UED Capability & Status

Marcus Babzien

22nd ATF Program Advisory Committee (APAC) and User’s Meeting
Brookhaven National Laboratory
December 3-5, 2019
Overview of UED Upgrades & Plans

- Water chiller upgrades
- Beam collimator replacement
- Low-level RF stability improvements
- Drive laser pulse shortening
- Support tunable pump wavelength
- Digital low-level RF with diagnostics & lower drift
- Bunch length diagnostic
- Repetition rate increase
- Study optimal operating point
Water Chiller Upgrades

- 2 redundant high-capacity outdoor chiller units in service
- Chilled water cooling distribution system operational
- UED Cleanroom operating on new high capacity chilled water supply
- Previous dedicated chiller in place as backup unit
- Facility operation now possible independent of weather conditions
- Additional laser power supply cooling loop being installed with dedicated heat exchanger to replace old refrigeration unit
Collimator Refurbishment

• Improved beam collimator downstream of solenoid prevents mechanical problems of old design, allows better alignment, and has multiple apertures installed

• Final assembly currently in progress
Drive Laser Pulse Shortening

- Drive laser currently produces ~250 fs pulses for UED sample pumping. (e⁻ probe is typically shortened via compression)

- The drive laser amplifier stretcher/compressor/optics are designed for bandwidth supporting down to 50 fs pulses, and the current 160 fs oscillator does not produce a chirped pulse long enough to completely optical avoid damage at nominal output energy

- Shorter oscillator seed pulse would lead to improved temporal resolution closer to that available at other UED facilities

- Autocorrelator studies in progress to minimize pulsewidth in current configuration

- Replacement 16 nm bandwidth oscillator received last month:
LLRF stability improvements

- Added slow phase control loop with independent phase measurement and software feedback to overcome drift that degraded long-integration time experiments
- Beam setup and tuning enhanced by improving IQ modulator calibration:
  now provide a much larger range of usable & orthogonal phase and amplitude adjustment to operators
Digital Low-Level RF Diagnostic

- Will replace existing analog chain
- Although phase noise floor is ~3 dB higher, internal mixers and diagnostic elements will provide more comprehensive monitoring, jitter & drift measurement, and feedback
- Modified version of chassis used extensively at NSLS-II
- Unit in place & ready for installation & interfacing
Support Tunable Pump Wavelength

• BNL Early career award for mid-IR pump-probe materials science requires an Optical Parametric Amplifier to access the desired range of Mid/LW-IR wavelengths

• To reach the OPA output energy levels of \(~100 \mu\text{J} \) at \(\lambda=1-11 \mu\text{m}\), a more energetic pump pulse from a new Ti:sapphire booster amplifier is needed

• “Topas HE” OPA for experiments is on order from SpectraPhysics

---

Seed input from laser
Nd:YAG output

P
P

L
L

LE

Grating

Output

Nd:YAG

P

\(\lambda/2\)

\(\lambda/2\)
Support Tunable Pump Wavelength

- Booster amplifier assembled and initial testing completed
- Achieved over 20 mJ, <250 fs, close to anticipated specification
- Further optimization of pulse duration may be possible (TBWP~0.6)
- Awaiting delivery date from OPA manufacturer
- Parallel optical trombones for synchronization and transport optics still to be installed

Amplified Beam Profile

Spectra Through MOPA Chain

Autocorrelation
Bunch Length Diagnostic

• CTR Interferometer & Detector commissioned by LDRD experiment

• Currently installed, but must be removed to pass large diffracted UED beam

• More compact version to be designed and tested downstream at UED screen, then moved upstream to UED sample location for routine use
Repetition Rate Increase

• BNL UED has higher charge than many other UED facilities, but would still benefit from increased repetition rate

• Long integration times limit the rate of parameter scans and increase sensitivity to drift

• Klystron is capable of 50 Hz

• Radiation study results suggest no exposure limitation at 10x increase in repetition rate

• Klystron and triggering modifications underway to enable increase once safety review is approved
Repetition Rate Increase
UED radiation background improvement

June 28, 2017. Radiation levels:
- Background ~ 0.12 mrem/hr, RF ON ~ 0.81 mrem/hr,
- Generated radiation (5 Hz rep rate): Δ ~ 0.69 mrem/hr

August 07, 2019. Radiation levels:
- Background ~ 0.15 mrem/hr, RF ON ~ 0.57 mrem/hr,
- Generated radiation (5 Hz rep trate): Δ ~ 0.42 mrem/hr

November 7, 2019. Radiation level:
- Background ~ 0.15 mrem/hr, RF ON ~ 0.19 mrem/hr,
- Generated radiation (5Hz rep rate): Δ ~ 0.04 mrem/hr

Cathode was polished in 2018
RF pulse width changed
Optimal Operating Point Study

- Probe pulse charge should be maximized for single-shot sensitivity, but spot size increases and reduces spatial resolution.
- A systematic study of optimized spot size versus charge will enable selection of optimal tradeoff for different experimental needs.
- Needs dedicated running time in schedule.
Conclusions

- Significant upgrades to the UED facility have been completed this year
- Both instrument operating parameters and operational efficiency have been improved
- Near term upgrades underway
- UED facility continuing to mature and become more capable

<table>
<thead>
<tr>
<th></th>
<th>BNL</th>
<th>SLAC</th>
<th>MSU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy, MeV</td>
<td>3</td>
<td>3.68</td>
<td>0.03</td>
</tr>
<tr>
<td>N e\textsuperscript{-} per pulse</td>
<td>1.25 E+6</td>
<td>3.8E+5</td>
<td>500</td>
</tr>
<tr>
<td>Temporal resolution, fs</td>
<td>180</td>
<td>102</td>
<td>300</td>
</tr>
<tr>
<td>Beam size diameter, μm</td>
<td>300 (100 best)</td>
<td>400 (10 best)</td>
<td>20-40</td>
</tr>
<tr>
<td>Max repetition rate</td>
<td>5 (will be 50)</td>
<td>120 (180 best)</td>
<td>1,000</td>
</tr>
<tr>
<td>N e\textsuperscript{-} per sec per μm\textsuperscript{2}</td>
<td>88 (will be 880)</td>
<td>360</td>
<td>400</td>
</tr>
<tr>
<td>Advantage</td>
<td>short bright pulse</td>
<td>short bright pulse</td>
<td>DC (no jitter)</td>
</tr>
</tbody>
</table>