FEL PHYSICS

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SPARC-SPARX
COLLABORATION

STARTING POINT

Preso, dunque, atto dell'interesse dell'Università di Roma "Tor Vergata" di ospitare SPARX nella sua versione finale, risulta opportuno, per ragioni tecniche ed economiche, avviare la realizzazione di una sorgente - che offra le prestazioni di una facility per l'utenza e di R & D per nuove soluzioni nell'ambito della Fisica dei laser ad elettroni liberi - presso i laboratori dell'INFN di Frascati per poi realizzare le successive azioni presso il Campus di "Tor Vergata" attraverso la stipula di una apposita convenzione, ferma restante la disponibilità delle risorse economiche.

Resta inteso che, per rendere concreta l'iniziativa, è necessario avviare immediatamente l'iter di costituzione del Consorzio LUCE con lo scopo di gestire le necessarie azioni e regolamentare i rapporti reciproci tra le Parti e tra esse e i Soggetti finanziatori.

In fede,

Renato Lauro | Giovanni Lelli | Luciano Maiani | Roberto Petronzio

Key Elements

- CONSTITUTION OF THE CONSORTIUM TO GET “MONEY” FROM FINANCING INSTITUTIONS
- Design of a device offering:
- The performances of a facility for users
- A tool for Research and Design of new solutions and technologies for FEL devices

USERS…

- “Traditional” users
- The users include now FEL people
- The project could be conceived in a flexible enough way to provide a wide offer (Nuclear Physics, Astrophysics, beam handling…)
- Further room technological developments (new materials)

We have missed an opportunity!!!

- Even though the choice of two “big” FEL devices in Italy has been questionable from the very beginning, the two design conceptions were different and therefore there was room for tools dedicated to “complementary” users in different research areas with different economical, industrial, political, geographyc… configurations

The point: We cannot miss an other opportunity

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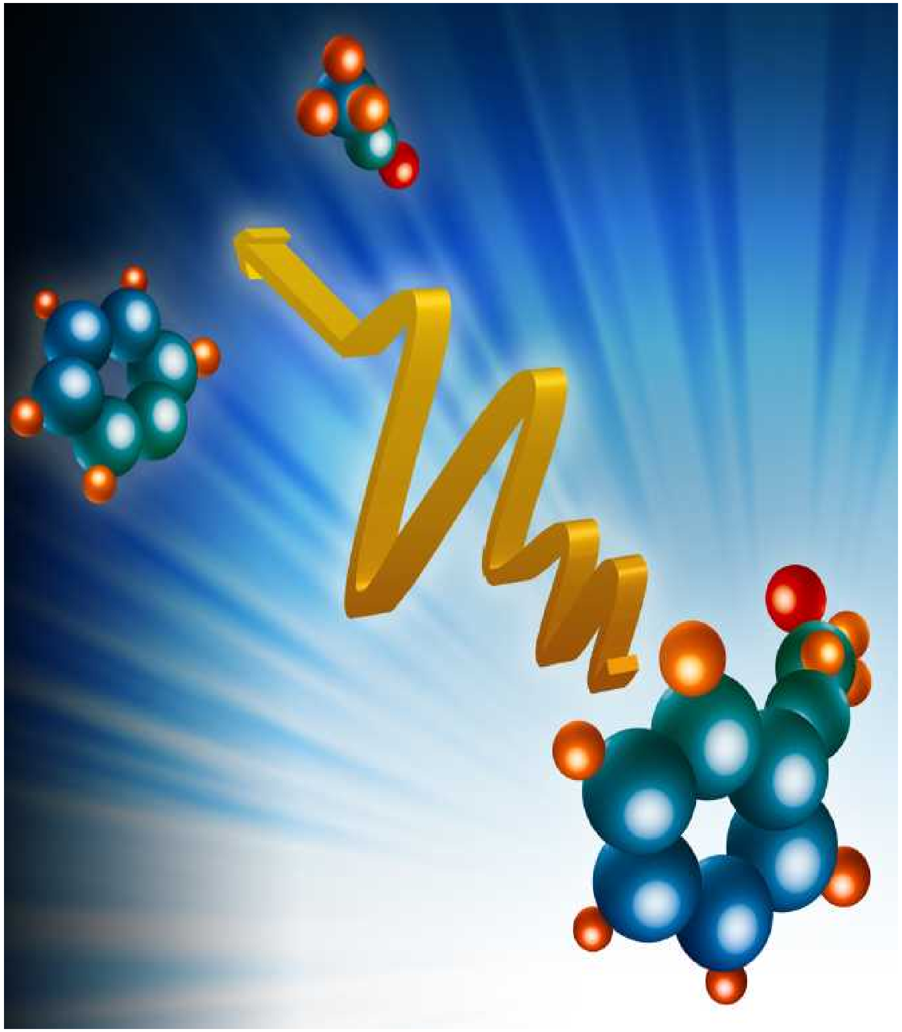
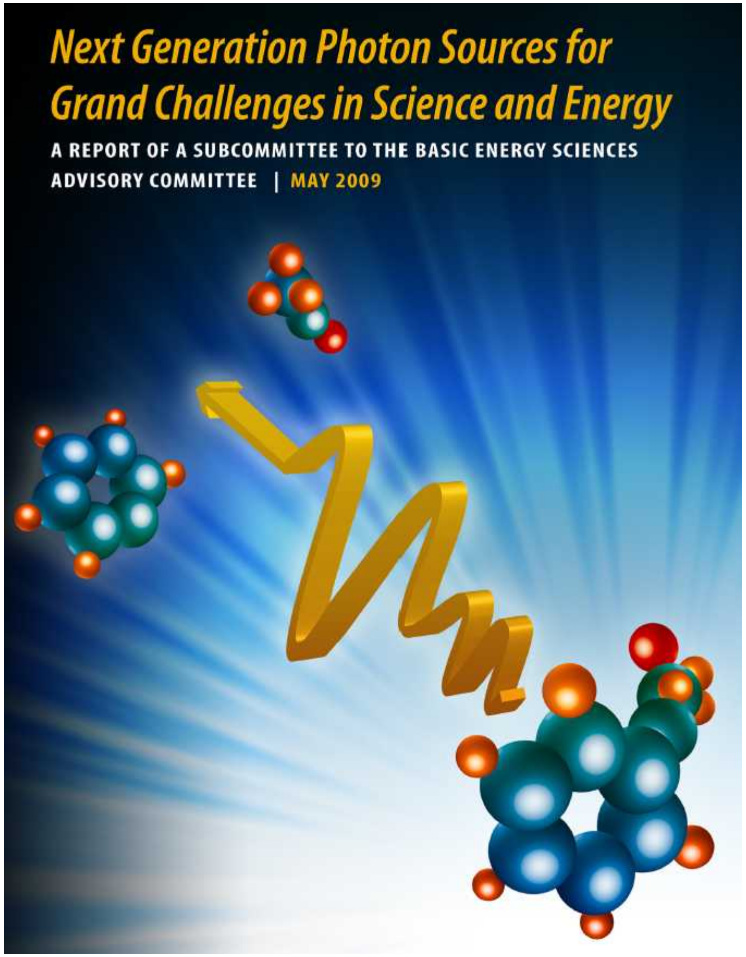


Why we cannot miss an other opportunity?

- Because this is the last!!!
- Constraints:
- USERS+R&D MONEY
- CHOICES FOR
- Near Future
- Mid term Future
- Far Future (I will be retired but why not to care for those who will be active at that time)

USERS


Next Generation Photon Sources for
Grand Challenges in Science and Energy
A REPORT OF A SUBCOMMITTEE TO THE BASIC ENERGY SCIENCES
ADVISORY COMMITTEE | MAY 2009

What are we able to provide As a research tool?

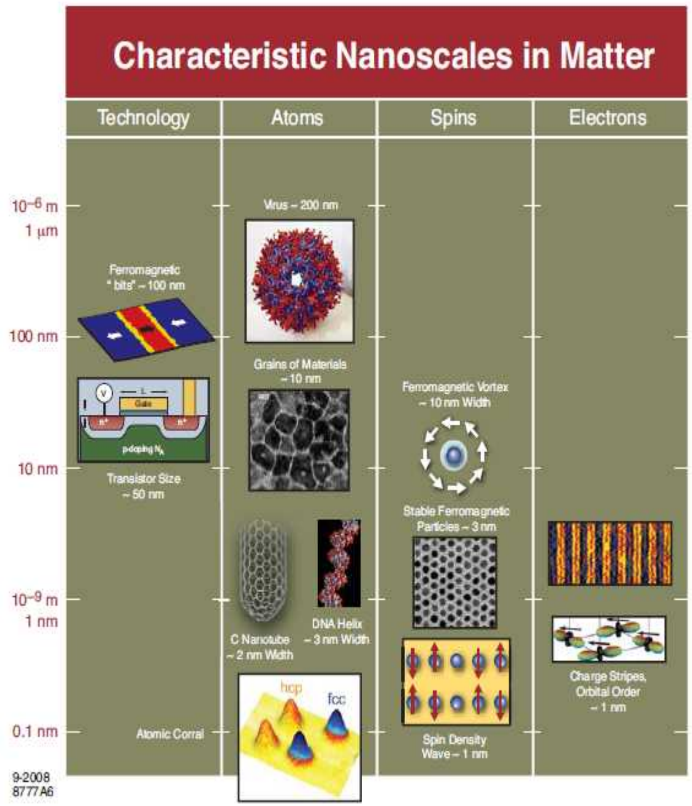


Figure1.1. Illustration of characteristic features on the level of atoms, electrons, and spins on nanometer length scales in comparison with typical lateral length scales in present advanced technological devices.

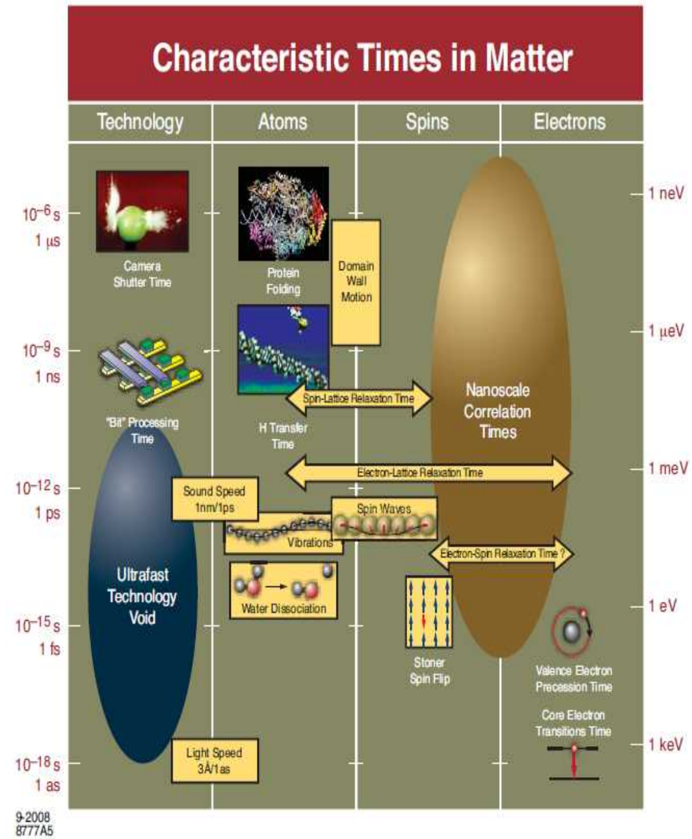


Figure 2.1. Illustration of our present knowledge about typical times involved in the interactions of atoms, electrons, and spins. On the right, we have indicated the corresponding quantum-mechanical interaction energies as estimated from the energy–time correlation $\Delta E \cdot \Delta t = h \sim 4$ fs·eV.

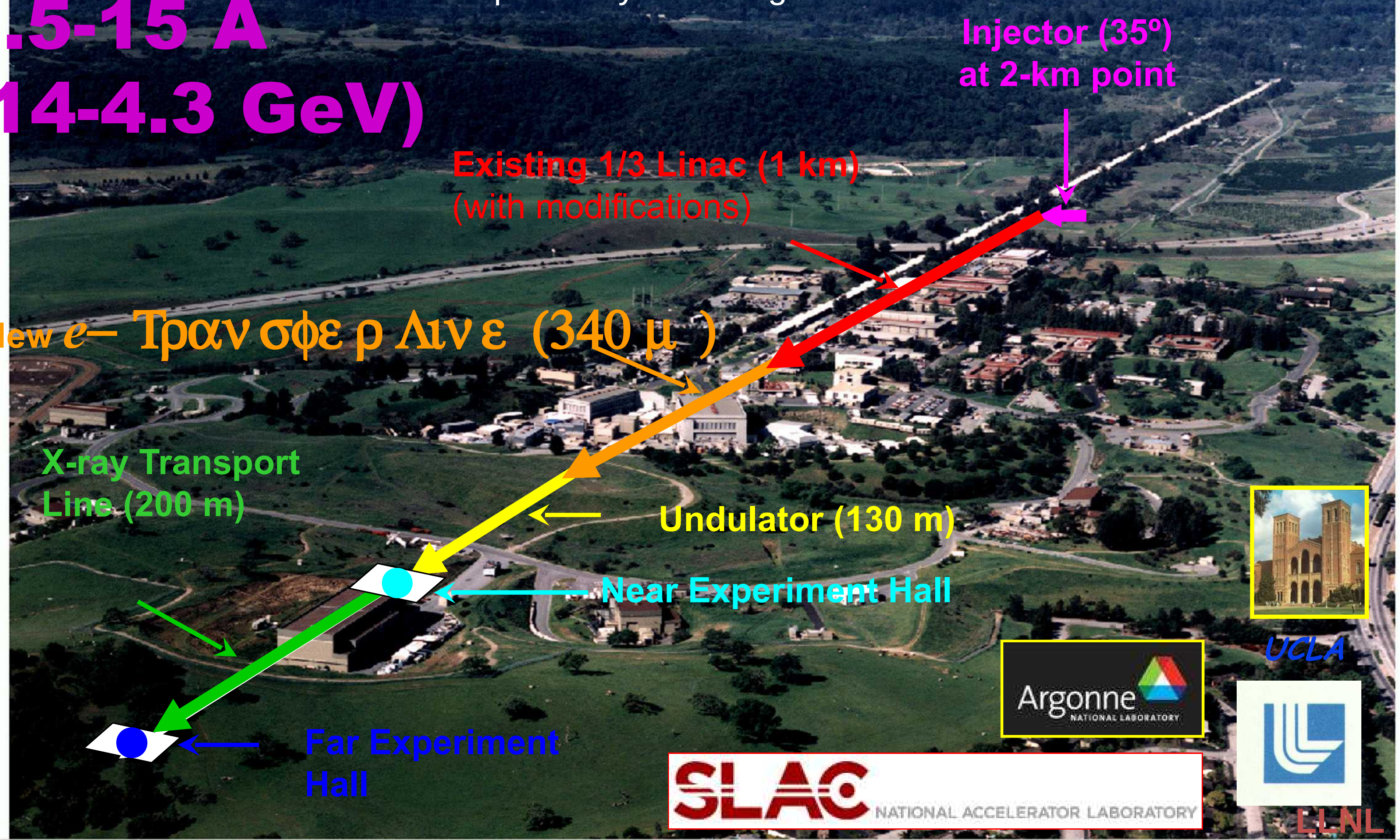
We should at least compete!!!...

- Compete with
- new ideas
- New solutions
- Smart design
- …
- But…!!!

Linac Coherent Light Source at *SLAC*

X-FEL based on last 1-km of existing 3-km linac

Proposed by C. Pellegrini in 1992



meters of FEL Undulator Insta

25 undulators installed... 8 more to

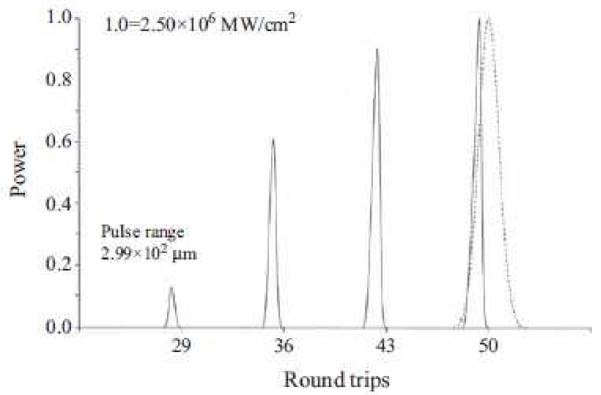
Far future start from now

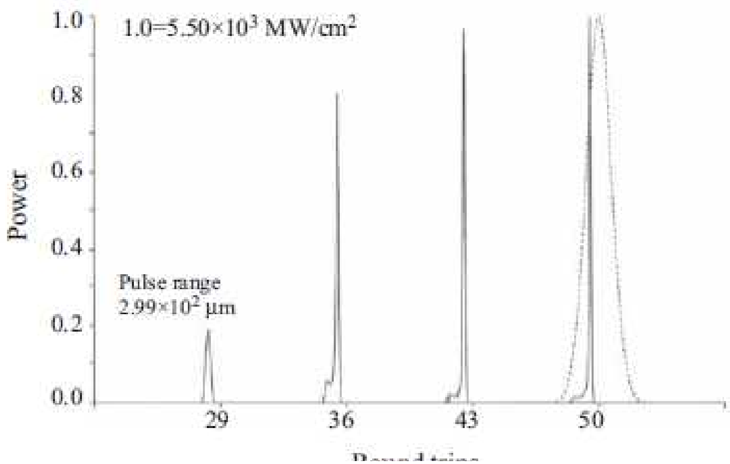
- Any choice we will do now will be the seed for the future and we cannot change things while they are progressing

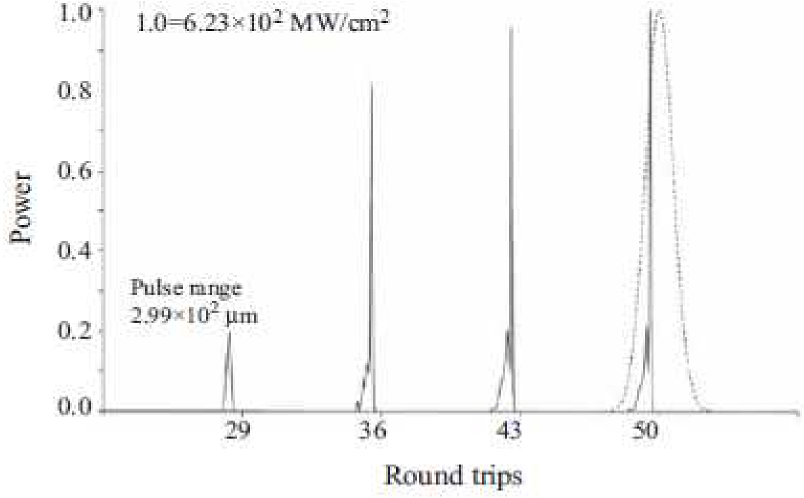
Mid-Term feature

- What choices
- Moderate beam energy <500 MeV
- Oscillator?
- New Gun(s)
- Different accelerating structures
- Mirror technology

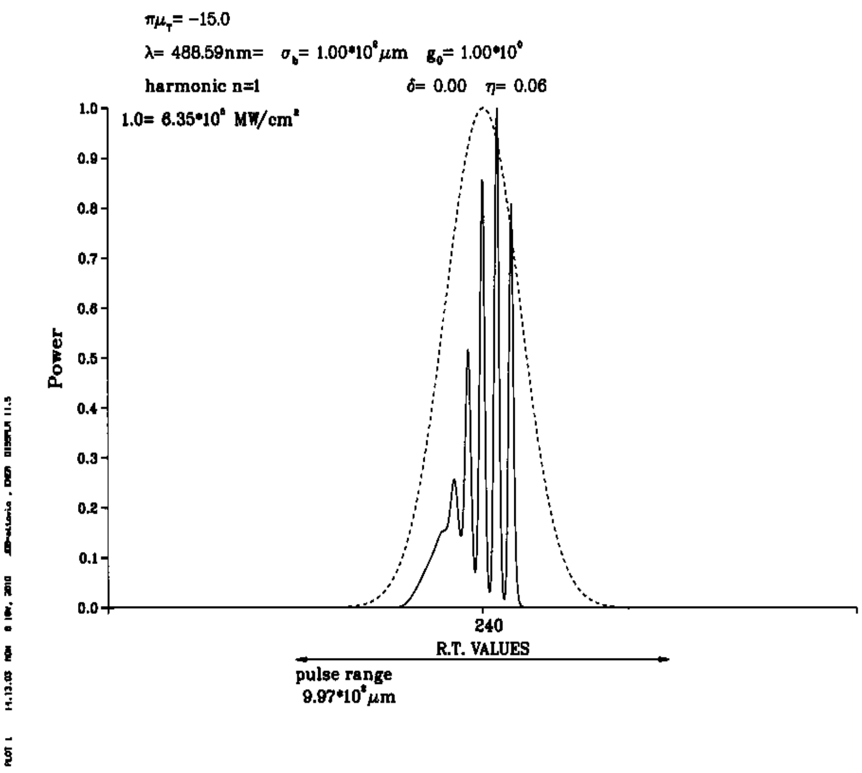
Pulse modelization





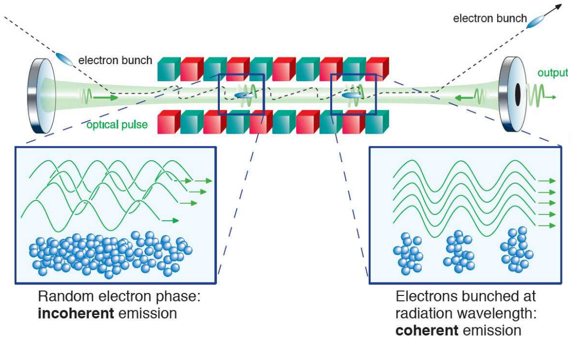


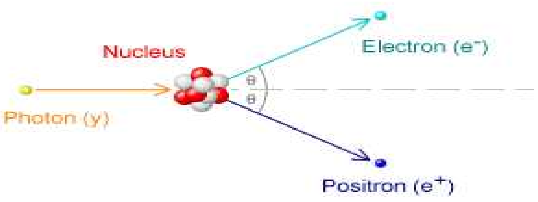
Comb-like structure

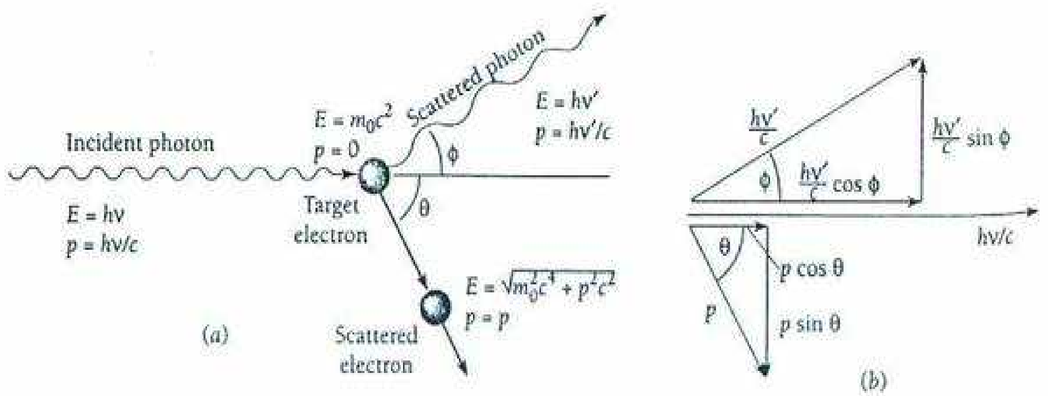


Intracavity Compton backscattering

$$\lambda_C \cong \frac{\lambda_F}{4\gamma^2} = \frac{\lambda_u}{8\gamma^4}(1+\frac{K^2}{2})$$







Monocromatic Gamma’s
HI “g”S (Danilo Babusci

Table 5
Parameters of high-flux, quasi CW HIγS operation

Parameter	Value	Comments
E-beam configuration	Symmetric two-bunch beam	
E-beam current (mA)	10–80	In two bunches
γ-ray energy, E_γ (MeV)		
With mirrors 1064 to 190 nm	1–84	Available with existing hardware
With 156 nm mirror	85–158	Require FEL and mirror development
Total flux (γ/s)		
(a) No-loss mode ($\leq$20 MeV)		
$E_\gamma = 1–3$ MeV	$5 \times 10^7–5 \times 10^8$ [a]	
$E_\gamma = 3–5$ MeV	$5 \times 10^8–1 \times 10^9$	
$E_\gamma = 5–10$ MeV	$1 \times 10^9–2 \times 10^9$	
$E_\gamma = 10–20$ MeV	$2 \times 10^9–3 \times 10^9$	
(b) Loss mode (>20 MeV)		
$E_\gamma = 21–60$ MeV	$>2 \times 10^8$ [b]	
$E_\gamma = 61–84$ MeV	$>1 \times 10^8$ [b]	190 nm mirror
$E_\gamma = 85–158$ MeV	$>1 \times 10^8$ [c]	156 nm mirror
Linear and circular polarization	>95%	Depending on collimator size

[a] High flux horizontally polarized γ-ray beams can be produced by the OK-4 FEL. The circularly polarized γ-ray flux is low due to the dynamic impact of OK-5 wigglers.
[b] The flux is currently limited by the capability of sustaining a high intracavity power by the FEL mirrors.
[c] Radiation resistive FEL mirrors at 156 nm need to be developed and the FEL wigglers need to be powered at 4000 A.

Gamma appl.

- **Nuclear Astrophysics**
- Reaction g + 16O → alfa + 12C (8-10 MeV)
- **Nuclear Physics**
- Drell Hearn Gerasimov Sum rule (gamma deuterium)

$$I^{GDH} = \int_{\omega_{th}}^{\infty} (\sigma_P(\omega) - \sigma_A(\omega)) \frac{d\omega}{\omega}$$

$$= 4\pi^2 e^2 \frac{\kappa^2}{M^2} S,$$

…

- Deuterium spin polarizability

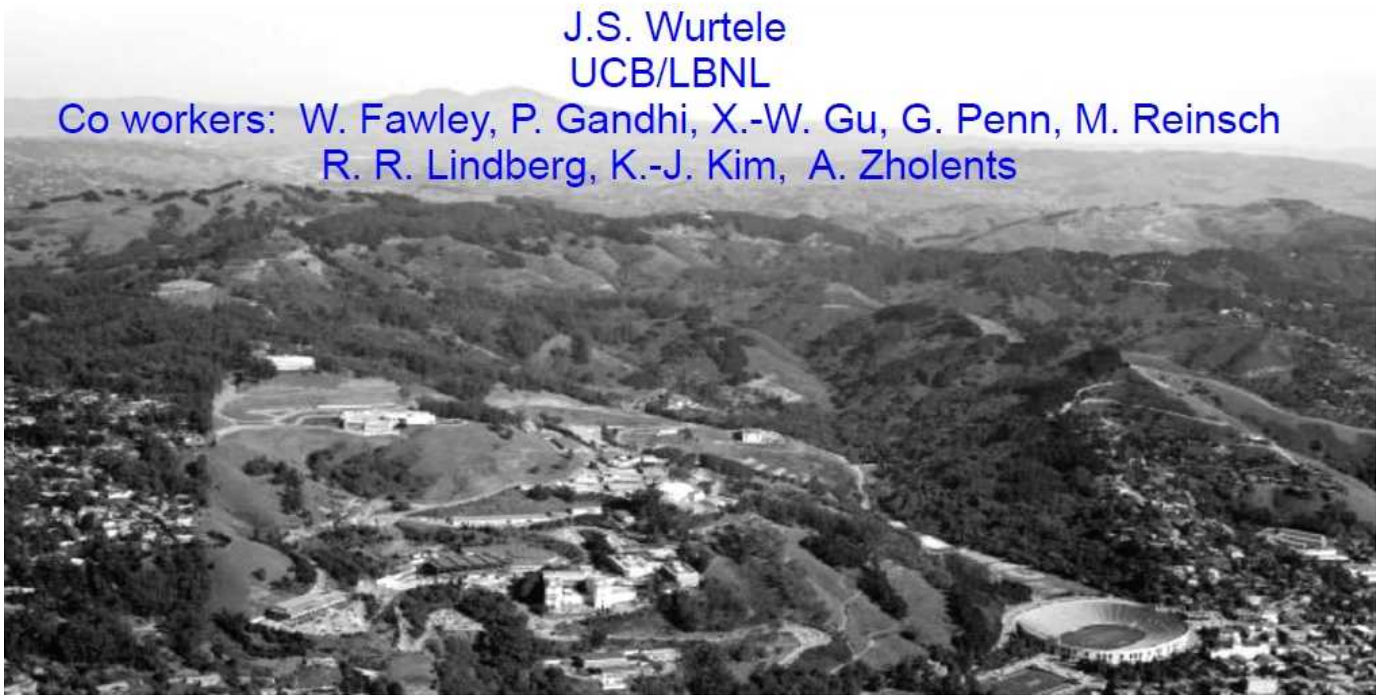
$$\gamma_0 = \frac{-1}{8\pi^2}\int_{\omega_{th}}^{\infty}(\sigma_P(\omega) - \sigma_A(\omega))\frac{d\omega}{\omega^3}.$$

- Neutron Spin polarizability…
- Towards gamma ray laser
- Dattoli, Giannessi, Sabia, Surrenti
- FEL 2010

Compete with new ideas… Nemo prŏphēta in Patria

Soft X-ray FEL Oscillators

32nd International Free Electron Laser Conference
Malmo, Sweden



Oscillator-Amplifier scheme
ECHO SCHEME

F

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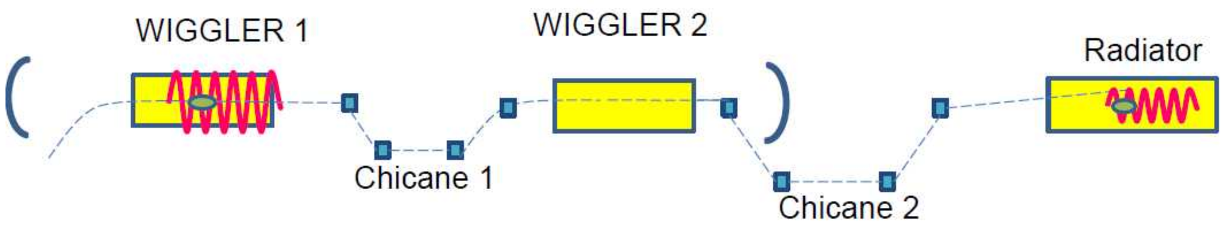
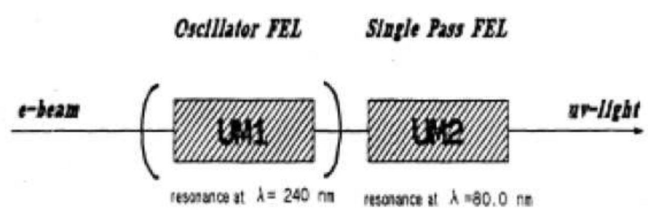
Oscillator Bunching and Radiator



Chicane 1 acts to reduce bunching and lower intracavity power
Chicane 2 bunches at desired harmonic for radiator

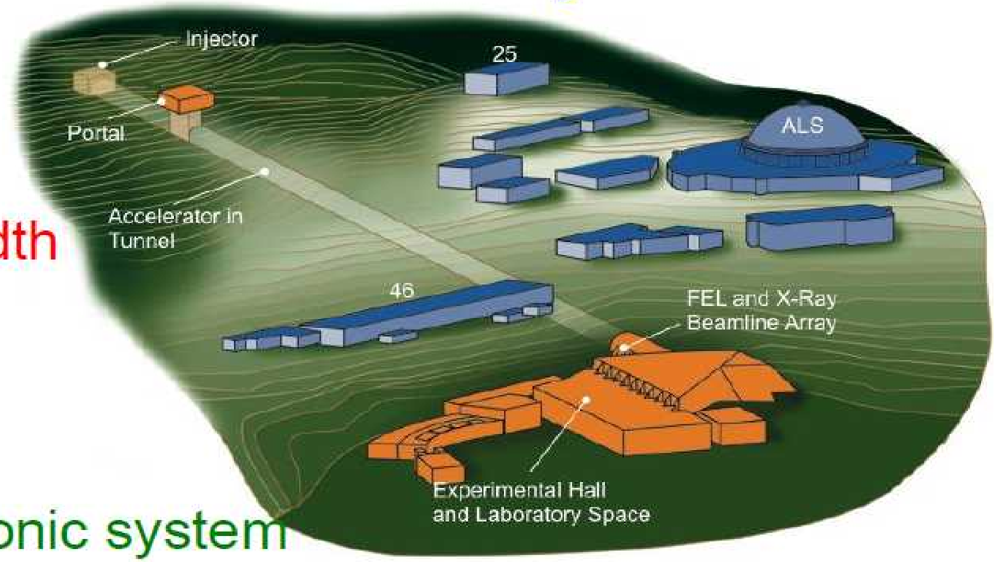


Barbini et al 1990 BNL 52273

Later with optical klystron configuration [Dattoli et al 2004]

A coherent CW soft x-ray laser

Next Generation Light Source at LBNL



- 10 eV - 1 keV range

Tunability and time-bandwidth limited pulses <=1ps

High repetition rate

- Seeding by laser,
  - *OR* Oscillator-driven harmonic system

- High average power – below damage threshold peak power for low scattering rate experiments

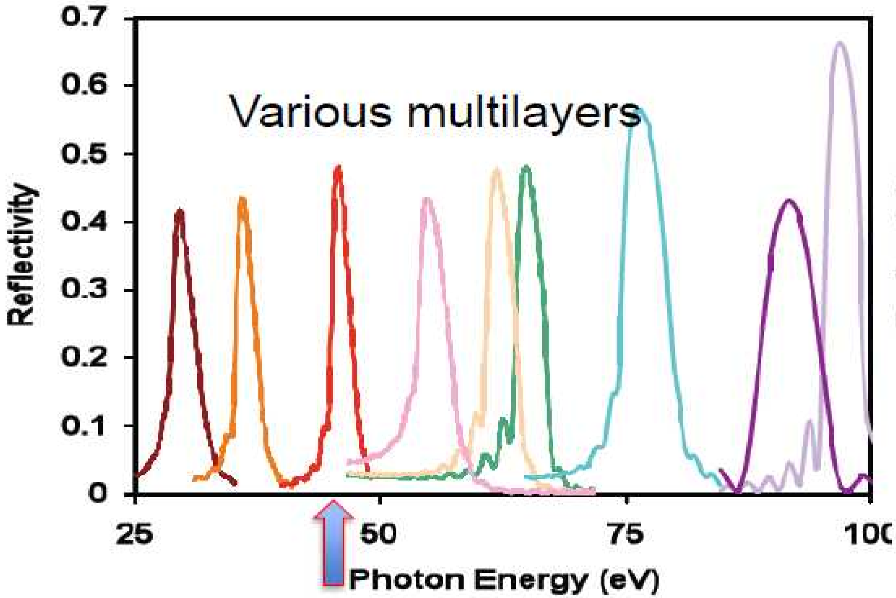
What can we do in the soft X-ray regime?

- Cannot use Bragg reflection in the soft X-ray regime
- Reflectivity at 1nm is poor for layered dielectrics
- High repetition rate sources at 1nm are not available
- Short bunch (single SASE spike): we consider longer bunches
- layered dielectric mirrors good for 13.4 nm and longer wavelengths

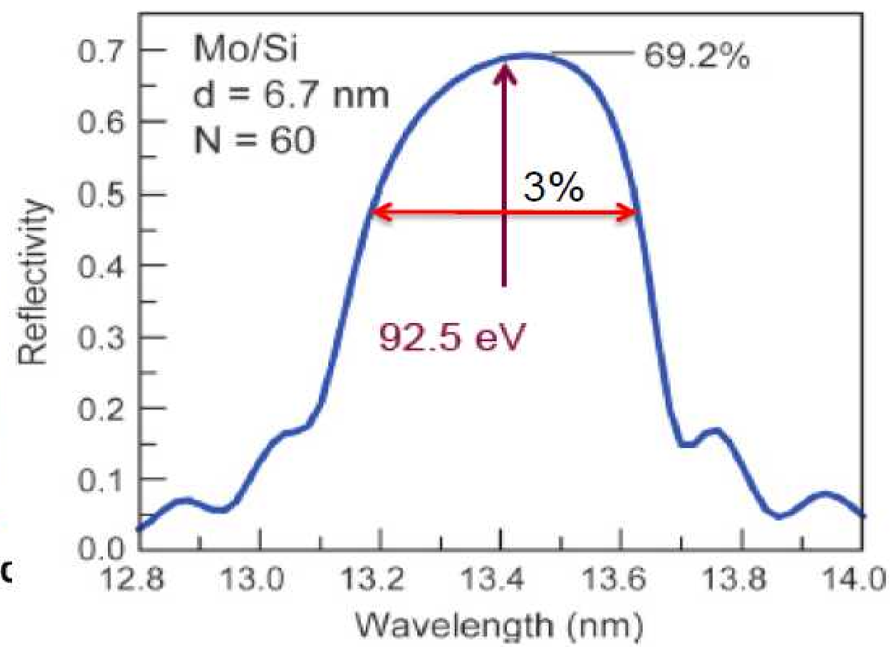
→ ECHO scheme for high harmonics and tuning

→ Source can be FEL itself using an oscillator

High reflectivity multilayer mirrors



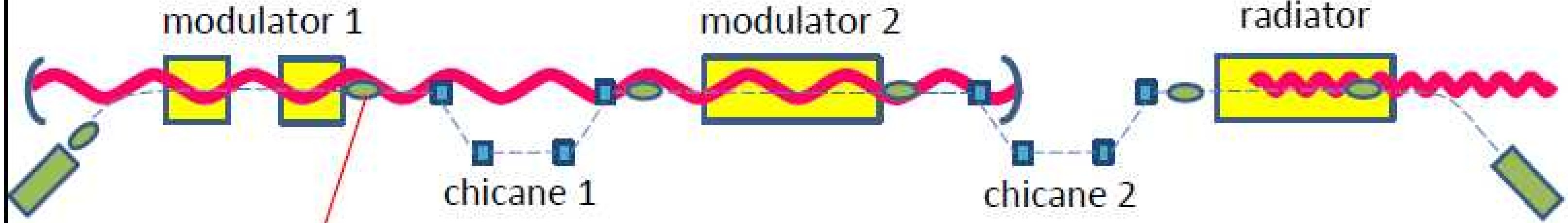
The gold standard for soft x-ray mirrors



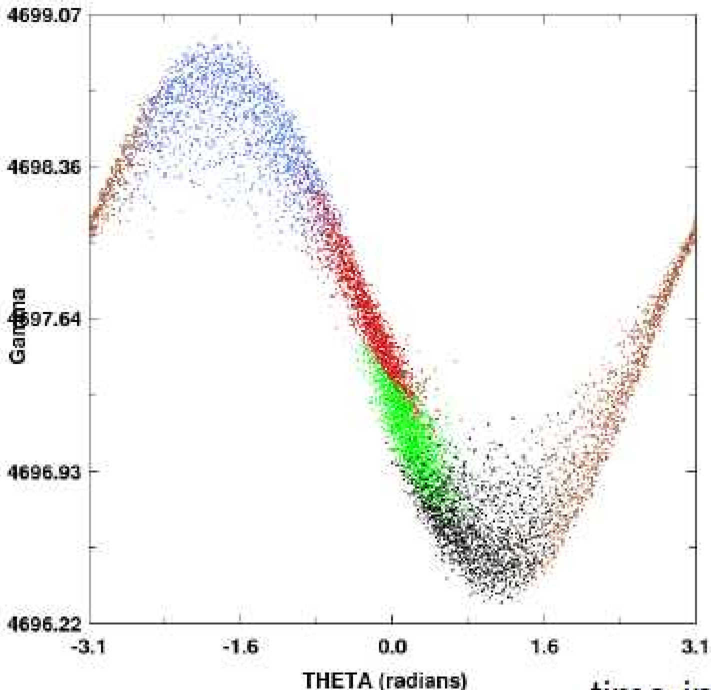
Need to operate at high harmonic for full tunability

Courtesy Eric Gulickson and David Attwood, LBNL

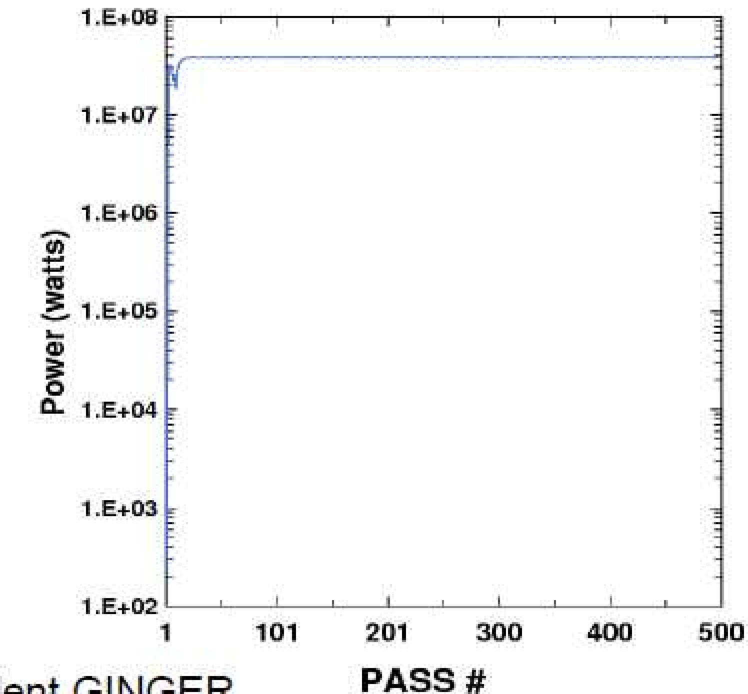
ECHO Oscillator Configuration: single cavity 13nm



Phase space end of modulator 1



Output power in oscillator



time-independent GINGER

What do we need, to avoid the missing of this last chance?

- Constitution of the Consortium
- Clear Choices
- Good Governance (wide and widely accepted)
- Open discussions
- Competence
- Scientific perspectives
- Long term Planes…
- Otherwhise it is better to stop now!!!