FERMI@Elettra: from the first flashes of light towards the experimental programs

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The night between December 13 and 14 2010 was very gratifying for the Sincrotrone Trieste team. FERMI@Elettra, the newly-built free-electron laser for materials analysis and the development of nanoscience, generated its first flashes of coherent light in the far ultraviolet.

In the last decade the use of free electron lasers has become an important tool for several fields of science and the number of user facilities based on such a kind of source are rapidly increasing. In order to provide users with the capability offered by this, Sincrotrone Trieste has been engaged in an intensive teamwork since 2006.

The light of FERMI has a similar coherence and intensity as that of the most powerful lasers, but it can reach intensities and wavelengths that are outside the range of traditional lasers. Additionally, it can be synchronized with the internal dynamics of the materials and processes under observation, allowing to perform new kind of experiments that would not be possible on the existing synchrotron radiation sources.

FERMI is housed in a long tunnel – over 300 meters in length – dug 5 meters below ground in the karst rock. It is a single pass free electron laser based on a 200 m long linear accelerator that produces high quality electron beams with energy variable between 0.9 and 1.5 GeV. In FERMI these electrons will be sent into two seeded FEL lines that cover the whole spectral range from 100 nm down to 4 nm with fully coherent pulses.

Using the high gain harmonic generation scheme initiated by a tunable laser in the UV, FERMI will be characterized by high quality FEL pulses both in term of spectral purity and temporal reproducibility. Indeed, the adopted scheme allows FERMI to produce light characterized not only by transverse coherence, that can be also achieved with simpler schemes like the Self Amplified Spontaneous Emission, but also by a very high temporal coherence.

Parameter	FEL1	FEL2	Units
Output Wavelength (fundam.)	100 – 20	20 – 4	nm
Output Pulse Length, rms	≤50	≤50	fs
Peak Power	1 – 5	> 0.3	GW
Photons per Pulse	$> 10^{13}$	$> 10^{12}$	
Peak Brightness (ph./(sec.•mm^2•mmrad^2•01%Bdw)	$>10^{28}$	$>10^{29}$	
Power Stability	<30	<50	%
Transverse Stability	<10%		e-size
Repetition Rate	10	50	Hz

Table 1. Photon beam parameters of the two FERMI@Elettra FELs.

This will also improve the capability to perform pump and probe experiments, where an initial flash (the "pump") illuminating the sample provides the energy required to initiate the reaction, and it is followed by a second pulse (the "probe") photographing the process status at a precise point in time.
Both FERMI FELs will produce their coherent radiation using specially designed APPLE-II undulators that allow the control of the FEL polarization. Both horizontal and vertical and circular polarizations are possible.
The parameters that describe the FERMI FELs photons are reported in table 1.
After less than two years of commissioning of the linear accelerator, FERMI entered into its final commissioning in December 2010, till the first evidence of a coherent signal in the range from 60 to 20 nm has been demonstrated (see figure 1).

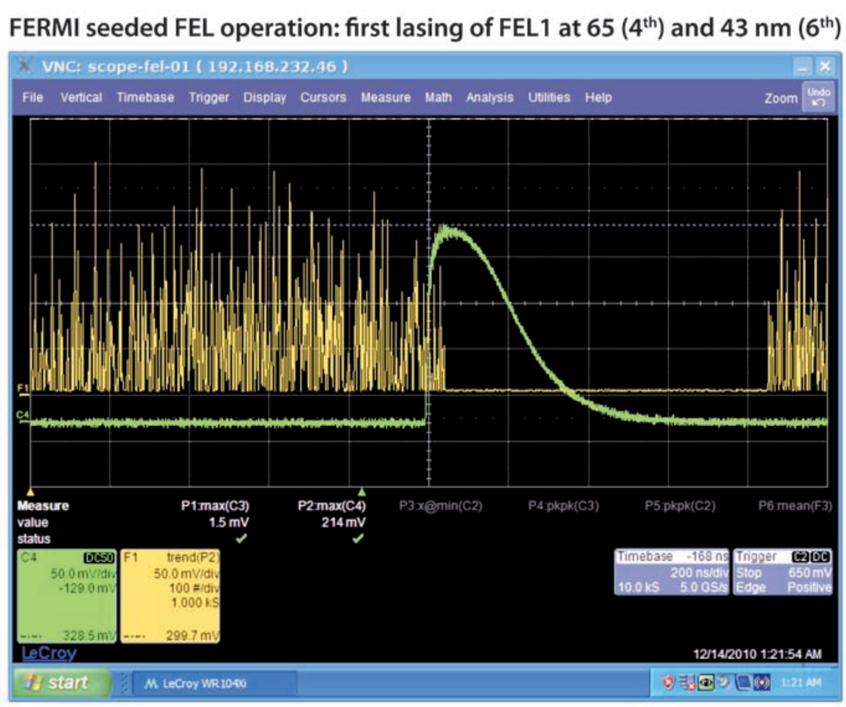

Figure 1. Seeded coherent emission from FEL-1 measured by means of a fast photodiode located in the FERMI experimental hall. The undulators were tuned at 43 nm. The green trace shows the time profile of a single pulse with the photodiode in saturation. The yellow trace shows a series of seeded FEL pulses being turned on (left) and off (center-right) by changing the superposition between seed laser pulses and electron pulses.

A second phase of commissioning started in January 2011 with the goal of producing the first FEL light to be sent into the experimental chambers. After a careful optimization of the electron beam parameter and of the FEL system in the last commissioning run, it has been possible to clearly show the evidence of coherent emission from the various undulators of FEL-1.
The further system optimization necessary to reach the final FEL performance, to allow the FERMI users to start performing their new experiments, is now ongoing at Sincrotrone Trieste.