VUV/Soft X-ray Oscillators

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- Basic Requirements
- Early designs
- Recent work, Daresbury and JLAMP

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What is Needed to Make a VUV/Soft X-ray Oscillator FEL?

- With conventional wigglers need energy ~1 GeV.
- Need transverse emittance ~1 mm-mrad. (5 nm, 1.2 GeV)
- Need high gain design
  - Optics are very poor (~50% reflectance)
  - Guiding becomes essential element of design
  - No transparent substrates - need scraper or hole coupling.
  - Energy spread has to be less than Pierce parameter ρ.
- Need CW or very long pulse accelerator for oscillator to work (round trip times in oscillator are ~1 μsec)
- If unconventional wiggler is used, smaller emittances are also required.

Early VUV FEL Designs

- Earliest schemes assumed storage rings due to their CW, high energy design.
  - Biggest challenge was getting the emittance down and peak current up.
  - High gain implies long, small gap wiggler, high current implies short large gap wiggler to reduce impedance.
- In 1987 Los Alamos started construction of the first photocathode RF gun.
  - Beam brightness improved by X100 from thermionic guns.
  - Adiabatic damping opposite storage ring behavior
  - Linacs now look like possible sources for VUV/soft X-ray lasers
- Integrated simulation codes came on line about the same time (e.g. FELIX)
  - Could use simulated electron beam distributions
  - Included mirror aberrations
  - Full 3D simulation for the FEL

Los Alamos Design (1987)

QuickTime™ and a
decompressor
are needed to see this picture.

Whispering Gallery Resonator

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Total external reflectance of vacuum deposited aluminum used to produce high reflectivity. Hyperboloid-paraboloid used to expand and collimate the beam.

Effects of Guiding

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Guiding alters the stability condition for the FEL. There exist two solutions that produce optimum guided solution. Only one is also stable for low gain.

M. Xie, D. A. G. Deacon, and J. M. J. Madey, NIM A296 (1990) 672.

Progress towards a Device

- High brightness, high duty cycle, high energy accelerators very expensive. After SDI there was very little money available.
- Many groups tried exotic methods to get to XUV oscillators
- SASE was considered easier but still very hard. As of 1997 100% of FELs were still oscillators.
- Early SASE lasers were mostly very low duty cycle. It is easier to make a high brightness source at low duty cycle.

RAFEL Simulations for 4GLS

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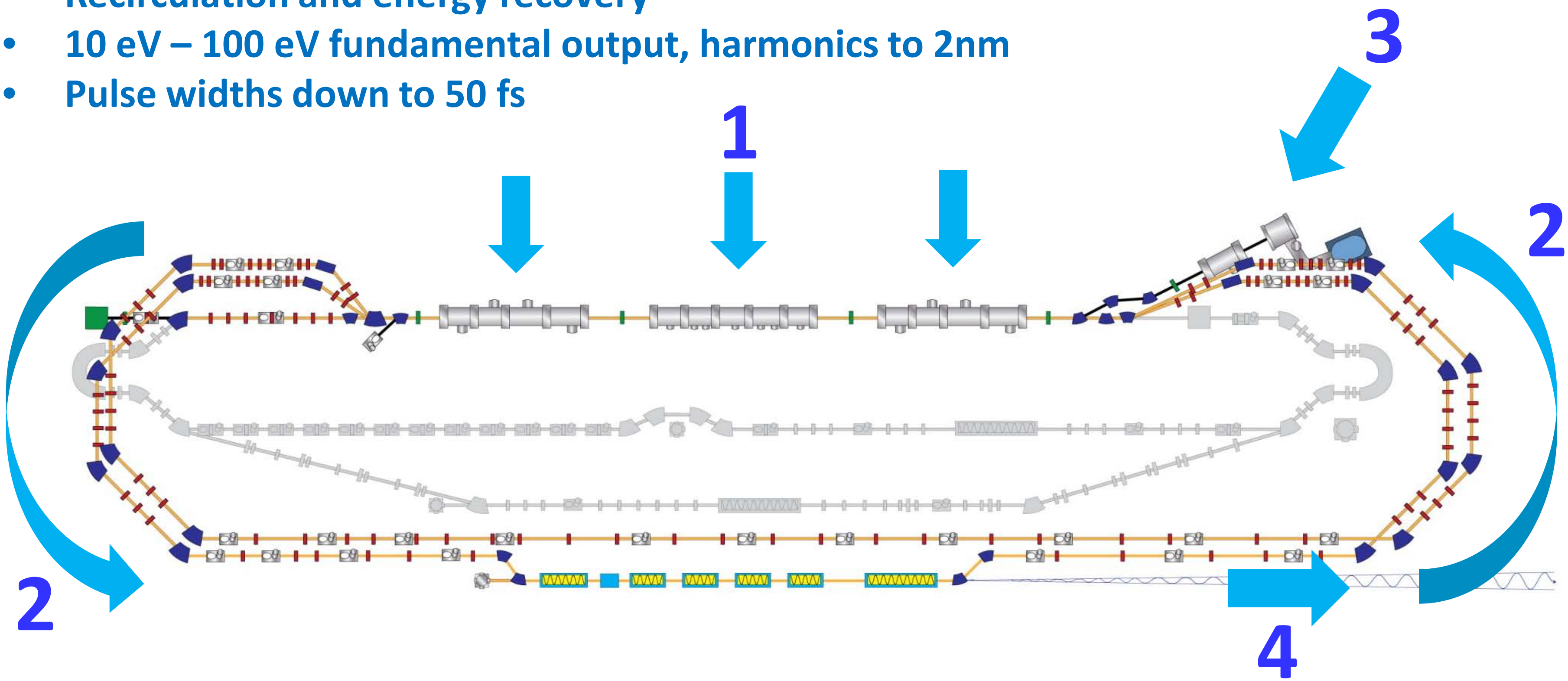
Peter Van der Slot calculated the response of a RAFEL configuration oscillator at 10 eV using room temperature silicon mirrors with deformations.

For 4.3 MHz operation the effect on lasing was minimal.

McNeil et all found that the optimum feedback was 5e-6.

JLab Conversion to JLAMP

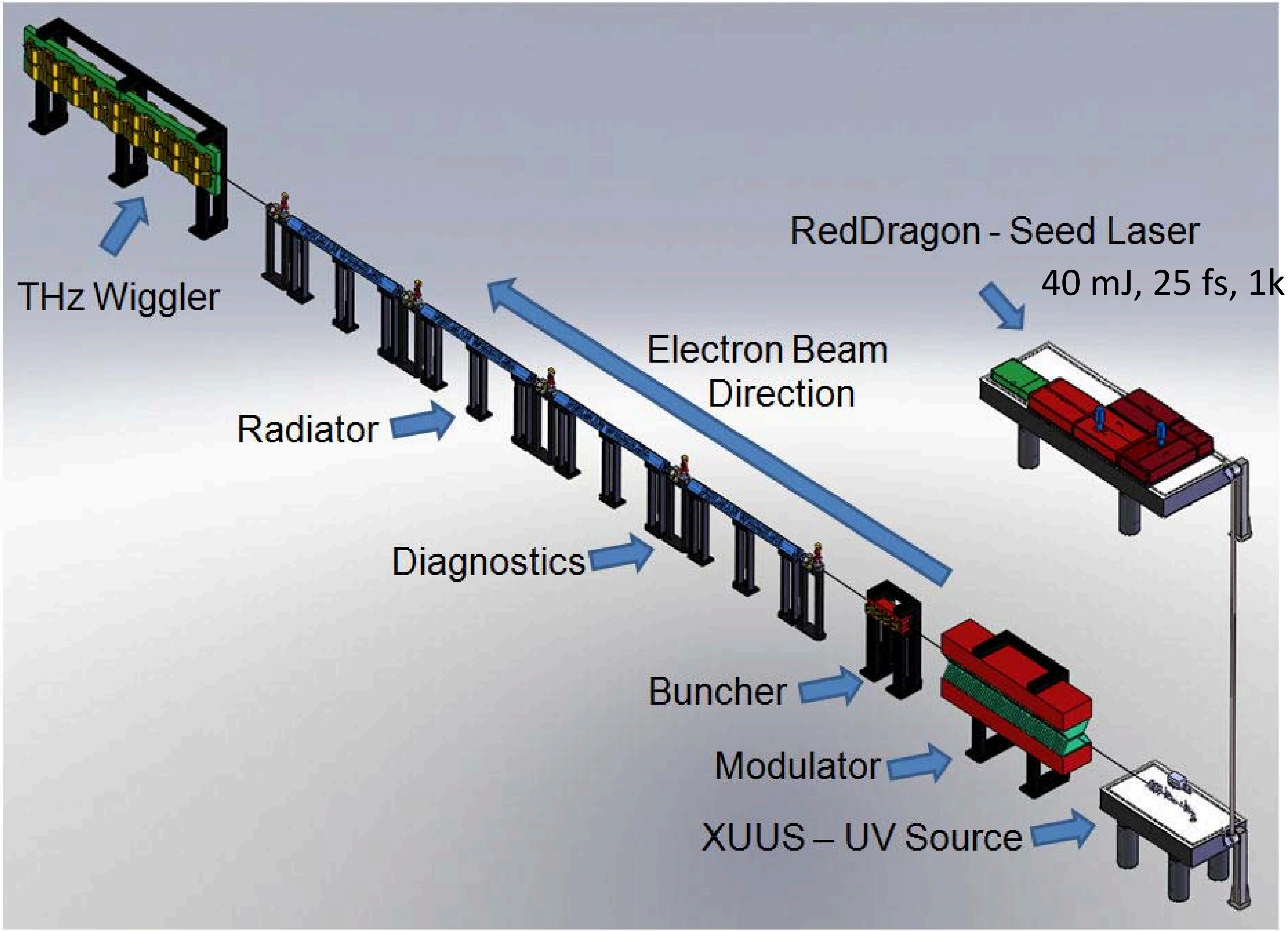
- 4 steps
- 600 MeV, 2 pass acceleration
- 200 pC, 1 mm mrad injector
- Up to 4.68 MHz CW repetition rate
- Recirculation and energy recovery
- 10 eV – 100 eV fundamental output, harmonics to 2nm
- Pulse widths down to 50 fs



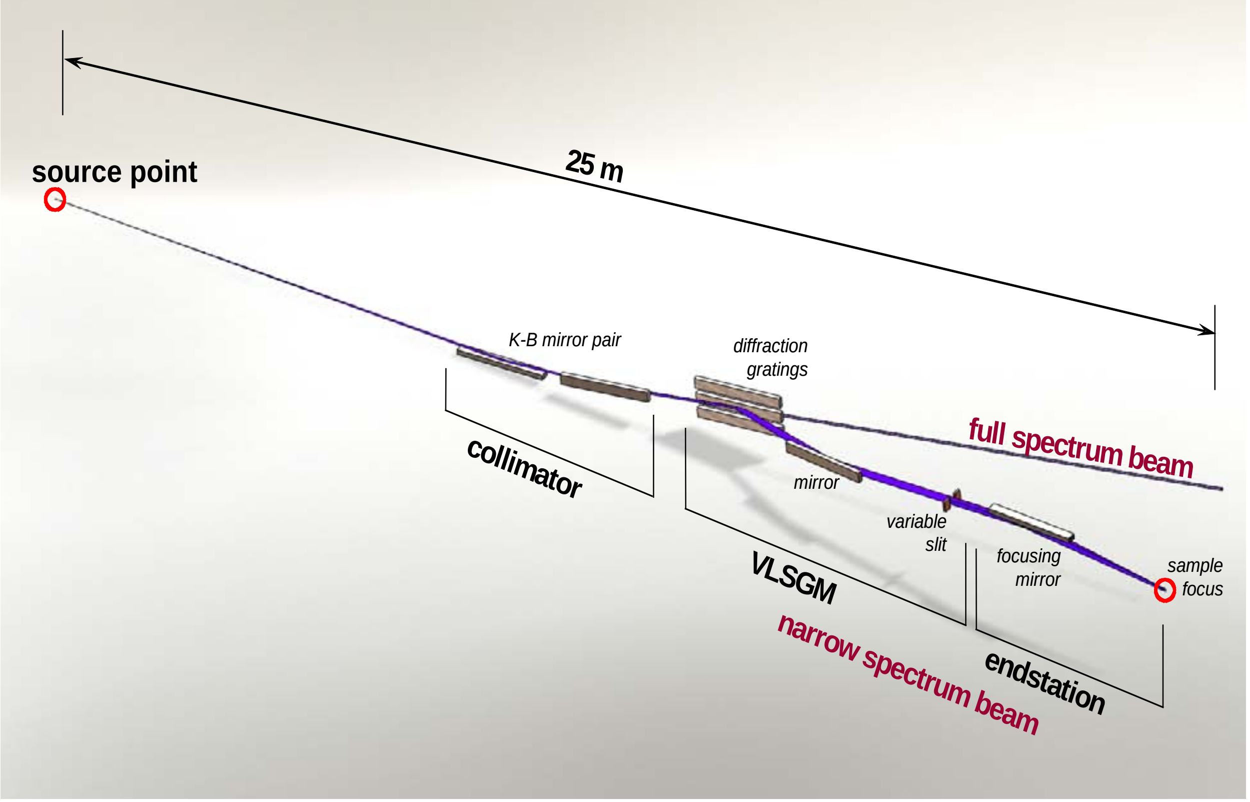
Accelerator Physics and Technologies Addressed by JLAMP

- High gradient cryomodules
- RF separation of high brightness beams.
- High brightness guns
- High prf seed laser technology
- Preservation of high brightness, moderate average current beams through multiple passes.
- Bunch compression in a machine with recirculation
- CSR, LSC, wakes, in high brightness beams.
- Multipass BPMs.
- RF drive of multiple cavities.
- Halo control

JLAMP - undulators/seed laser



Don’t Forget the beamlines

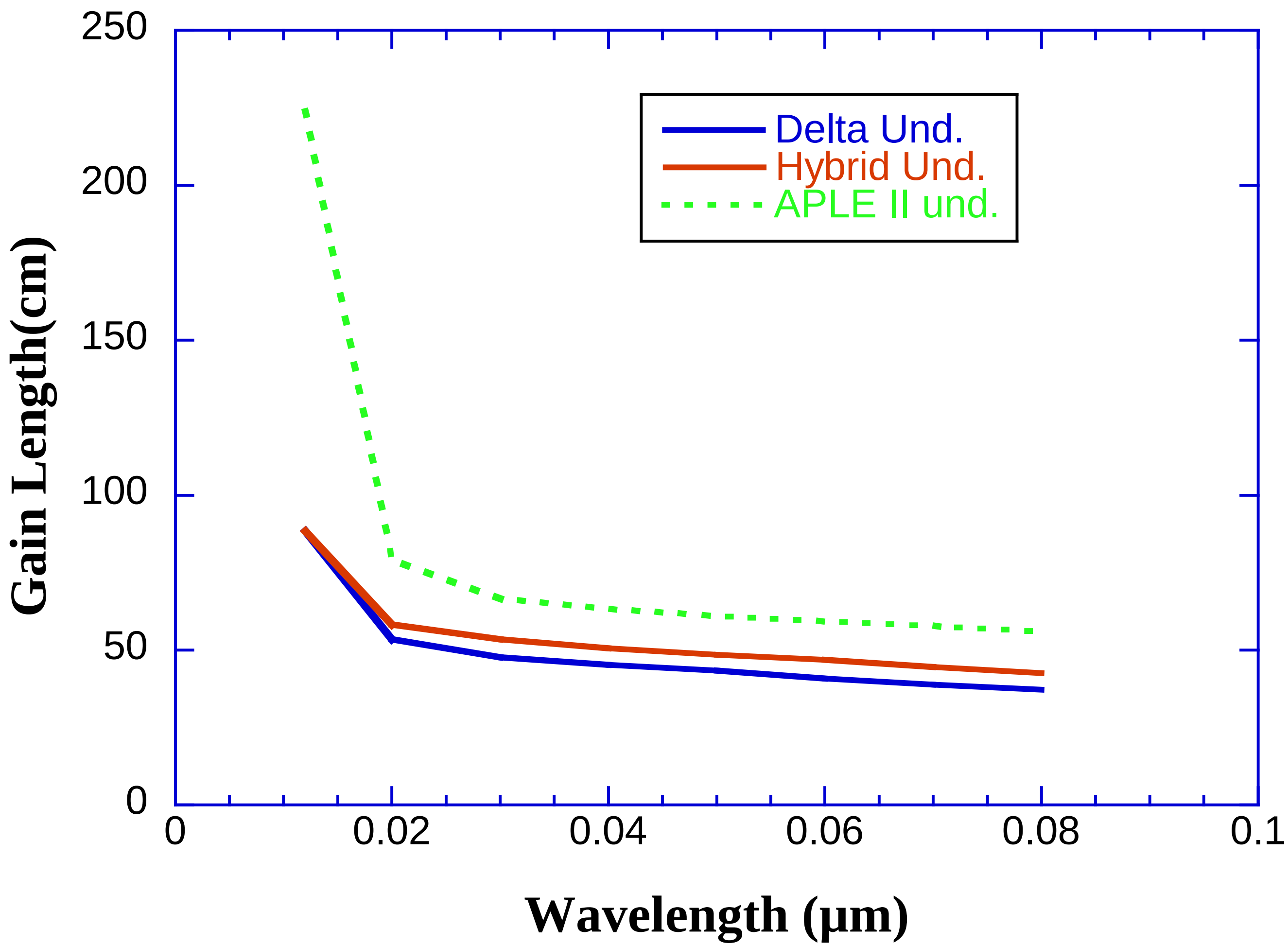


Three beamlines:

1. **Normal incidence, < 30 eV**
2. **Grazing incidence to 1 keV**
3. **Required figure errors are really small to maintain brightness.**

….are collaborating with NSLS on this.

Gain length calculations



Summary

- Need very high duty cycle, very high brightness accelerators for VUV oscillators
- Present designs are good enough for 20 nm, maybe good for 10 nm.
- Optical resonators are very challenging. Need figure errors <1 nm at 10 nm (though over small areas)
- Distortion of mirrors very challenging. Really cries out for cryogenic mirrors. Take advantage of VUV beamline technologies from existing SR beamlines.

The Jefferson Lab FEL Team

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