Installation and Commissioning of an Ultrafast Electron Diffraction Facility as Part of the ATF-II Upgrade

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Outline

• UED purpose
  – Scientific case
  – UED beamline details

• ATF UED beamline commissioning
  – Commissioning milestones

• ATF UED future plans
UED scientific case
Structural changes in nature


By courtesy Junjie Li
MeV-UED data taking

Setting time delay and integration time

By courtesy Junjie Li
La$_{2-2x}$Sr$_{1+2x}$Mn$_2$O$_7$


By courtesy Junjie Li
ATF UED comissioning
UED at BNL milestones

- UED beamline was in operation at BNL Source Development Laboratory since 2010

- In 2016 beamline moved to Bldg 912 and become part of ATF II facility complex
ATF-II in BNL Bldg. 912

- **Gun & Linac**
- **RF & Electronics Equipment Room**
- **Experimental Hall #1**
- **Experimental Hall #2**
- **CO₂ Laser and Experimental Area**
- **UED and Laser Room**

**UED commissioning by Mikhail Fedurin for AAC'16**
Beam source:
photocathode gun 1.6 cell 2,856 MHz

Operational beam energy: 2.8 MeV
Operational beam charge: 1 pC

Laser:
Ti:Sapphire, pulsed 160 fs
1 µJ at photocathode
100 µJ at sample chamber
UED beamline layout

Beam energy = 3 MeV,
Operational charge = 1 pC
Repetition rate = 1 Hz (<5Hz)

UED beamline diagnostics:
YAG screen at Gun has Basler camera and Faraday cup;
Detector has phosphor screen with Andor camera;
Faraday cup at beam dump.

Diagram of detector

- Photon beam
- Major e\textsuperscript{-} beam
- Phosphor screen: convert electron into photon, hole size: D=4.5 mm

Steering manganite, Max I=3A, Which correspond a steering angle<0.022 radian, which is covered by the end lead brick

UED beamline diagnostics:

- RF Gun
- Sample Chamber
- Solenoid
- Andor Camera
- detector
- Beam stop
- Beam energy = 3 MeV,
- Operational charge = 1 pC
- Repetition rate = 1 Hz (<5Hz)

Phosphor screen at Gun has Basler camera and Faraday cup;
Detector has phosphor screen with Andor camera;
Faraday cup at beam dump.

Steering manganite, Max I=3A, Which correspond a steering angle<0.022 radian, which is covered by the end lead brick
UED milestones

• December 2015: new layout was developed and approved
• January – February 2016: RF system and beamline was assembled in new location
• March 2016: RF system was commissioned, klystron and gun were conditioned to operational power, control system was ready for operation
• April 2016: UED readiness review; laser system commissioning
• May-June 2016: beamline commissioning, dark current and first beam observed at detector
• June 2016: first diffraction pattern at detector
UED operation diagram with assigned Operation Procedure Manuals

- **UED sweep**
  - OPM 21-07-05

- **RF modulator**
  - OPM 21-07-01, 5.1.2

- **Drive laser**
  - OPM 21-07-01, 5.1.1

- **Shift transfer and / or Sample change**
  - OPM 21-07-03

- **UED beamline operation**
  - OPM 21-07-01, 5.1.3

- **Chipmunk or ODH alarm response**
  - OPM 21-07-02

- **Shutdown procedure**
  - OPM 21-07-01, 5.2

- **Emergency shutdown**
  - OPM 21-07-01, 5.3
- VME64x I/O (DACs, ADCs, SSRs)
- Database generation on SBCs
- GUI generation and use on SBCs

Above: ATF-II crate installed in UED RF rack
Right: Sample screen capture – UED GUI
Crate also runs “spec” / “fourc” X-ray diffraction software
• June 1, 2016: dark current observation on 1st BPM

Sol = 95 A

Sol = 100 A

Sol = 105 A

Sol = 110 A

Sol = 115 A

Sol = 120 A
UED photocathode beam
Calibrated steering magnet was installed
Beam energy was calculated by measured
displacement on the detector screen

Integrated field .................. 510 G·cm
Peak field ....................... 38 G
Magnetic length ................. 13.4 cm
Max current per axis .......... 3.0 A
Voltage per axis .............. 0.6 V
Calibration ....................... 169 G·cm/A
Remnant Field ................... < 10 G·cm
Samples chamber has cartridge to hold multiple samples for efficient operation
UED diffraction pattern

June 30, 2016
Environmental control

Laser and Experimental rooms have monitored environmental control with logging to database
ATF UED future
Compress electron bunch of 50pC (~$10^8$ electrons/bunch) to 160fs, focus to 30 μm size

Application: UED, UEM

Test principle of the method to remove time jitter between laser and electron bunch

By courtesy Li Hua Yu
We developed a novel unconventional scheme to combine the correlated energy spread with the energy dependent path length to compress the electron bunch. The main point is to use space charge to generate the time-energy correlation.

Unconventional compressor developed in electron beam slicing:
Focusing $\rightarrow$ space charge increase energy of electrons at head (chirped bunch) $\rightarrow$
high energy particle comes earlier, but takes longer path ($R56>0$) $\rightarrow$ compression

Approach: Use space charge effect to compress and focus electron bunches in space charge dominated domain
• On June 2016 UED beamline was re-commissioned in its new location and formally become the first operating element of the ATF II complex
• BNL ATF will operate UED beamline for users
• ATF team together with the BNL user group will continue work to improve UED beam parameters