First Lasing of FERMI FEL-2 (1° stage) and FERMI FEL-1 recent results update

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on behalf of the FERMI commissioning team
First Lasing of FEL-2 (1° stage)

- Seeded cascade FELs
- High - peak power 0.3 - 1 GW range
- Short temporal structure sub ps →100fs
- Longit. and transv. Coherence
- Tunable wavelength APPLE II - type Undulators variable polarization horizontal/circular/vertical from KYMA
  1 mod + 6 rad in FEL 1 &
  2 mod + 8 rad in FEL-2

Spectral Ranges
FEL-1: 80 - 20 nm
FEL-2: 20 - 4 nm
FERMI LAYOUT

FEL-1 @ full specs

- High gain and SASE
- Emission at high harmonics order (h29)
- Double stage cascades &
- Harmonic cascade
Main goal was to achieve evidence of coherent emission from FIRST STAGE (one modulator – two radiators) to
- Test Alignments of various components
- Demonstrate that installed systems were properly working

Available diagnostic only consists of IUFEL screens and a YAG screen in PADReS and electron energy spectrometer after the undulator
To detect a non optimized FEL we first look for the interaction between the electron beam and the seed laser looking at the e-beam spectrum.

The laser induced energy spread on the beam is clearly visible on an energy/phase chirped beam and allow to optimize the seed synchronization.

Heated electrons show up as a «hole» in the energy distribution (example from FEL-1 commissioning).
After a quick optimization of parameters we detected photons at 52 nm in the two screens after the radiator.

The (few) available screens and irises in between radiators allowed to transport the beam to diagnostics at the end. The FEL spot has been clearly seen on the YAG installed in PADReS, 55 m far from the emitting radiator.
FERMI FEL-1 increase of performances

New «Tools» available to control of longitudinal phase space

- High Energy RF Deflector
- Laser Heater
- X-Band cavity for phase space linearization

- Higher peak current (500-600A)
- Lower energy spread (dep. on laser heater)
- Uniform beam parameters over a longer time interval (400-500 fs)

Beam based alignment of magnetic components and better control of beam optics and orbit through spreader/injection line and undulator
FERMI FEL-1 recent results

@ 52 nm (h5)

Coherence: B. Mahieu TUOA04

Spectrum: E. Allaria TUOB02

Optimization via taper of last three UM (up to Δλ/λ ≈ 1.8%)

2200s ≈ 37min Mean 320 μJ
FERMI FEL-1 recent results

@ 26 nm

(\textit{h10})

\approx 250 \mu J
Taper \Delta \lambda/\lambda \approx 0.9\%

@ 20 nm

(\textit{h13})

\approx 90 \mu J
Offset \Delta \lambda/\lambda \approx 0.9\%
We could not measure intensities because of the interference of longer wavelength radiation mainly emitted off axis.

\[ \lambda = \lambda_{\text{max}} \text{ nm} \]
FERMI FEL-1 double stage cascade

Seed $\lambda=260\text{nm}$

Disp

$\lambda=10\text{ nm (h2)}$

$\lambda=10\text{ nm (h2)}$

$\lambda=20\text{ nm (h13)}$

$\lambda=260\text{nm}$

Acquisition averaged over 50 events

$\lambda=10.0\text{ nm}$

$\lambda=10\text{ nm}$

~ $7\times$
FERMI FEL-1 double stage cascade

The last two undulators tuned to h3 of the previous ones

Seed \( \lambda = 260\text{nm} \)

Disp \( \lambda = 20\text{ nm (h13)} \)

\( \lambda = 6.67\text{nm (h3)} \)

\[ \lambda = 6.67 \pm 0.97 \text{ nm} \]

K (peak) \( \approx 0.61 \)
FERMI FEL-1 harmonic cascade

\[ \lambda = 6.67 \text{ nm} \]

Seed $\lambda = 260 \text{ nm}$

Disp

$\lambda = 20 \text{ nm (h13)}$

$\lambda = 8 \text{ nm (h5)}$

U1

U2

Frequency

$N=5$

$M=2$

$c/\lambda_n$

$c/\lambda_m$

$\lambda = 4 \text{ nm}$

Water window

Wavelength (nm)

FEL-1 wavelength range

First evidence of coherent emission in the water window from a seeded FEL
Summary

- First lasing of the first stage of FEL-2
- FEL-1 in user operation at specifications in the range 20nm → 52nm
- High harmonic order multiplication factor observed from FEL-1
- First demonstration of
  - a double stage cascade seeded FEL
  - Harmonic cascaded FEL with coherent emission in the water window

... and the first lasing of FEL-2 first and second stage, in October (hopefully).
December, 10-11
Seeding and Self-seeding at New FEL Sources

Scientific Organizing Committee

- List of invited speakers:
  - M. Couprie SOLEIL
  - G. Geloni European XFEL
  - A. Lutman SLAC National Accelerator Laboratory
  - B. McNeil University of Strathclyde
  - F. Parmigiani Universita' di Trieste
  - G. Penn Lawrence Berkeley National Laboratory
  - S. Reiche Paul Scherrer Institute
  - G. Stupakov SLAC National Accelerator Laboratory
  - T. Tanaka Spring-8 – SACLAL
  - D. Wang Shanghai Institute of Applied Physics, Chinese Academy of Sciences
  - J. Welch SLAC National Accelerator Laboratory
  - W. Zhang Dalian Institute of Chemical Physics, Chinese Academy of Sciences

http://www.elettra.trieste.it/SSSFEL12/

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Thank You
Summary of FERMI contributions

Coherence Properties of FERMI@Elettra
  B.Mahieu TUOA04

Spectral Characterization of the FERMI Pulses in the Presence of Electron-beam Phase-space Modulations
  E. Allaria TUOB02

Photon Beam Transport Systems at FERMI@Elettra: Microfocusing FEL Beam with a K-B Active Optics System
  L. Raimondi THOA02

FERMI@Elettra Progress Report
  Poster TUPD01

Commissioning of the FERMI@ELETTRA Laser Heater
  Poster MOPD58

Dependence of FEL Intensity on the Available Number of Undulators for FERMI FEL-1
  Poster WEPD11

Linear Polarization Control with Cross-polarized Helical Undulators at FERMI
  Poster THPD21

Time-Sliced Emittance and Energy Spread Measurements at FERMI@Elettra
  Poster WEPD20