JLab High Average Power FEL Program Status

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Jefferson Lab

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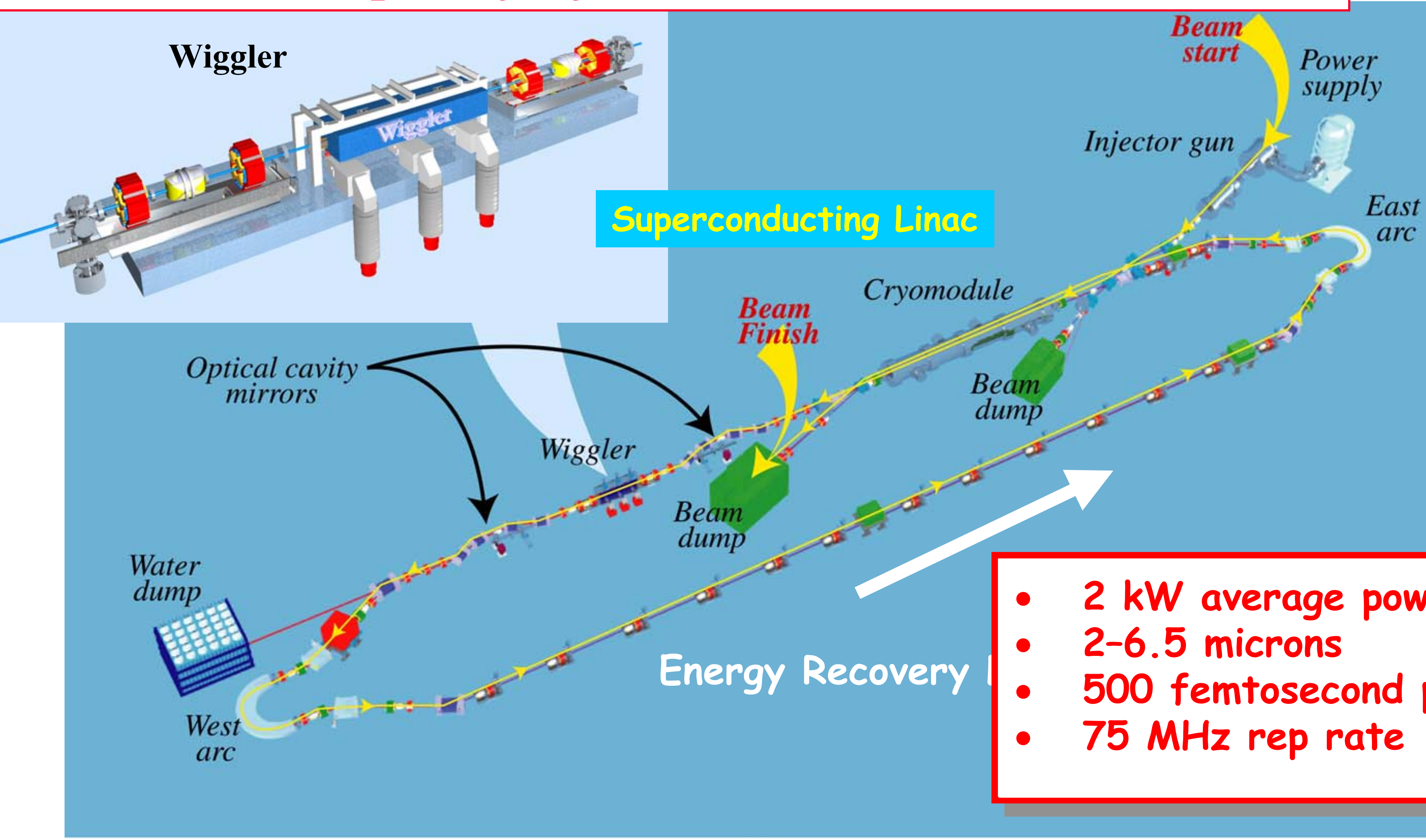
LPC

The past: the IR Demo Laser

the world's most powerful femtosecond laser, tunable IR laser
the world's most powerful femtosecond THz source

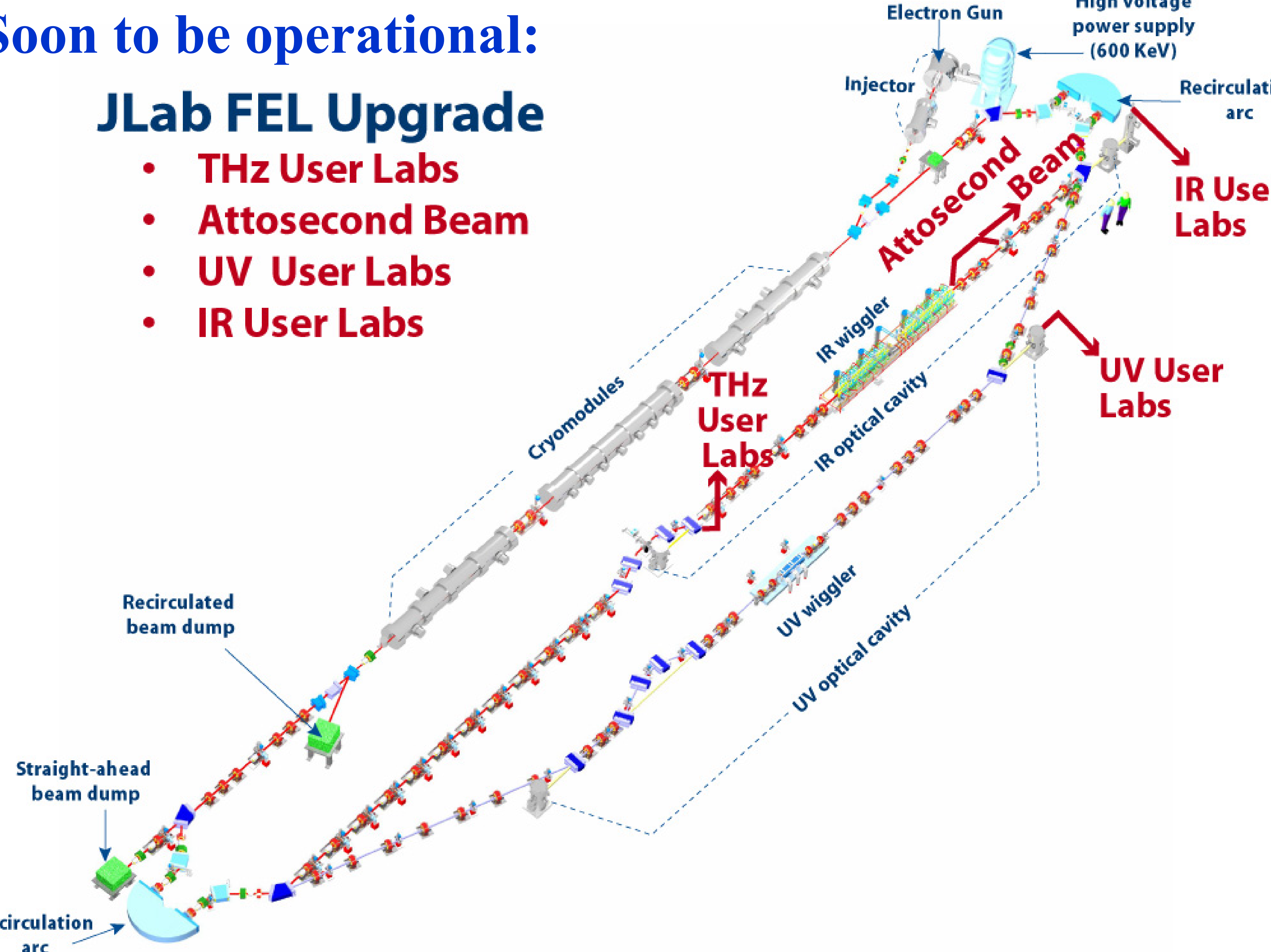


- 2 kW average power
- 2–6.5 microns
- 500 femtosecond pulses
- 75 MHz rep rate

Soon to be operational:

JLab FEL Upgrade

- THz User Labs
- Attosecond Beam
- UV User Labs
- IR User Labs



IR Upgrade Specifications

• Average Power	> 10000 W
• Wavelength range	1.5 to 4 μm, 4 to 6.5 μm, 6.5 to 14 μm ("real time" tuning)
• Micropulse energy	> 100 μJ
• Pulse length	~0.1-2 ps FWHM nominal
• PRF	74.85 MHz ÷ 2x down to 4.68 MHz
• Bandwidth	~ 0.2–3 %
• Timing jitter	< 0.2 ps
• Amplitude jitter	< 10% p-p
• Wavelength jitter	0.02% RMS
• Position/Angle jitter	< 100 um, 10 μrad
• Polarization	linear, > 100:1
• Transverse mode	< 2x diffraction limit
• Beam diameter at lab	2 - 6 cm

JLab IR/UV Mirror Cassette works to very high power

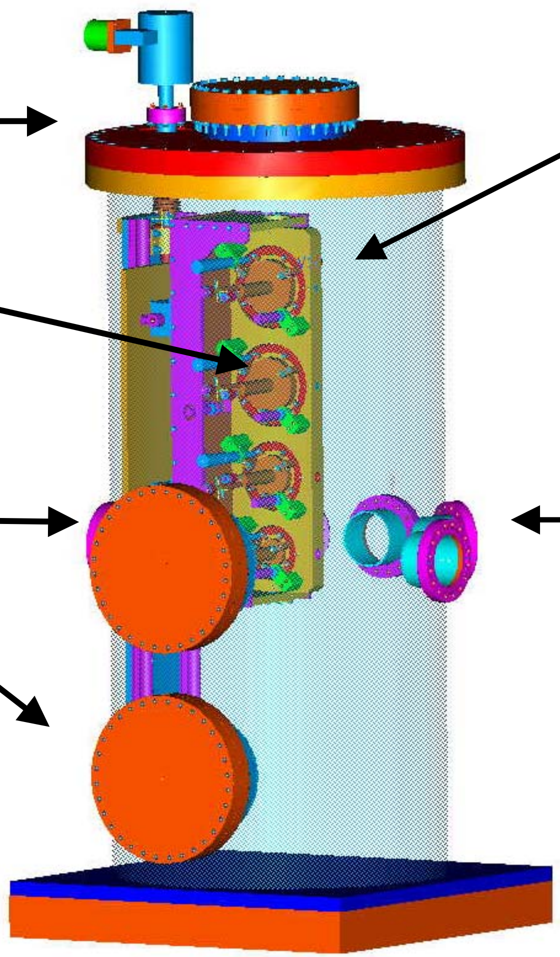
Conflat seals to achieve vacuum rating.

Mirrors on translation stage to change wavelength ranges

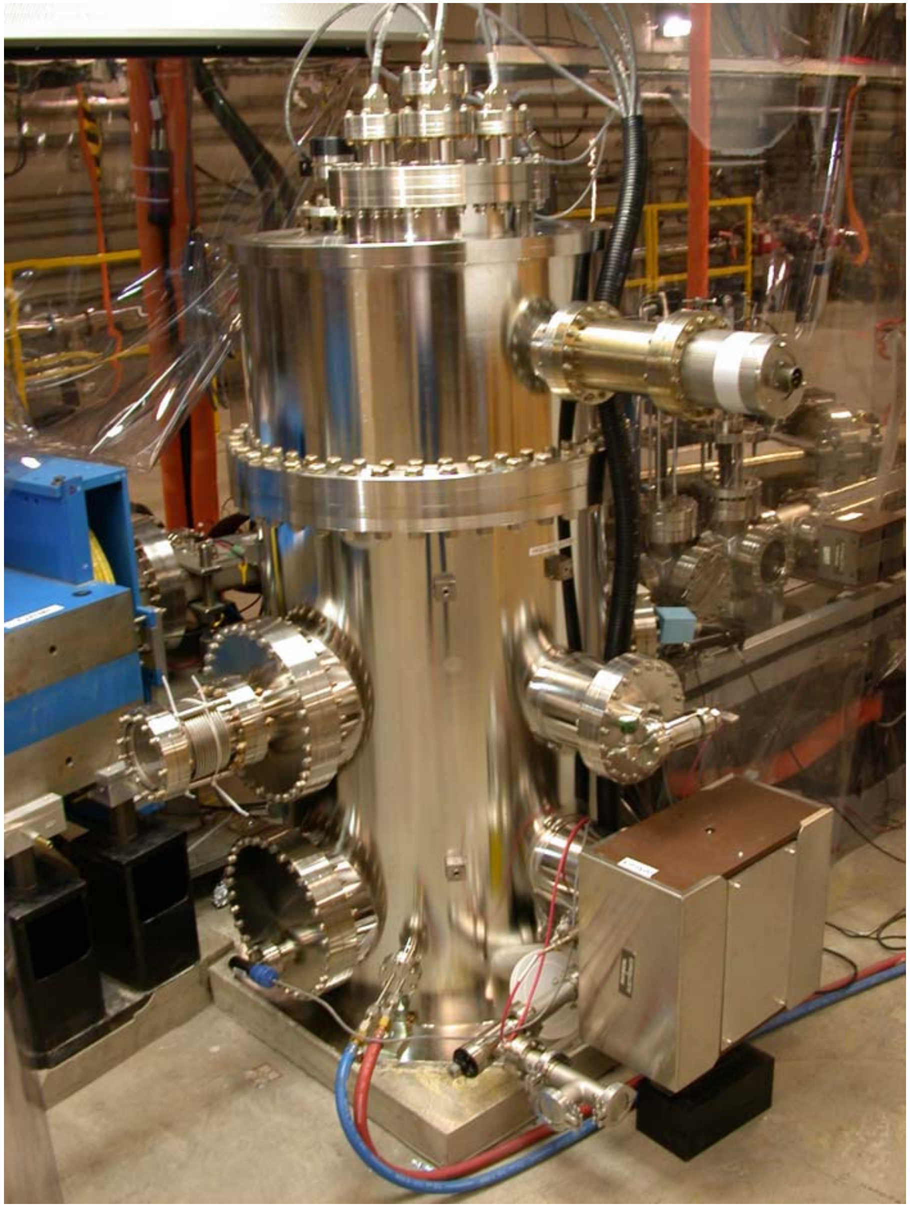
Deformable mirrors correct thermal distortion

Access ports for Survey and Alignment Team and diagnostics.

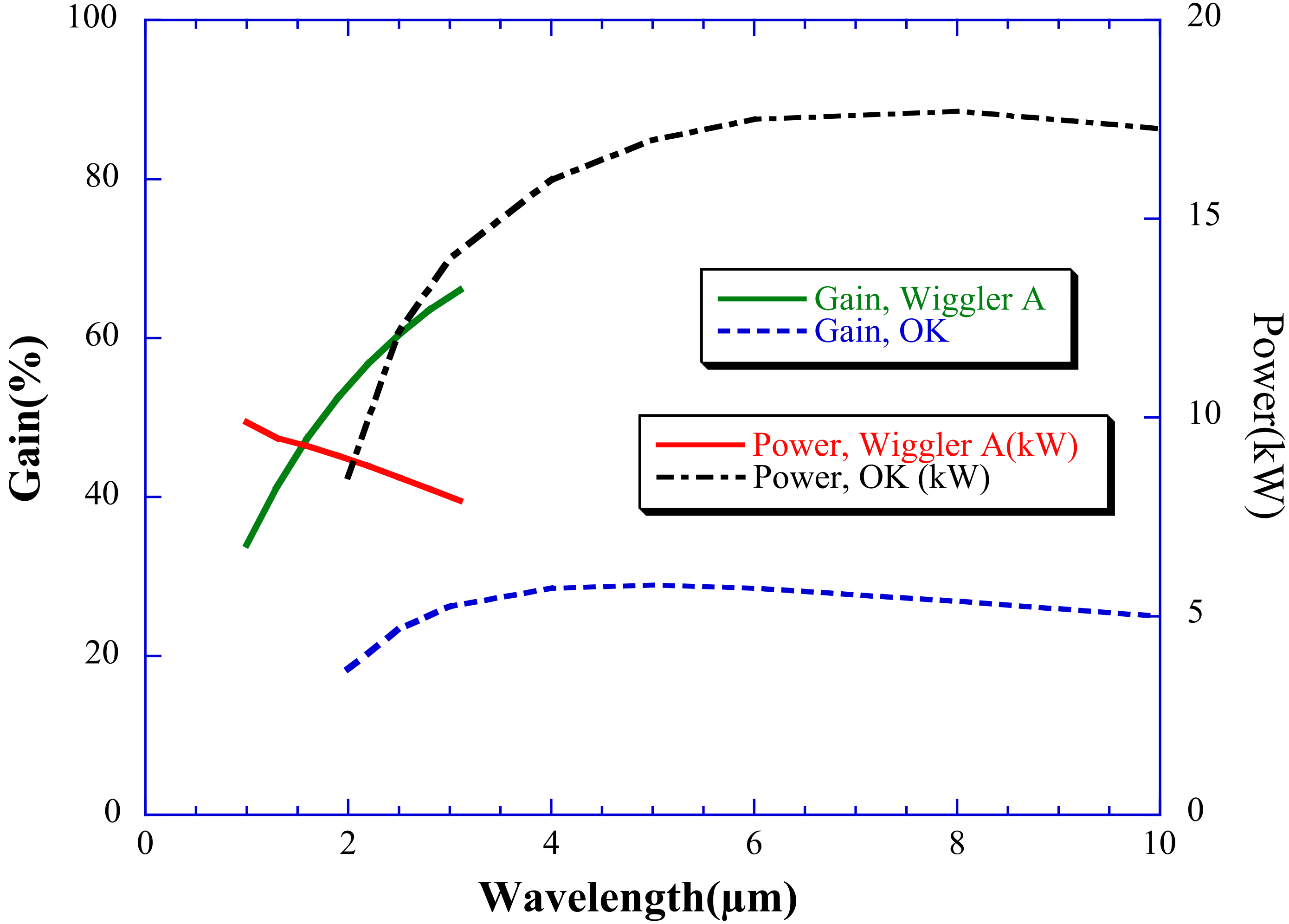
Access ports for installation or replacement of components.



Optical Cavity as Installed

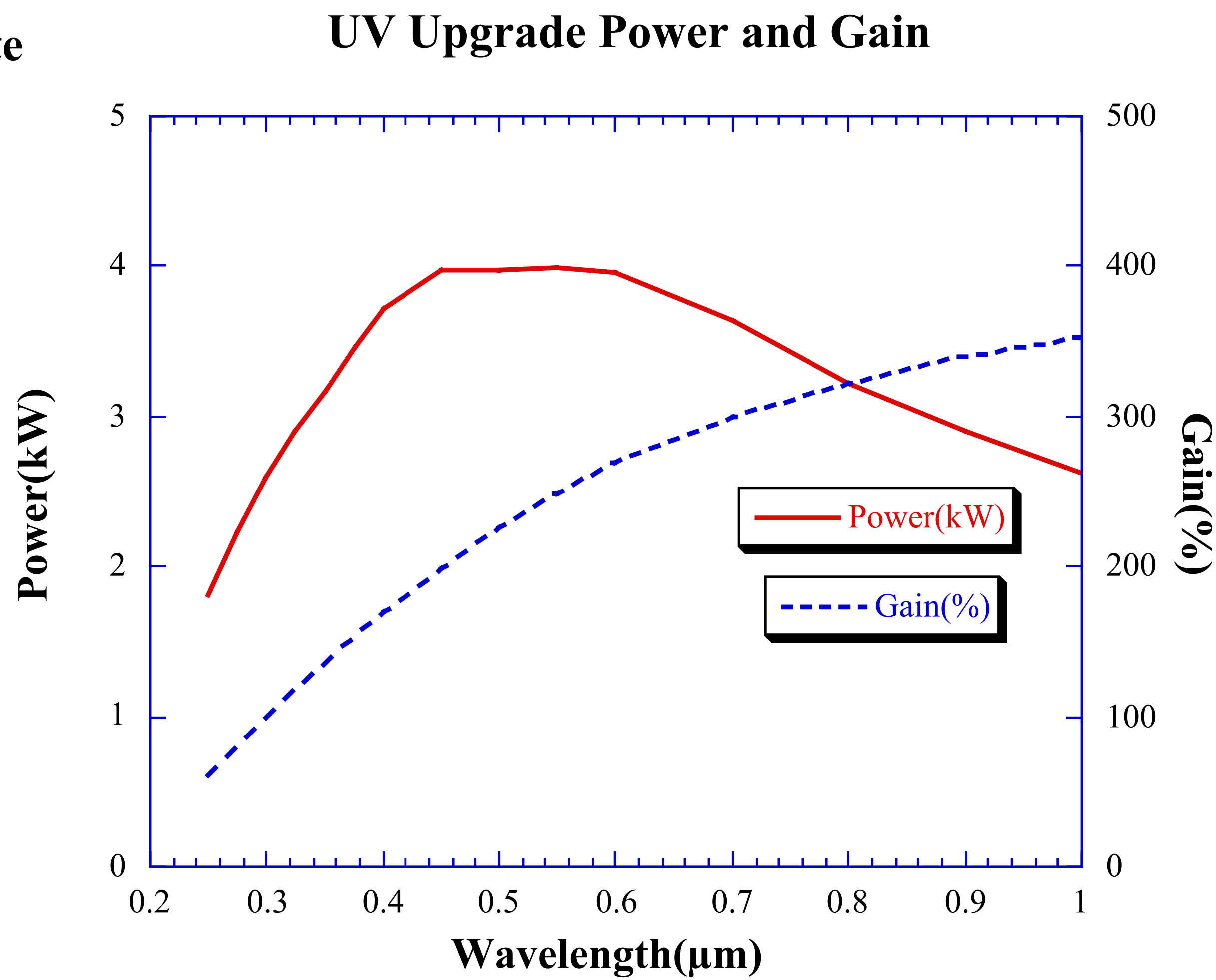


Comparison of New Wiggler with Optical Klystron

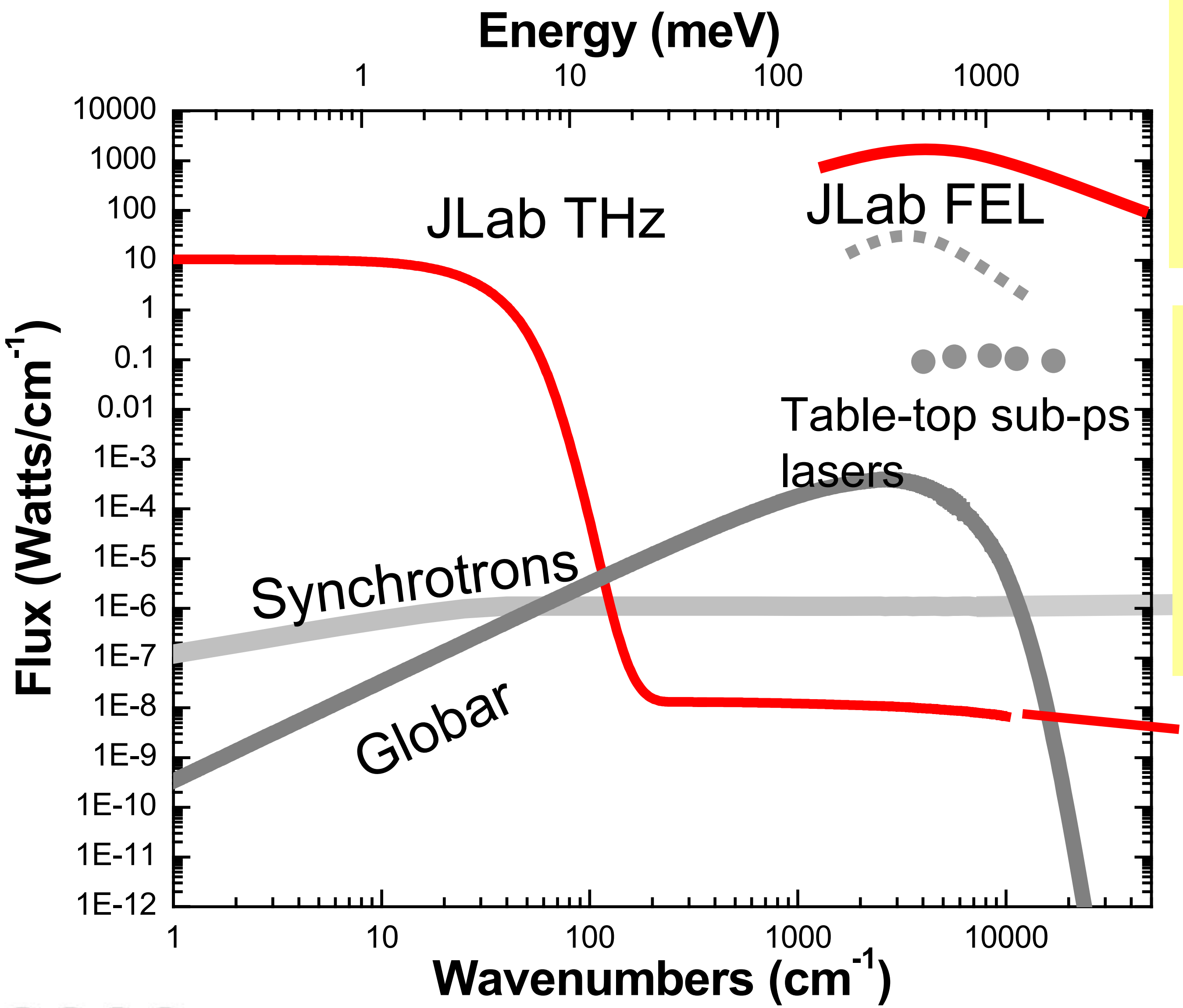


UV Upgrade Performance

- Tunable pulse energy to saturate electronic transitions
- Drive non-linear field effects
- High rep rate for S/N: e.g., molecular beams, gas phase



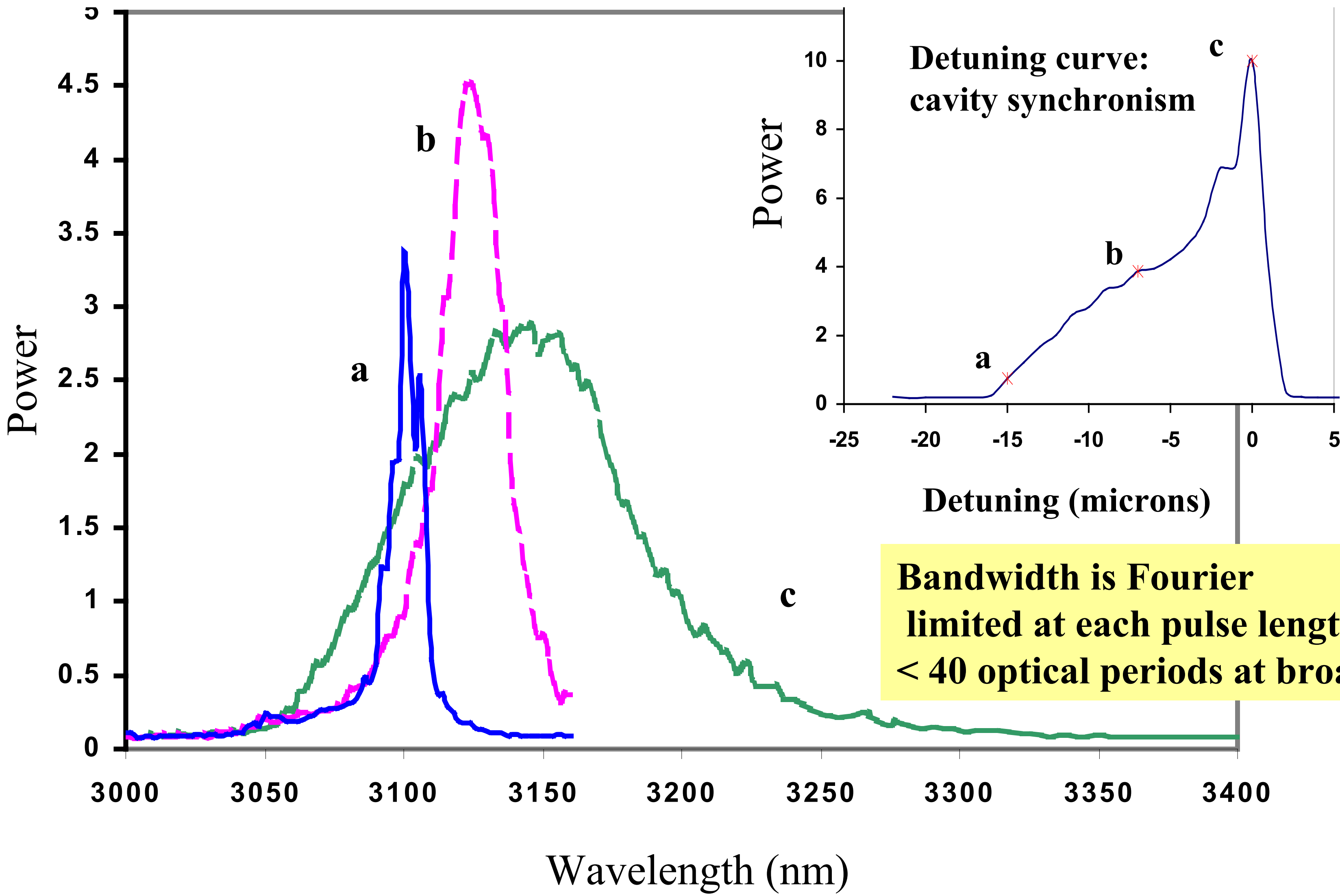
High power THz with sub-picosecond pulses



FEL proof of principle:
Neil et al. Phys. Rev.Letts 84, 662 (2000)

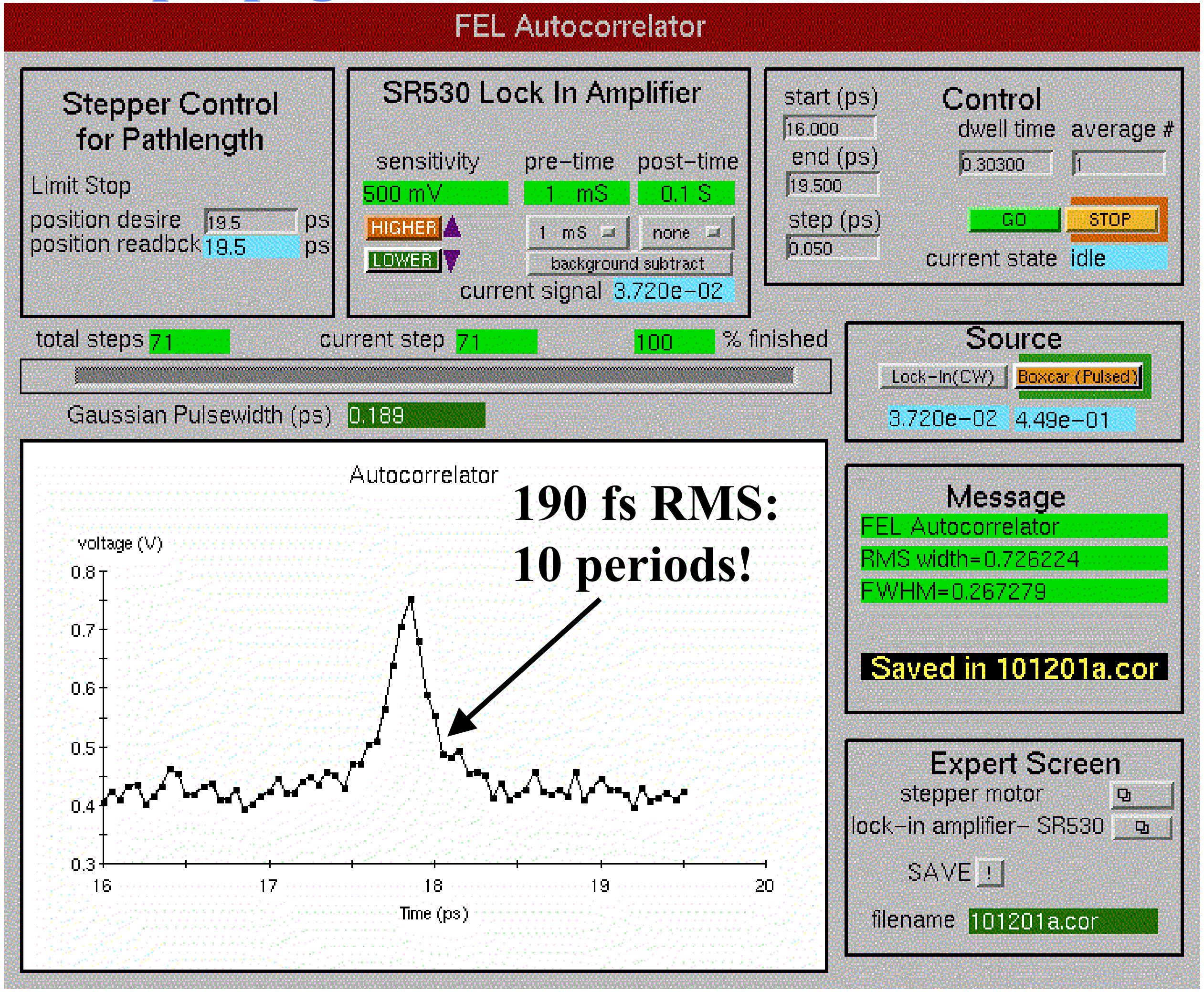
THz proof of principle:
Carr, Martin, McKinney, Neil, Jordan & Williams Nature 420, 153 (2002)

IR Demo Spectrum at Three Cavity Lengths shows control of bandwidth



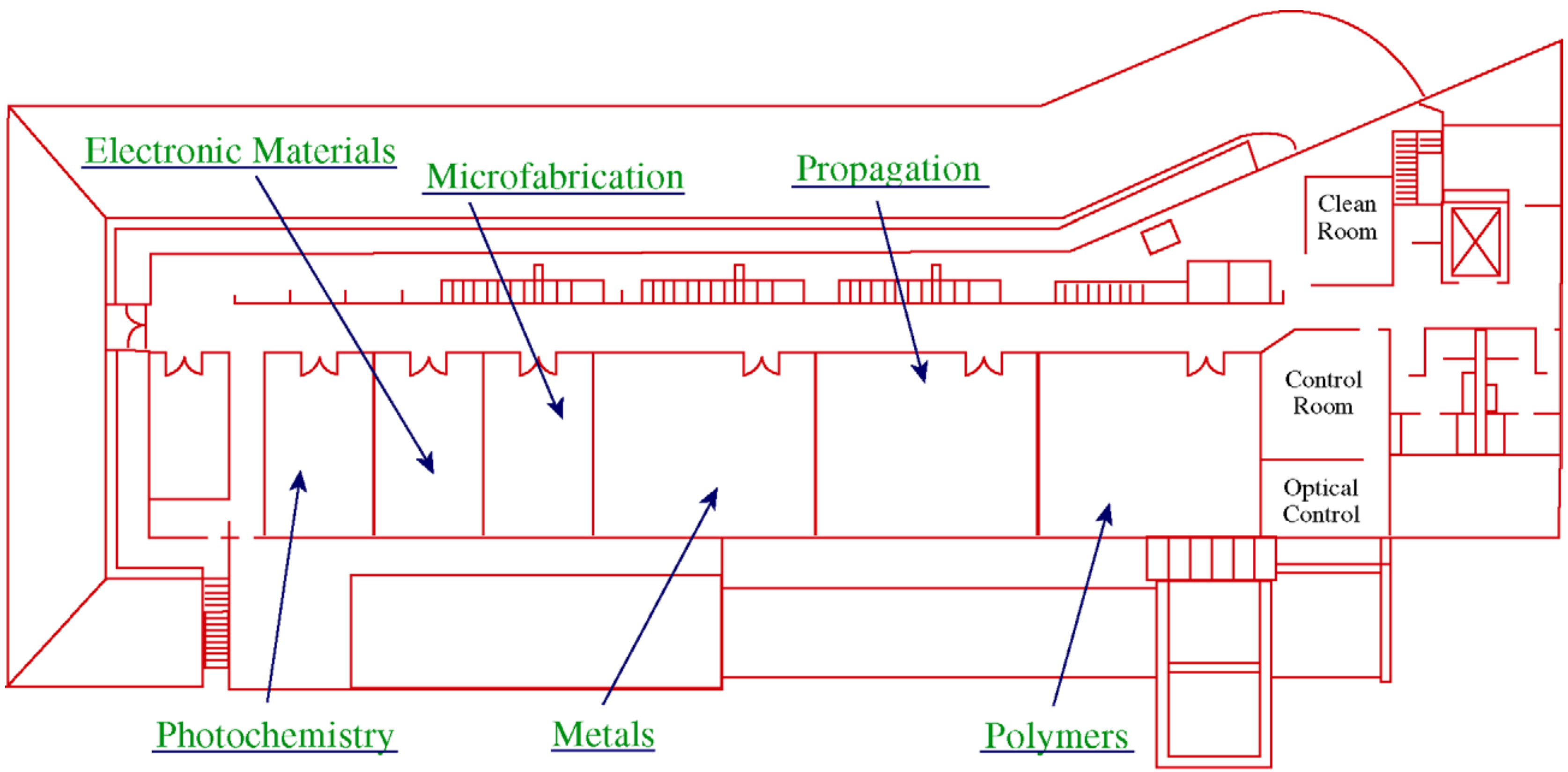
Bandwidth is Fourier limited at each pulse length; < 40 optical periods at broadest!

Many studies utilize ultrafast pulsewidth: 200 - 1000 fs - air propagation effects?



Free-electron Laser Facility provides six User labs for experimental activities

Existing JLab FEL Facility Upstairs Layout



JLab FEL Upgrade Status

- IR Upgrade FEL at JLab starting up at 10 kW
  - Characterization has begun : average power lasing achieved at 10 microns
  - Plan was 10 kW expected in 1 to 14 micron region
  - Initial results suggest mirror coating absorption is restricting operational power to ~ 3kW for wavelengths beyond ~ 7 microns. No reduction for shorter wavelengths.
  - Navy sponsor has focused our effort on achieving 10 kW milestone for the near term

JLab FEL Upgrade Status - accomplishments to date

. first lasing on June 16th ,2003

. first energy recovery in Aug. 2003

. 750 W CW at 10 microns

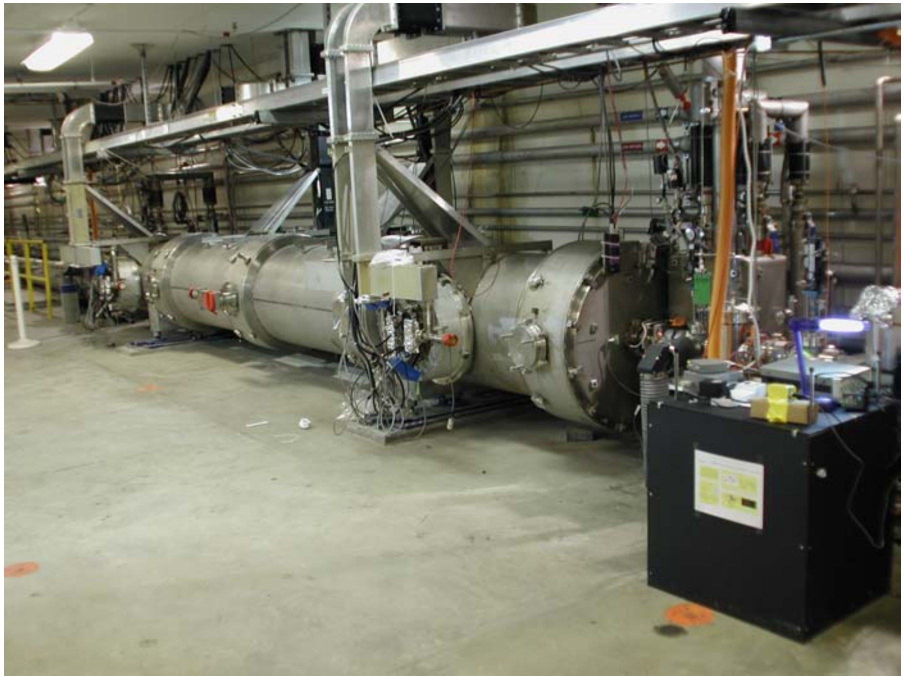
. 2.5 kW pulse at 10 microns

. 1.5 kW CW at 6 microns

. ~60 kW of stored optical beam at 6 microns

. ~560 kW of energy recovered electron beam

Installed and Commissioned Cryomodules



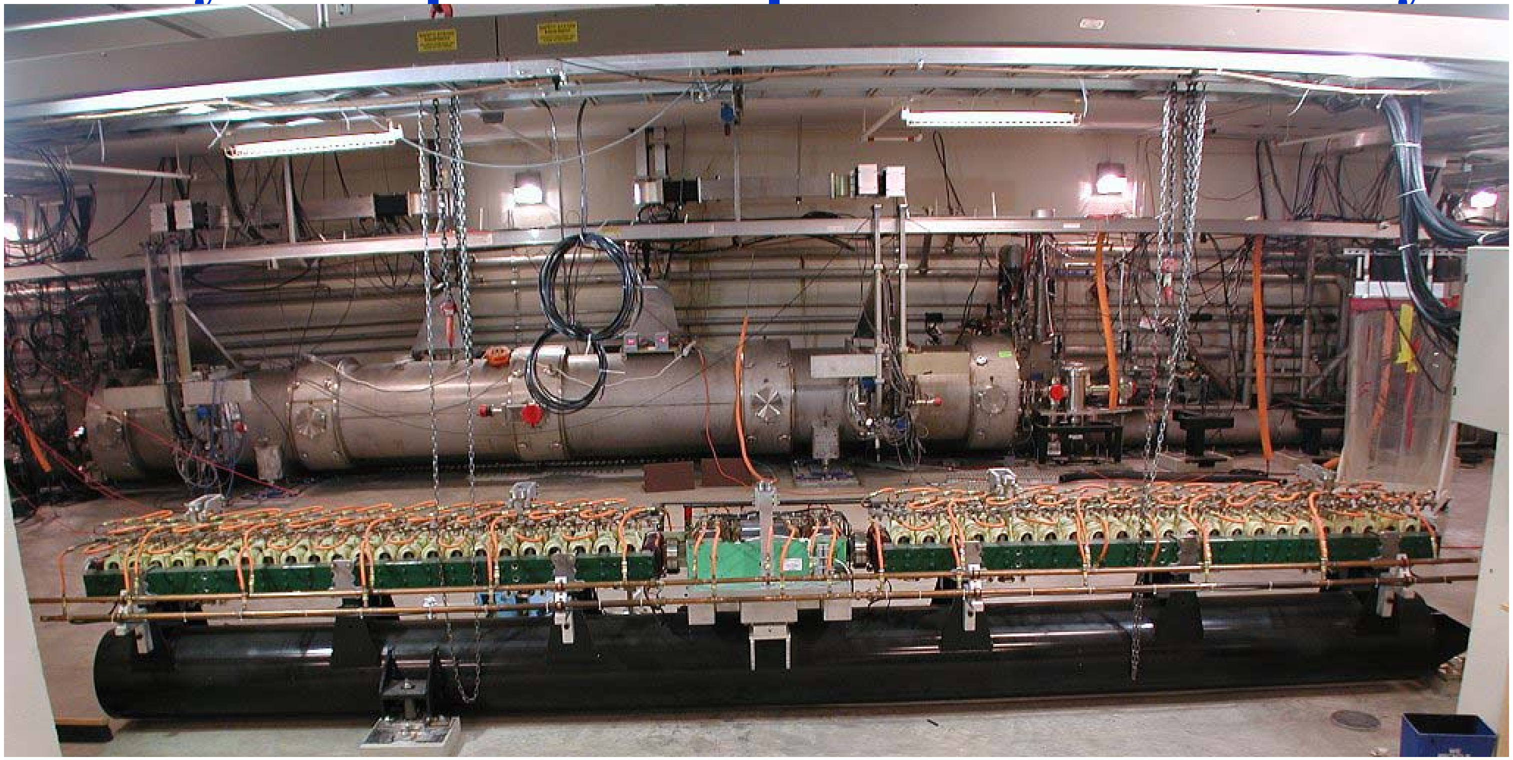
First and third cryomodules are CEBAF style modules

- **Each capable of 40 MV acceleration**
- **Eight 5 cell cavities**
- **HOM loads at 50 °K**
- **10 meter slot length**

JLab FEL Upgrade Status - Approach

- To resolve these issues we are pursuing a number of fixes in parallel:
  - Cryogenically cooled ZnSe outcoupler
  - Scraper outcoupler (not useful long term because of bad beam quality)
  - New electromagnetic wiggler install in May for 1 micron
  - New permanent magnet wiggler install in July for 1 micron - initial system does not include gap tuning
  - Increase beam energy with third cryomodule
- Other activities are second priority till we get this resolved

Optical Klystron provides operational flexibility



Wavelength	20 cm
K^2	1–16
Number of periods	12 ea.
Gap	26 mm
Polarization	vertical
Phase error	<5 deg.

Dispersion section

Length	58 cm
Dispersion	>40 periods for K^2=16
Gap	26 mm

JLab FEL Upgrade Status- Bottom line

- We are constructing initial optical transport system ("OTS Lite") for first Lab, previous transport can work at 5 kW
- Also constructing THz beamline
- UV FEL system begins installation this summer, lase next winter if funding is available

Real user operations will depend on achieving 10 kW. We are hopeful this will be off our plate before mid-summer

The work discussed was performed by the FEL Team:

C. P. Behre, S. V. Benson, M. E. Bevins, G. Biallas, J. Boyce, W. Chronis, J. L. Coleman, L.A. Dillon-Townes, D. Douglas, H. F. Dylla, R. Evans, A. Grippo, D. Gruber, J. F. Gubeli, D. G. Hardy, C. Hernandez-Garcia, R. Hiatt, K. Jordan, L. Merminga, J. Mammosser, G. R. Neil, J. Preble, R. Rimmer, H. Rutt, M.D. Shinn, T. Siggins, H. Toyokawa, D. Waldman, R. Walker, G. Williams, N. Wilson, M. Wiseman, B. Yunn, and S. Zhang

With the help of lots of others at JLab

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IR Upgrade tuning spans the near/mid IR