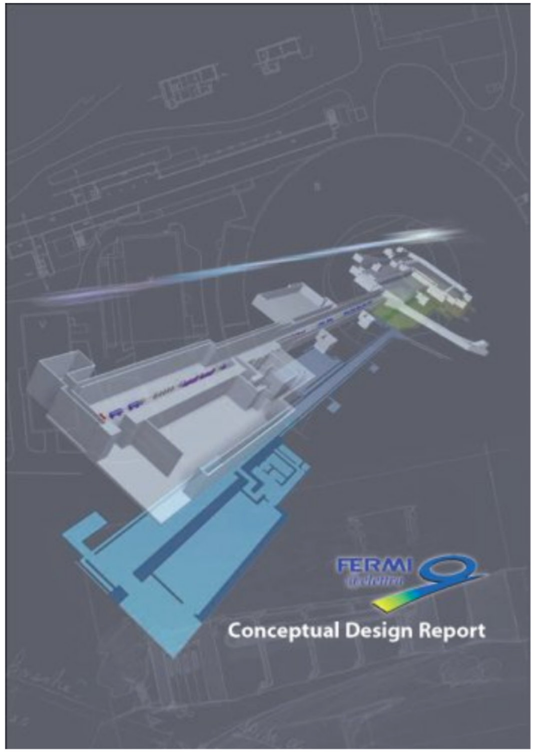
FLASH2020+ project overview

Enrico Allaria, DESY

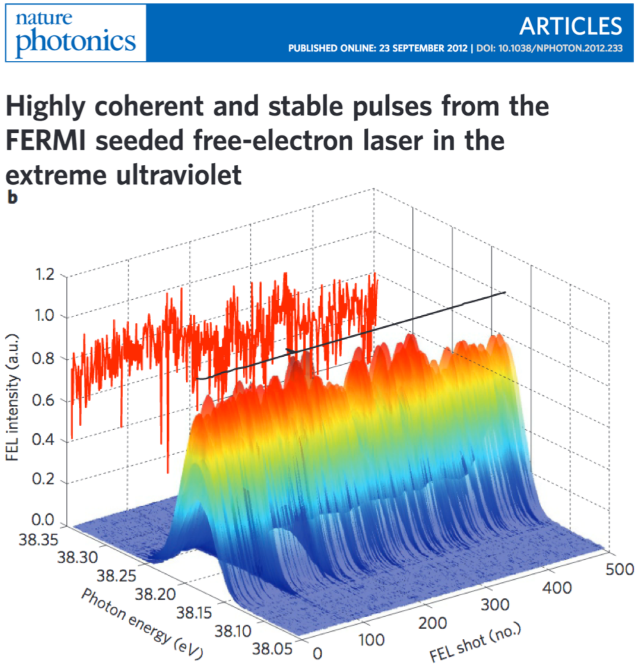
Outline

- Introduction
- Free Electron Laser and seeding
- FLASH and FLASH 2020+

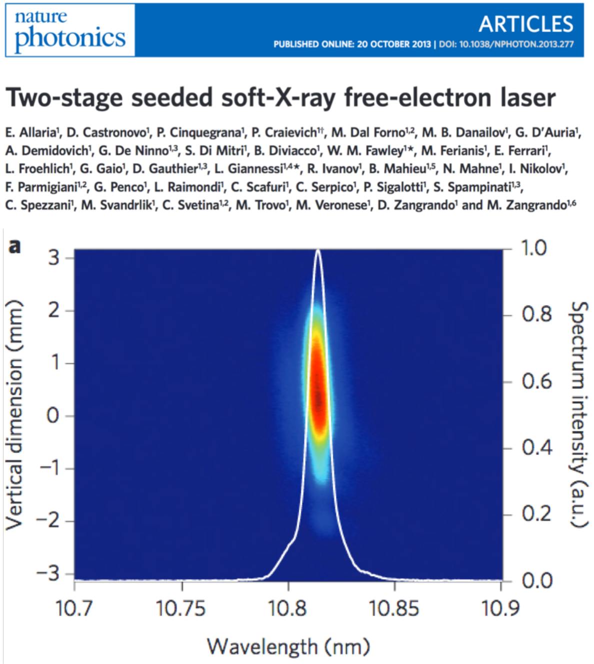
Introduction



I joined the FERMI team at Elettra – Sincrotrone Trieste in 2005 during the phase leading to the FERMI Conceptual Design Report

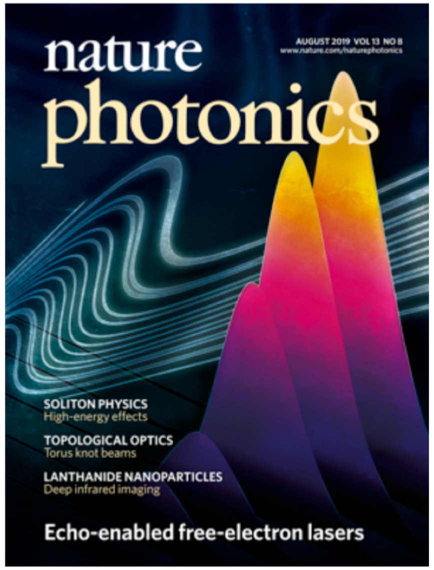


Since 2009 leading the FEL studies and activities at FERMI. Member of the commissioning team.



Since 2012 member of FERMI steering team in charge of operation.

In 2018 responsible for the Echo Enhanced Harmonic Generation (EEHG) experiment at FERMI

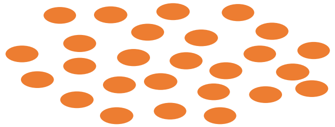


Free Electron Laser: basic ingredients

FLASH 2020+

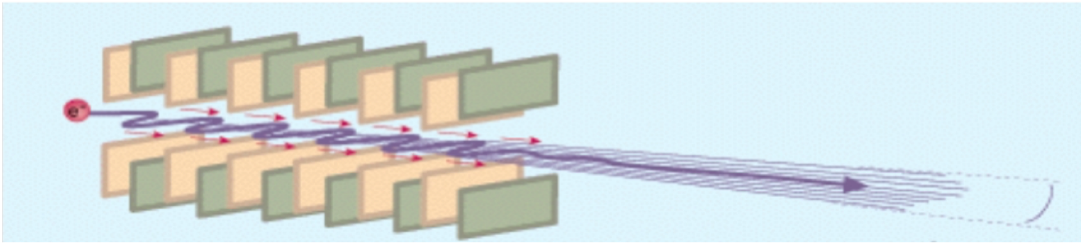
A **Free-Electron Laser** is a light source exploiting the induced coherent emission of a relativistic electron beam "guided" by the periodic and static magnetic field produced by an undulator.

1) Relativistic **electron beam**



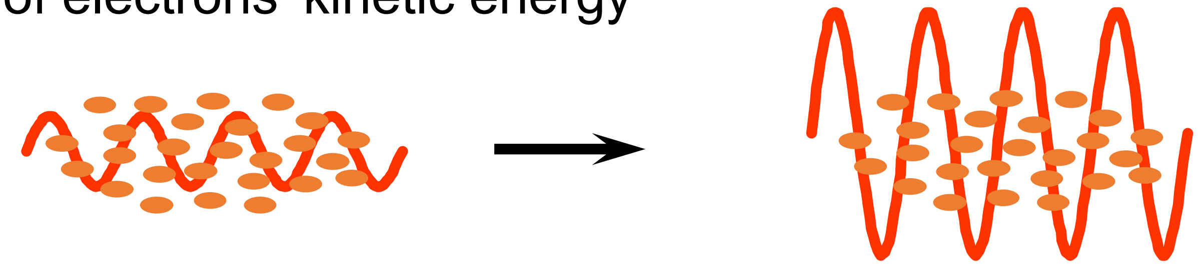
Energy (γ)
Current (I)
Emittance (ε)
Energy spread ($\delta\gamma$)
Dimensions (σ)

2) Undulator



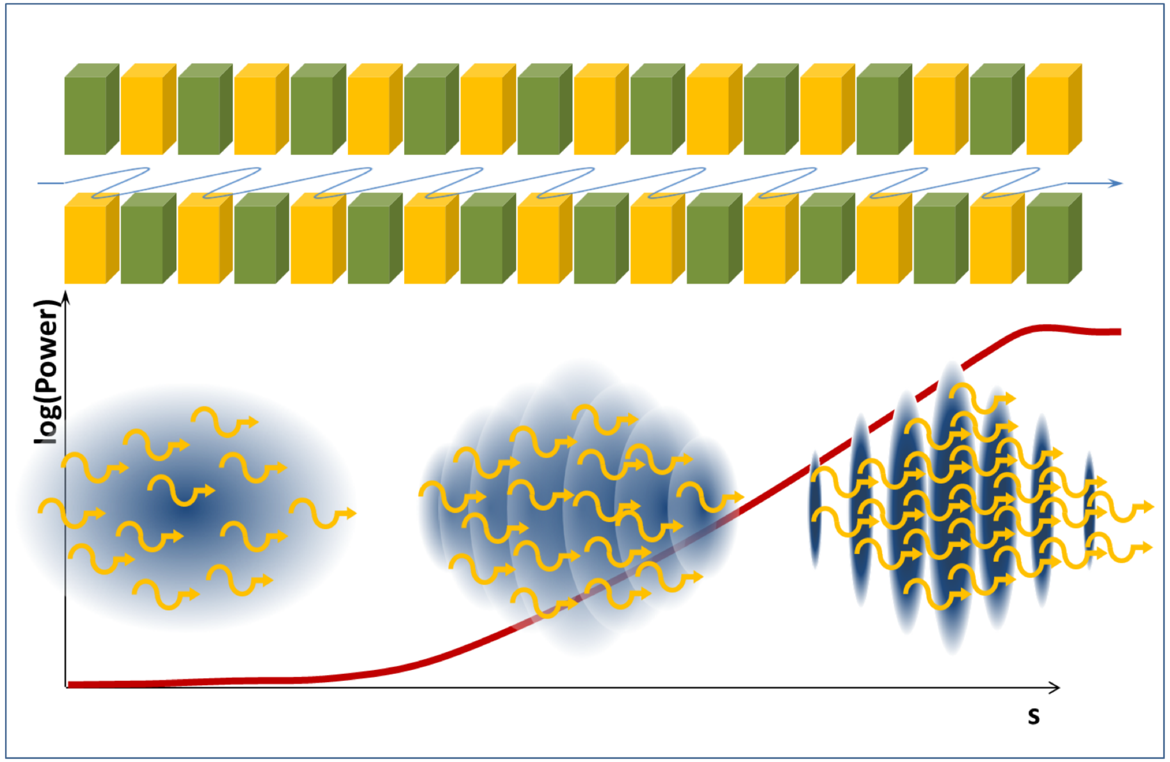
Magnetic period (λ_w)
Magnetic strength (K)
Undulator length (L)

3) **Electromagnetic field** co-propagating with the electron beam and **getting amplified** to the detriment of electrons' kinetic energy



Wavelength (λ)
Power (P)

Free Electron Lasers: amplification



When required condition are satisfied incoming radiation is amplified.

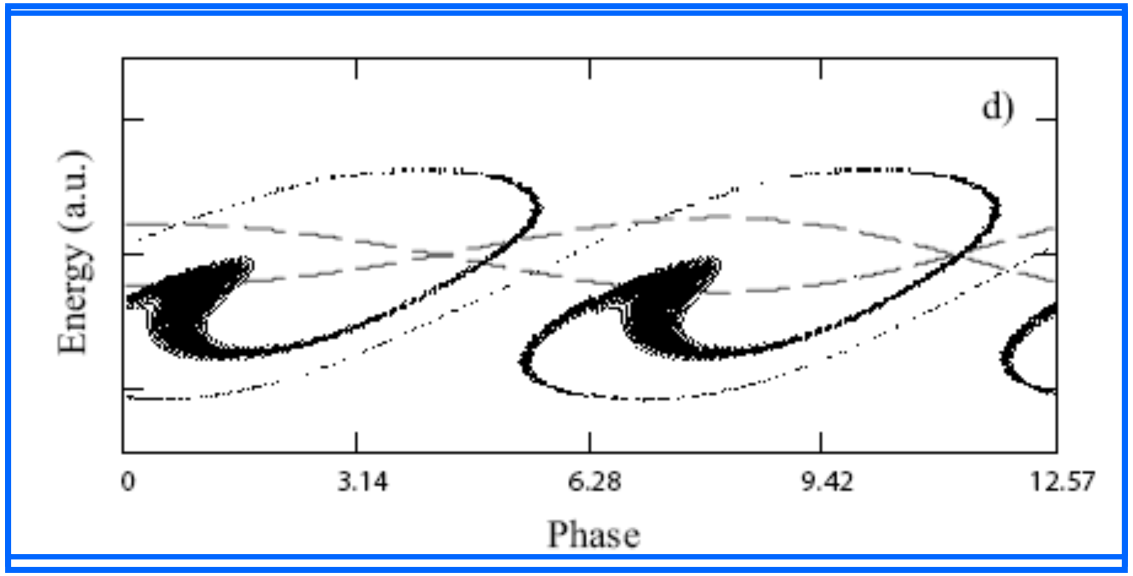
Coherent emission is achieved and very high power X-ray pulses can be produced.

$$E_{\text{field}} \propto \sqrt{N_{ele}} \xrightarrow{\text{coherent}} E_{\text{field}} \propto N_{ele}$$

Radiation and electron beam dynamics in FEL are highly non-linear and complex.

Control of all the parameters is crucial for a proper control of the produced radiation.

Electron evolution during FEL amplification

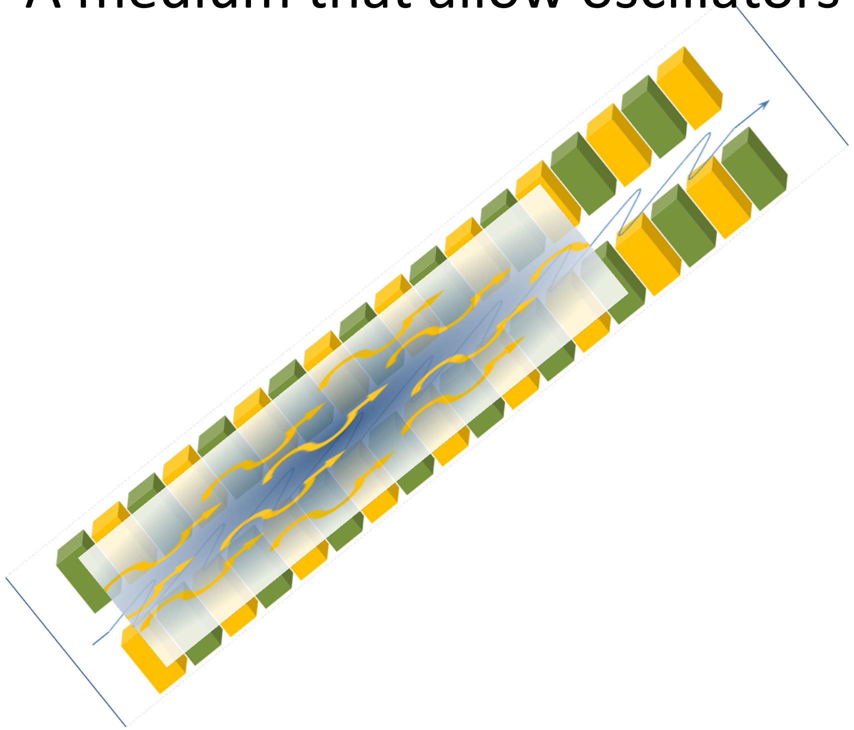


FEL in real life

FLASH 2020+

To get FEL one need a large number of oscillators

A medium that allow oscillators to interact one with the other



from youtube

Passage of the oscillator in the medium induces a synchronous oscillation and amplification

The same process occurred “undesired” at the inauguration day of the Millennium bridge in London **producing the first human SASE.**

Seeding the instability

In the case of the SASE highly dense electron beam is required and there are limited options to control the field parameters.

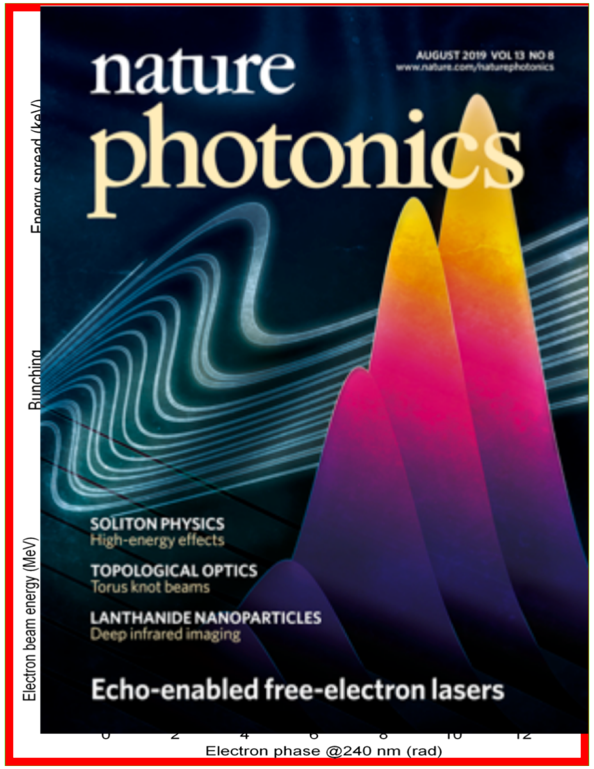
By controlling few crucial oscillators one can have a full control of the field oscillations.

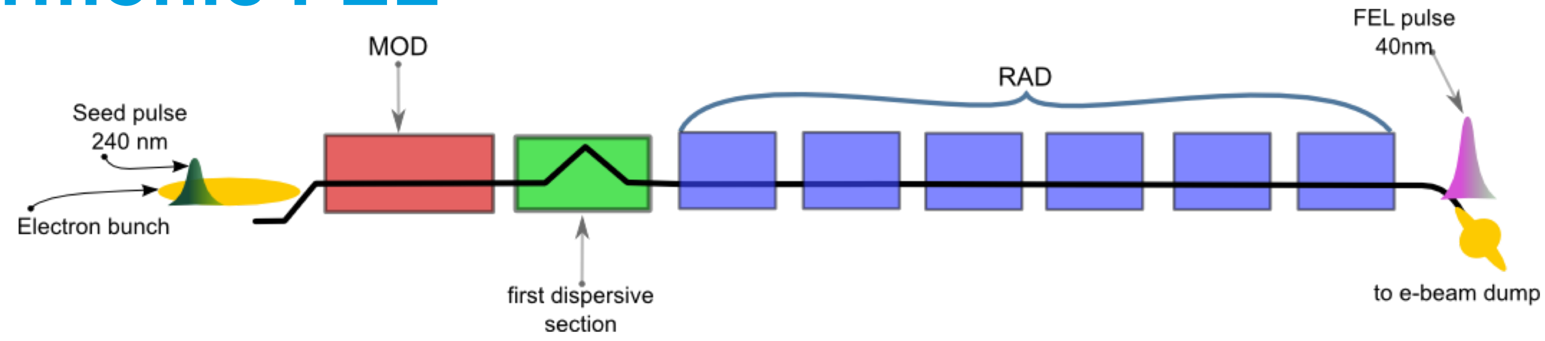
from youtube

By injecting a signal into the system one has a better control on the instability and FEL pulse properties.

Controlling electron at nm scale is not as easy as controlling people over a bridge.

FEL: seeded harmonic FEL

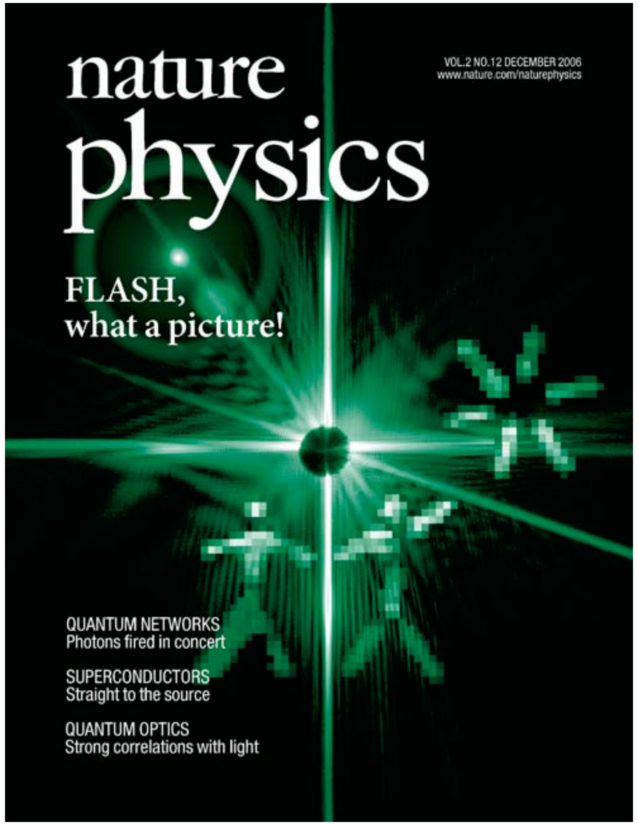


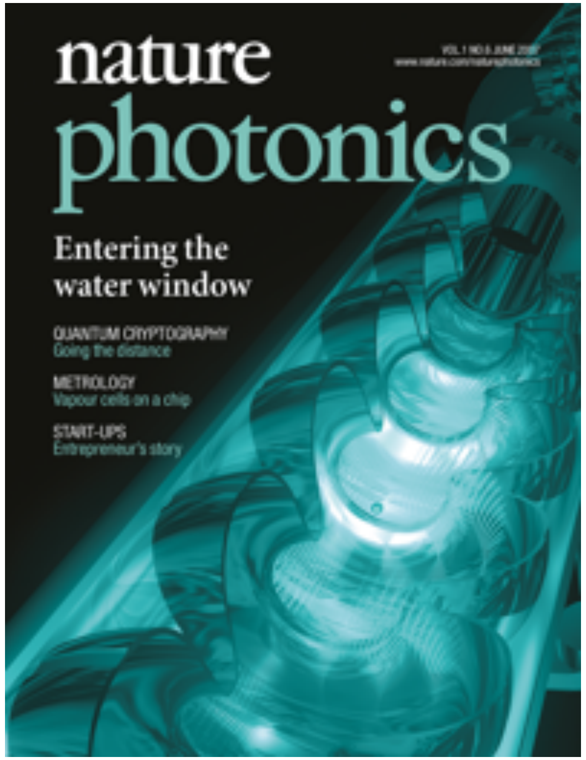


- Control of electron with nm resolution is done using the interaction between an external optical laser and the electron beam. Periodic modulation of the electron beam energy is produced.
- In a dispersive region, energy modulation is converted into density modulation with nm resolution.
- Coherent bunching produces coherent emission in the radiator at the desired harmonic that is then amplified.
- This schemes has been successfully used at FERMI for coherent at tens of nm.

FLASH has pioneered the X-ray development occurred over the past 15 years.

All existing FEL facilities have learned from FLASH.



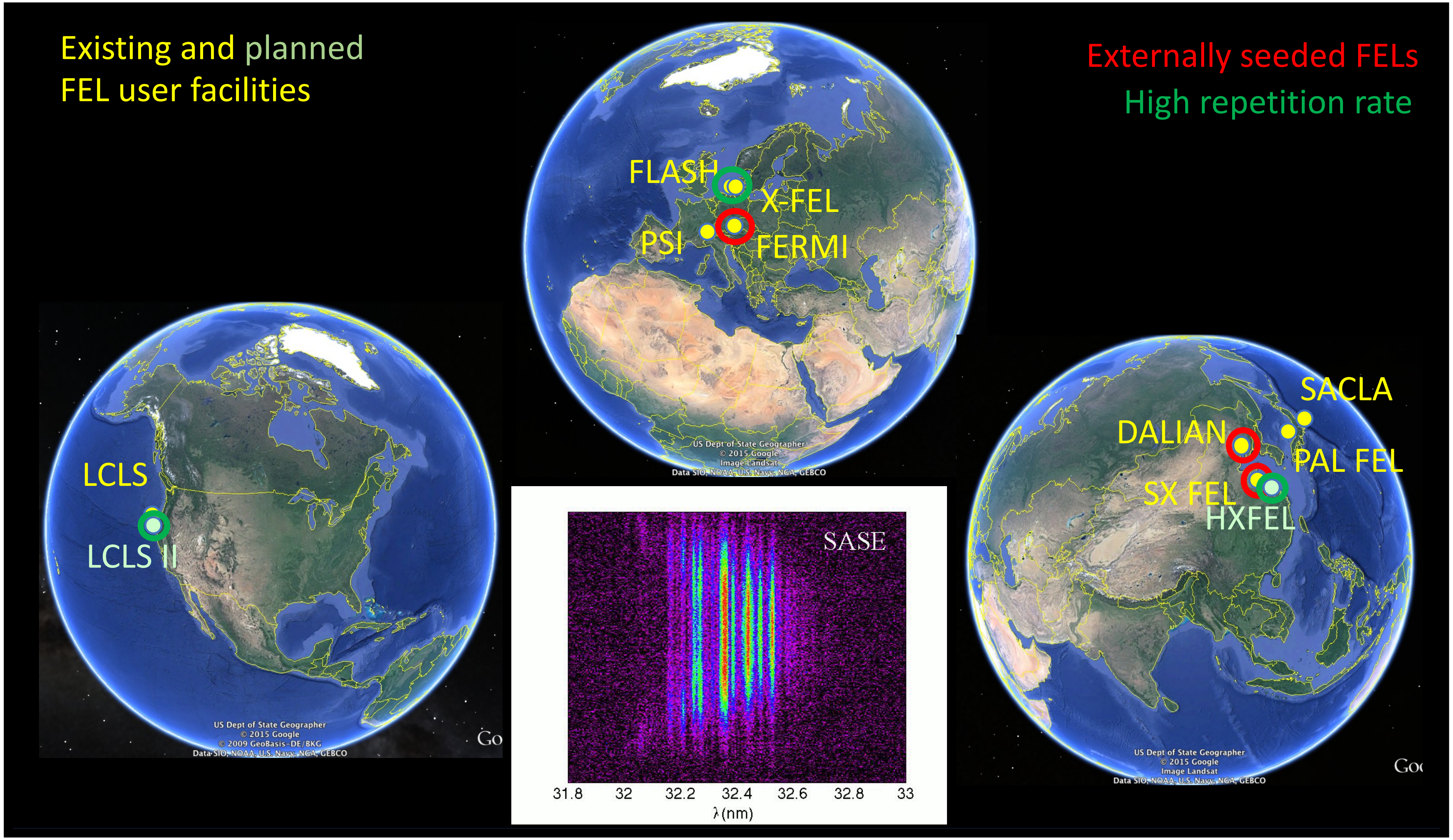


New options became available and of interest for future development.

FLASH is in the condition to exploit this and lead again the FEL and X-ray progress.

Free Electron Lasers user facilities

FLASH 2020+



FLASH 2020+ Conceptual Design Report

A concept to secure a bright future for the next decade

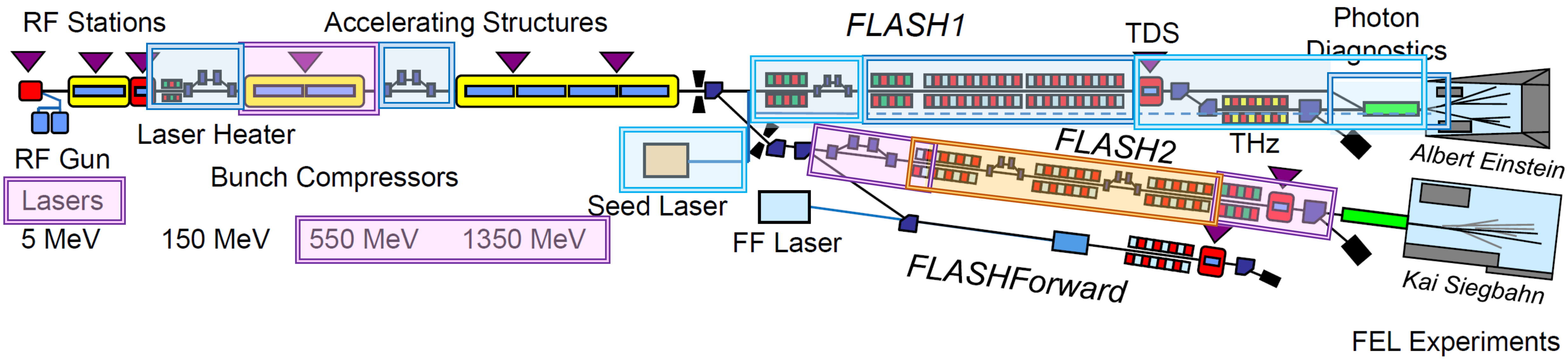
The CDR for FLASH2020+ has been completed under the supervision of Wilfried Wurth and approved by all DESY advisory committees.

- FLASH2020+ Conceptual Design Report (CDR) includes:
  - The science case
  - An upgrade of the accelerator
  - New undulators with variable gaps and polarization for FLASH1
  - Seeding at FLASH1 with high repetition rate (goal 1 MHz)
  - New configuration of magnet structures at FLASH2 for novel lasing concepts

FLASH2020+ will be executed in four phases

FLASH
2020+

Initial upgrades were started 3 years ago and funding for full project secured in 2019/2020



Phase 0
Energy upgrade
3rd BC (FLASH2)
TDS (FLASH2)
Injector Laser
Afterburner FLASH2

Phase 1
Variable gap undulators (FLASH1)
Pump-probe laser (FLASH1)
Laser heater in 1st BC
New 2nd bunch compressor (BC)

Phase 1+
High rep.rate seeding (FLASH1)
Photon diagnostics (FLASH1)

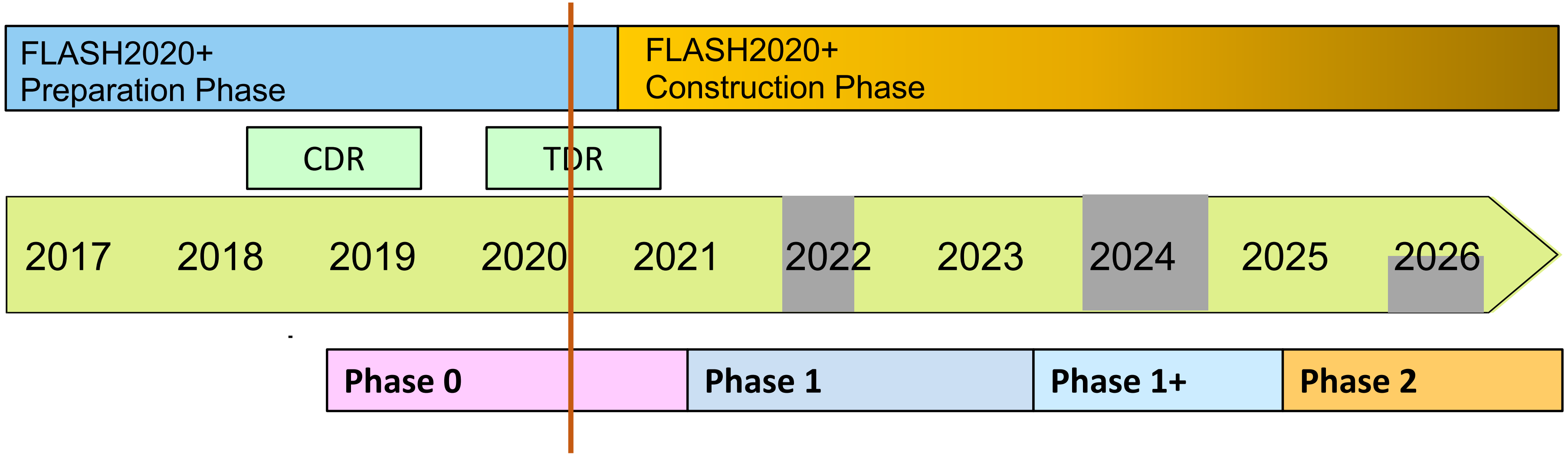
Phase 2
New variable gap undulators
Chicanes for new lasing concepts (FLASH2)

- The FLASH2020+ Project is endorsed by the DESY Scientific Council and the Foundation Council
- Part of DESY’s priority projects

Timeline

FLASH 2020+

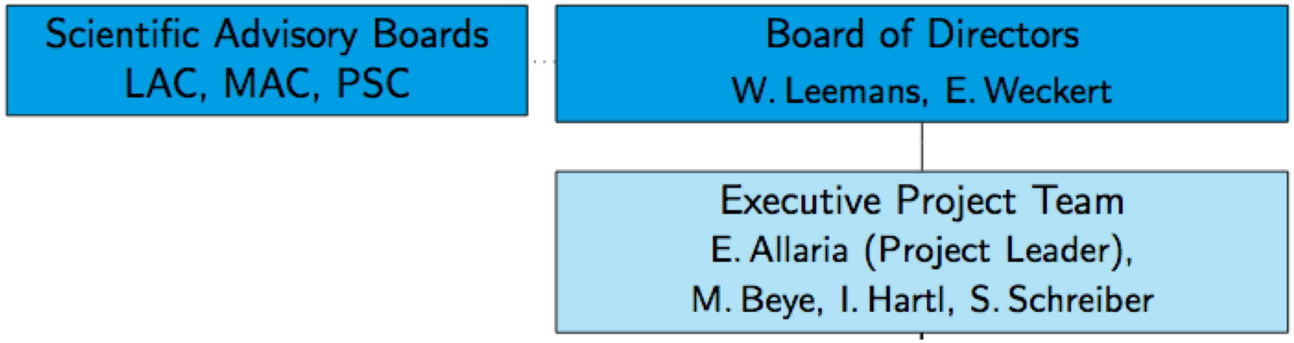
Most activities will be completed prior to main construction phase of PETRA IV



- **Phase 0:** Upgrade Linac (beam energy, new compression scheme, TDS, afterburner) – 2021/22
- **Phase 1:** New variable gap undulators FLASH1, laser heater, pump-probe laser FLASH1 – 2024
  + Upgrade FLASH1 Photon diagnostics, seeding with high repetition rate 100kHz+ – 2024
- **Phase 2:** New configuration of magnet structures at FLASH2 for novel lasing concepts – 2026

Project structure

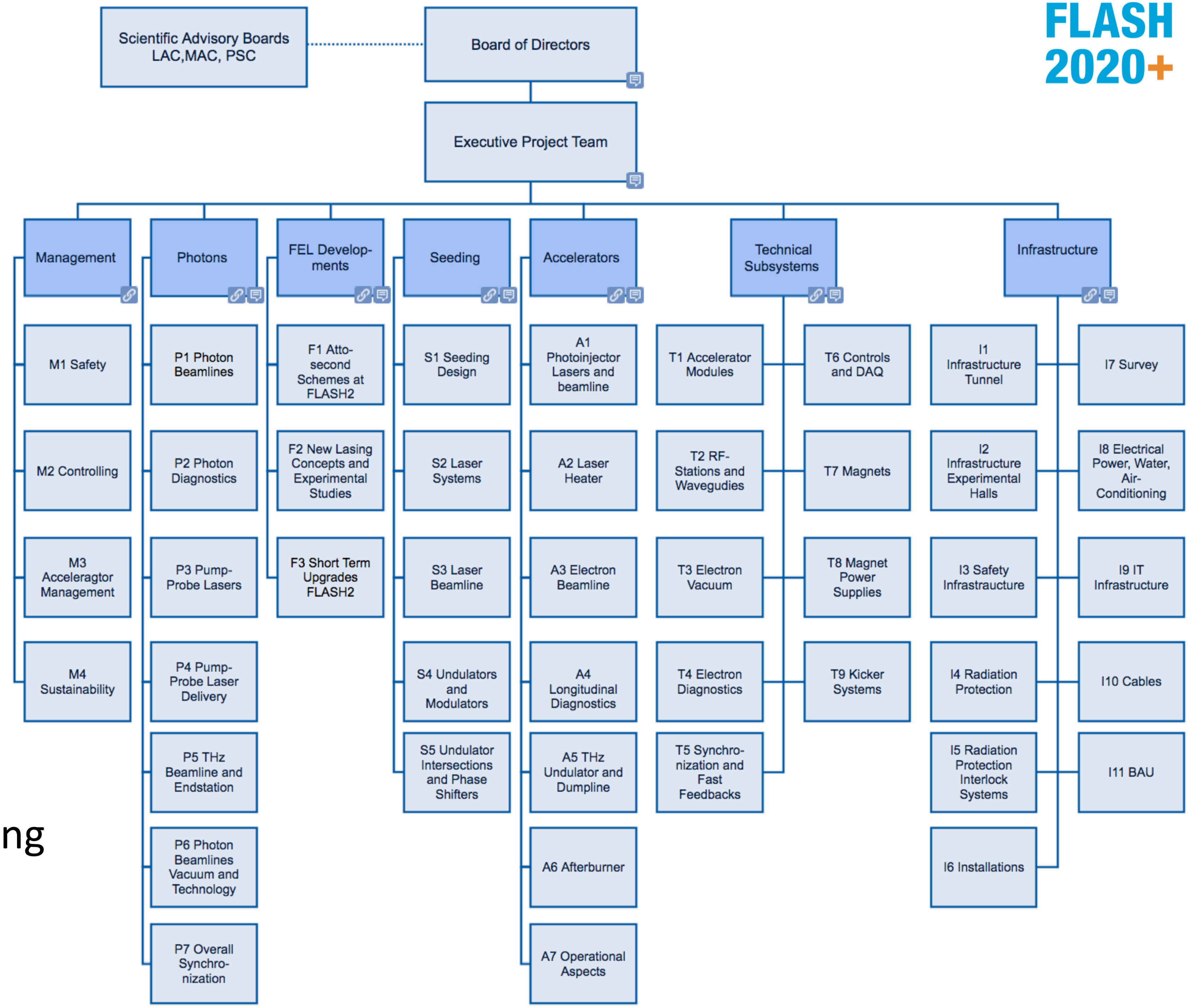
The FLASH2020+ project results from the decision of both **accelerator** and **photon science** divisions to invest in putting FLASH at the forefront of X-ray users facilities.



An Executive Project Team has been set up to manage and run the project.

Project structure

The project work is divided in seven pillars.

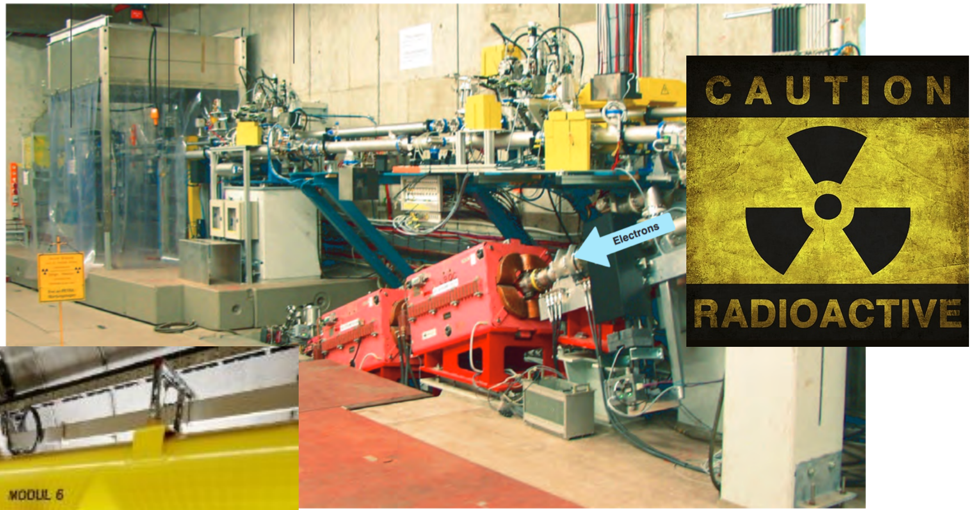


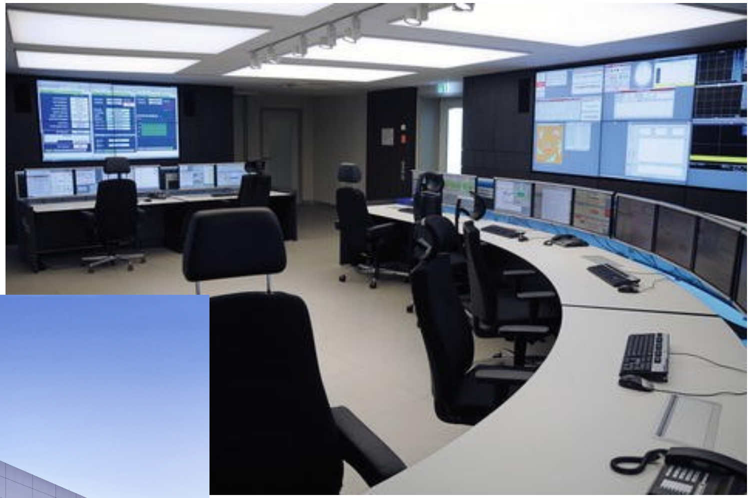
Each pillar has a leader monitoring corresponding work packages.

Infrastructure

J. Müller-Dieckmann, O. Rasmussen

- I1 Infrastructure Tunnel
- I2 Infrastructure Experimental Halls
- I3 Safety Infrastructure
- I4 Radiation Protection
- I5 Radiation Protection Interlock
- I6 Installations
- I7 Survey
- I8 Electrical Power, Water, Air Conditioning
- I9 IT-Infrastructure
- I10 Cables
- I11 BAU



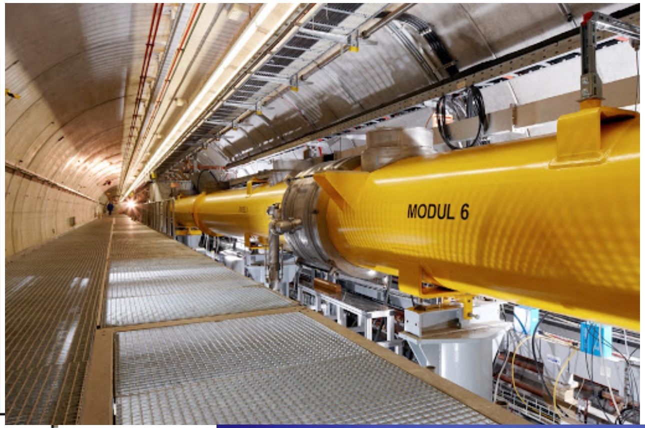


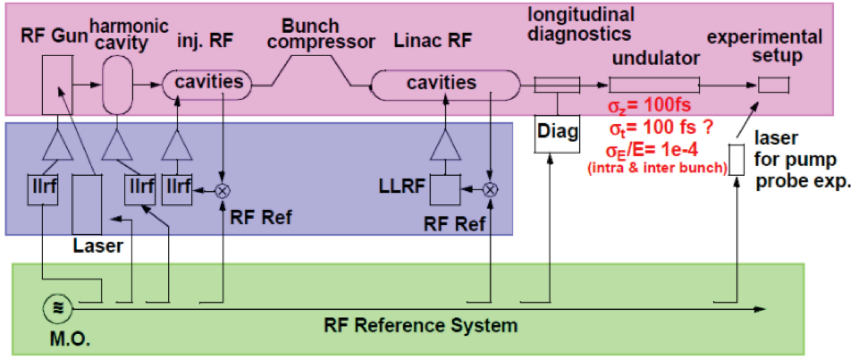
Technical Subsystems

C. Grün

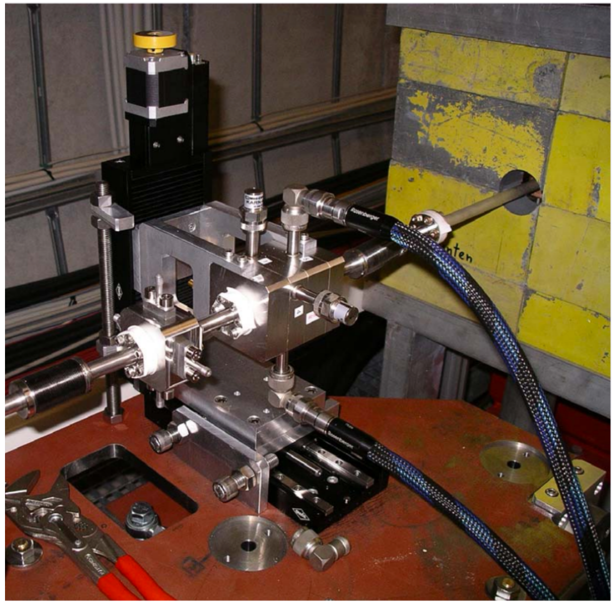
- T1 Accelerator Modules
- T2 RF-Stations and Waveguides
- T3 Electron Vacuum
- T4 Electron Diagnostics
- T5 Synchronization and Fast Feedbacks
- T6 Controls and DAQ
- T7 Magnets
- T8 Magnet power supplies
- T9 Kicker Systems

> Normal conducting 1.3 GHz RF gun
> Ce_2Te cathode
> Nd:YLF based ps photocathode laser





@K. Czuba

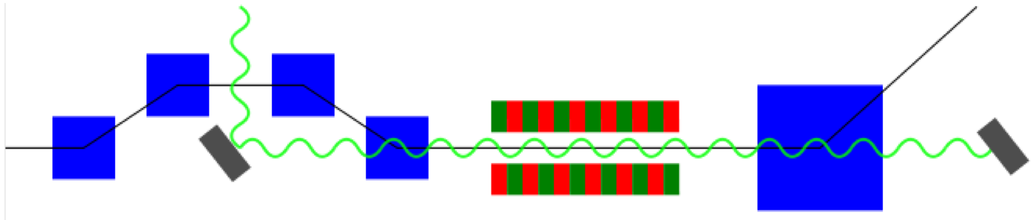


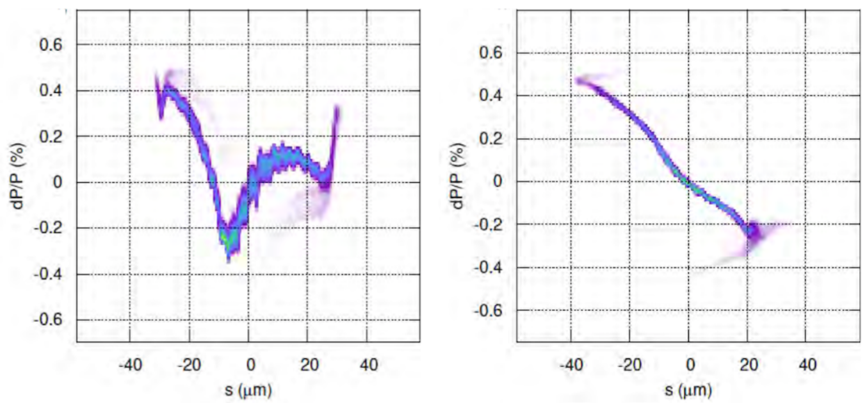
Accelerator

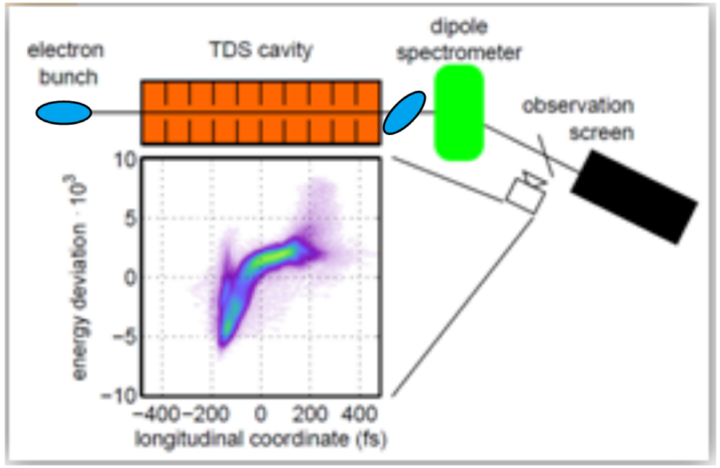
FLASH 2020+

J. Zemella

- A1 Photoinjector Lasers and beamline
- A2 Laser Heater
- A3 Electron Beamline
- A4 Longitudinal Diagnostic
- A5 THz Undulator and Dumpline
- A6 Afterburner
- A7 Operational aspects







Seeding

FLASH 2020+

L. Schaper

- S1 Seeding Design
- S2 Laser Systems
- S3 Laser Beamline
- S4 Undulators and Modulators
- S5 Undulator Intersection and phase shifters

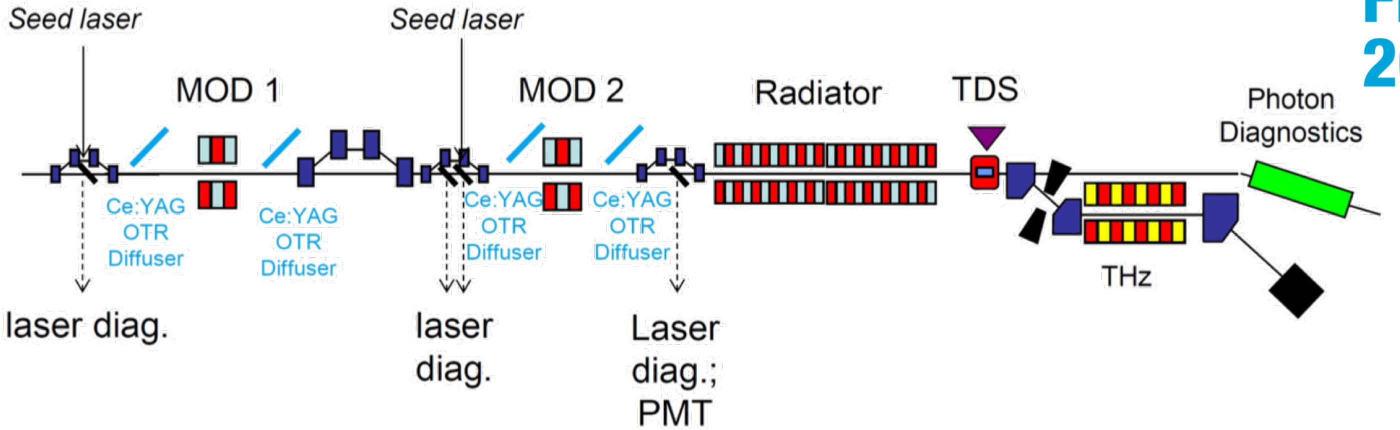
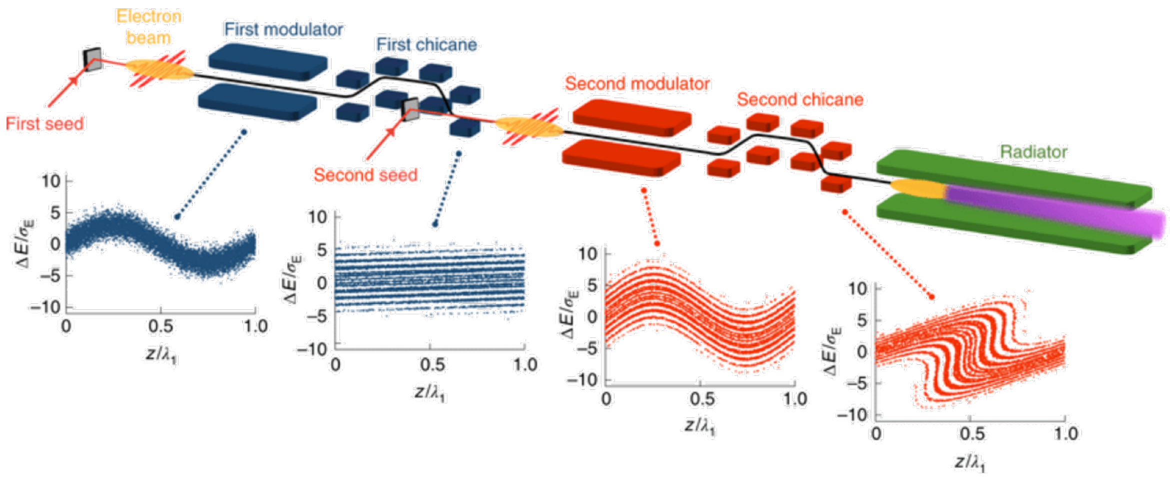
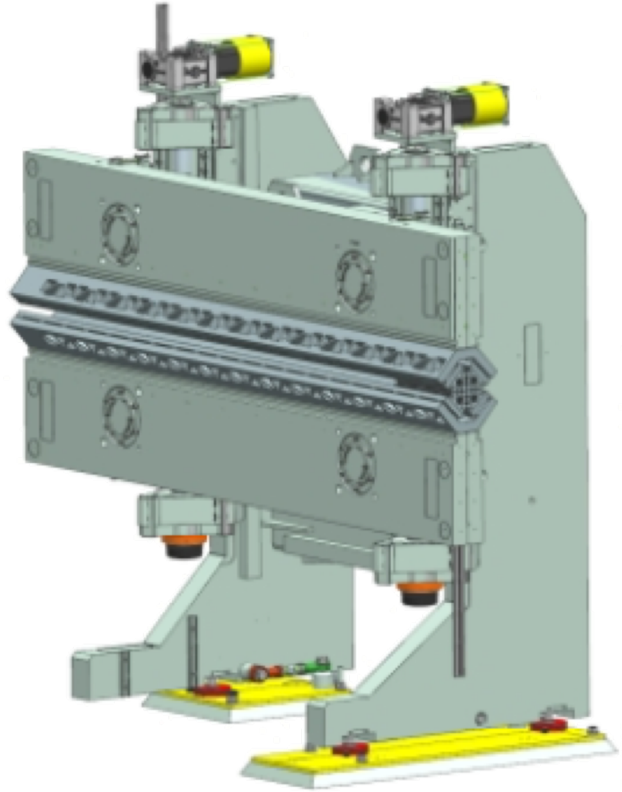


Figure 4.7: *Schematic layout of a seeding section implementing EEHG seeding. From the first modulator on, the quadrupoles (not shown) need to be on quadrupole movers for kick-free operation.*





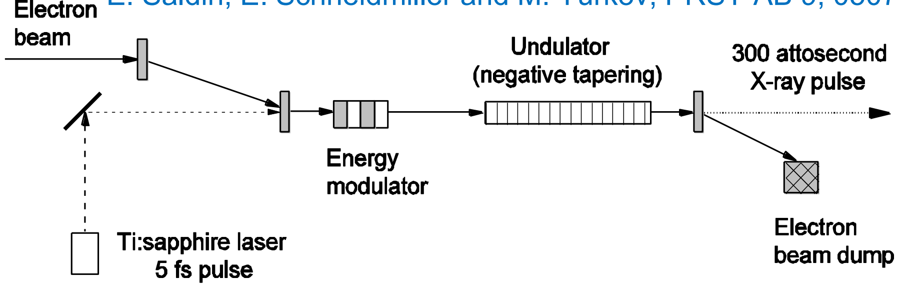
FEL development

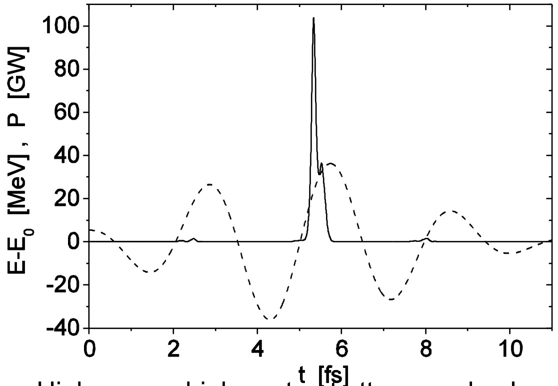
FLASH 2020+

E. Schneidmiller, M. Yurkov

- F1 Attosecond Schemes at FLASH2
- F2 New Lasing Concepts and Experimental Studies
- F3 Short Term Upgrades FLASH2

E. Saldin, E. Schneidmiller and M. Yurkov, PRST-AB 9, 050702 (2006)





High power, high contrast attosecond pulses

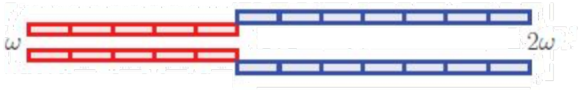


Figure 9. Scheme of frequency doubler operation.

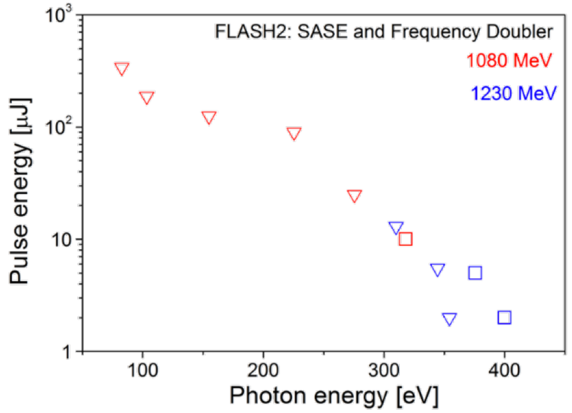
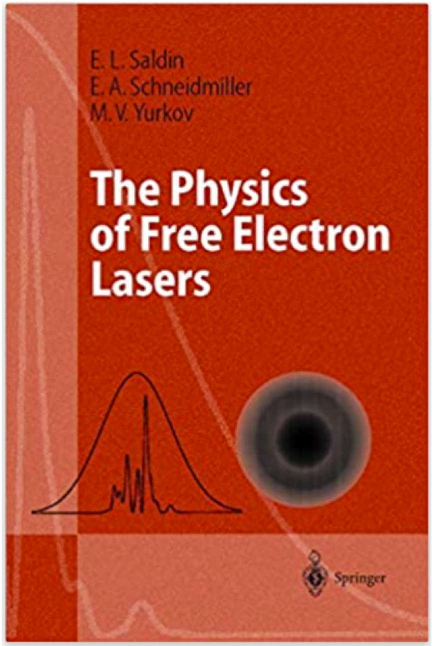


Figure 10. Setting the first part of the undulator to twice the final wavelength (squares), the final wavelength that can be reached with reasonable pulse energy is much shorter and has more stable intensity than with setting all undulators to the same resonant wavelength (triangles).



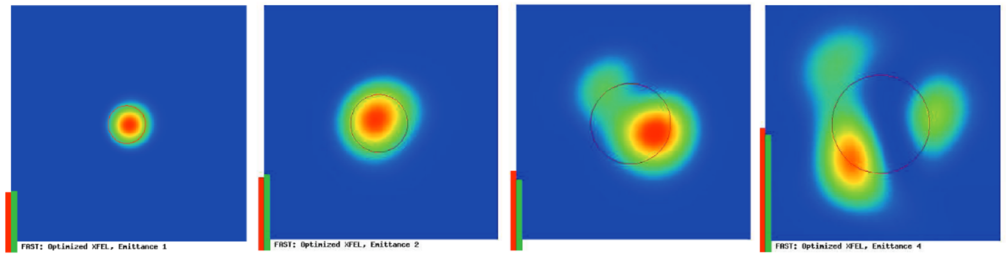
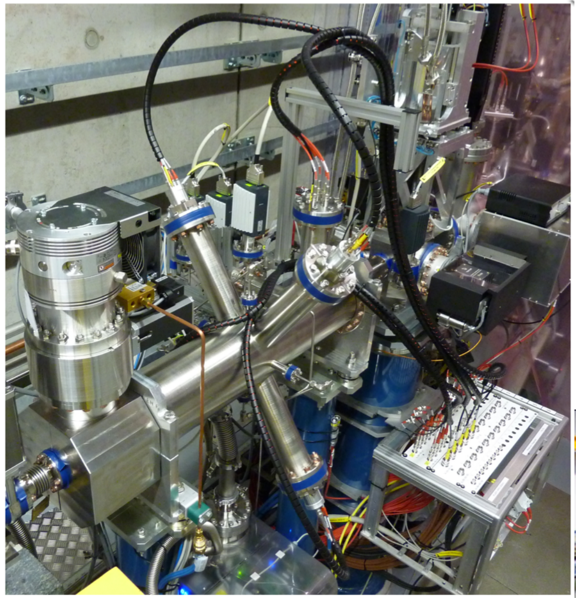
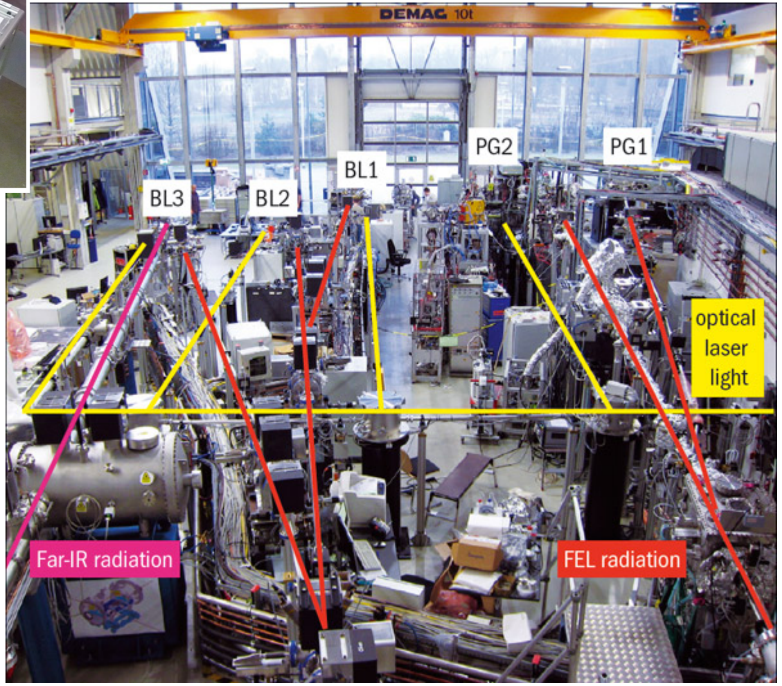


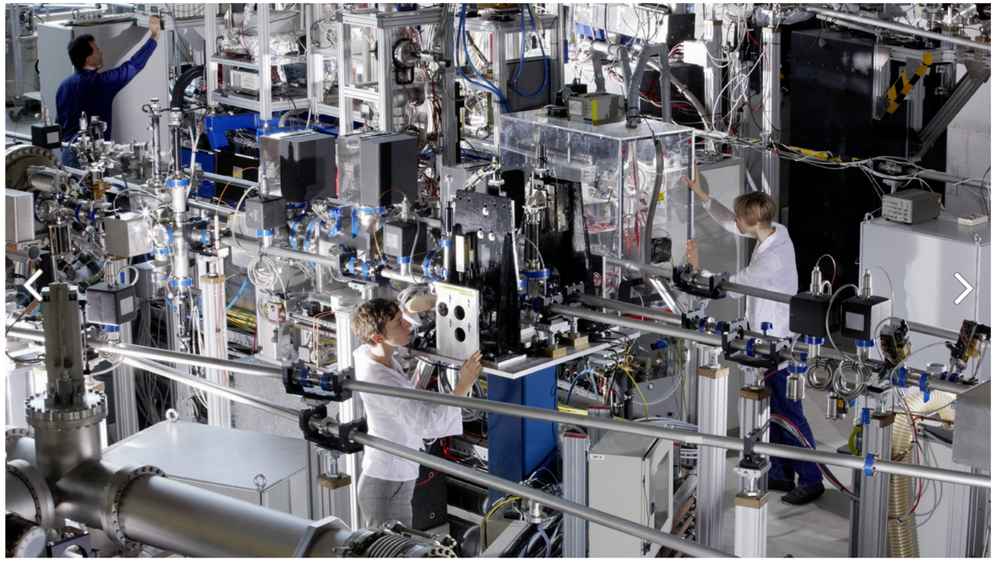
Figure 5: Typical slice distribution of the radiation intensity for optimized SASE FELs with $\hat{\epsilon}$ = 1, 2, 3, 4 (from left to right). Circle denotes rms spot size. SASE FELs operates in the saturation. Simulations have been performed with code FAST [20].

S. Toleikis, K. Tiedtke

- P1 Photon Beamlines
- P2 Photon Diagnostic
- P3 Pump-Probe Laser System
- P4 Pump-Probe Laser Delivery
- P5 THz Beamline and Endstation
- P6 Photon Beamline Vacuum and Technology
- P7 Overall Synchronization



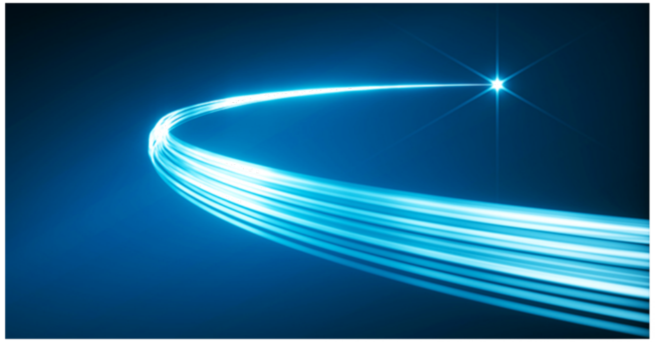




DESY/Heiner Müller-Elsner

Management

- M1 Safety
- M2 Controlling
- M3 Accelerator Management
- M4 Sustainability



PETRA IV

FLASH 2020+ meetings

FLASH 2020+

Executive Project Team:

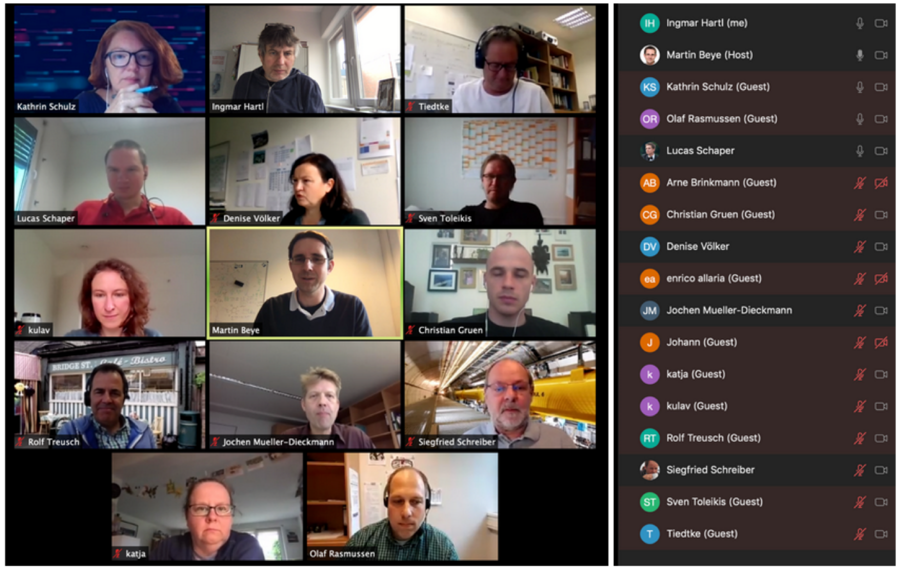
- Meets every Tuesday at 1 pm
- Every other week the meeting is enlarged to all Pillar Leaders
- *Monthly meeting with all work package leaders*

Pillar Leaders:

- Periodic meetings with Work Package Leaders

Work Package Leaders:

- *Work package status report 3 times per year*



Thank you