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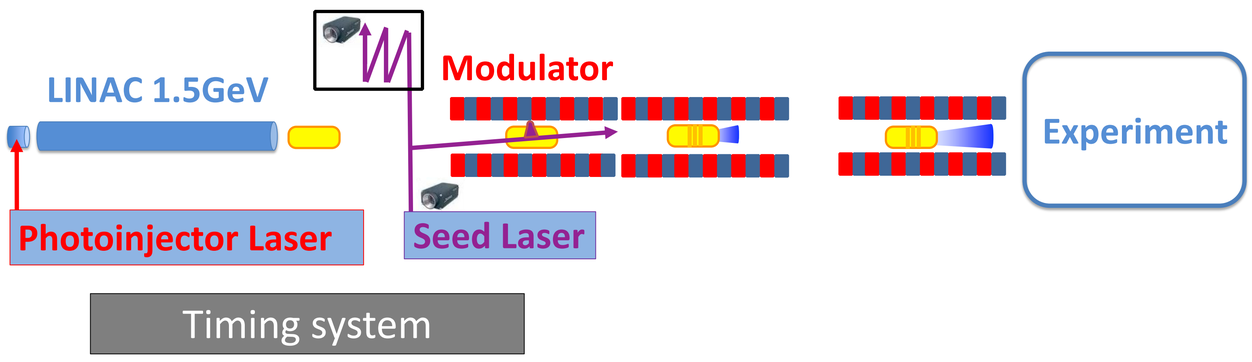
ADVANCES IN AUTOMATIC PERFORMANCE OPTIMIZATION AT FERMI

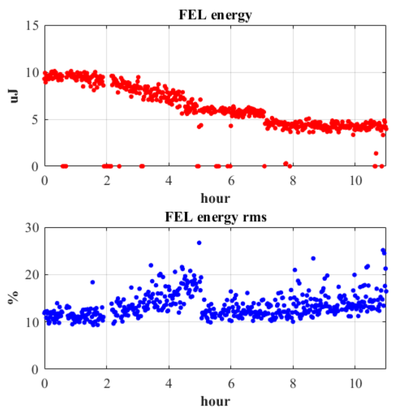
TUMPA07

Despite the large number of feedback loops running simultaneously at the FERMI Free Electron Laser (FEL), they are not sufficient to maintain the optimal working point in the long term, in particular when the machine is tuned in such a way to be more sensitive to drifts of the critical parameters. In order to guarantee the best machine performance, a novel software application which minimizes the shot-to-shot correlation between these critical parameters and the FEL radiation has been implemented. This application, which keeps transversally and longitudinally aligned the seed laser and the electron beam, contrary to many algorithms that inject noise in the system to be optimized, run transparently during the experiment beam times. In this paper we describe the status of the FERMI optimizers and present a newly developed method to calculate a FEL quality factor starting from the images provided by a photon energy spectrometer which tries to mimic the evaluation of machine physicists, as well as the first results obtained using two model-less algorithms to optimize the FEL performance through maximization of the quality factor.

1: FERMI: Free Electron Laser (HGHG single stage)



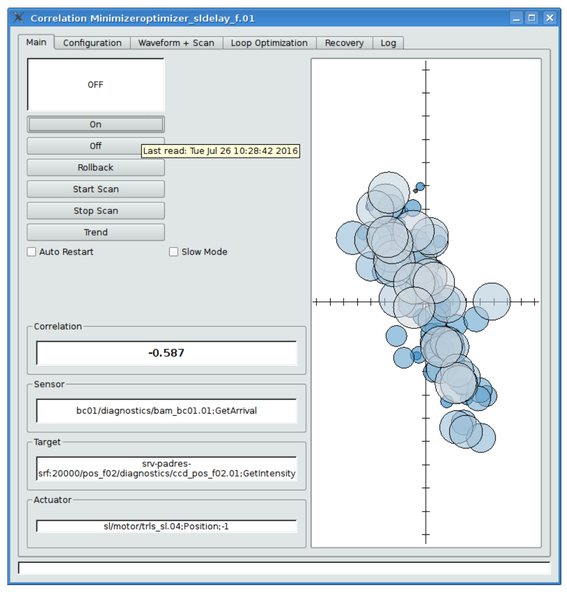
2: Problem description

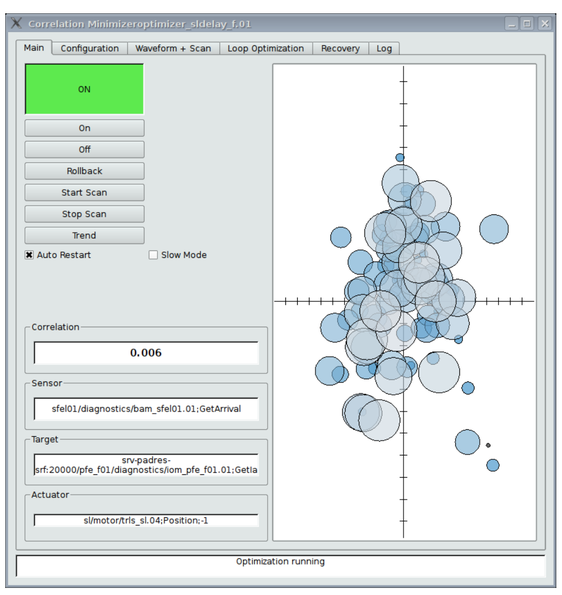


The FEL performance in the long term could be affected by a slow decay of the FEL intensity and a consequent increase of the jitter. One of the main causes is the spatial (transversal and longitudinal) misalignment between the electron and seed laser beams. Despite the large number of feedback system there are still some machine variables not controllable or difficult to model in a sort of deterministic feedback scheme.

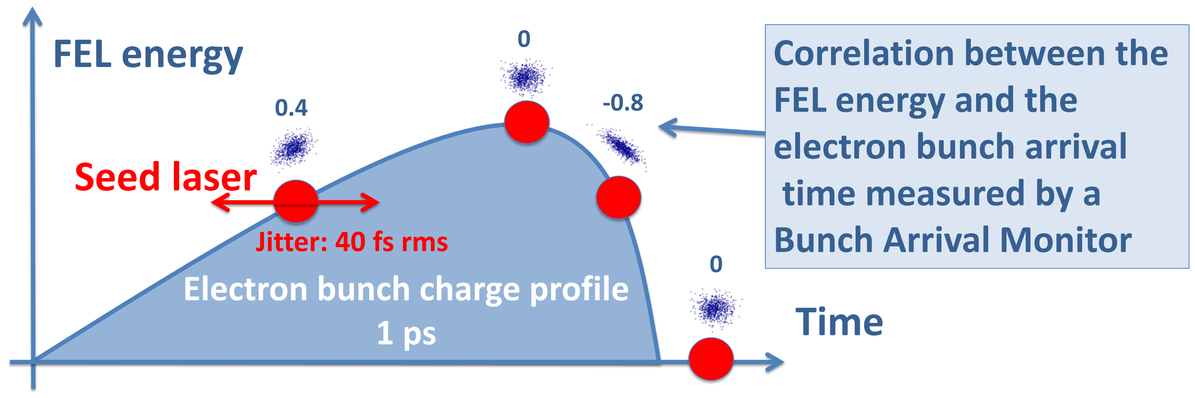
3: Automatic optimization through correlation

The idea is to exploit the correlation between the jitter in the machine variables and the jitter of the FEL and use it for a sort of modeless optimization algorithm able to maximize FEL performance transparently (no excitation) to the user experiments.





4: Example of continuous longitudinal (temporal) optimization between electron beam and seed laser beam

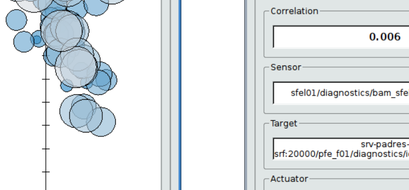


Negative correlation: move seed laser to the left.
Positive correlation: move seed laser to the right.
The algorithm moves automatically the seed laser across the electron bunch to get the maximum FEL energy without excitations.

5: Short and long term results in seed laser – electron bunch overlap optimization

Short term

Automatic optimization of the longitudinal overlap between seed laser and electron beam by measuring the correlation between the electron bunch arrival time and the FEL energy and, accordingly to the correlation sign and changing a mechanical delay line.



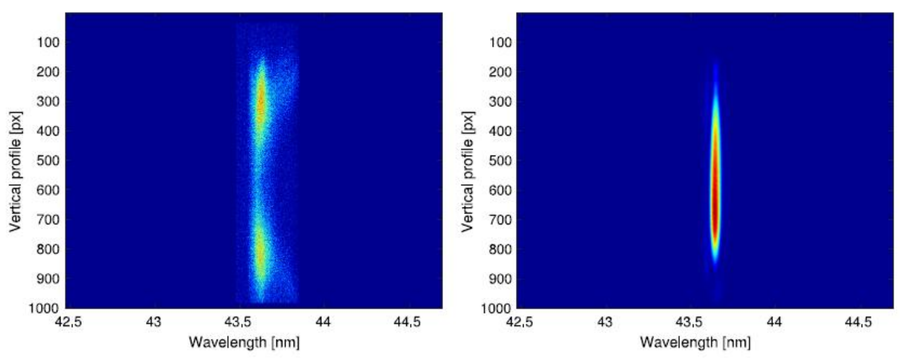
Automatic optimization of the transversal overlap between seed laser and electron beam by measuring the correlation between the position of the seed laser acquired two CCDs (used by the seed laser pointing feedback) and the FEL energy.

Long term

Continuous optimization of the transverse overlap between electron bunch and the seed laser optimizing the position of the seed laser on one CCD over a period of 48 hours.

6: FEL Quality Factor Index

The FEL Quality Factor (*FELQFactor*) is an index which summarizes in a number the most important features of the photon energy spectrum. The idea was to develop an algorithm capable of evaluating the spectrum image as an expert does. The *FELQFactor* has been used in some preliminary machine optimization tests. Two optimization algorithms have been used: Descent Gradient and Extremum Seeking.



FEL spectrum before (left) and after (right) optimization based on the *FELQFactor* index. The horizontal axis in the images is the photon energy, while the vertical axis represents the vertical photon beam distribution.

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