JLab High Average Power FEL Program Status

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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.
- Deformable mirrors correct thermal distortion.
- Access ports for installation or replacement of components.
- Mirrors on translation stage to change wavelength ranges.
- Access ports for Survey and Alignment Team and diagnostics.
Optical Cavity as Installed
Comparison of New Wiggler with Optical Klystron

![Graph showing comparison of new wiggler with optical klystron. The graph plots Gain in percentage on the y-axis against Wavelength in microns on the x-axis. The graph includes green and red lines labeled Gain, Wiggler A and Power, Wiggler A (kW), and blue and black dashed lines labeled Gain, OK and Power, OK (kW).]
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


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?

190 fs RMS: 10 periods!
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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Dispersion section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wavelength</td>
<td>20 cm</td>
<td>Length</td>
</tr>
<tr>
<td>$K^2$</td>
<td>1–16</td>
<td>Dispersion</td>
</tr>
<tr>
<td>Number of periods</td>
<td>12 ea.</td>
<td>&gt;40 periods</td>
</tr>
<tr>
<td>Gap</td>
<td>26 mm</td>
<td>for $K^2=16$</td>
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<tr>
<td>Polarization</td>
<td>vertical</td>
<td>Gap</td>
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<tr>
<td>Phase error</td>
<td>&lt;5 deg.</td>
<td>26 mm</td>
</tr>
</tbody>
</table>

Operated by the Southeastern Universities Research Association for the U.S. Dept. Of Energy
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:

With the help of lots of others at JLab

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IR Upgrade tuning spans the near/mid IR