UED Capability & Status

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Brookhaven National Laboratory

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BROOKHAVEN NATIONAL LABORATORY

U.S. DEPARTMENT OF ENERGY

Overview of UED Upgrades & Plans

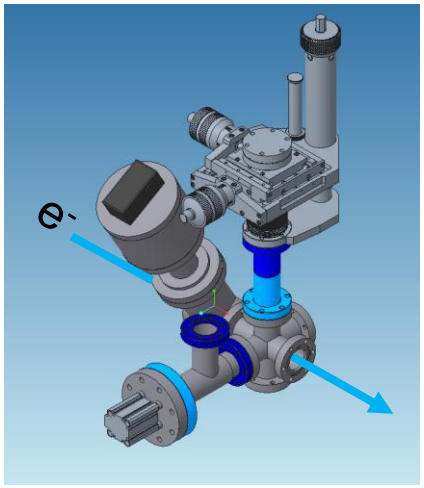
- Water chiller upgrades
- Beam collimator replacement
- Low-level RF stability improvements
- Drive laser pulse shortening
- Support tunable pump wavelength
- Digital low-level RF with diagnostics & lower drift
- Bunch length diagnostic
- Repetition rate increase
- Study optimal operating point

Water Chiller Upgrades

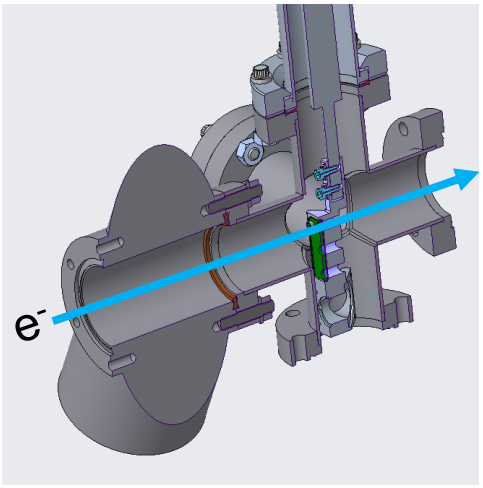
- 2 redundant high-capacity outdoor chiller units in service
- Chilled water cooling distribution system operational
- UED Cleanroom operating on new high capacity chilled water supply
- Previous dedicated chiller in place as backup unit
- Facility operation now possible independent of weather conditions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

Collimator Refurbishment

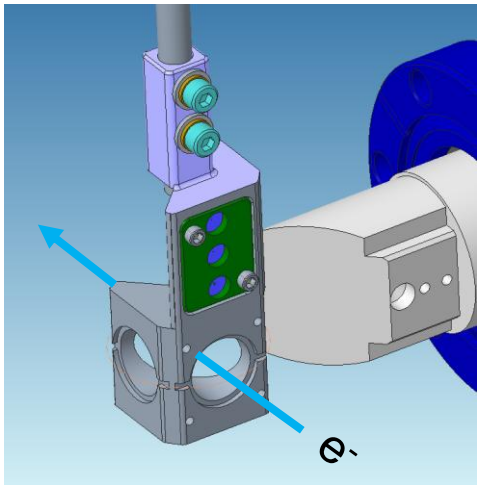
- Improved beam collimator downstream of solenoid prevents mechanical problems of old design, allows better alignment, and has multiple apertures installed



Beamline Assembly



Collimator Insertion

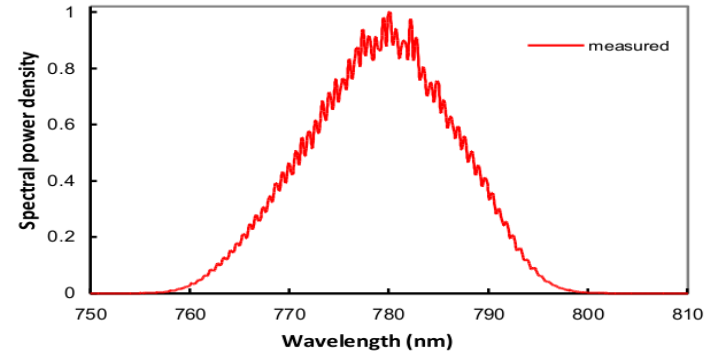


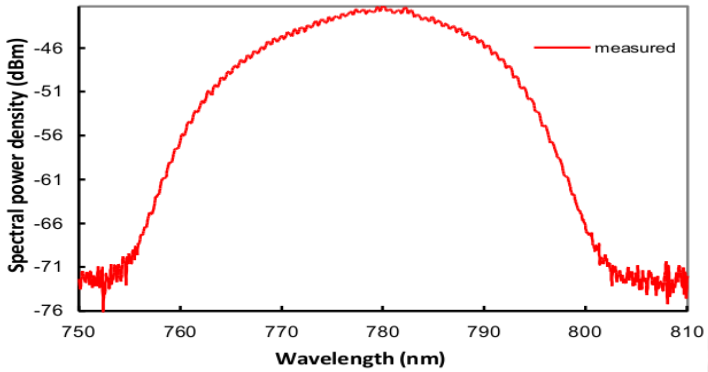
BPM Configuration

- 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:



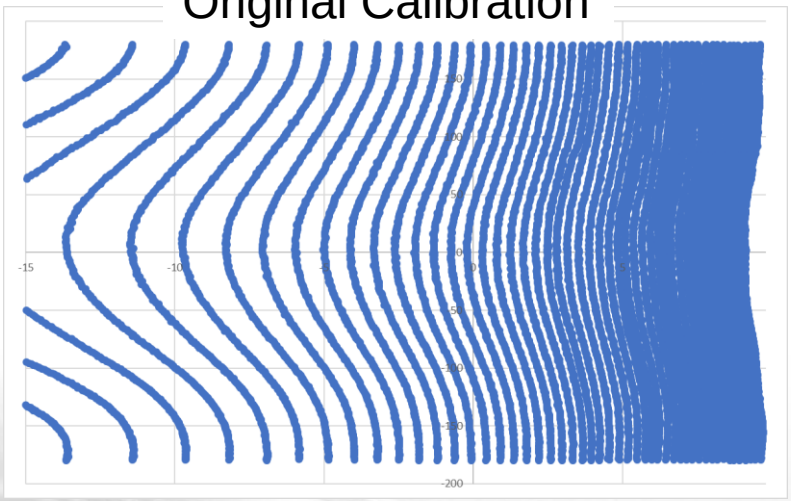


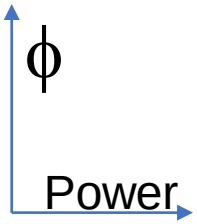
LLRF stability improvements

- 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:

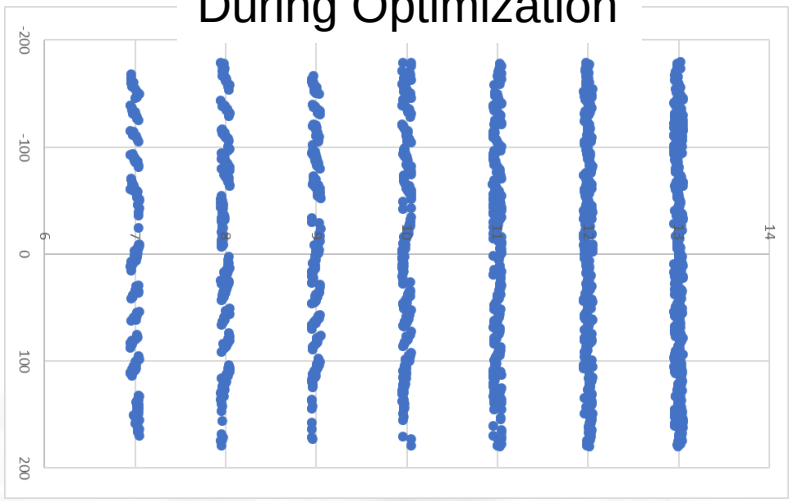
  now provide a much larger range of usable & orthogonal phase and amplitude adjustment to operators

Original Calibration

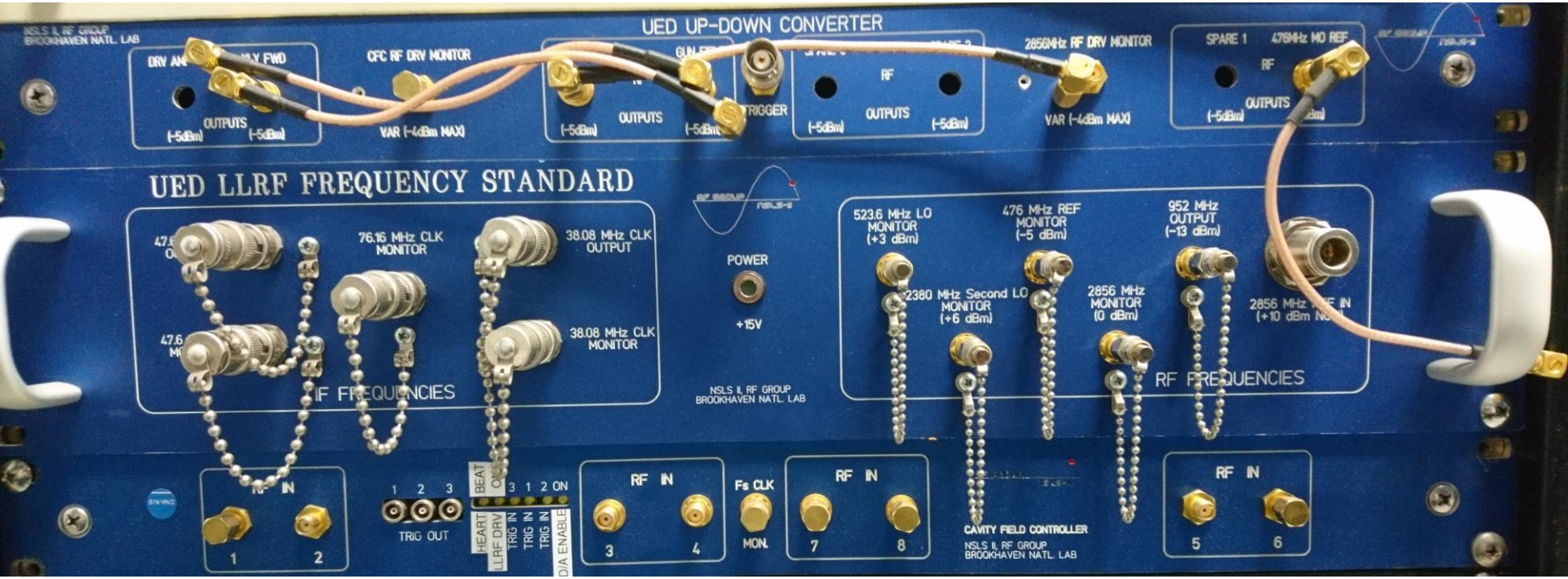




During Optimization



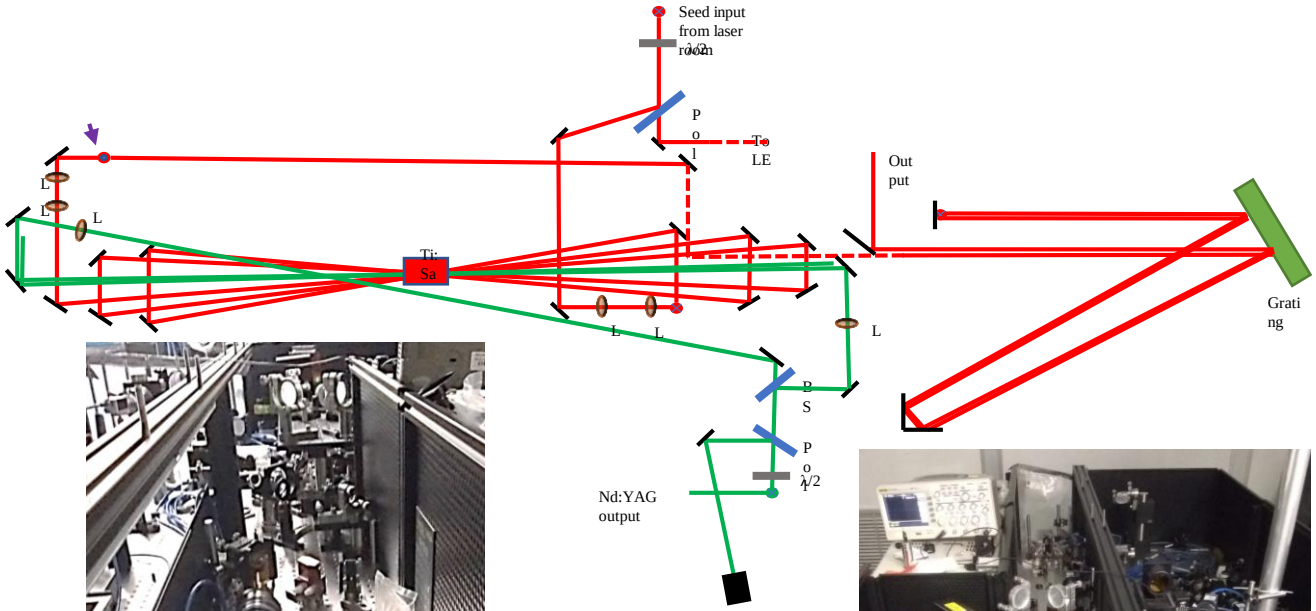
Digital Low-Level RF Diagnostic

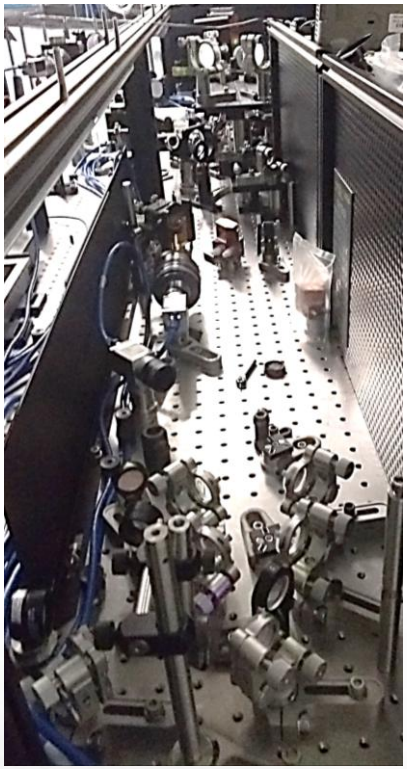


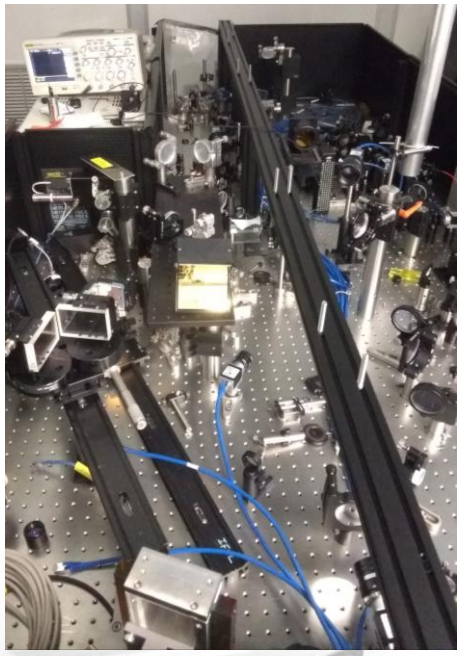
- Will replace existing analog chain
- Although phase noise floor is ~3 dB higher, internal mixers and diagnostic elements will provide more comprehensive monitoring, jitter & drift measurement, and feedback
- Modified version of chassis used extensively at NSLS-II
- Unit in place & ready for installation & 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 μJ at λ=1-11 μm, a more energetic pump pulse from a new Ti:sapphire booster amplifier is needed
- "Topas HE" OPA for experiments is on order from SpectraPhysics

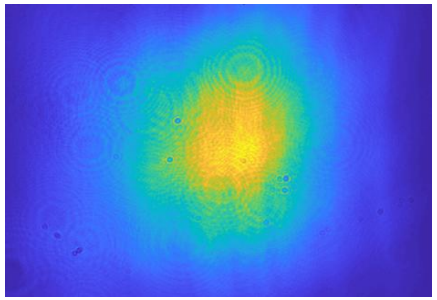




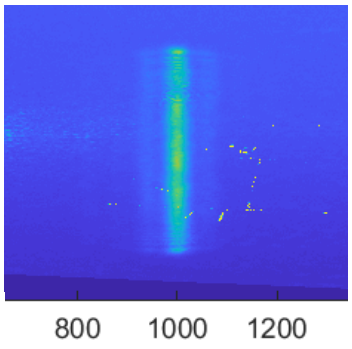


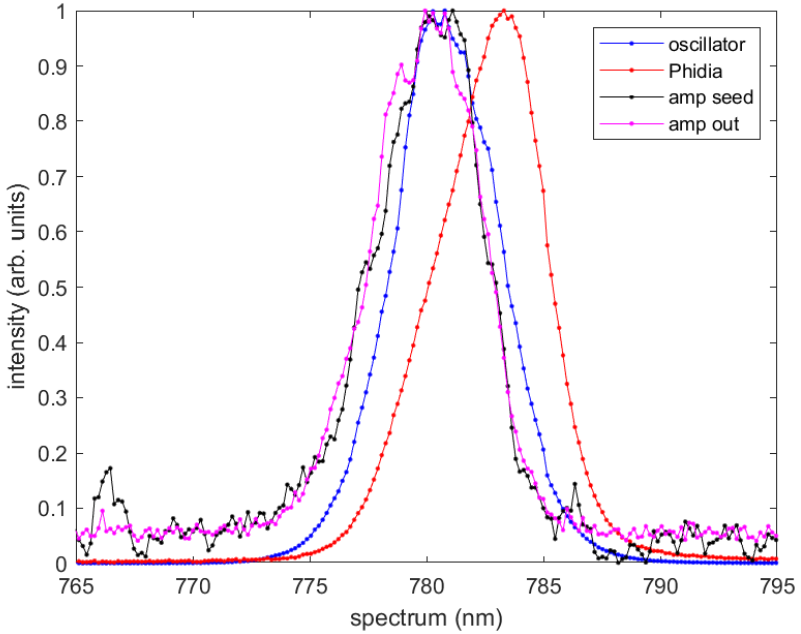
Support Tunable Pump Wavelength

- 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

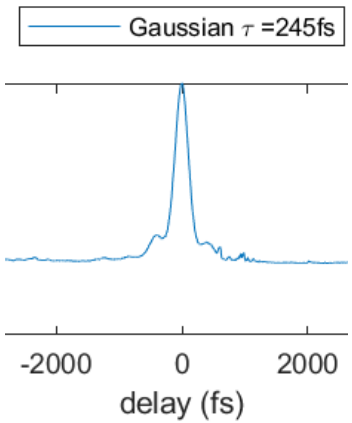


Amplified Beam Profile





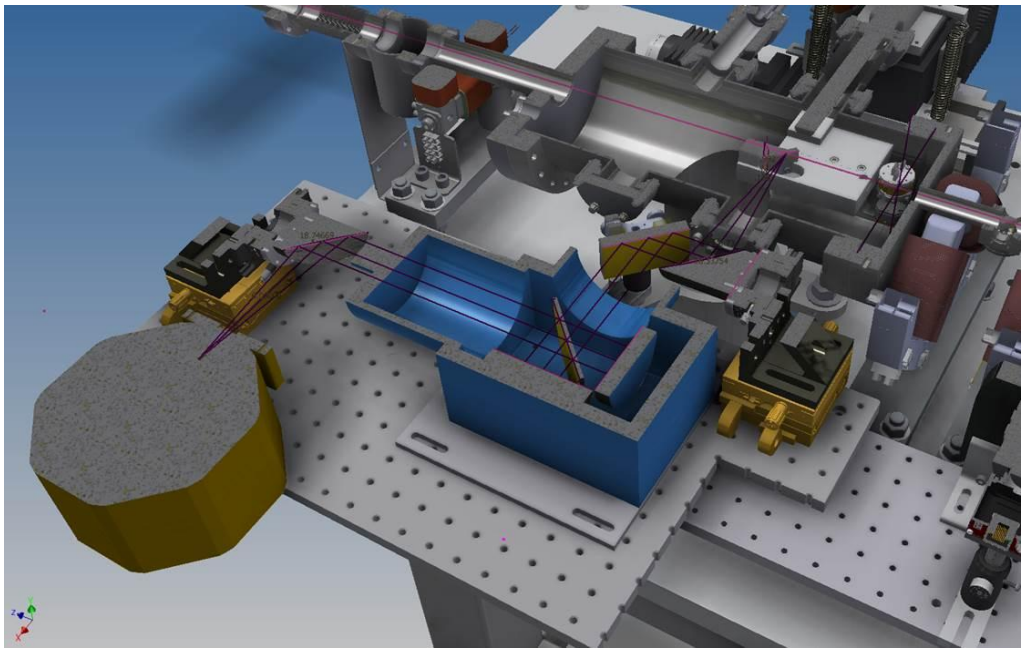
Spectra Through MOPA Chain



Autocorrelation

Bunch Length Diagnostic

- CTR Interferometer & Detector commissioned by LDRD experiment



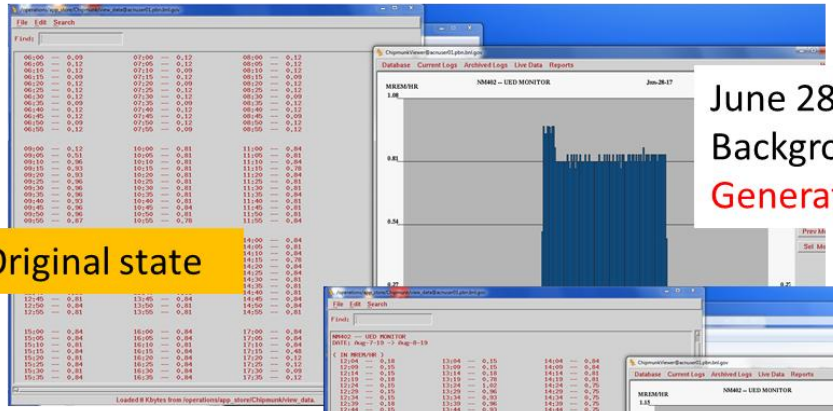
- Currently installed, but must be removed to pass large diffracted UED beam
- More compact version to be designed and tested downstream at UED screen, then moved upstream to UED sample location for routine use

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

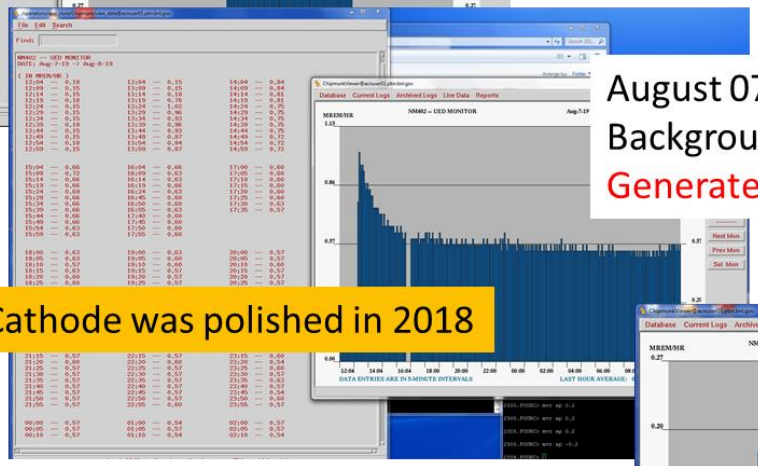
Repetition Rate Increase

UED radiation background improvement



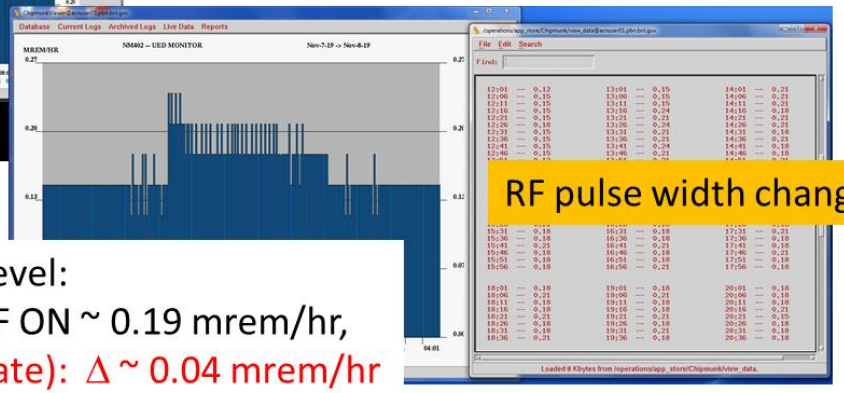
Original state

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



Cathode was polished in 2018

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



RF pulse width changed

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

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

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