MEASUREMENT OF ELECTRON-BEAM AND SEED LASER PROPERTIES USING AN ENERGY CHIRPED ELECTRON BEAM*

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Abstract

We present a new method that uses CCD images of the FERMI electron beam at the dump spectrometer after the undulator to determine various electron beam and external seed laser properties. By taking advantage of the correlation between time and electron beam energy for a quasi-linearly chirped electron beam and the fact that the FERMI seed laser pulse (~180 fs) is much shorter than the electron beam duration (~1 ps), measurements of the e-beam pulse length and temporally local energy chirp and current are possible. Moreover, the scheme allows accurate determination of the timing jitter between the electron beam and the seed laser, as well as a measure of the latter's effective pulse length in the FEL undulators. The scheme can be also provide an independent measure of the energy transferred from the electron beam to the FEL output radiation. We describe the proposed method as well as some experimental results obtained at the seeded FERMI FEL.

SEEDED FEL AT FERMI

FERMI is a seeded Free Electron Laser user facility based on normal conducting linac [1]. Electron beams generated in the photocathode [2] are compressed and accelerated up to the final energy of 1.2 GeV. A schematic layout of the FERMI complex is shown in Fig. 1. Electron beam compression is obtained by introducing a linear chirp in the beam before entering into the compressor chicane (BC1). If not properly removed by operating the second part of the linac off crest the linear chirp needed for the compression remains on the beam. As a result the electron beam entering in the radiator has a linear correlation between energy and time as shown in Fig. 2.

FERMI FEL is based on a HGHG scheme. An UV external laser is used to induce into the electron beam an energy modulation after the interaction that occurs in the modulator. Energy modulation is converted into spatial modulation and bunching at the seed laser wavelength and his harmonics. The final radiator is tuned to one of the harmonics and the electron beam produces coherent emission, finally FEL emission is amplified along the radiator.

As a result of the seeding the electrons that interact with the laser become energy modulated and a local energy bump is created.

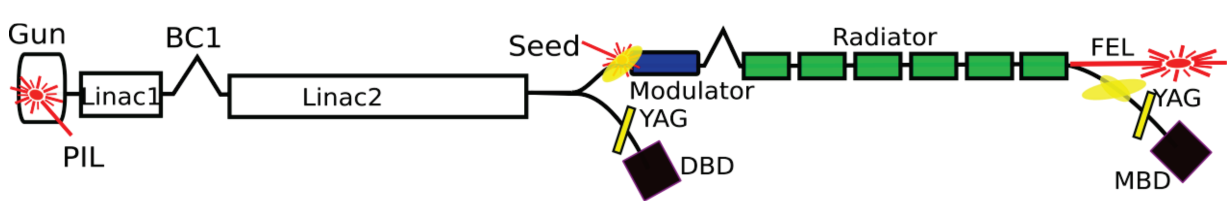

Figure 1: Layout of the FERMI linear accelerator and FEL.

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The Electron Beam

The electron beam used during the reported experiment is characterized by the parameters reported in Table 1.

Table 1: Electron Beam Parameters

Parameter	
Peak current (A)	~300
Charge (pC)	500
Energy (GeV)	1.2

Due to the compression scheme adopted in the experiment a significant linear chirp characterizes the longitudinal phase space of the electron beam. Figure 2 reports the longitudinal phase space of the electron beam measured in the DBD by combining the dispersion of the dump with a vertical deflecting cavity.

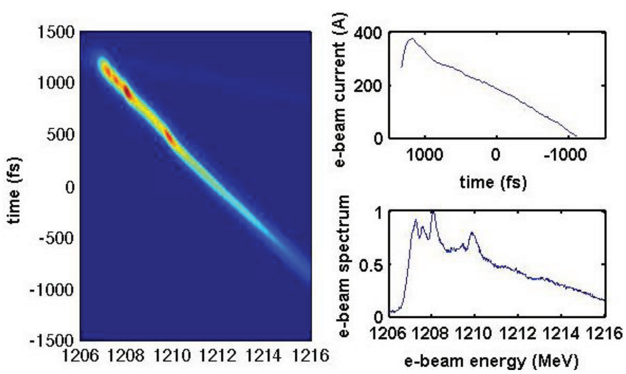

Figure 2: Measured phase space, current profile and energy spectrum for the beam in DBD.

EFFECT OF SEEDING

The effect of seeding on the electron beam has been studied by means of numerical simulations. FEL simulations of the seeding process have been done using as an input electron beam a particle file with the same phase space than the one measured in DBD.

The phase space of the electron beam after the FEL interaction is reported in Fig. 3. As it is possible to see the region where the electron interacted with the seed (*t=0*) is characterized by a large increase of the energy spread.

The effect of the seeding is also clearly visible on the electron beam spectrum (Fig. 3 bottom panel) and is manifested by a hole in the spectrum. In the case of a beam with a linear chirp like the one used here the position of the hole in the spectrum is correlated to the time arrival of the seed laser with respect of the electron beam. Any change of the time arrival of the seed will be seen as a movement of the seed induced hole in the spectrum.

Such a property can be used for performing a direct measurement of the timing between the electron beam and the seed laser. Additional uses of this effects have been discussed in [3].

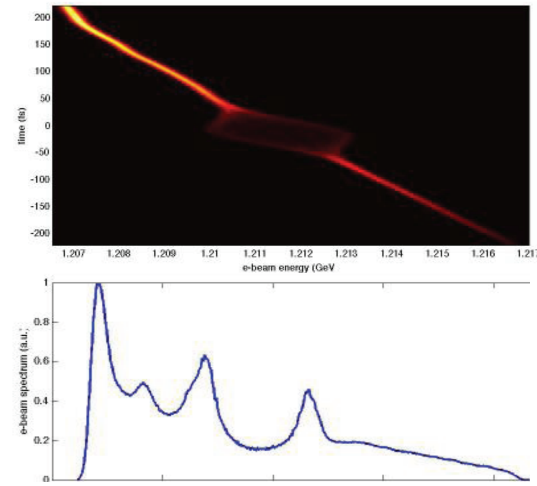

Figure 3: Simulated phase space and energy spectrum of the seeded electron beam.

Experimental Evidence of the Seed Induced Hole

Figure 4 reports a typical image of the unseeded beam at the YAG in the MBD, here the energy is dispersed in the horizontal axis while vertical axis show the vertical size of the beam at the screen.

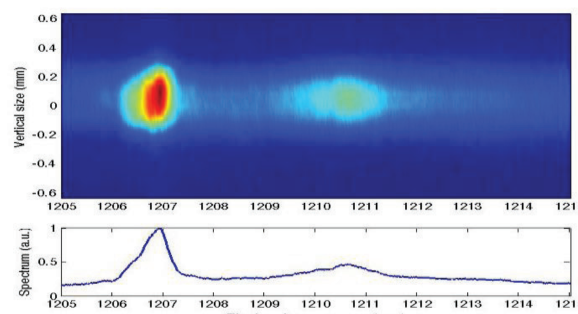

Figure 4: Measured spectrum of an unseeded electron beam in MBD.

When the seeding is acting on the electron beam and FEL is on the energy distribution at MBD is significantly changed as shown in Fig. 5.

Similarly to what observed in the case of numerical simulation a hole in the electron beam spectrum appears and as expected his position depend on the setting of the seed laser delay.

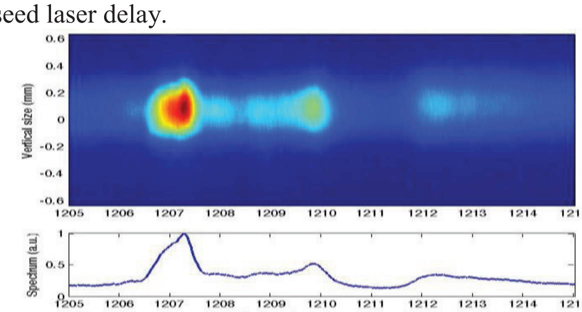

Figure 5: Measured spectrum in MBD of a seeded electron beam, showing the seed induced hole around 1.211GeV.

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JITTER MEASUREMENTS

By collecting a long sequence of seeded electron beam spectra it is possible to see that the position of the seed induced hole is not constant but has some oscillations (Fig. 6). We have implemented a procedure that automatically recognize the center of the hole and allow reconstructing a curve of the hole evolution (magenta curve in Fig. 6).

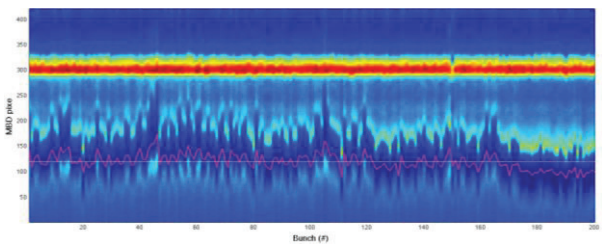

Figure 6: Long sequence of electron beam spectra in MBD of the seeded electron beam.

After a proper calibration that allows to convert the MBD pixels in fs it is possible to associate to each spectra a time and with this measure the timing jitter between the electron beam and the seed laser. Calibration has been done by measuring the average position of the hole as the seed laser timing is varied by +/- 100 fs [3]. With this method we have been able to measure a timing jitter in the case of FERMI of about 70 fs. Such a number is in agreement with prediction based on independent measurements done on the electron beam and the seed laser separately.

CONCLUSIONS

We have shown a new method to measure the jitter between an electron beam and the seed laser in the case of an HGHG FEL. This method can be easily be implemented in seeded FEL facilities.

REFERENCES

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