Status of the JLab IR/UV Upgrade

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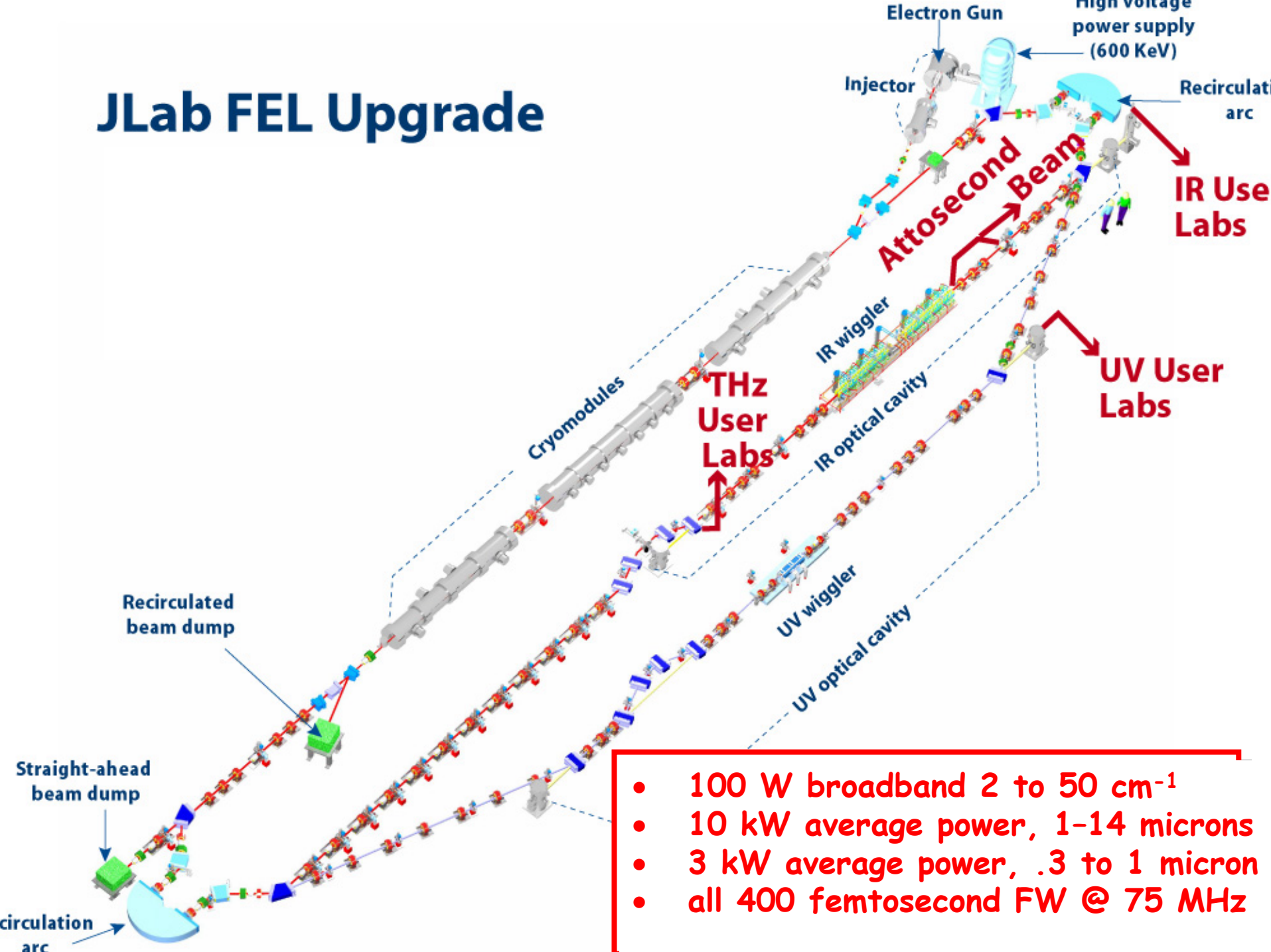
Jefferson Lab
Newport News, Virginia

LPC
Newport News
March 9, 2005

JLab FEL Upgrade



- 100 W broadband 2 to 50 cm^{-1}
- 10 kW average power, 1–14 microns
- 3 kW average power, .3 to 1 micron
- all 400 femtosecond FW @ 75 MHz

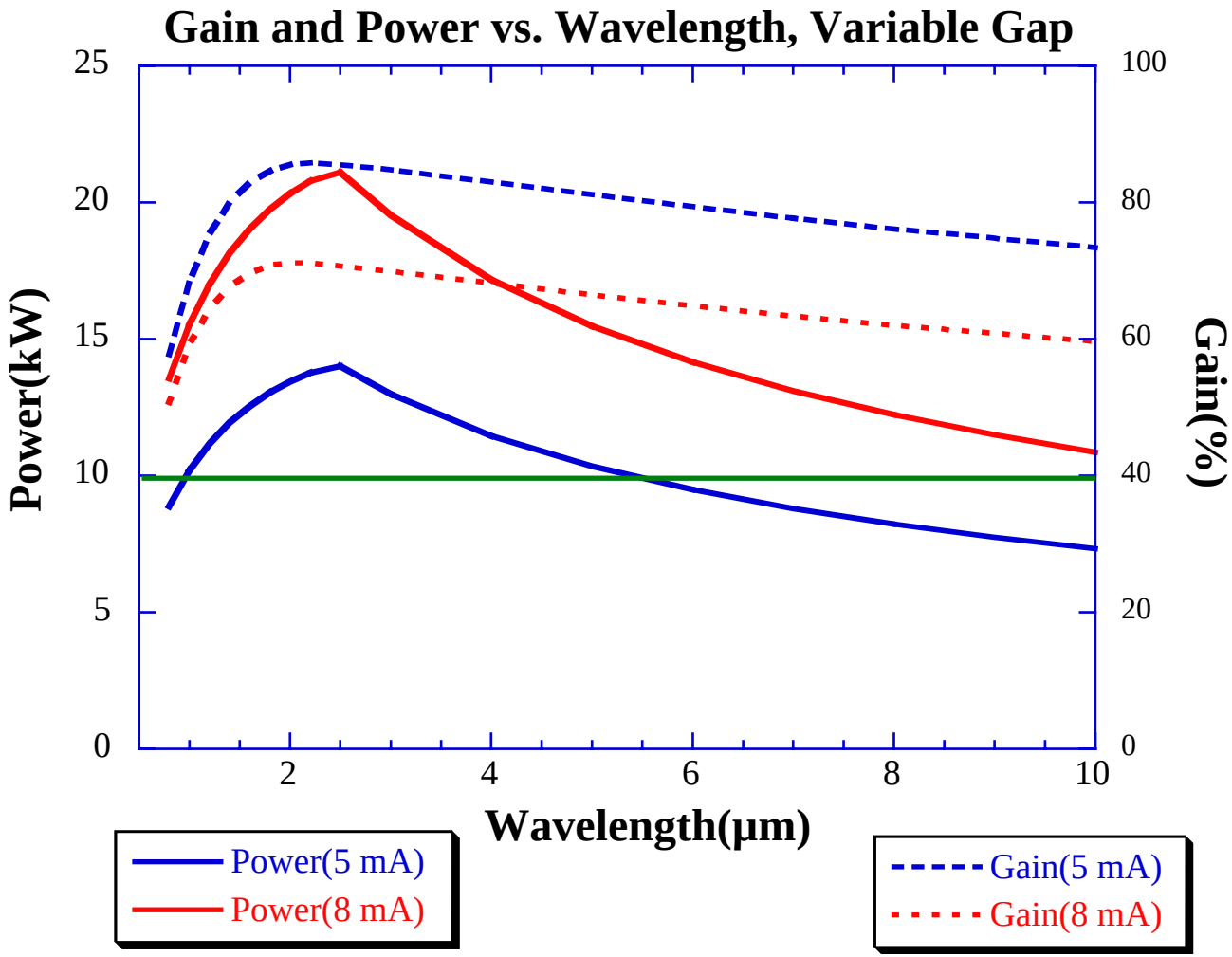
JLab FEL Upgrade Status

- THz system installed and ready to begin user experiments
- IR Upgrade FEL at JLab starting up at 10 kW
  - Characterization has begun : 10 kW average power lasing achieved at 6 microns
  - Lased at moderate powers at 2.8 - 3microns with broadband mirrors
  - User experiments getting ready; have provided alignment beam into Lab 1
- UV installation this year
  - User experiments late next fall
- Some setbacks: lost some gradient capability in linac; may not be able to make 1 micron at full power or UV lasing on fundamental until replacement cryomodule is ready. User program will continue:
  - Third harmonic 1 micron lasing
  - 700 nm lasing and doubled

IR Upgrade Specifications

- **Average Power** > 10,000 W
- **Wavelength range** 1 to 14 μm
- **Micropulse energy** > 100 μJ, in pulse train 50 μs to CW, arbitrary prf
- **Micropulse length** ~0.1-2 ps FWHM (adjustable)
- **PRF** 74.85 MHz ÷ 2x down to 4.68 MHz
- **Bandwidth** ~ 0.2–3 % (always Fourier transform limited!)
- **Position/Angle jitter** < 100 um, 10 μrad
- **Polarization** linear, > 1000:1
- **Transverse mode** < 2x diffraction limit. Gaussian profile
- **Beam dia. at lab** 2 - 6 cm, wavelength dependent

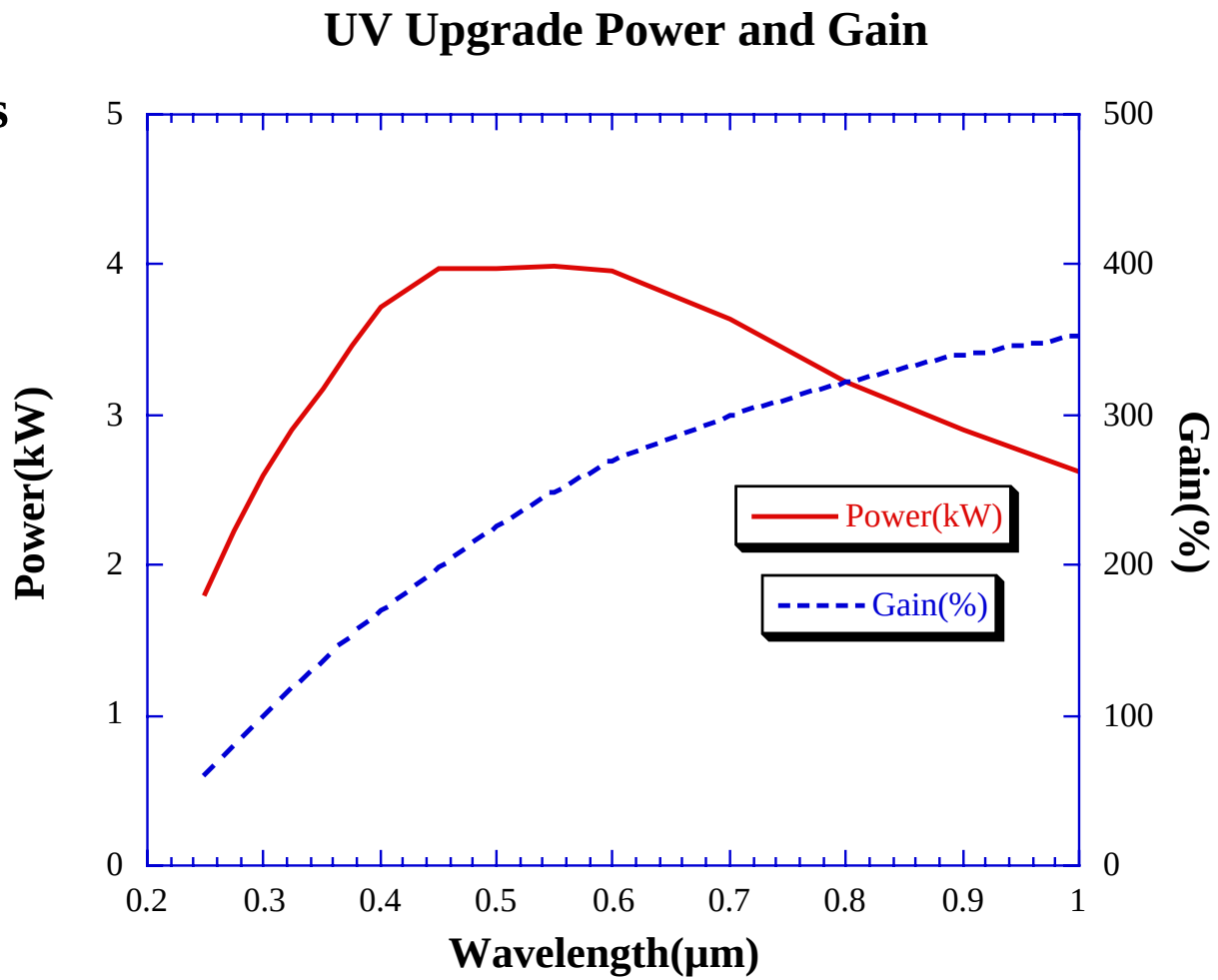
Performance with Variable Gap PM Wiggler



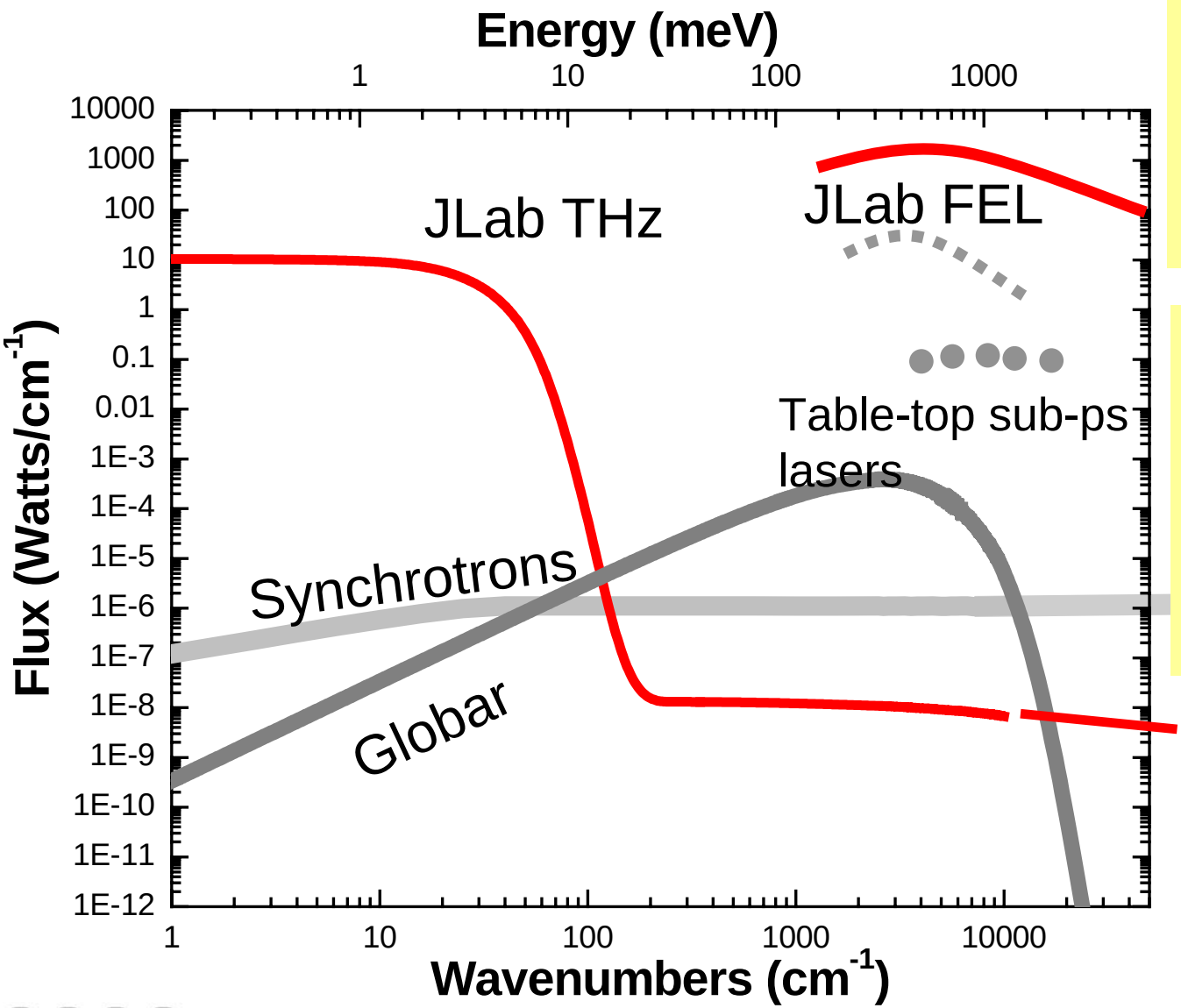
Minimum beam energy=80 MeV, Energy <160 MeV. Energy spread constant

UV Upgrade Performance: Installation next summer

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



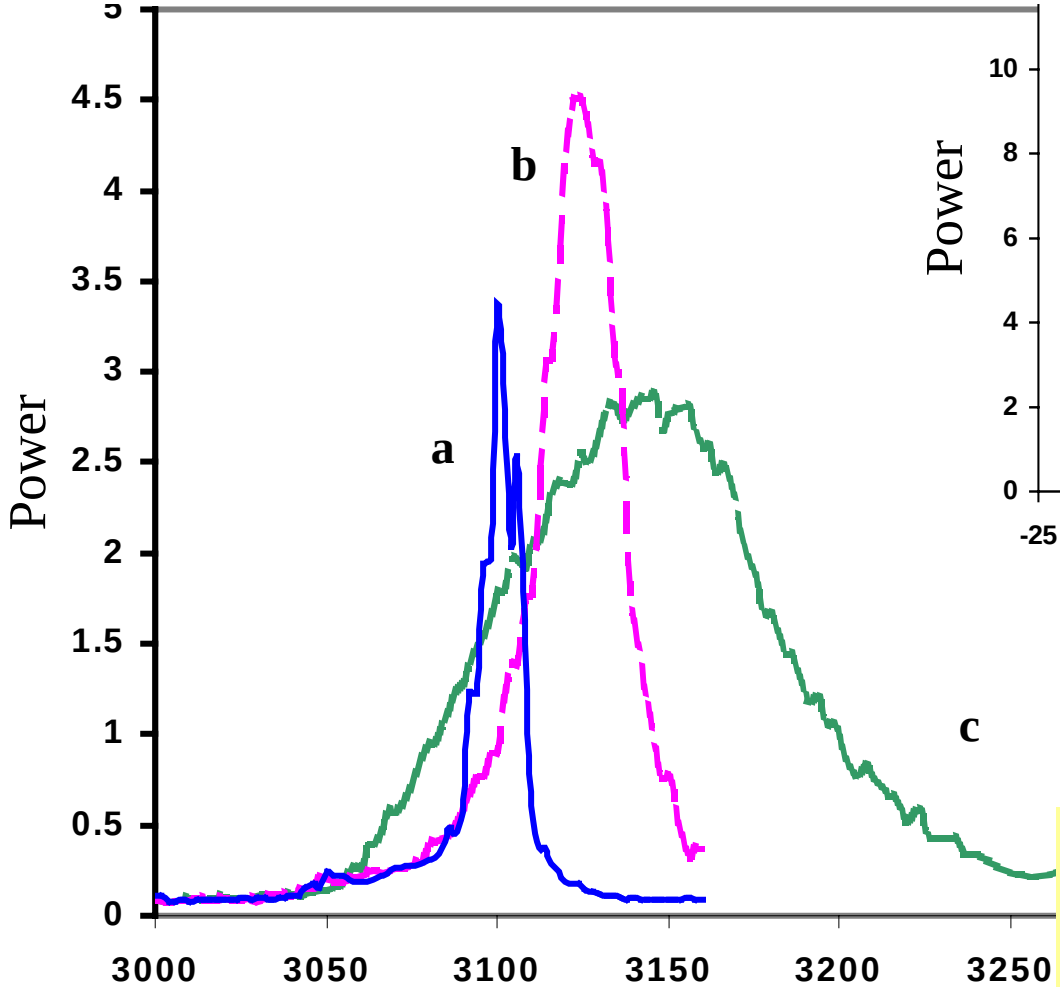
High power THz with sub-picosecond pulses is produced parasitically from electron beam

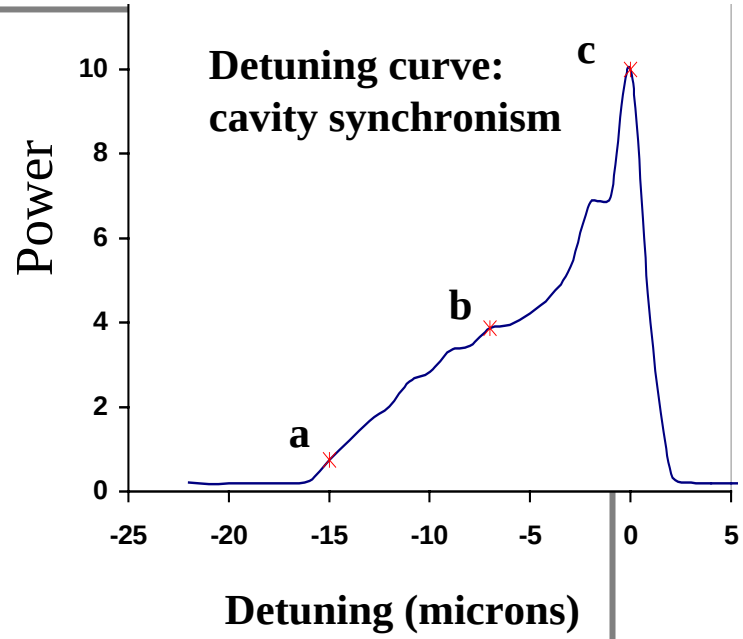


FEL proof of principle:
Neil et al. Phys. Rev.Letts 84, 662 (2000)

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

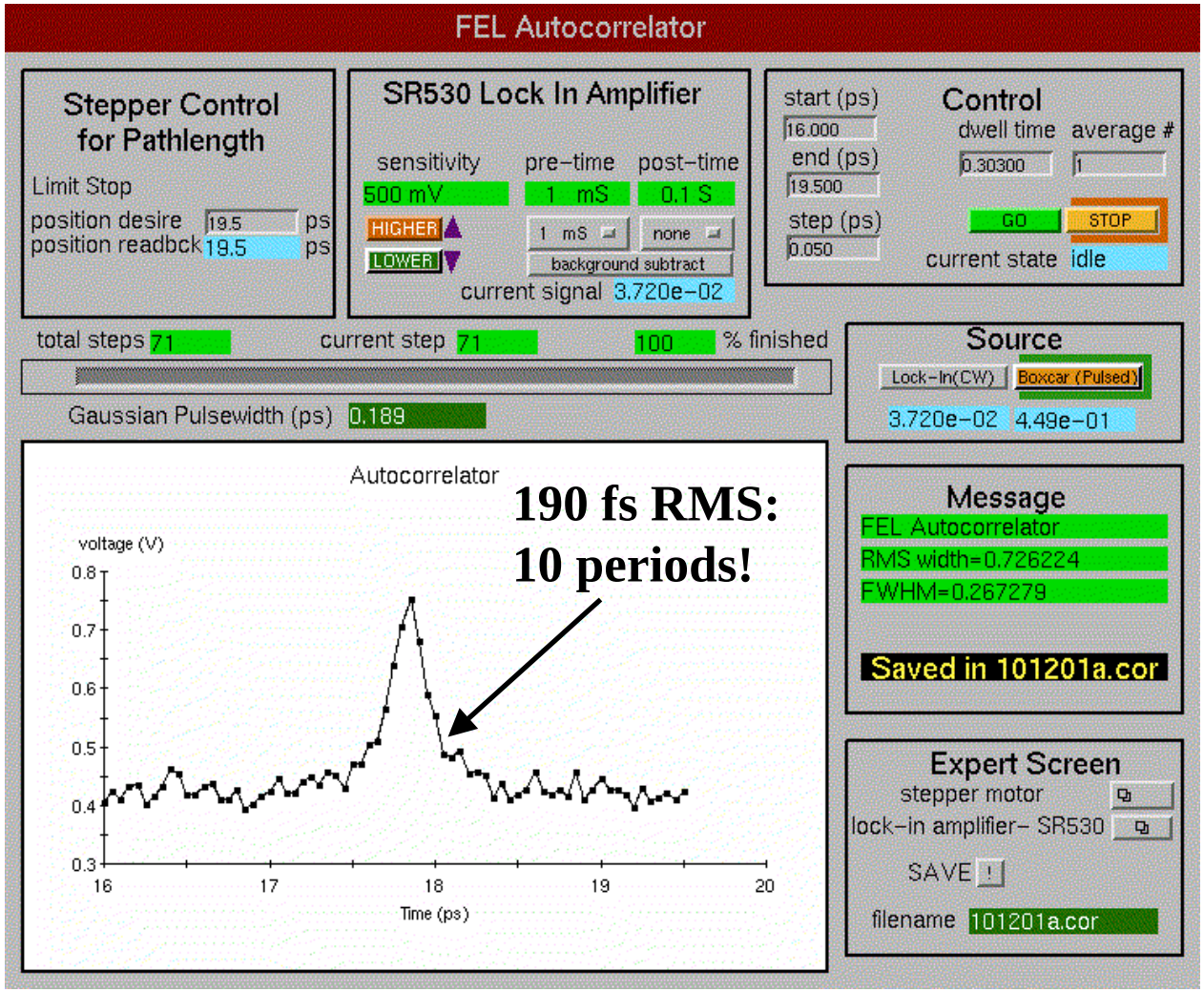
IR Demo measured bandwidth varies as a function of optical cavity length



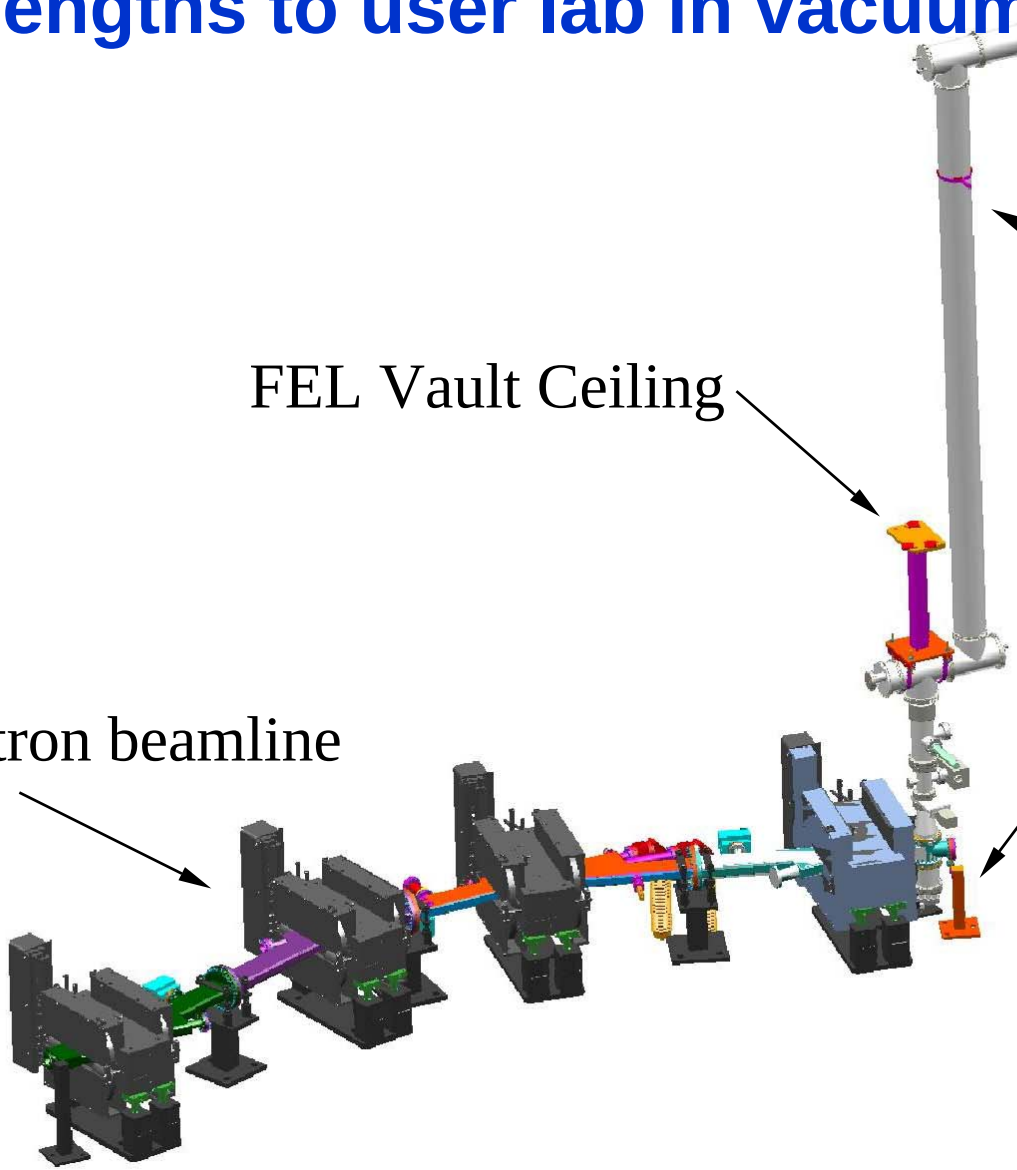


Bandwidth is Fourier limited at each pulse length; < 40 optical periods at broadest!

Many studies use ultrashort pulses: IR Demo autocorrelation data

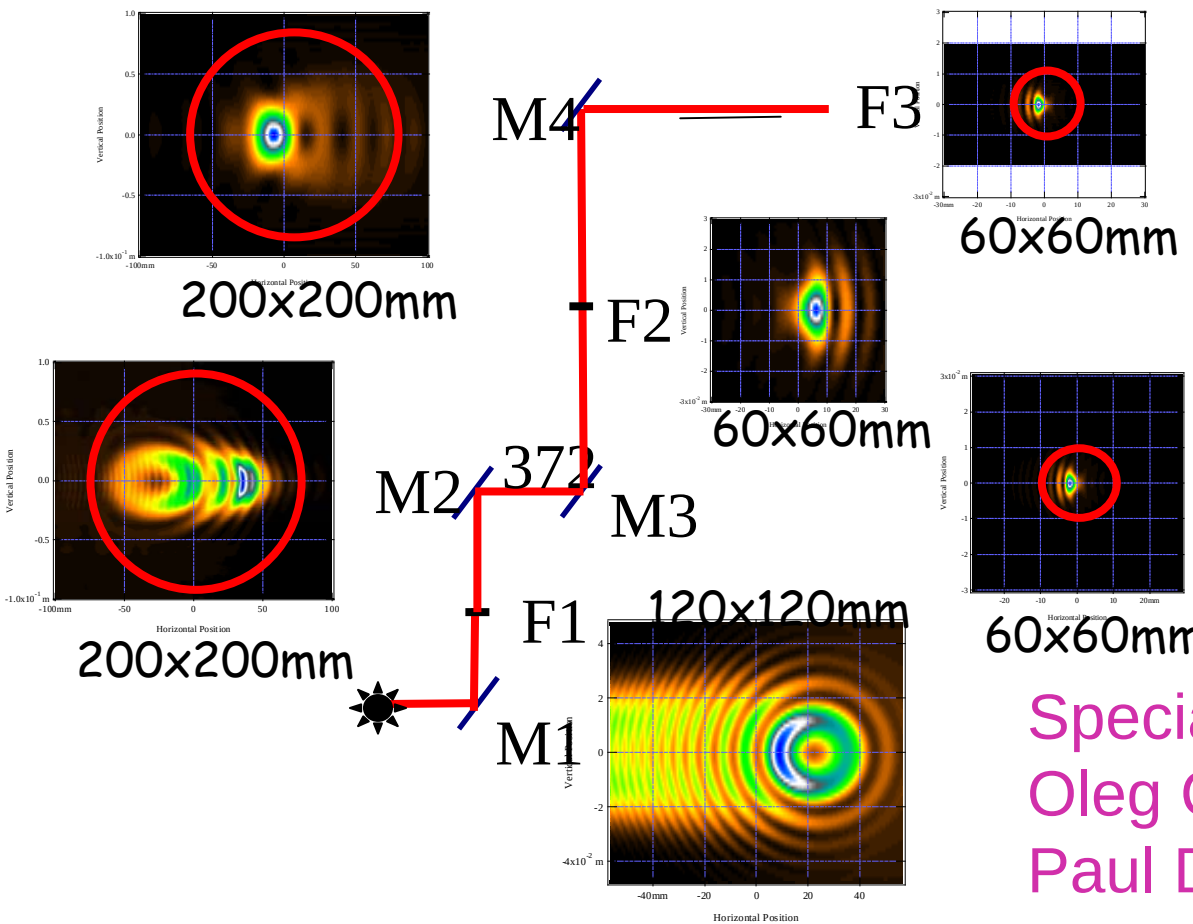


Terahertz beamline transports visible to 5 mm wavelengths to user lab in vacuum



See G. Williams, MM4.3

JFEL THz Beamline Calculated Optical Beam Patterns



Special thanks to Oleg Chubar, Paul Dumas.

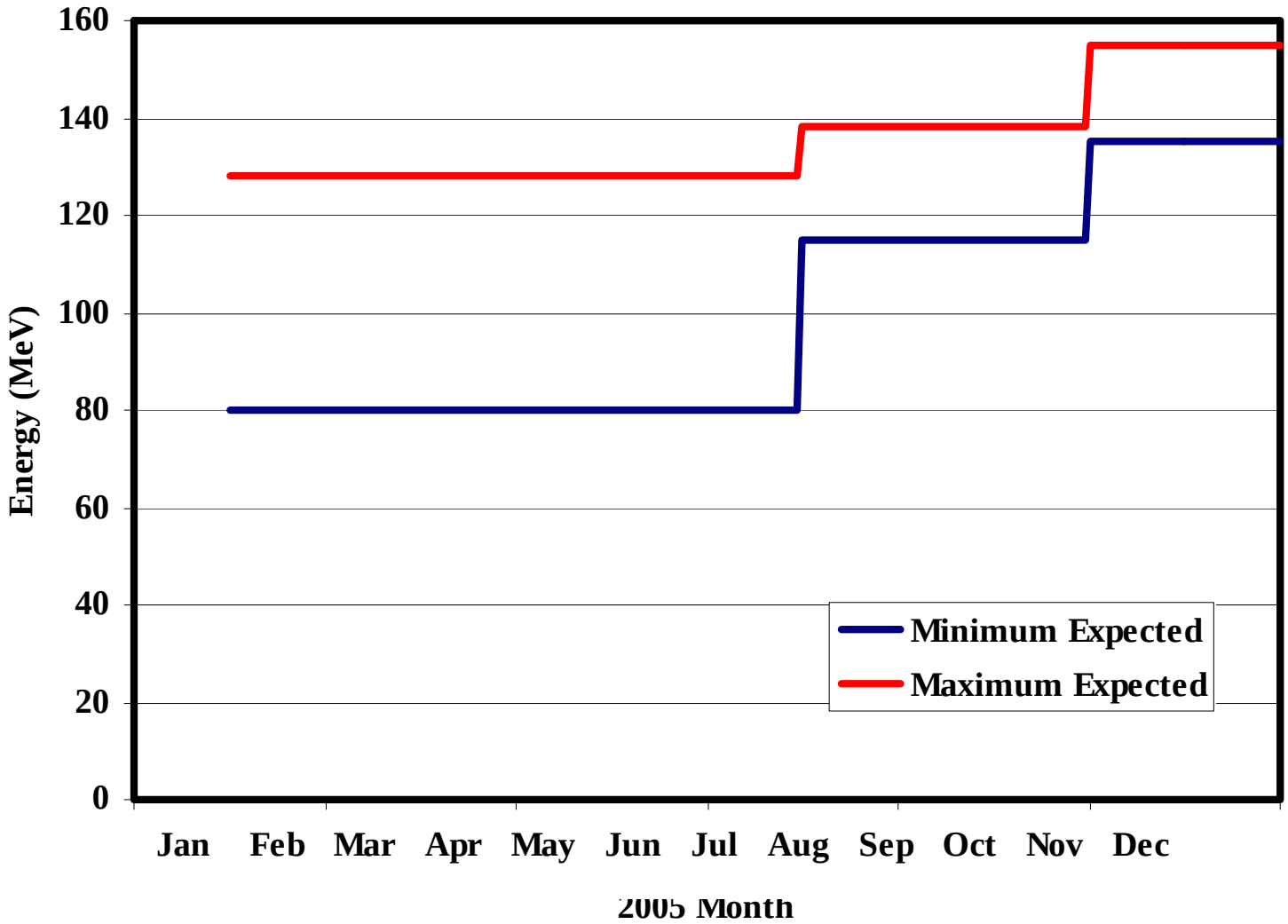
Lasing Capability – IR Upgrade

- We have several sets of high power mirrors capable of multi-kW but these are narrow band
  - 6 microns, 2.8 microns, 1 microns, (1.6 microns, (2.2 microns on order)
- We also have hole outcouplers and broadband mirrors for lasing from 1 to 10 microns at ~ 50 W output
- Instantaneous tuning is limited only by wiggler (K^2 goes from ~0.7 to 1.1
- Alignment light has been brought up to Lab 1 and the facility is essentially ready for User experiments

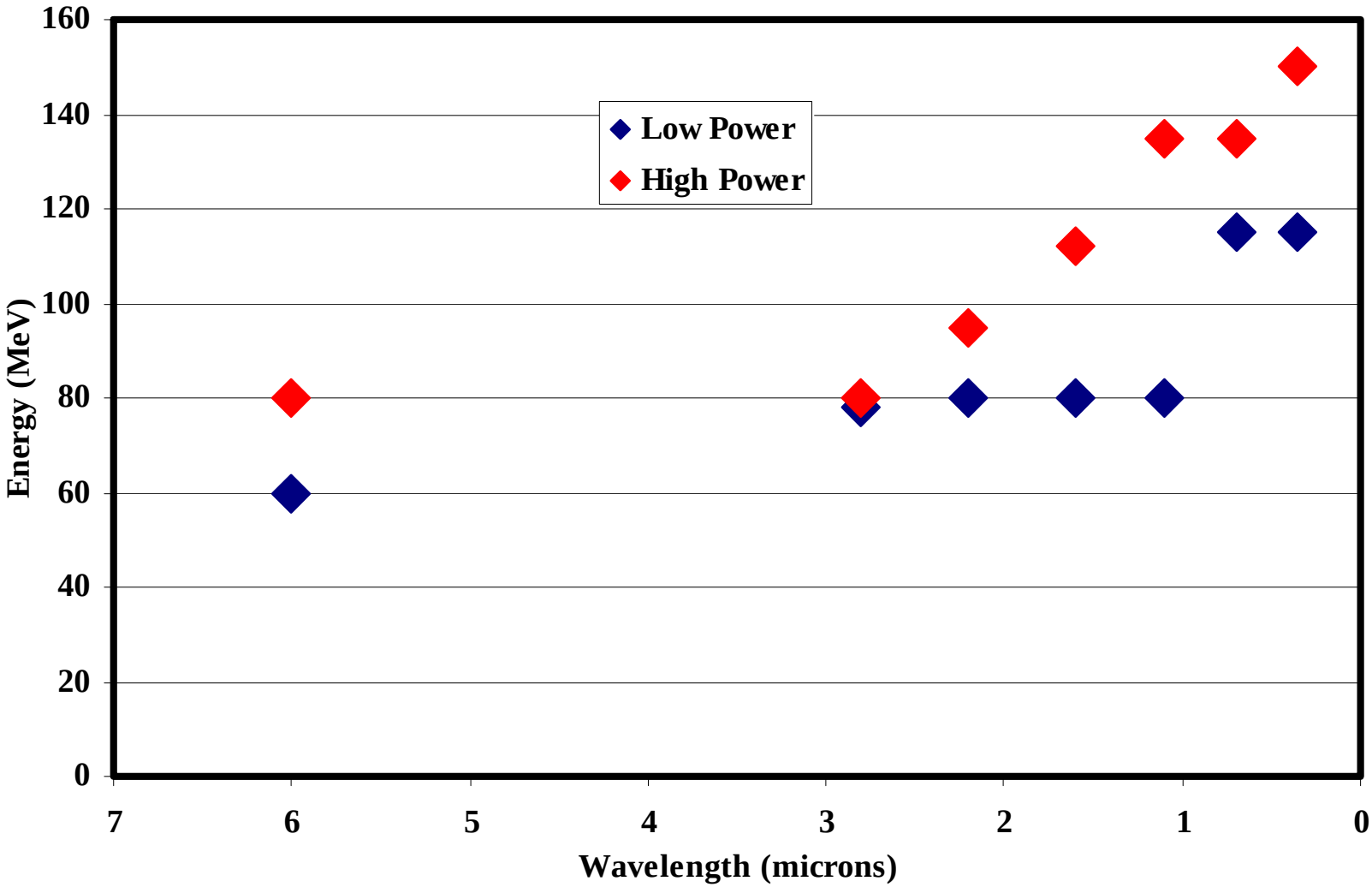
Capability projections – the bad news

- We have several ailing srf cavities that have reduced our energy capability. This will negatively impact the wavelength and power we can achieve
- Exact performance limits are not known at this time; a number of possible approaches and fixes are under investigation; we will know more in the next few weeks
- Additional srf modules may be available in June (standard design) and September (high gradient)
- We also have additional wigglers under procurement and the option of doubling and tripling the FEL output as well as lasing on the third harmonic
- The following slides broadly summarize our expectations; low power means 10's to a few hundred W, high power means multiple kW

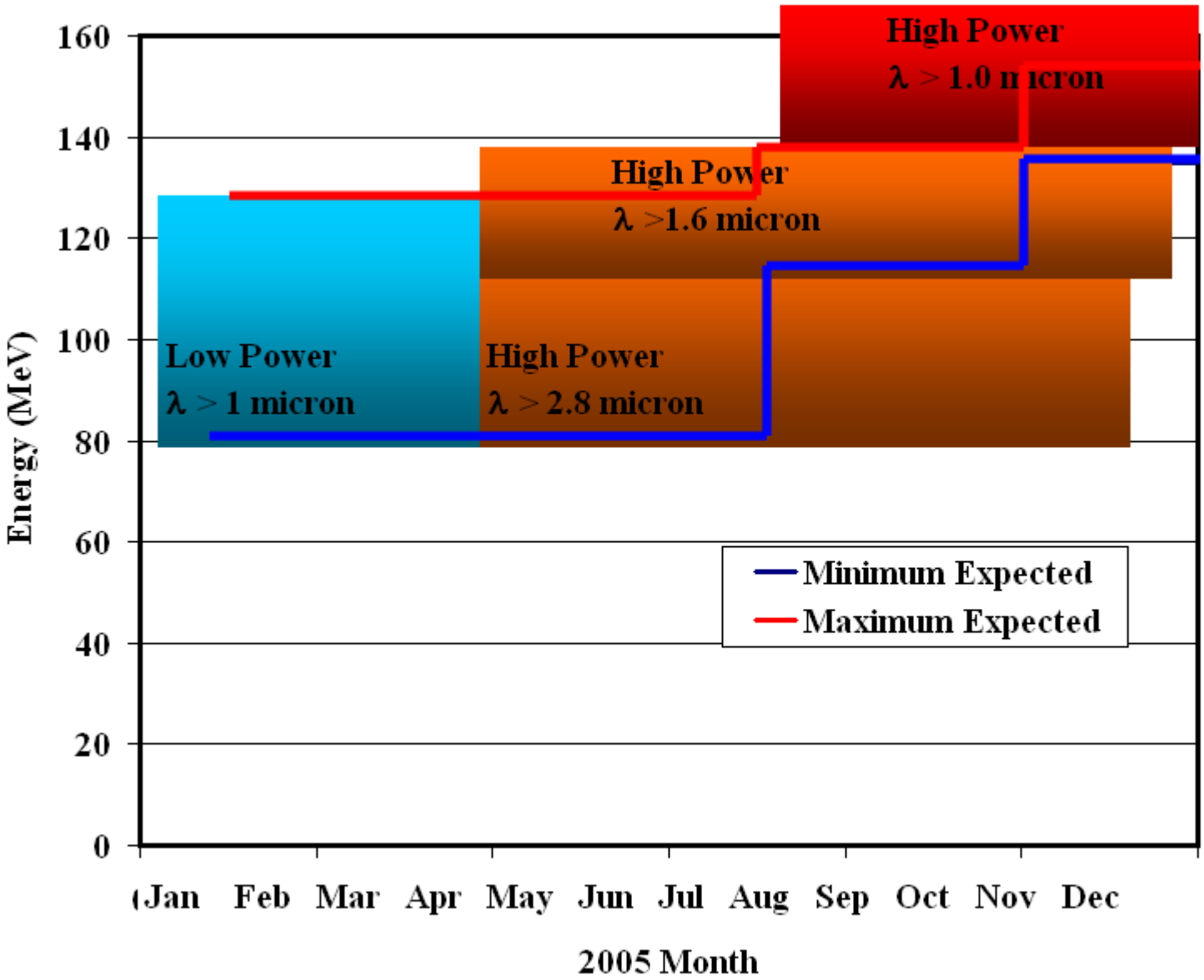
Projected energy available



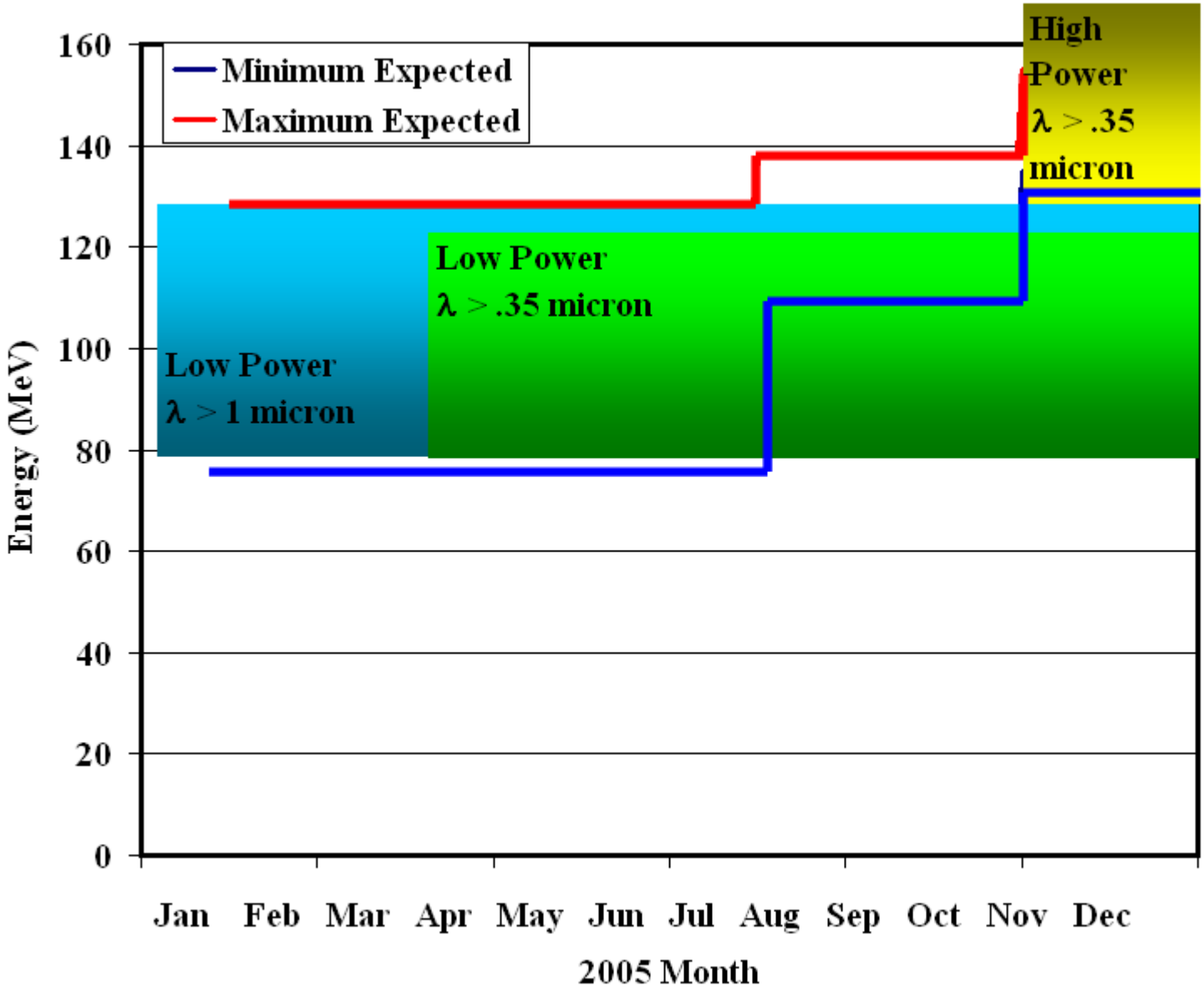
Energy requirements for specific programs



Lasing Capability – IR Upgrade



Future plans – UV Upgrade



Summary

- JLab Upgrade FEL is coming on line as a user facility with THz, IR, and (soon) UV light
  - Broadly tunable
  - Sub-picosecond pulses
  - Excellent beam quality
  - Unmatched power, pulse energies
  - (also have conventional lasers synchronized with FEL)

We are about ready to put first IR light into a User Lab

- The capabilities of this facility will gradually be increasing over the next year in terms of short wavelength operation and higher power capability

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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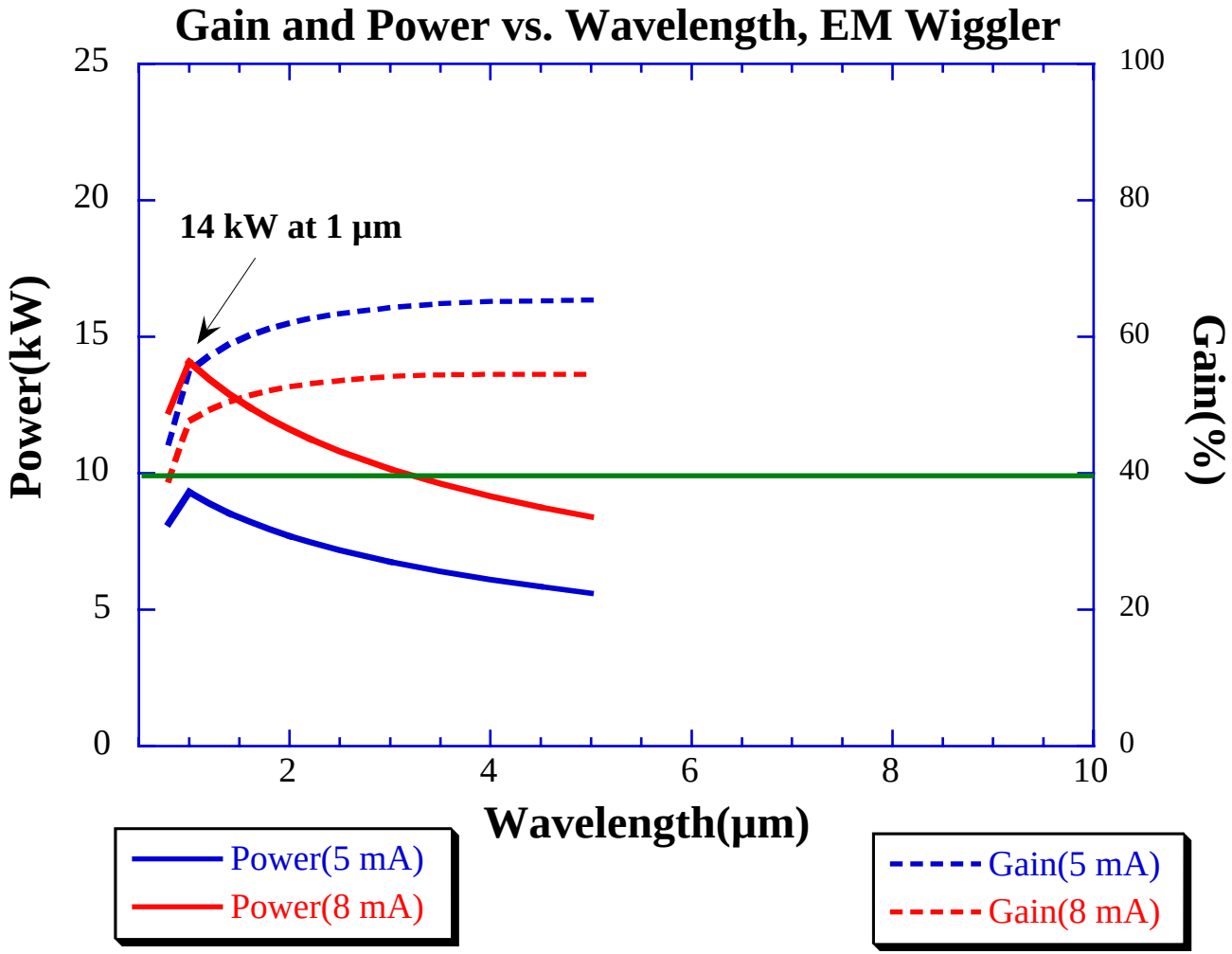
Spreadsheet Model Predictions for EM Wiggler



No absorption in mirrors assumed in these calculations. Minimum energy=70 MeV, Max K=1.115. Energy spread constant. Can't guarantee operation longer than 4 μm.