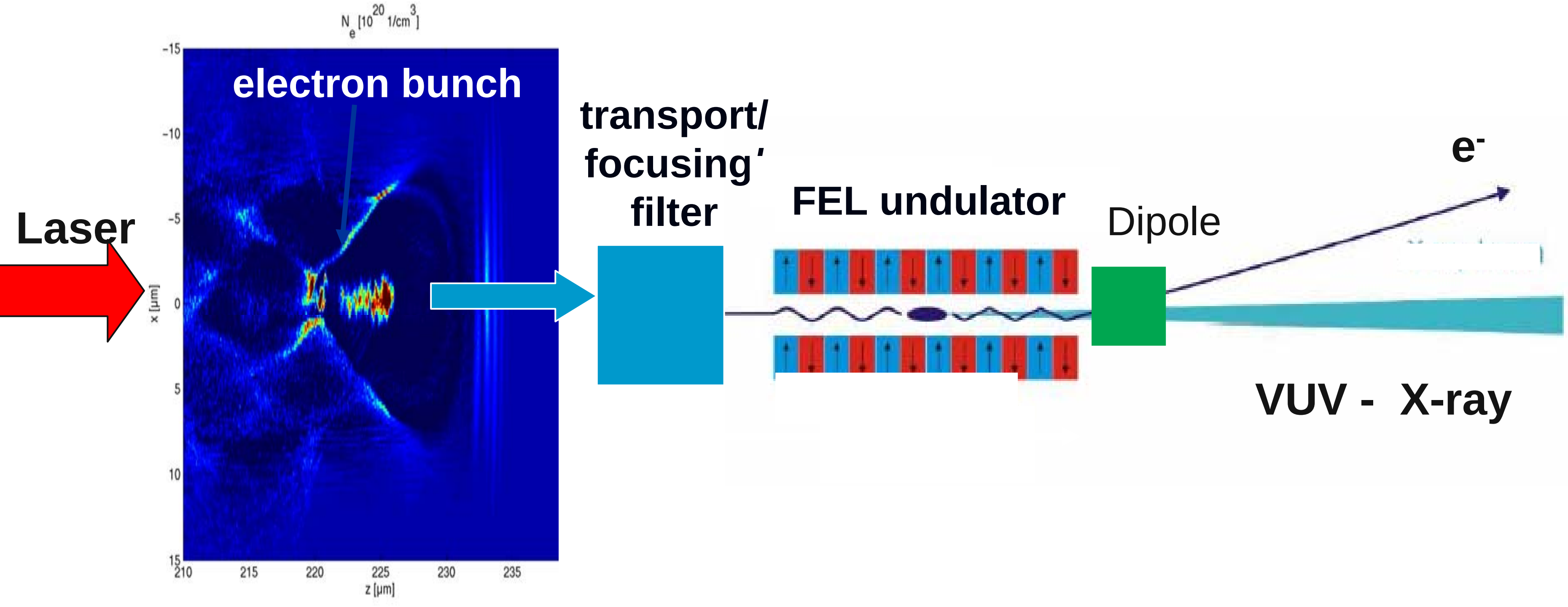
LOA

Leemans et al., Nature Physics, september 2006

ENSTA · CNRS · École Polytechnique

Courtesy of V. Malka

TUHFF as an Ultrafast x-ray/VUV Source



- **X-ray absorption, scattering studies of solvent structure and dynamics**
- **VUV (1-photon) probing of excited states**

SUMMARY

- *The ANL LWFA is preparing for quasi-monoenergetic beam generation tests in CY07.*
- *Rapid progress in the LWFA community on generating higher charge and more controllable beams by using some form of electron injection process has occurred.*
- *Charge, energy spread, and beam emittance are still challenges that need addressing to move from an LWFA beam driving spontaneous radiation to FEL. First spontaneous results recently at Jena. Like to see e-beams so well defined that OTR techniques apply with standard camera.*
- *The next LWFA community target is to generate a 10-GeV beam by the AAC08 meeting in July 2008.*
- *Plans at LBNL and LOA for FEL experiments soon.*

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