DUV-FEL Current Status

Free Electron Laser Development for Naval Applications Workshop

5-6 June 2001

Erik D. Johnson

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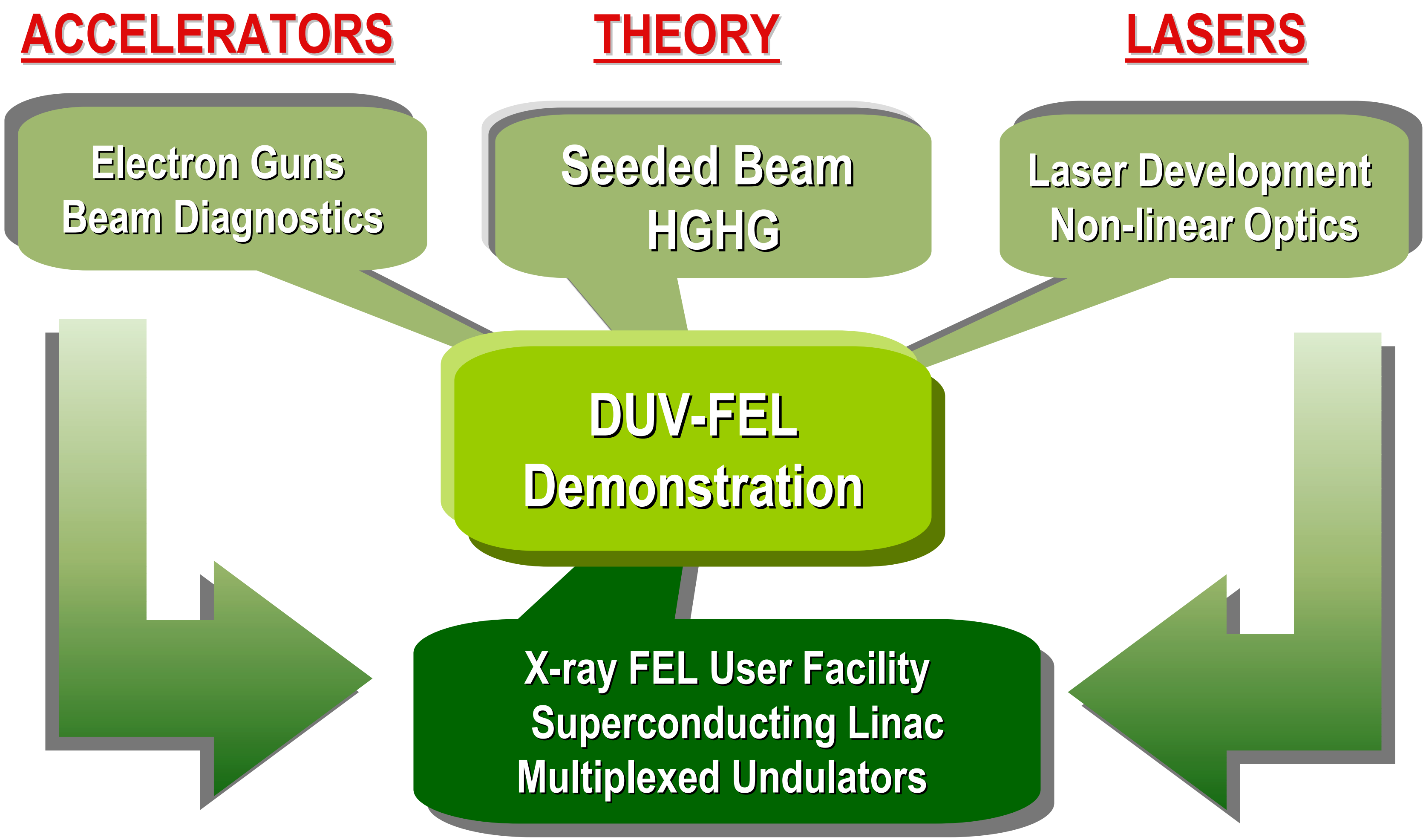
Project Manager Deep UV Free Electron Laser

http://nslsweb.nsls.bnl.gov/nsls/org/SDL

DUV-FEL Amplifier Installation Status

3 June 2001

Fourth Generation Source Development at Brookhaven National Laboratory



The Deep Ultra Violet – Free Electron Laser

Function

The project objective is to facilitate the *coordinated development* of sources and experiments to produce and utilize coherent sub-picosecond ultra-violet light

Features

Experience base from the NSLS and ATF

Recovered equipment; 200 MeV Linac (SXLS) and 10m long Undulator (NISUS)

Breadth of collaborators (DOE Labs, Universities, Industry)

Technology coupled with the Linac Coherent Light Source (LCLS) collaboration

Advanced Source Development at Modest Cost

Fundamental contributions to pursuit of ‘Fourth Generation Light Sources’

DUV-FEL Activities

Linac Development

Prepare and integrate linac components (including linac energy upgrade)

Test to specification for FEL program

FEL Development

SASE Demonstration / FEL Commissioning

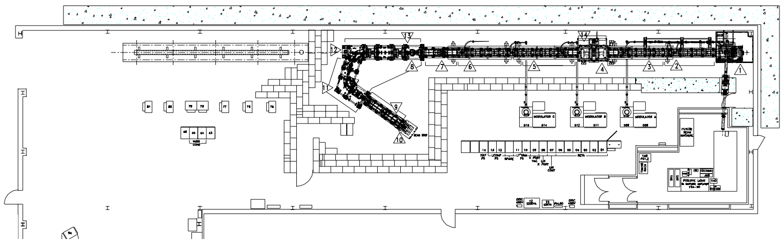
HGHG Configuration Development

Experimental Utilization

Integration of planned experiments to FEL operation

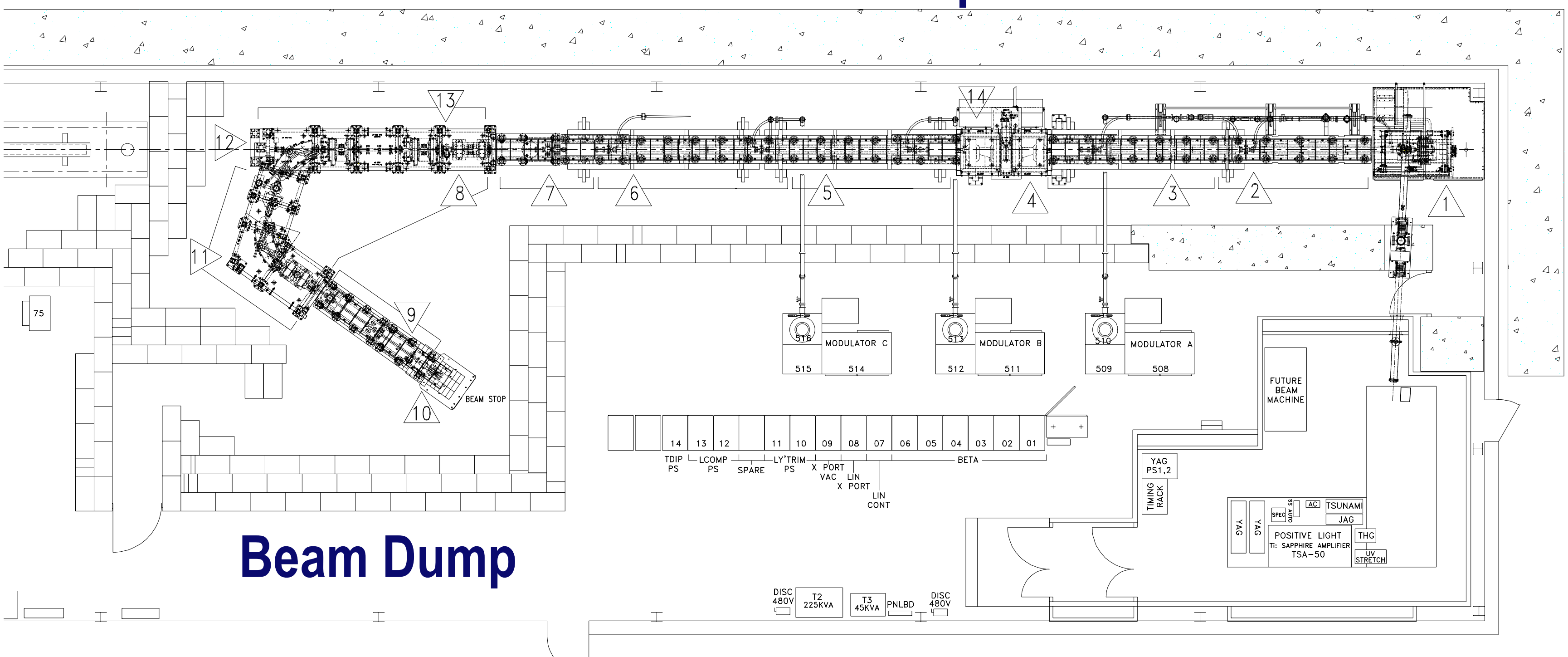
Development of new experiments based on FEL performance

DUV-FEL Configuration



Linac Development Phase

Achromat Linac Compressor Linac Gun



Beam Dump

Laser System

DUV-FEL Milestones

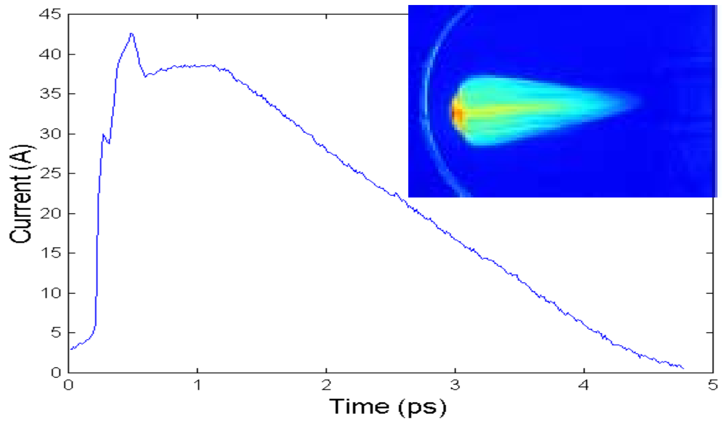
Linac Development

- Prepared Physical Plant (Building, Utilities, Cleanroom, Crane)
- Photo-injector System
  - Photocathode Gun Implementation
  - Gun Laser Development and implementation
- Linac Reconfiguration
  - Compressor
  - Controls and Diagnostics
  - Safety Systems

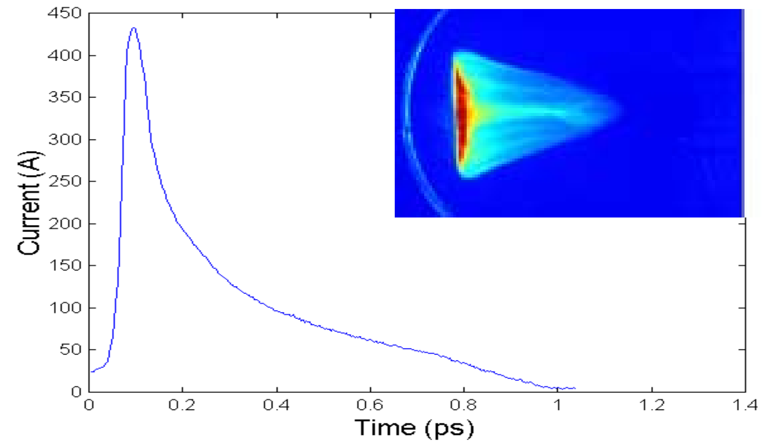
. . . . *Experimental Results*

Electron Beam Studies

Uncompressed, 40 A peak, 3 ps FWHM



Compressed, 425 A peak, 0.2 ps FWHM

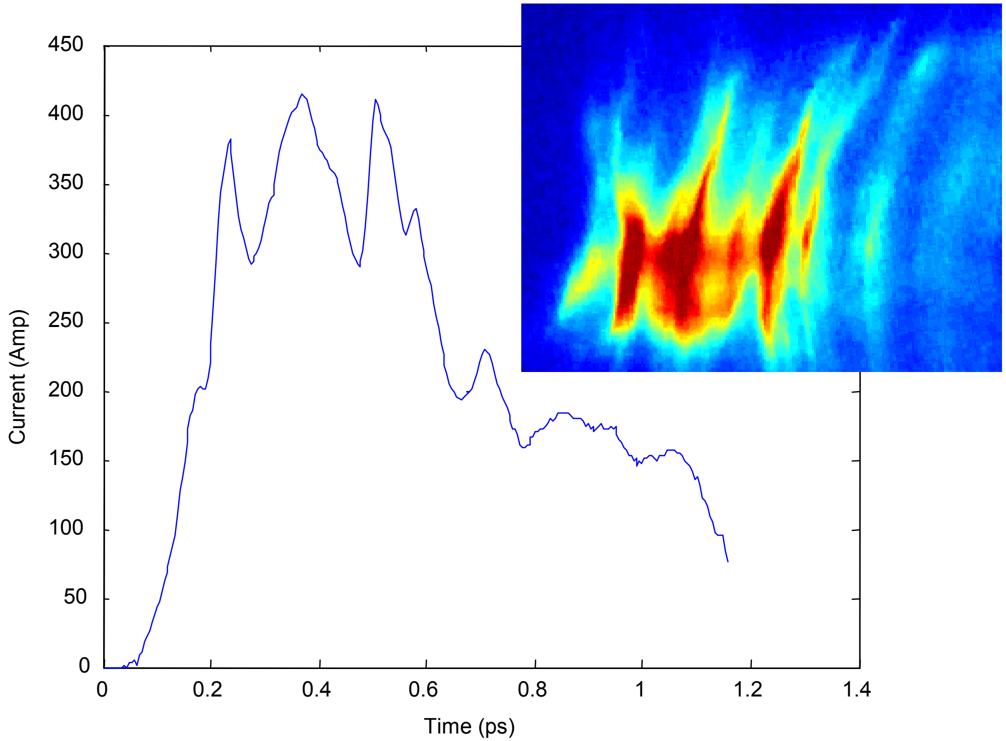


Beam Parameters		Measured	Required
Energy	[MeV]	200	140
Energy Spread	[%]	0.07	0.1
Bunch Length	[FWHM ps]	0.2 - 5	1.0
Charge	[pC]	250	400
Peak Current	[Amp]	400	400
Emittance	mm-mrad]	2-5	5
Timing Stability	[ps]	0.5-1	0.5

DUV-FEL Milestone

Compressed Beam Results

Meets basic parameters for initial FEL Commissioning



Parameters

	Vis SASE	Measured
E [MeV]	140	110
$\Delta E/E$ [%]	0.1	0.05
σ_z [ps]	1	0.27
Q [pC]	400	250
ε [μm]	5	~5
I_p [A]	400	400

Note: Strong coherent bunching observed in compressed beam

DUV-FEL Milestones

Linac Development

Basic Photo-Injector Development (part of commissioning process)

Also supporting diagnostic development experiments

- COUR (COherent Undulator Radiation)
- Edge and Coherent Synchrotron Radiation Measurements

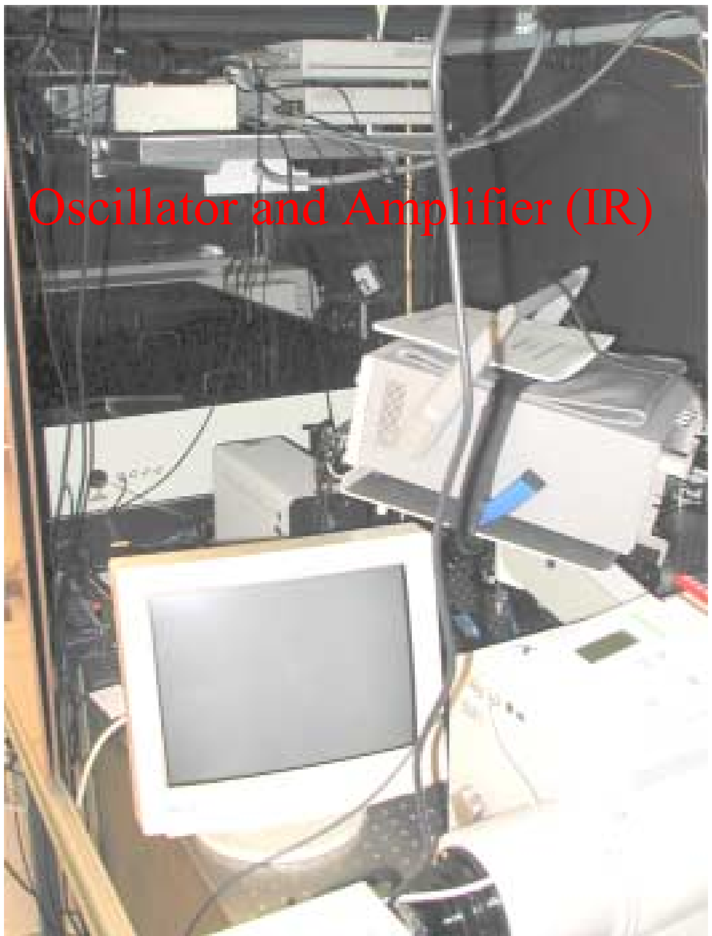
Complementary bunch length measuring techniques

Fundamental electron beam physics for transport of ultra-bright beams

Already shown unexpected bunching in beam (under investigation)

Several abstracts prepared for PAC 2001 (June)

LDRD Project 98-23A
Performance Enhancement in a Photoinjector Electron Linac



<u>Laser System:</u>

Ti:Sapphire Regen

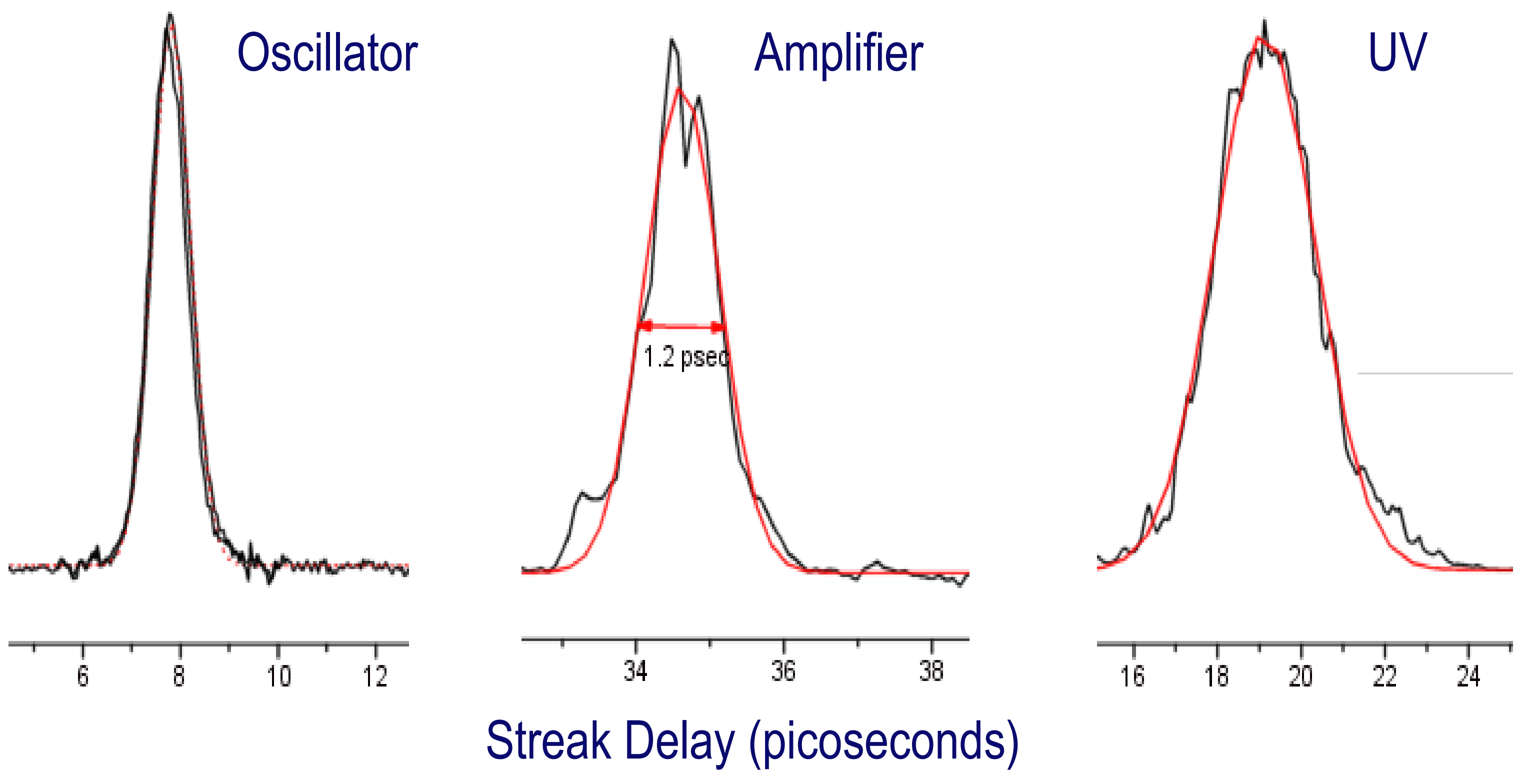
Triple to 266nm for Gun UV

Diagnostics for beam development

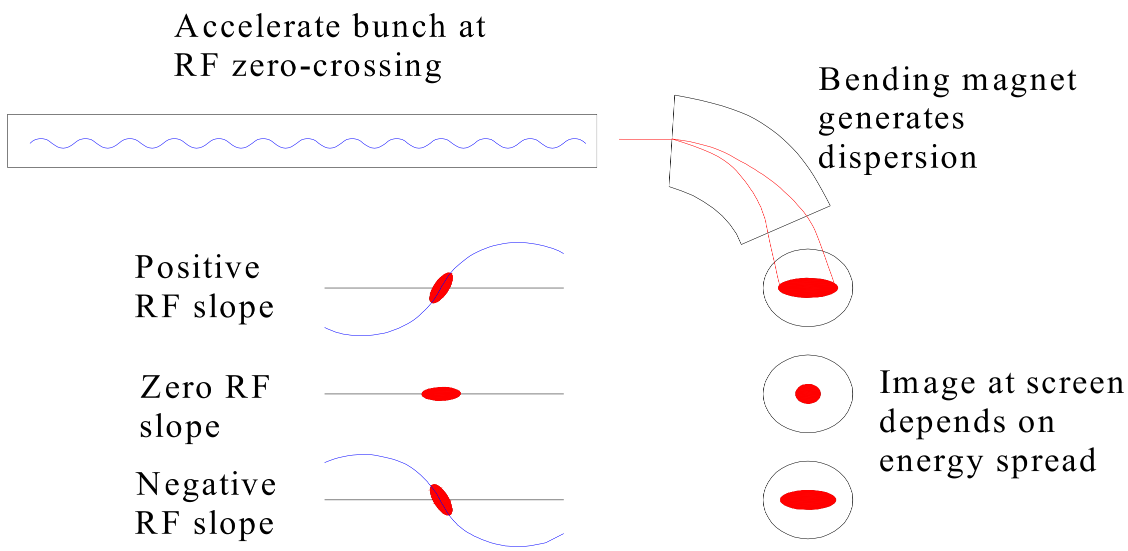
LDRD Project 98-23A
Performance Enhancement in a Photoinjector Electron Linac

Recent Streak Camera Measurements:

796 nm IR from Oscillator (synchroscan) and Regen (single shot)
266 nm UV from Tripler (single shot)



RF Zero Phase I

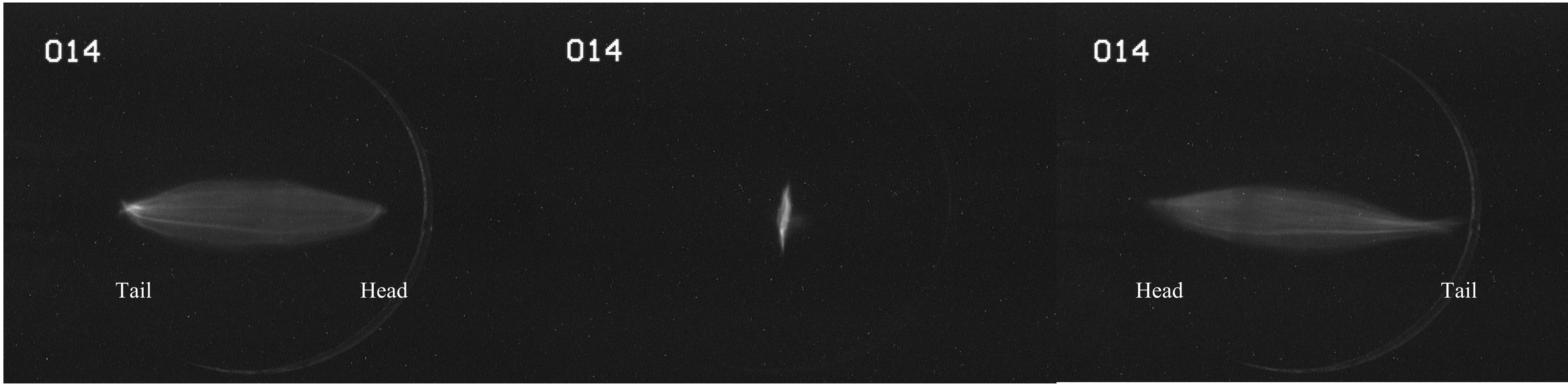


Measure bunch length by using linac to "streak" beam on profile monitor.

At DUV-FEL, use tank 3 to remove correlations from compression, tank 4 to produce chirp.

W.S. Graves Studies

RF Zero Phase II



Phase = -90 RF off Phase = +90

Charge	250 pC
Energy	75 MeV
Chicane	off
Tank 4	11 MeV

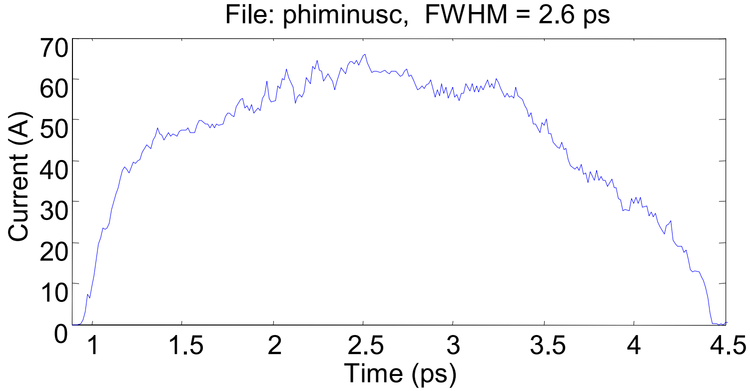
$$\sigma_t = \frac{E_0 \sigma_x}{\eta E_{rf} k_{rf} c} = \frac{(75\ \text{MeV})(120\ \text{um})}{(1.1\text{m})(60\ \text{MV})(60\ \text{m}^{-1})c} = 8\ fs\ \text{RMS time resolution}$$

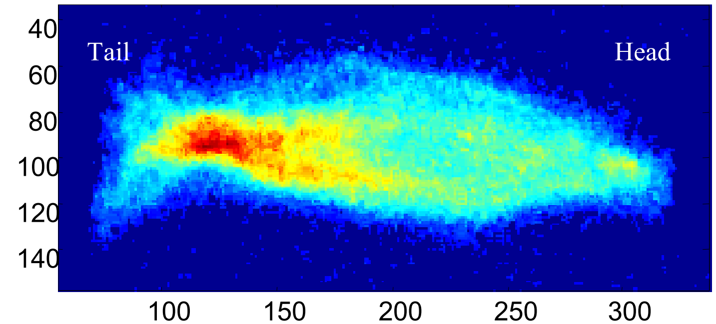
Much more information than bunch length is available.

W.S. Graves Studies

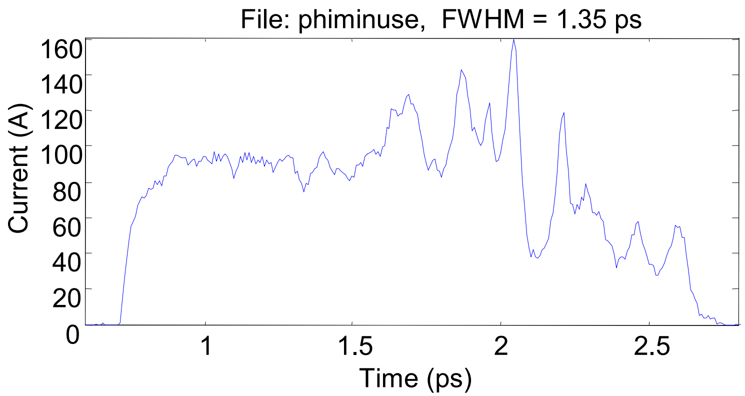
Microbunching at high compression

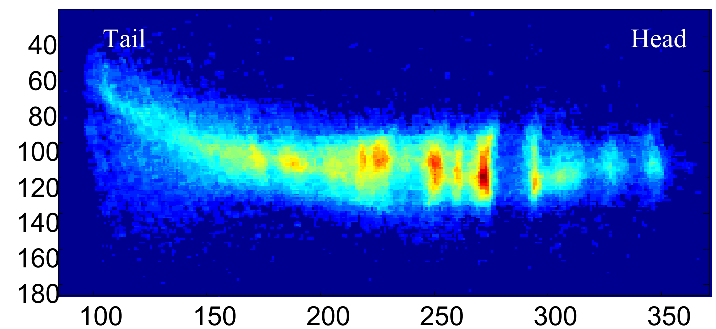
W.S. Graves Studies



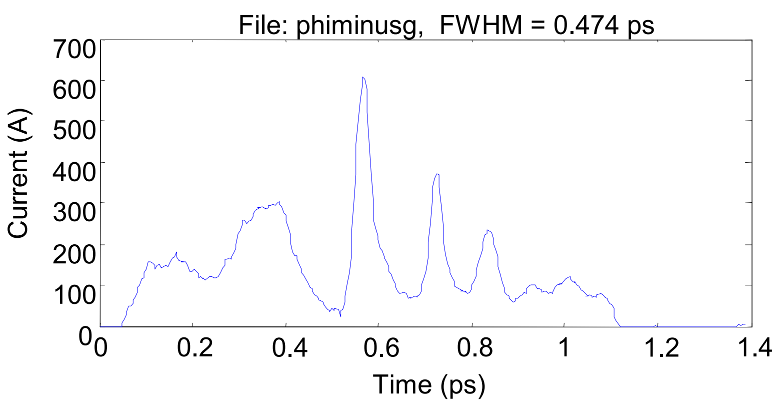


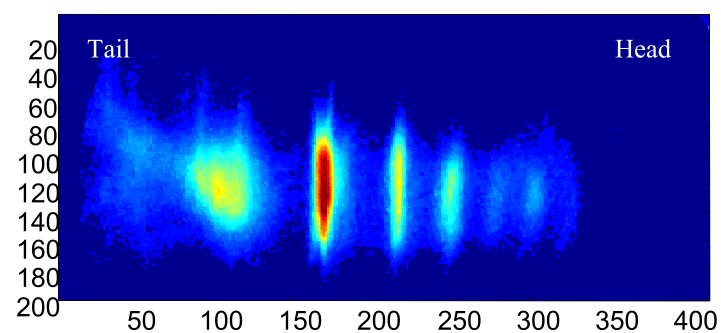
Uncompressed beam on pop14





Mild compression



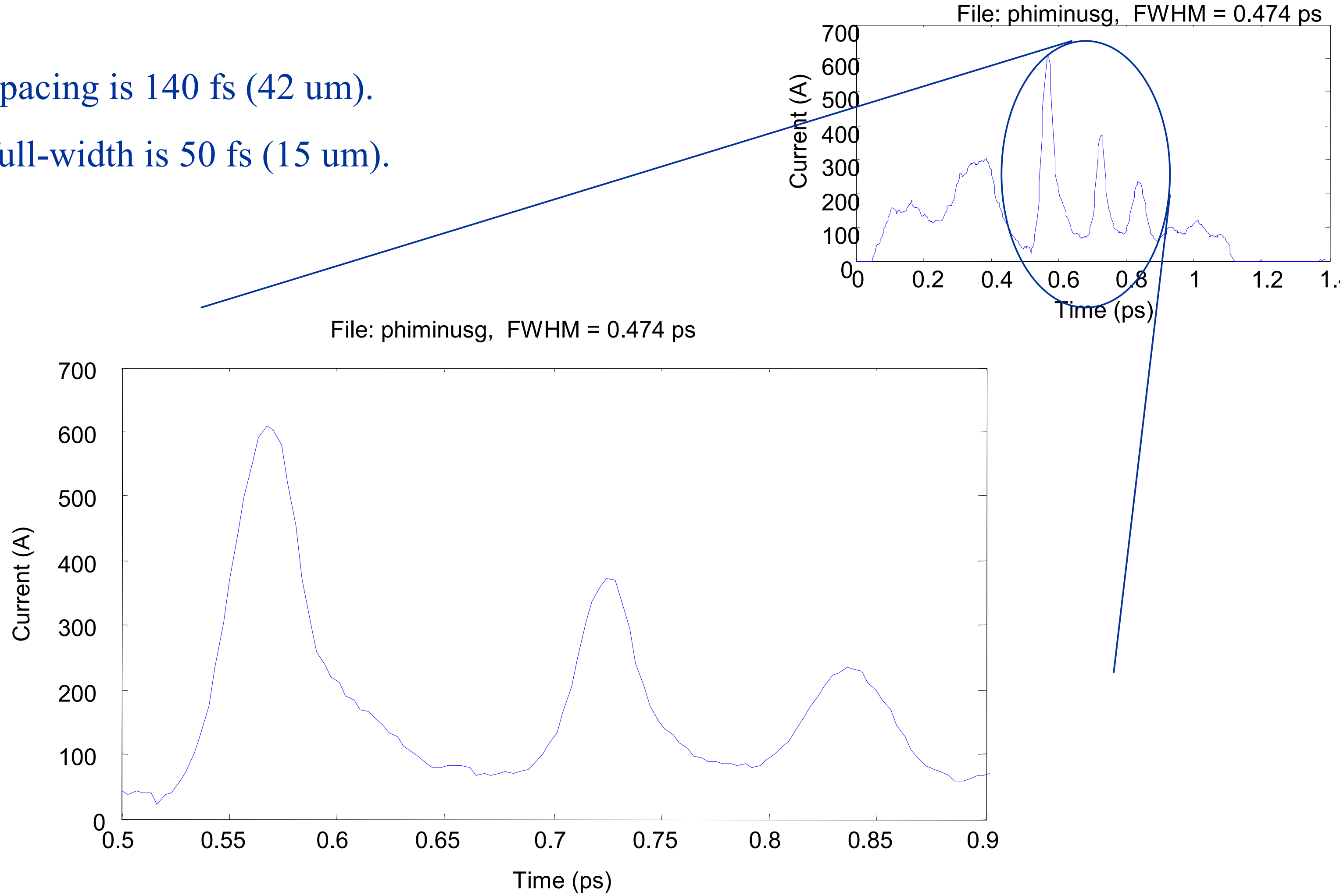


Strong compression.

50 femtosecond time resolution

Peak spacing is 140 fs (42 um).

Peak full-width is 50 fs (15 um).



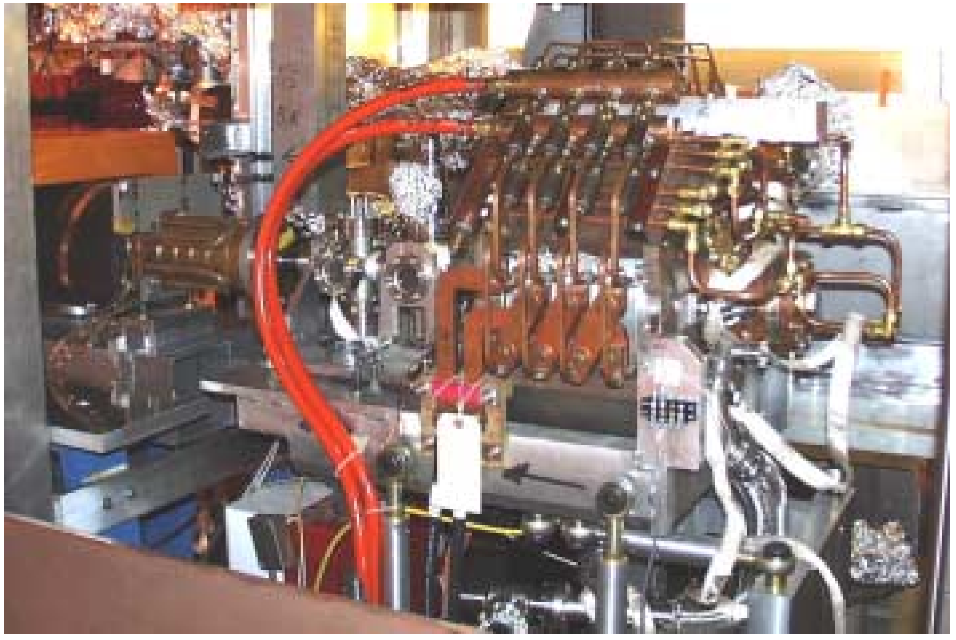
W.S. Graves Studies

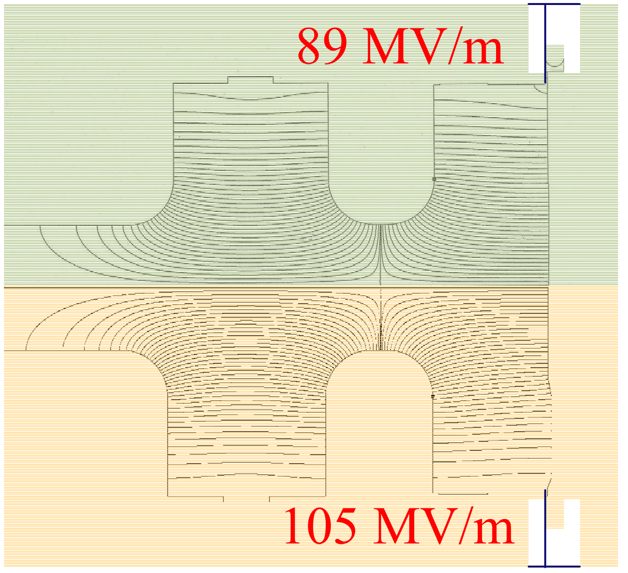
LDRD Project 98-23A
Performance Enhancement in a Photoinjector Electron Linac

<u>Photoinjector:</u> Gun IV (ATF Design)

Significant Study in this FY

Pathway to improved performance identified





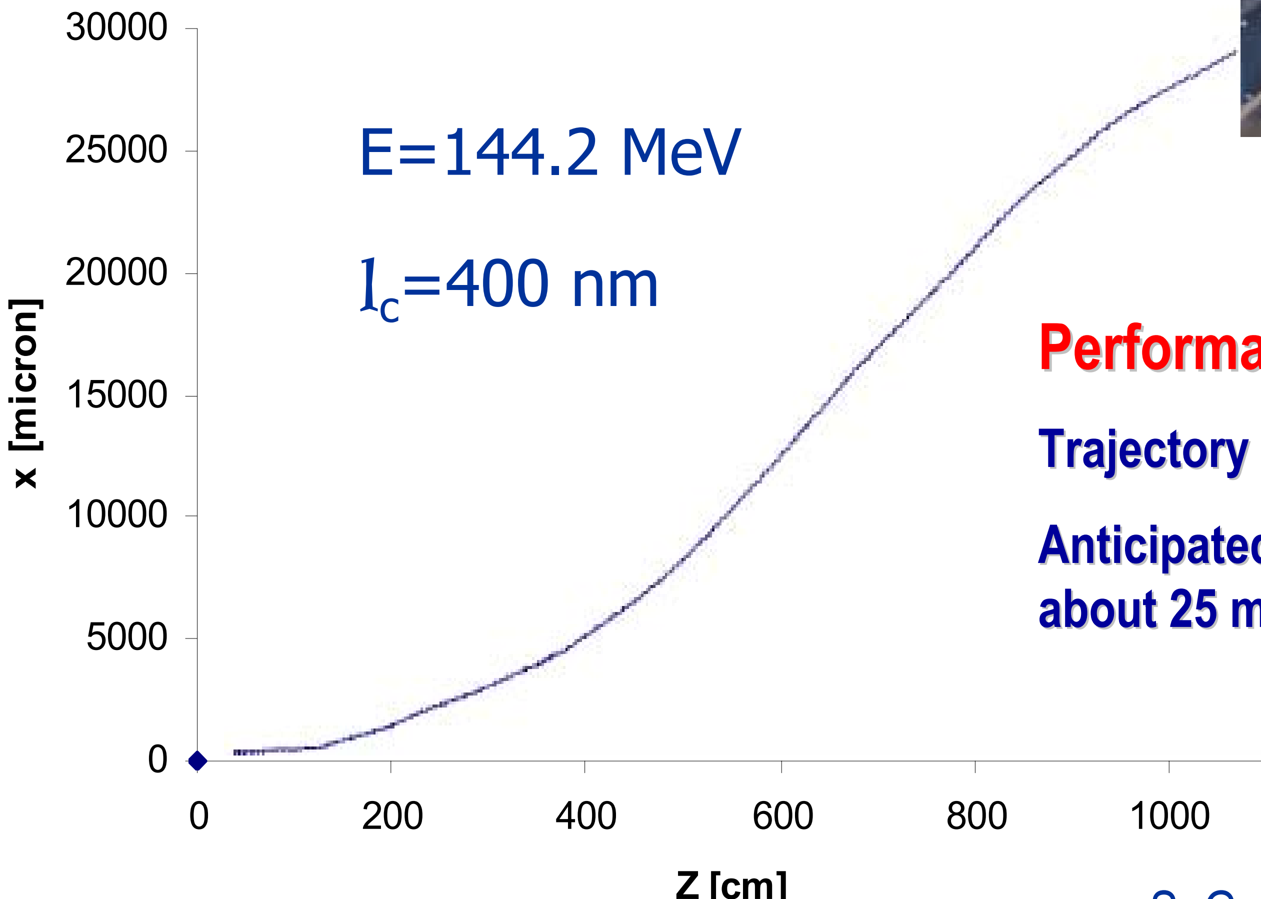
Add separate RF seal, no SS path

DUV-FEL Milestones

FEL Development For Visible SASE Experiment

- Prepare NISUS Undulator
  - Measure and Correct field
  - Vacuum System
  - Diagnostics and Alignment
- Transport line installation
- Safety Systems
  - Shielding
  - Interlocks
  - SAD & Other Administrative Requirements

NISUS Before Correction



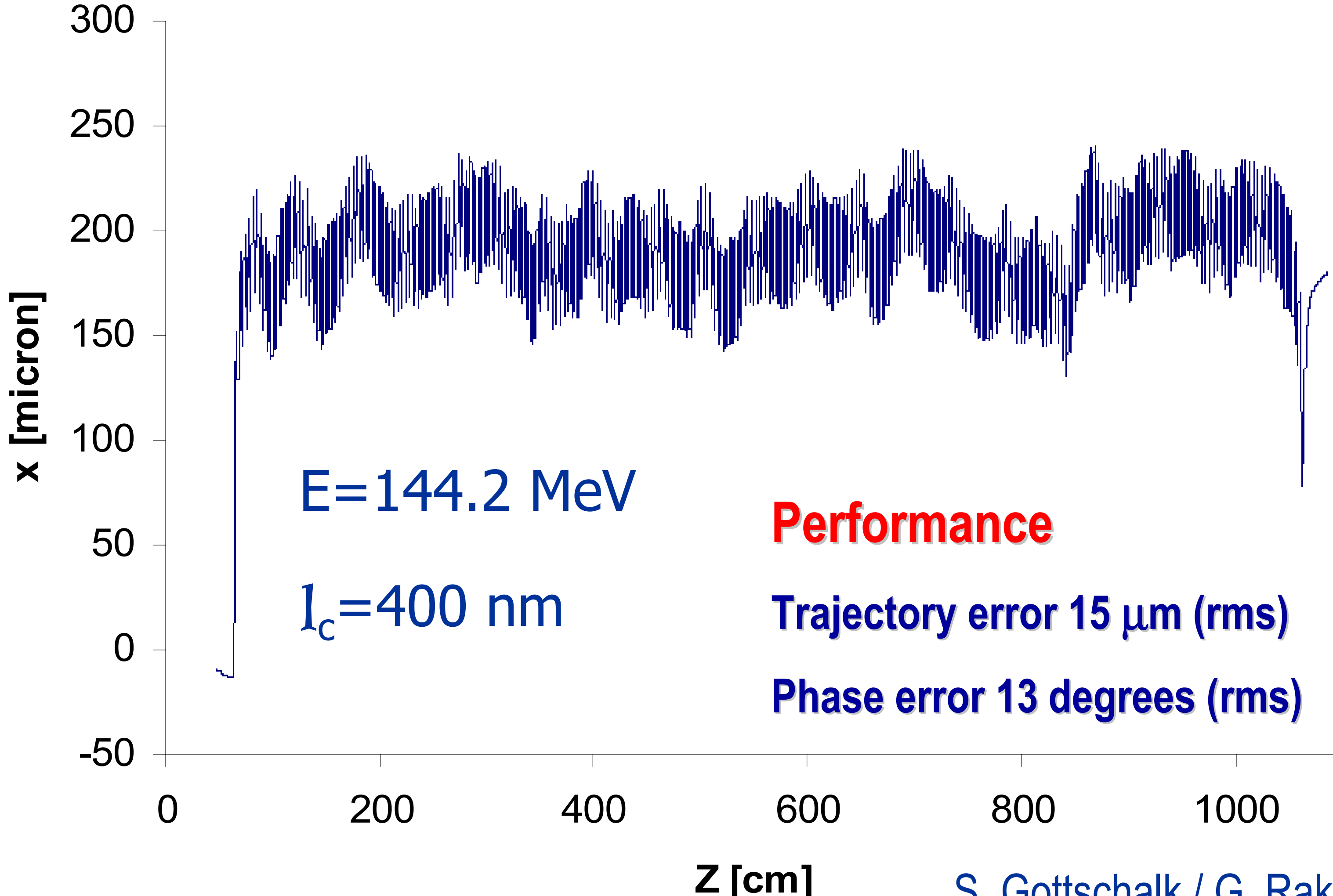
Performance Issues

Trajectory walk-off cm!

Anticipated wiggle amplitude about 25 micrometers

S. Gottschalk / G. Rakowsky

NISUS After Correction



Performance

Trajectory error 15 μm (rms)

Phase error 13 degrees (rms)

S. Gottschalk / G. Rakowsky

LDRD Project 99-51A

High Gain FEL Amplifier

Popin Diagnostic Monitor Station

Making them work….

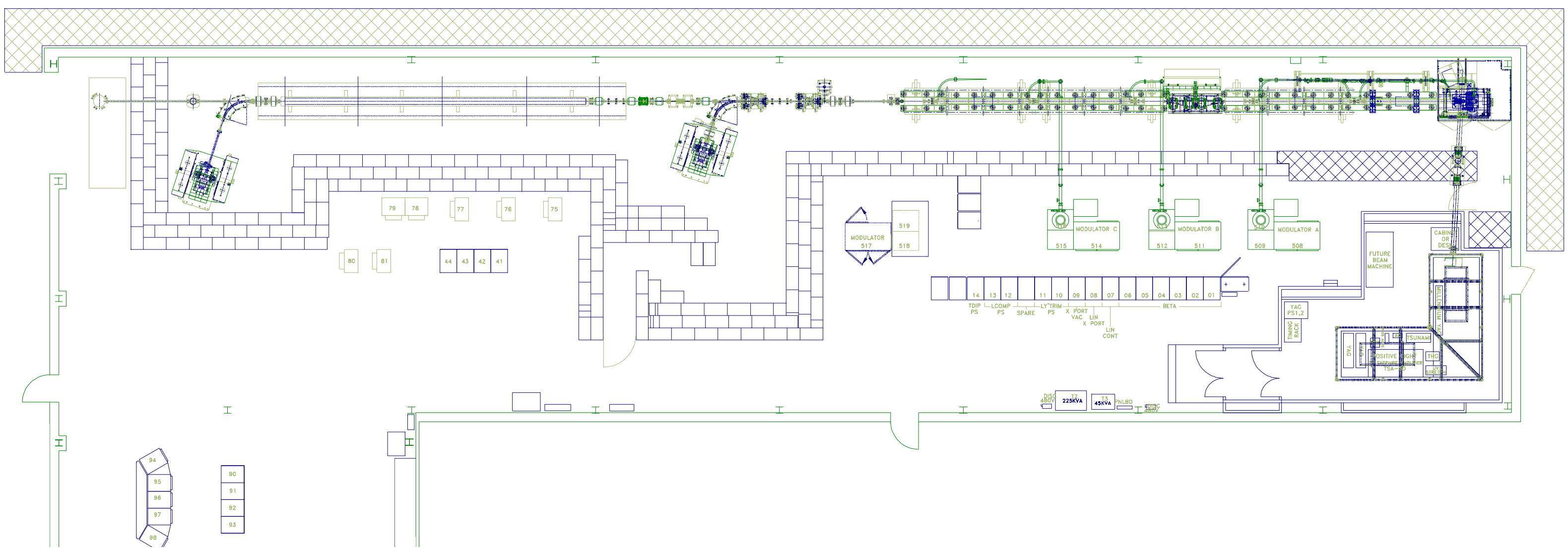
… Adnan Doyuran

(99-51B, Li-Hua Yu)

DUV-FEL Amplifier Installation Shutdown
3 June 2001

DUV-FEL Configuration

FEL Development



Anticipated Completion of Reconfiguration June 2001

DUV-FEL HGHG Plans

Parameter	Symbol	Units	Case I	II	III	IV
Seed Laser Wavelength	λ_{seed}	nm	800	400	300	400
Seed Power	P_I	MW	15	60	90	100
FEL Output Wavelength	λ_{out}	nm	400	200	100	100
Amplifier Gain Length	L_G	m	1.0	1.1	1.1	1.1
FEL Output Power	P_o	MW	150	180	130	12
Electron Beam Energy	E	MeV	197	210	299	299
Normalized Emittance	ε_n	Π mm-mrad	7	4	3	3
Peak Current	I_0	A	300	500	1000	1000
Energy Spread	σ	%	0.15	0.15	0.15	0.15

Note: Amplifier is NISUS with K of 1.14 (0.31T), Modulator is Mini-undulator
Cases III and IV require an upgrade of the linac energy.

Roles for BNL in Navy FEL Research

DUV-FEL Opportunities

- Long wavelength (1000 nm) operation possible
- Study merits of single pass configurations
- Platform for High peak power studies
- NISUS allows confirmation of Tapering behavior

Materials Characterization

- NSLS: Resource to examine relevant materials issues