An X-Ray FEL Oscillator: Introduction

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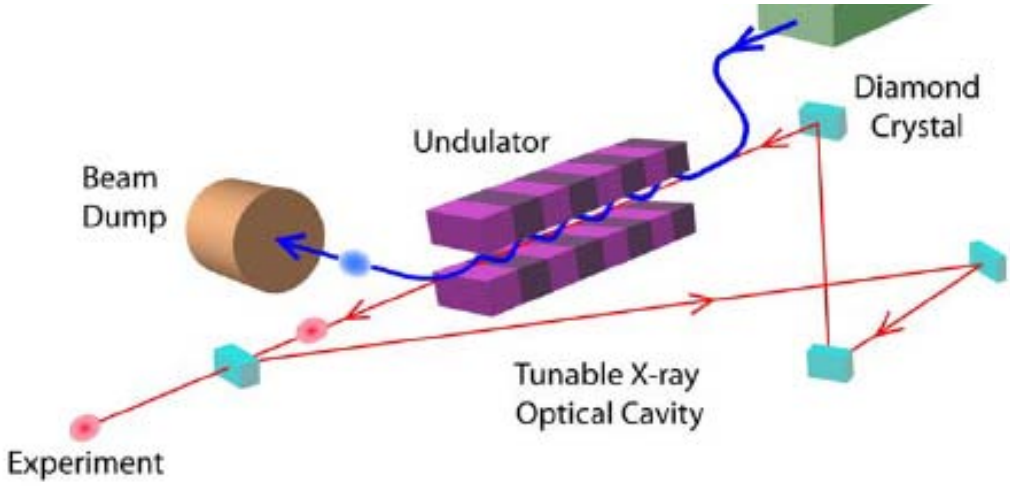
Future Light Source WS 2010: FEL WG

March 1-5, 2010

SLAC National Accelerator Lab

Menlo Park, CA

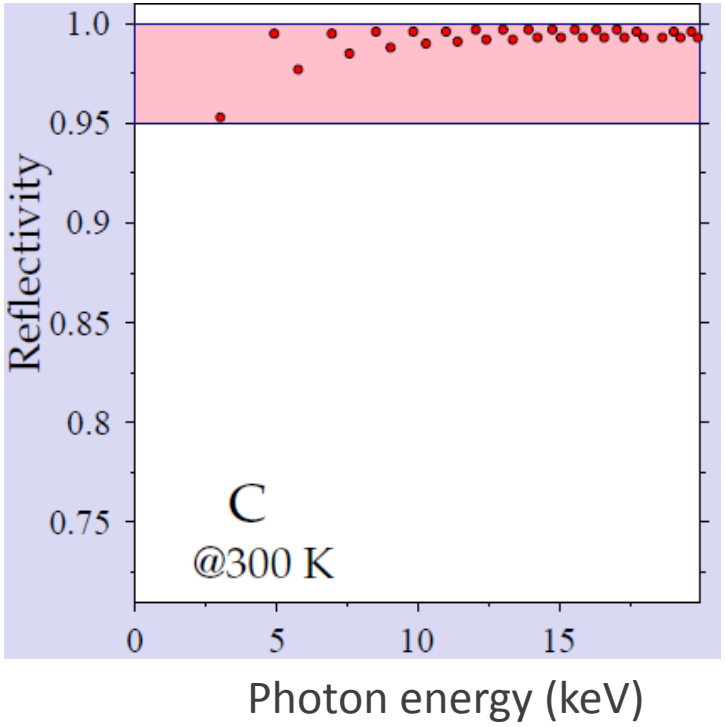
Hard X-Ray FEL Oscillator

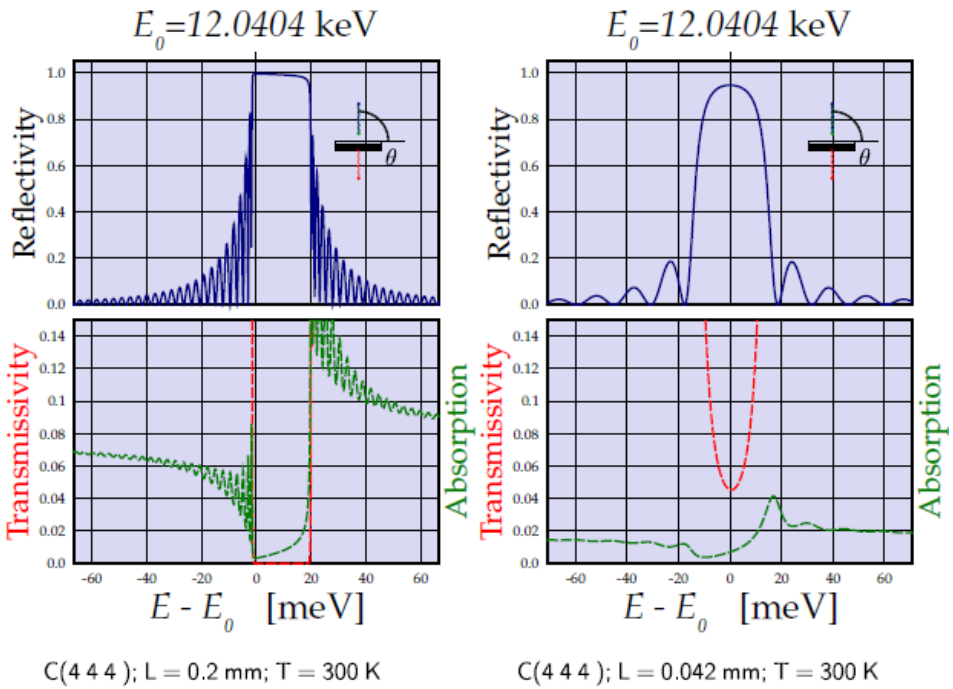


- **Store an X-ray pulse in a Bragg cavity→ multi-pass gain & spectral cleaning**
- **Provide meV bandwidth ($\Delta\omega/\omega \sim 10^{-7}$)**
- **MHz pulse repetition rate→ high average brightness**

Originally proposed in 1984 by Collela and Luccio and resurrected in 2008 (KJK, S. Reiche, Y. Shvyd'ko, PRL 100, 244802 (2008)

Diamond backscattering : High reflectivity and narrow bandwidth

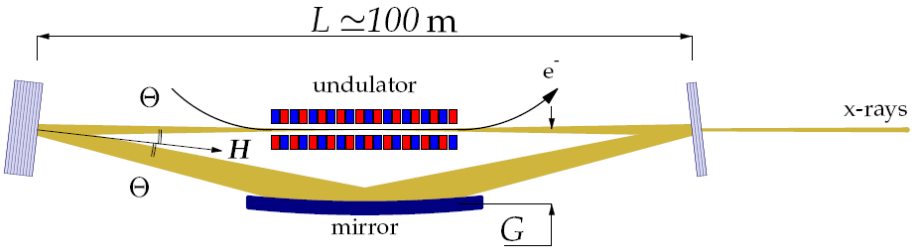


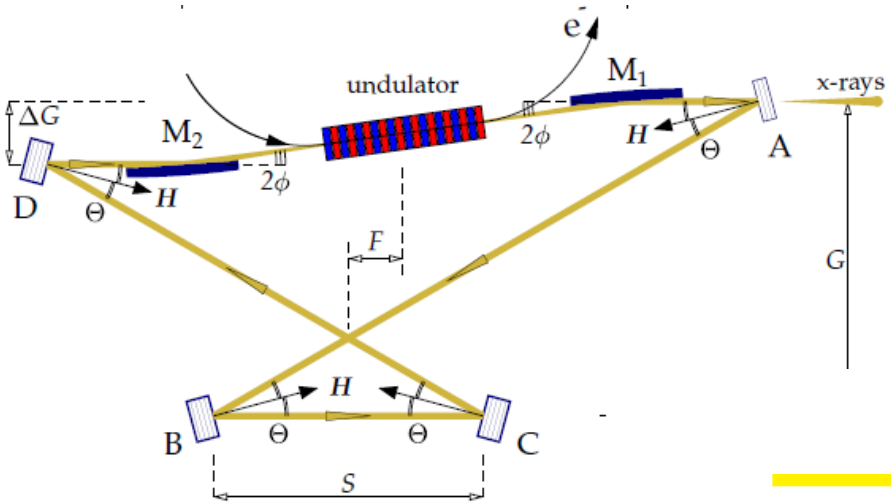


Courtesy of Yuri Shvyd'ko

Tunable X-ray Cavity

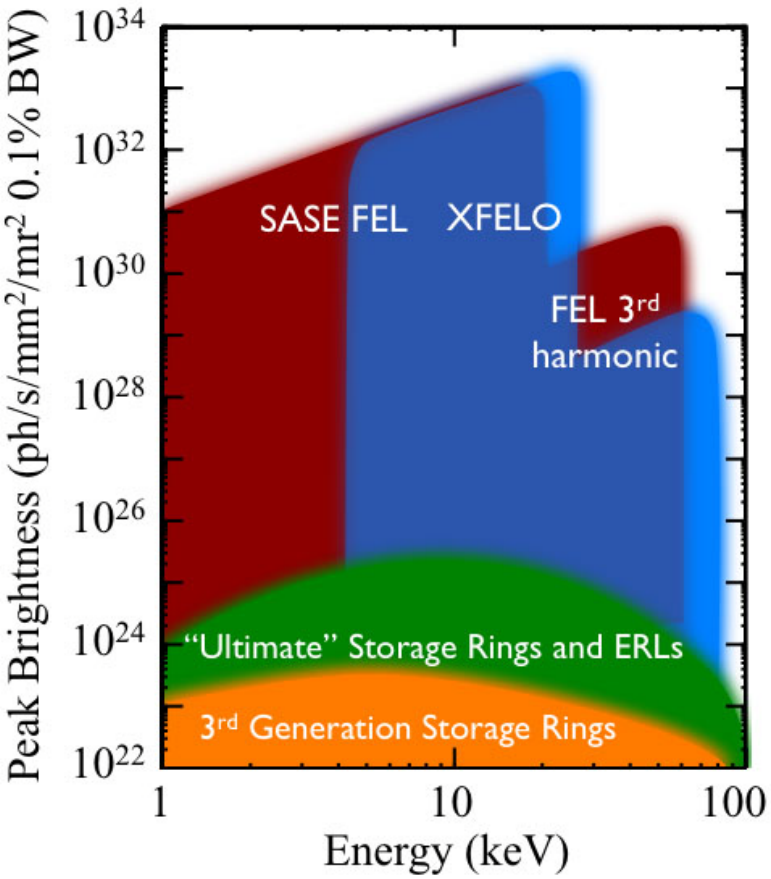
- **Two crystal scheme**
  - **a *very* limited tuning since θ must be kept small**
- **A tunable four crystal scheme**
  - **Any interesting spectral region can be covered by one chosen crystal material**
  - **Simplify the crystal choice →Diamond as highest reflectivity & best mechanical and thermal properties**

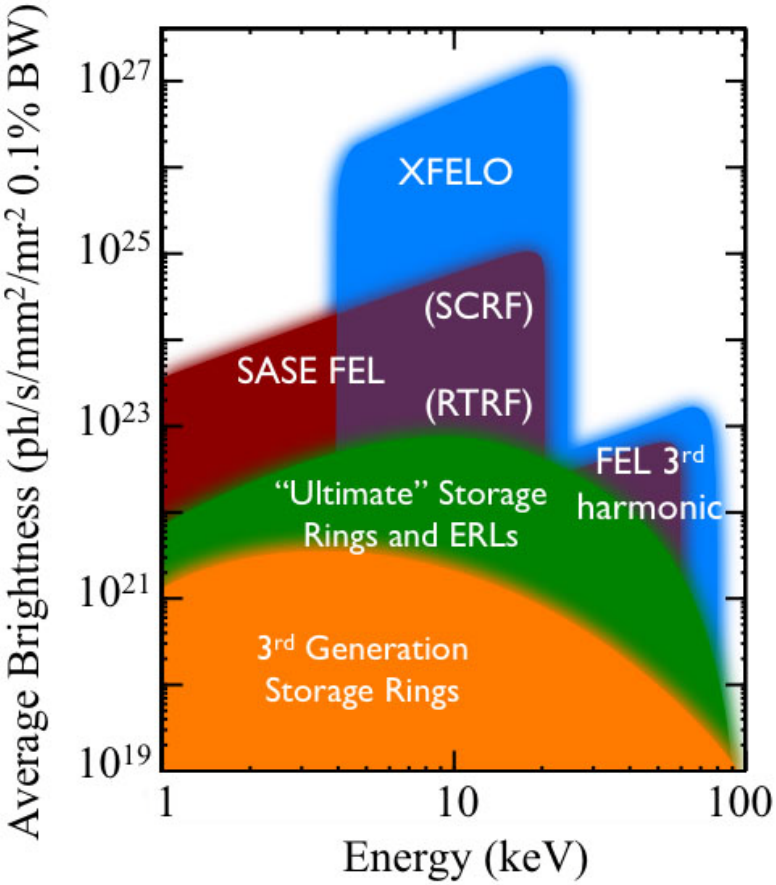




R. M.J.Cotterill, APL, 403,133 (1968)
KJK & Y. Shvyd'ko, PRSTAB (2009)

Brightness of Hard X-Ray Sources





XFELO Parameters

- **Electron beam:**
  - Energy ♦ 7 GeV
  - Bunch charge ~ 25-50 pC → *low intensity*
  - Bunch length (rms) ≤ 1 (0.1 ps) → Peak current 20 (100) A
  - Normalized rms emittance < 0.2 (0.3) mm-mr, energy spread (rms) ~ 2⊗10^{-4}
  - Constant bunch rep rate @ ~1 MHz
- **Undulator:**
  - L_u= 60 (20) m, λ_u ~2.0 cm, K=1.0 – 1.5
- **Optical cavity:**
  - 2- or 4- diamond crystals and focusing mirrors
  - Total round trip reflectivity > 85 (50) %
- **XFELO output:**
  - 5 keV ≤ ħω ≤ 25 keV
  - Bandwidth: $\Delta\omega/\omega$ ~ 1 (5) ⊗ 10^{-7} , pulse length (rms) = 500 (80) fs
  - # photons/pulse ~ 1⊗10^{9}
  - *Harmonics feasible if x-ray pulse sees a crystal before grazing incidence mirror*

Blue color indicates short-pulse mode for relaxed tolerances

XFELO will revolutionize the hard x-ray techniques developed at storage-ring-based light sources and find new applications in areas complementary to SASE

- **Inelastic x-ray scattering**
- **Mössbauer spectroscopy**
  - **10^3/pulse, 10^9/sec Mössbauer photons (14.4 keV, 5 neV BW)**
- **Bulk-sensitive Fermi surface study with HAXPES**
- **Time-resolved methods (0.1 -1 ps)**
- **X-ray imaging with near atomic resolution (~1 nm)**
  - **Smaller focal spot with the absence of chromatic aberration**
- **X-ray photon correlation spectroscopy**
  - **10^{15} photons/sec is a game changer, better time structure than LCLS, t-coherence is a huge advantage**
- ***Science/FEL WG (Tu. 1:30-4:00 PM)***

R&D Issues Towards an XFELO

- FEL beam dynamics, modeling
  - R. Lindberg and W. Fawley (this session)
- X-ray optics: crystals, stability
  - Y. Shvyd'ko (this session)
- Grazing incidence curved mirror
  - A. Barty (this session)
- Injector
  - *A. Nassiri: ERL/HBEB, Tu. 4:30-4:55 PM*
  - *N. Sereno: HBEB, Th. 9:00-9:30 AM*
- Main accelerator
  - A 7 GeV linac will be most versatile, accommodating other FELs
  - ERL Option: *R. Hajima, FEL/ERL WG, Th. 9:00-9:30 AM*
  - Recirculation: *M. Borland, ERL/FEL WG, Th. 9:45 -10:00 AM*

This Session

- **1:40 PM K.-J. Kim: *Introduction***
- **1:50 PM R. Lindberg: *Beam Dynamics and Performance***
- **2:10 PM Y. Shvyd'ko: *X-ray Cavity Feasibility Studies***
- **2:35 PM W. Fawley: *Simulation Issues***
- **2:50 PM J. Zemella: *An XFELO @ European FEL***
- **3:05 PM: A. Barty: *State of the Art X-ray Optics***
- **3:30 PM: All: *Discussion and Conclusion***