R&D Studies for Next Generation Light Sources

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Photon Source Landscape

1. There is a new generation of linac-based light sources.
2. For optimal operation, the linacs need to be able to run cw, and have to be superconducting.

   - copper linacs have to be pulsed (~100 Hz max.)

3. Jefferson Lab builds and tests sc linacs optimized for light sources.

Specific Program

1. Look at user requirements for brightness, calculate emittance and peak current requirements for linac.
2. Design high current and/or high gradient superconducting linacs for cw (rf) operation with parameters based on the scientific programs. . Note: most existing srf module designs are not optimized for light source applications. They would produce poorer beam quality and/or have excessive construction and operating costs.
3. Build cw superconducting linacs.
4. Install and test superconducting linacs with electron beams to explore dynamics.

Issues

1. **SRF performance.**

   - "tunnel or "real-estate" gradient" (combination of cavity gradient and packing), quality factor

2. **Electron beam transport, and learning to deal with the much higher peak currents than found in storage ring sources.**

   - coherent synchrotron radiation (CSR), beam breakup (BBU), microbunching instability (MBI), wakefield/impedance

3. **Maintaining emittance requirements during recirculation.**

   - potential capital and operational cost savings

4. **Studying FEL gain mechanisms to validate models.**

User requirements

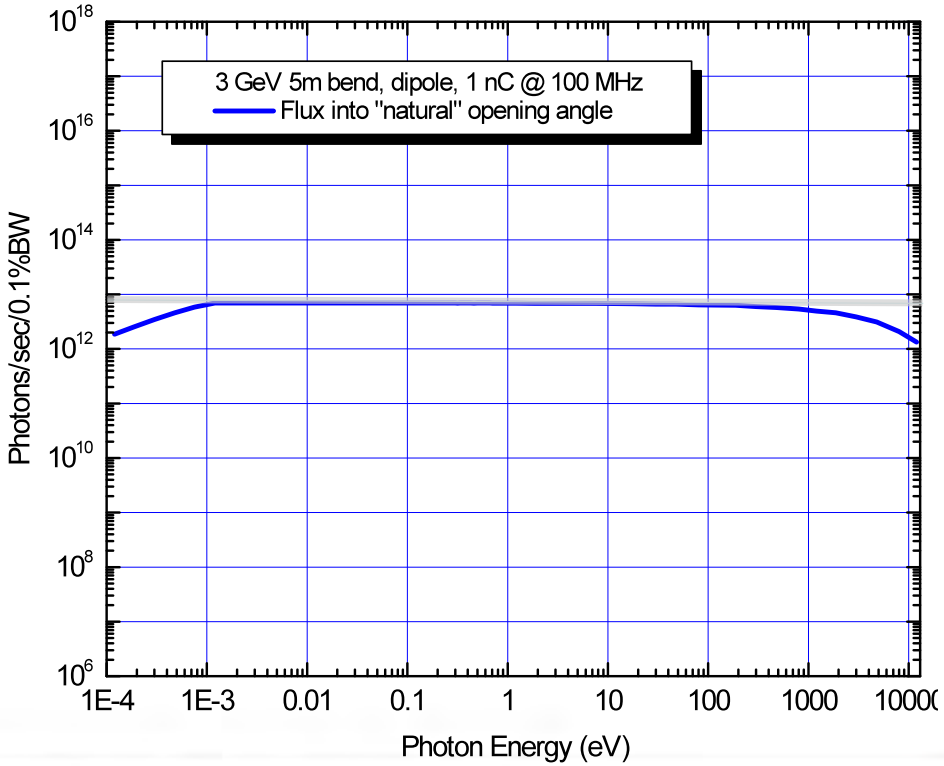
Photons/sec/0.1A/0.1%BW = 7.8×10^{12} **for all wavelengths** in coherent limit:

In basic physics picture, X-rays are more forgiving than UV/IR in peak current, see table, but situation is complicated - FEL gain falls inversely with energy requiring long undulators, lower energy spread, unless current rises to match. Emittance and pulse length also play key roles in the design phase-space!!

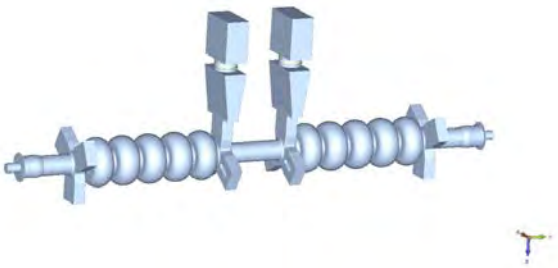
e.g. for 1 GW for 100fs

Ph.energy	**Pk Current**
1 eV	1110 A
10 eV	351 A
100 eV	111 A
1 keV	35.1 A
10 keV	11.1 A

S.L. Hulbert & G.P. Williams
*Rev. Sci. Instr. **80**, 106103 (2009)*



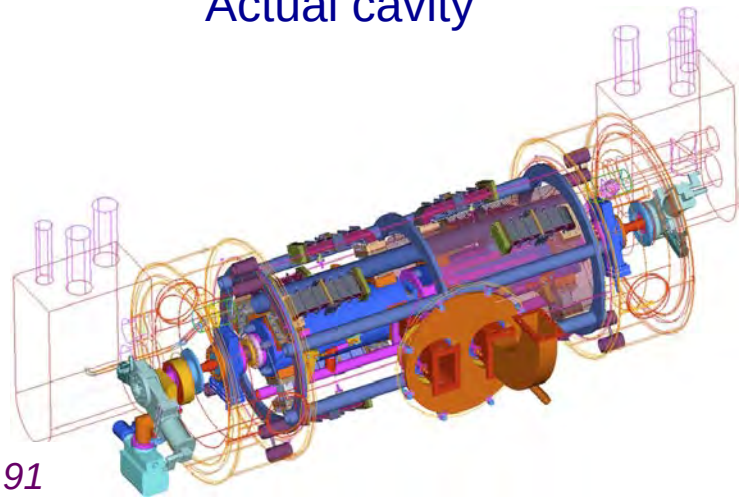
Designing the SC Linacs
- a High Current SC-Linac Test Module



Schematic of the rf coupling and higher mode damping for a high current cavity pair.

Actual cavity

Wang et al, PAC 05 p. 4191



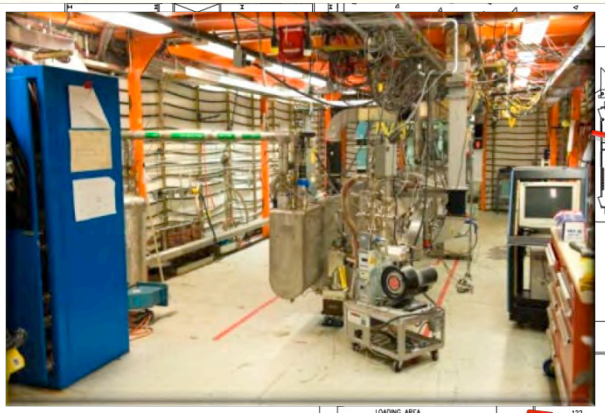
Cell shape modeling (work includes ERLs)

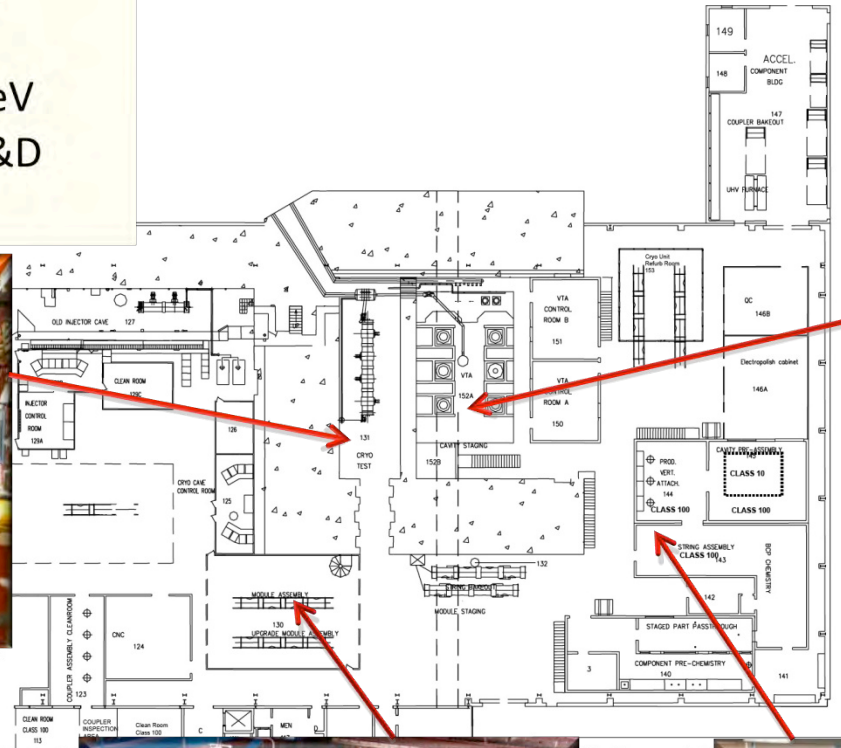
Cryostat assembly

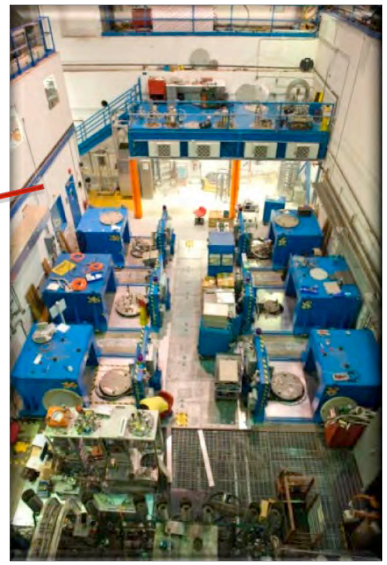
Building the SC Linacs – JLab SRF Institute

Established for CEBAF construction
Upgraded for SNS project in 2001
Supports 6 GeV operations & FEL
Working now on upgrade to 12 GeV
Leading US effort for SRF cavity R&D
Active education program

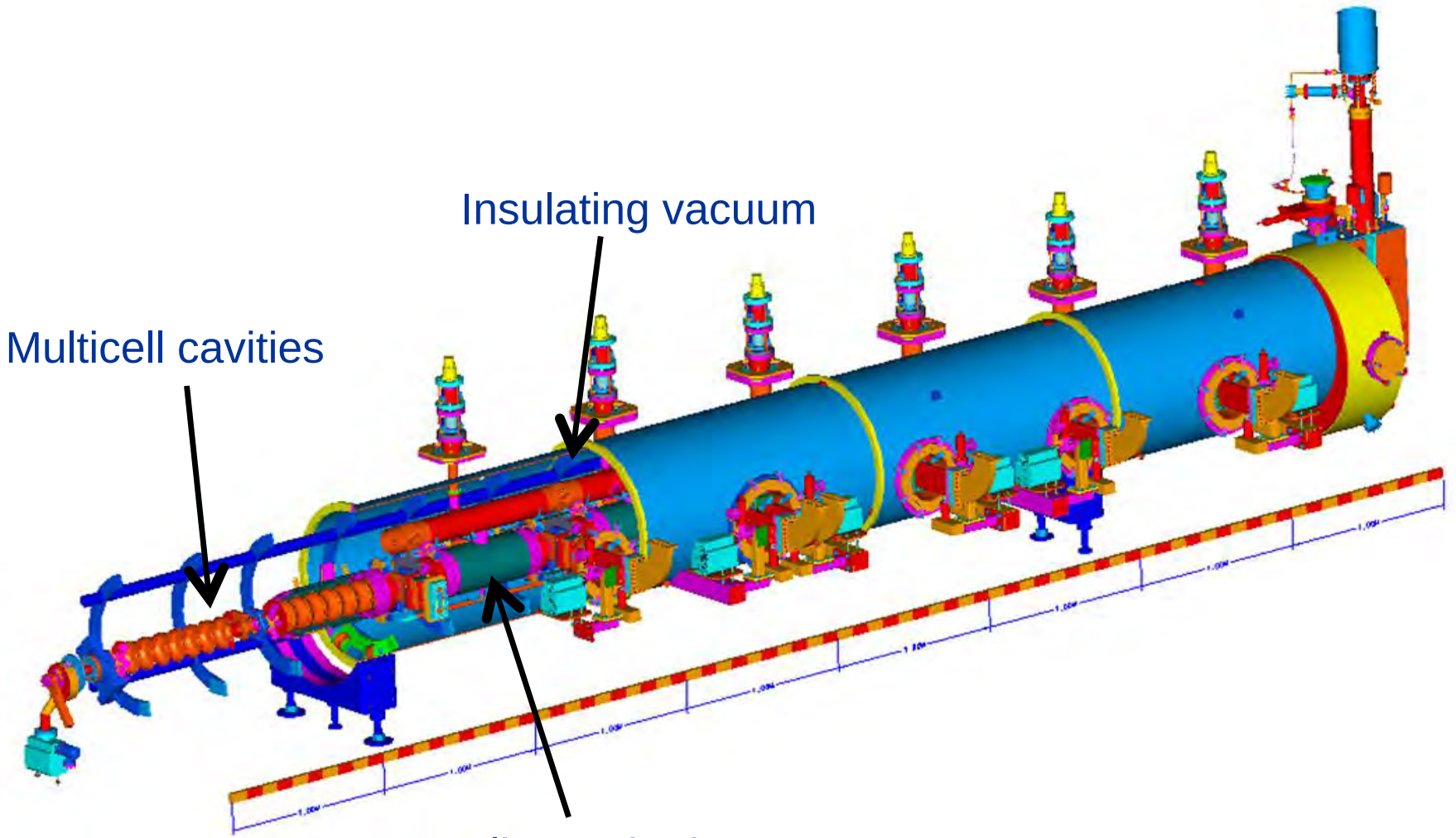
Only place in the world with concept-to-delivery SRF capability







A 100 MeV High Gradient SC-Linac Module



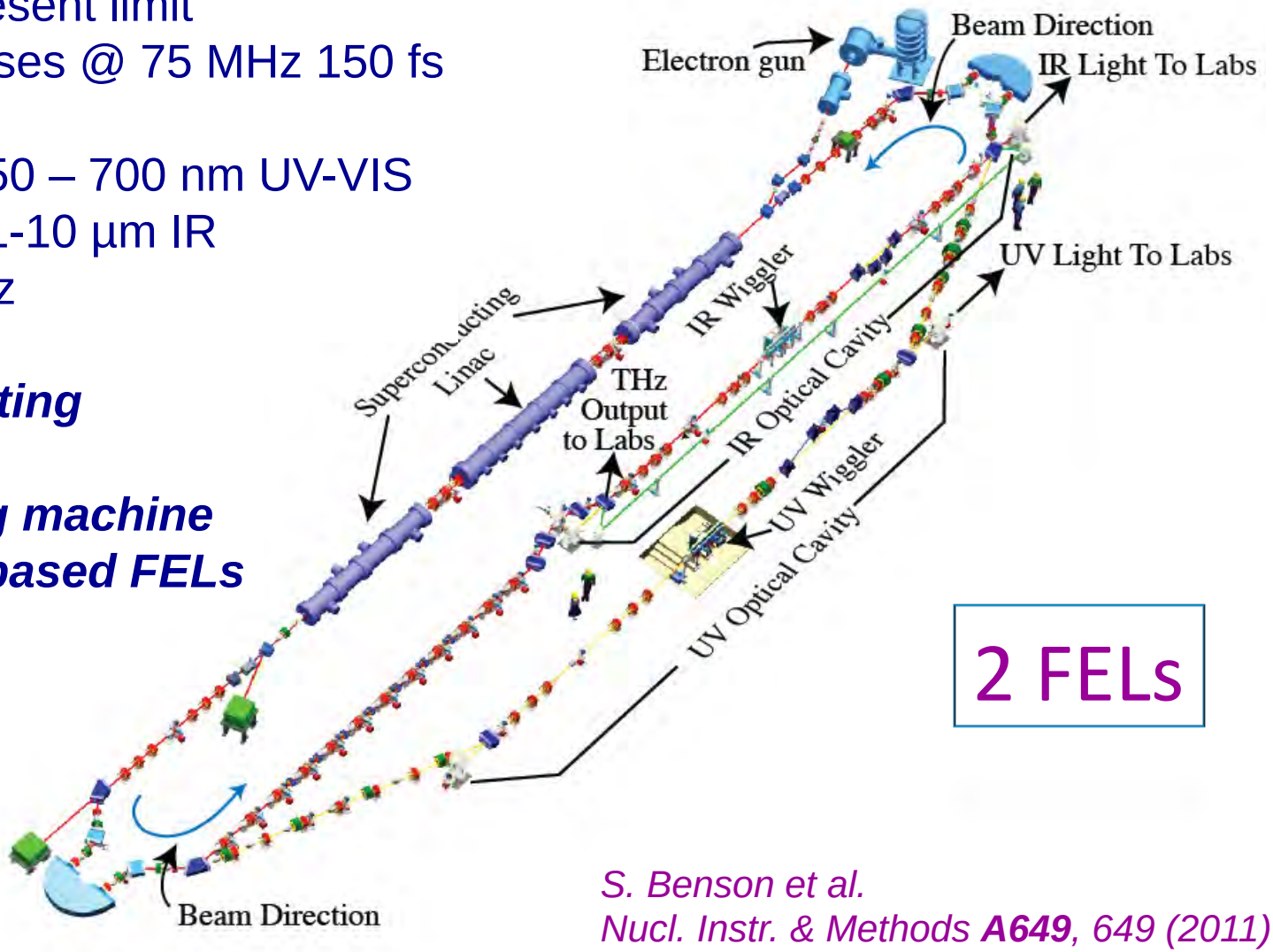
SC Linac Assembly

Testing the Linacs
JLab's Energy Recovered Linac Light Source R&D Facility

E = 135 MeV present limit
Up to135 pC pulses @ 75 MHz 150 fs

20 μJ/pulse in 350 – 700 nm UV-VIS
120 μJ/pulse in 1-10 μm IR
1 μJ/pulse in THz

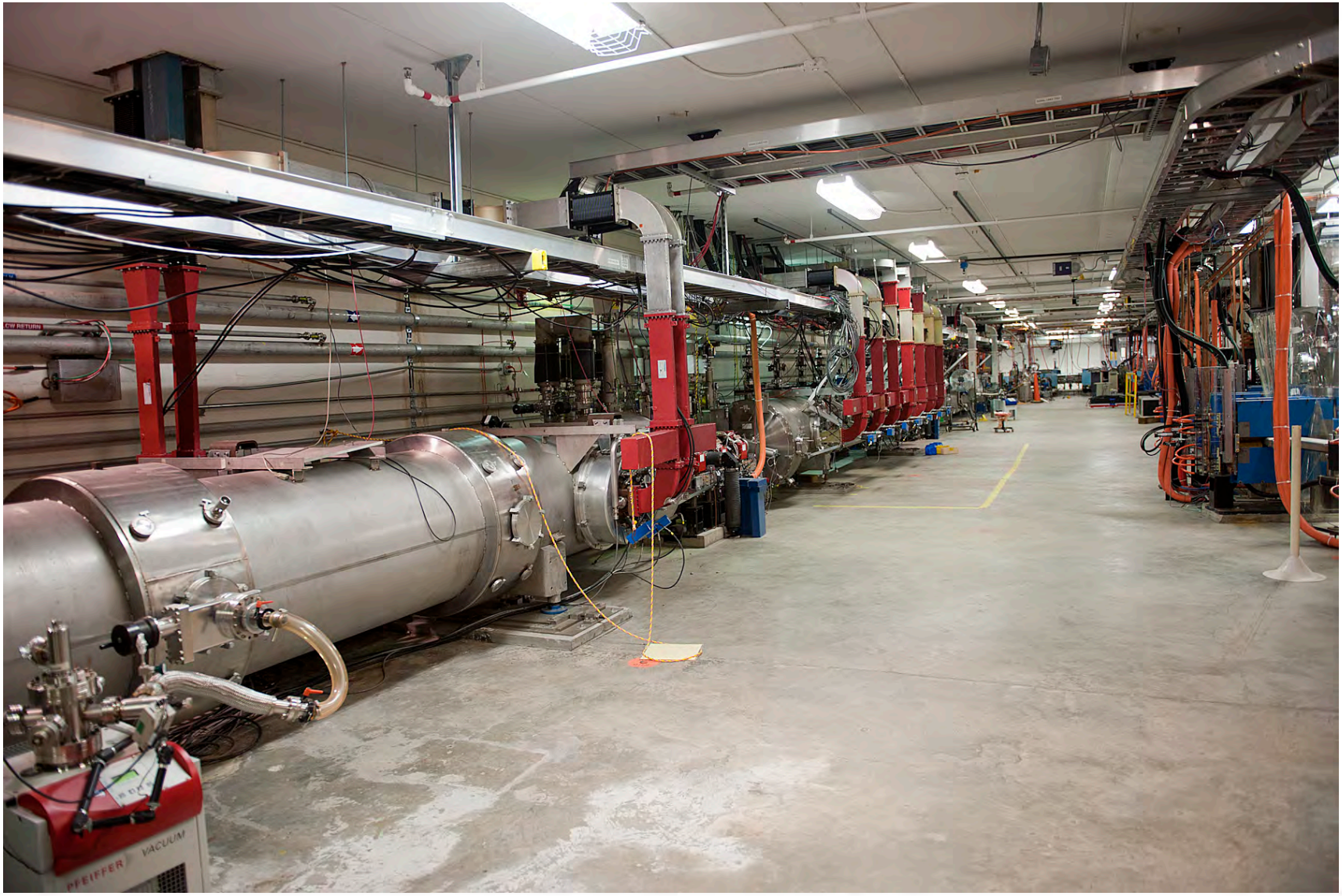
- ***Superconducting***
- ***CW operation***
- ***Re-circulating machine***
- ***2 Oscillator -based FELs***



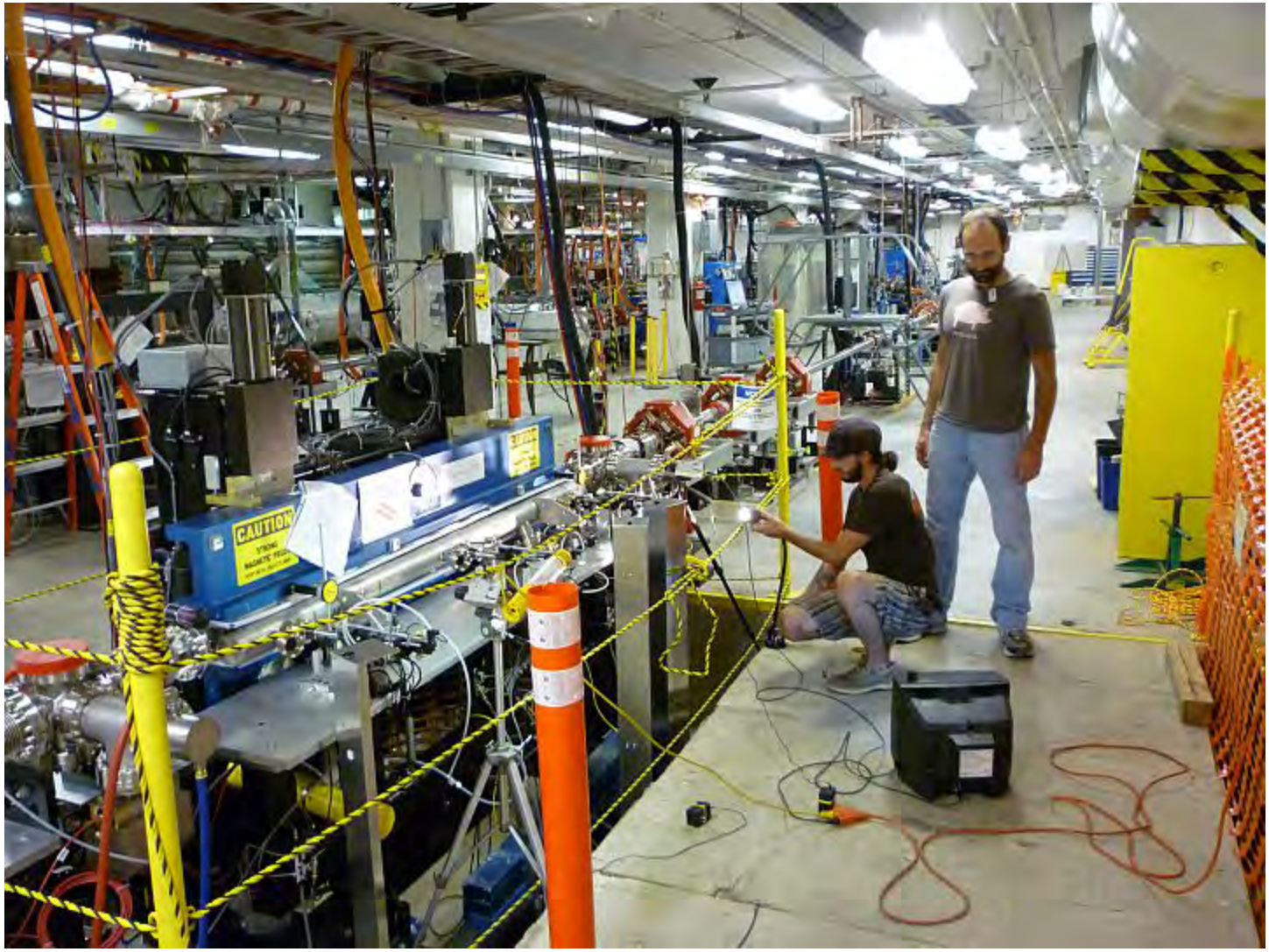
2 FELs

S. Benson et al.
*Nucl. Instr. & Methods **A649**, 649 (2011)*

JLab Light Source R&D Facility SC Linac Installation



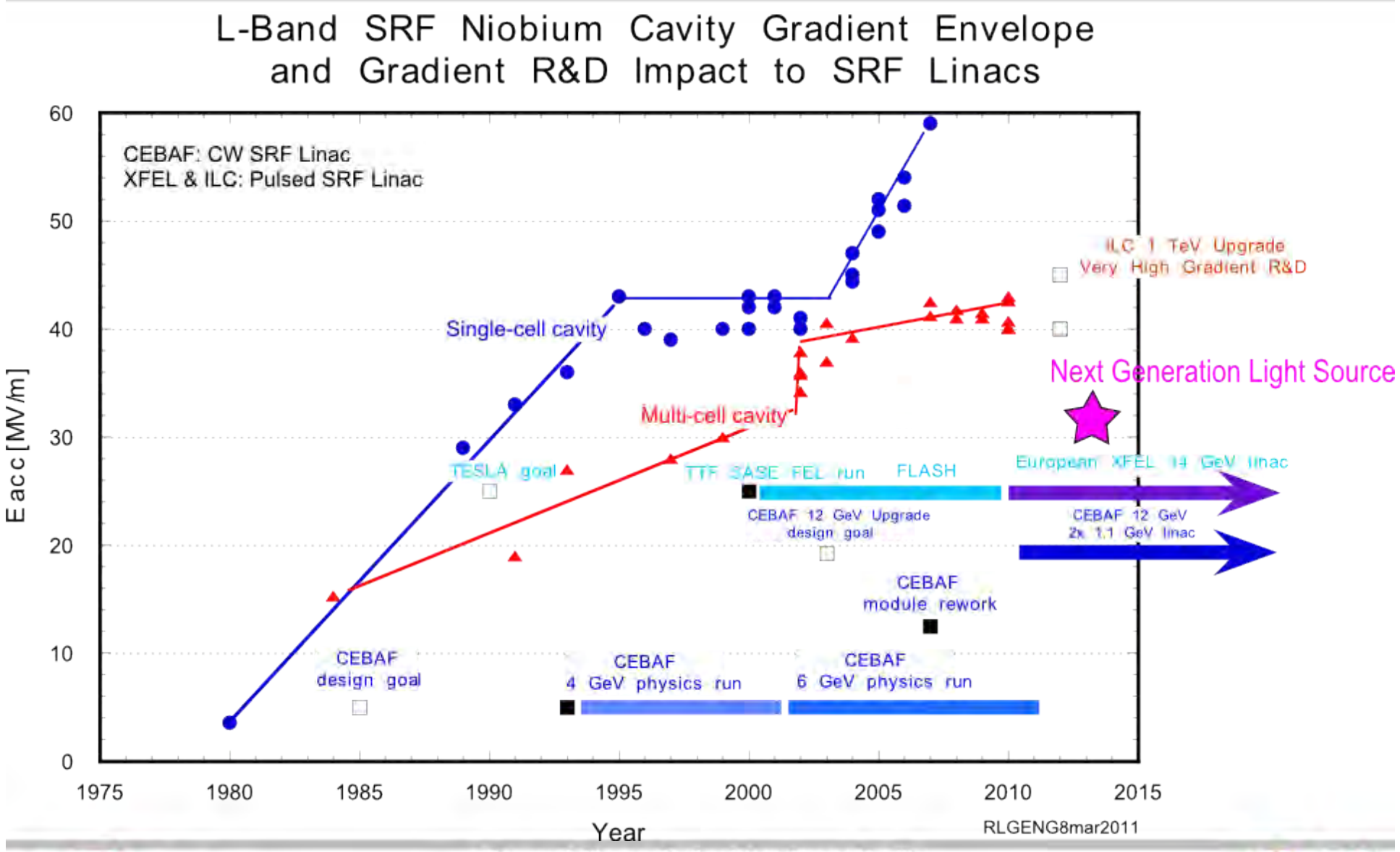
JLab Light Source R&D Undulator/Oscillator Installation



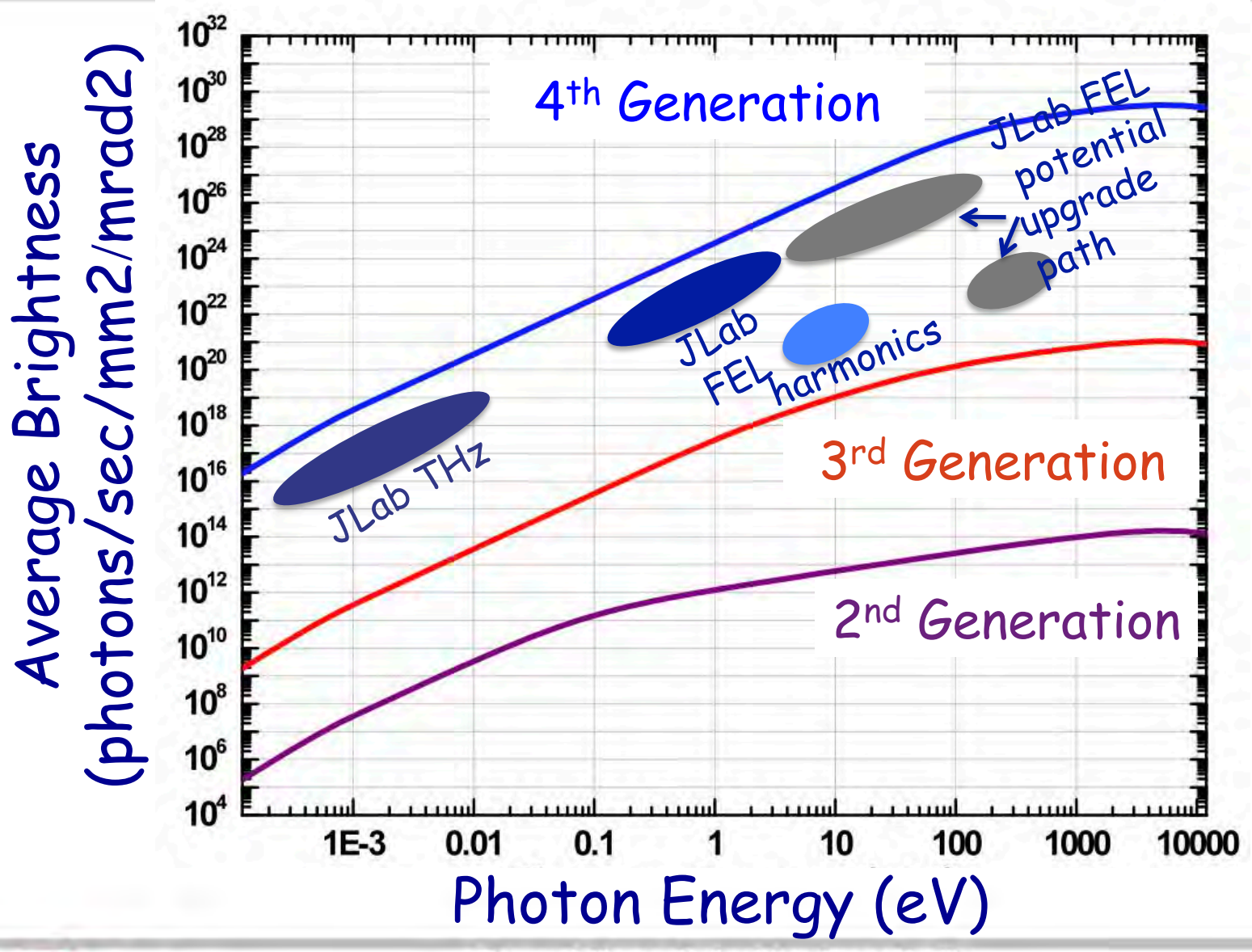
Results

1. Designed and built high current module.
2. Installed and tested highest gradient cw sc linac in world.
3. Calculated propagating fields in coherent limits.
4. Studied lasing mechanisms and produced 3rd harmonic at 10 eV
   - brightest source in the world, and programmatically significant.

SRF Progress for Light Sources



Performance of SC linac as light source driver



Future

1. **Continue srf optimization for future light sources.**

2. **Develop high dynamic range electron beam diagnostics appropriate for CW beams (Evtushenko talk) .**

3. **Continue investigation of beam dynamics in CW transport systems**

4. **Continue extension of oscillator designs to XUV region: full tunablility, higher brightness, MHz repetition rate*.**

**S. Benson et al*
J. Modern Optics in press (2011).

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