ERL R&D Update

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• Significant milestones reached for an ERL based x-ray source
  – Photoelectron source
  – RF superconductivity
Cornell ERL team


+ collaborators from other institutions
Cornell ERL R&D effort

- **CHESS**
  - X-ray science case (XDL’11 series of 6 workshops in Ithaca, NY for diffraction limited X-rays), undulator R&D, ERL facility planning
- **SRF group**
  - Manufactured the first main linac 7-cell cavities, main linac cryomodule prototype
- **ERL photoinjector facility**
  - Operating the world’s highest current and brightness CW photoinjector
- **Gun & cathode development lab**
  - Laser lab, Mark-II gun under construction, material science & engineering of high efficiency photocathodes
Progress in ERLs for Light Sources

XDL’11 workshops – exciting science enabled by X-ray ERLs

Beyond existing brightest x-ray sources
Progress in ERLs for Light Sources

Operations at JLAB
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury,
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP

Myoglobin structure
MbCO vs. Mb; rmsd < 0.2 Å

iron-heme displacement: Δd ≈ 0.33 Å
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA

3GeV ERL First Stage

7GeV Double Acc.

XFEL-O Second Phase
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS

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RF, DW & INS

Distance between RING and LINAC: 78m
600m (UNDULATOR & FEL BEAMLINE)

7 GeV Double Acc.

3 GeV ERL First Stage

Progress in ERLs for Light Sources

7 GeV

Synchrotron Radiation

Electron Gun

Injector Linac

Superconducting Main Linac

Merger

Accelerating Beam

Deaccelerating Beam

RF Phase

Return Loop

Beam dump

XFEL-O Second Phase
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK, HZB

3GeV ERL First Stage

7GeV Double Acc.
Progress in ERLs for Light Sources

Operations at JLAB, Daresbury, BINP
Designs at Cornell, KEK/JAEA, BAPS
Test loops at KEK, HZB, IHEP
ERL X-ray source R&D

• Essentials
  – Superconducting RF (high $Q_0$, $Q_L$ for low operation cost; HOM damping for > 100mA; cost-efficient cryomodule design & fabrication)
  – Photoinjector (demonstrate high current, longevity, brightness)
  – Generic facility strawman (undulators, beamline, magnets, power budget, cryoplant)

• And beyond
  – Multi-turn designs (depends on how cheap/efficient SRF can be made)
  – Marry XFEL solutions (simultaneous low rep rate beam operation with high current – e.g. KEK design)
Milestones reached at Cornell in 2011/12

- Superconducting RF (high $Q_0$, $Q_L$ for low operation cost; HOM damping for > 100mA; cost-efficient cryomodule design & fabrication)
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http://news.chess.cornell.edu/index.html
Frontier photoinjector work @ Cornell

- Pushing the state-of-the-art: 10MeV photoinjector
  
  ERL – Injector Prototype

- Now world’s highest brightness and current photoelectron source
Cornell photoinjector highlights

• Over the last year:
  – Maximum average current of 52 mA from a photoinjector demonstrated
  – Demonstrated feasibility of high current operation (> kiloCoulomb 1/e lifetime from the same laser spot)
  – *measured beam brightness already would surpass any existing storage ring if 5 GeV energy recovery linac were to be built today*

• Clear path exists for further improvements
  – Better photocathodes will result in brighter beams
  – The photoinjector itself was built to be future-looking R&D machine with highly optimized performance (yet to be fully realized)
Developing advanced photocathodes for accelerators

antimonide growth & analysis chamber

dedicated MBE system

over in Newman Lab

over in Phillips Hall

over in Wilson Lab

actual accelerator

Newman

Phillips

Wilson
SRF milestone: high $Q_0$ for efficient operation of future high current accelerators!

- **Cornell Horizontal Test Cryomodule:**
  - Dedicated to high $Q_0$ studies
  - **Goal:** show that (and how) high $Q_0$ can be maintained when cavity is installed in cryomodule
  - Reached $Q_0 > 4 \times 10^{10}$ in first test
    - >50% improved efficiency!

- **Operational goal for ERL:** $2 \times 10^{10}$

![Quality Factor Graph](image)

$Q_0 = 4$ to $6 \cdot 10^{10}$ at 1.6K in a cryomodule!
Conclusions

- World-wide interest in super-bright ERL x-ray source and much R&D effort underway

- Cornell team is significantly ahead of the competition
  - 2011/12 was year of many major accomplishments
  - ERL being redefined from a great concept to ‘it will work’ category

- Much remains to be done, but no showstoppers
Preparing our future

2011 CLASSE summer students

PhD students

> 30 Cornell undergrads throughout academic year