Progress of the FELICITA I Free-Electron-Laser Experiment at DELTA[1]

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Abstract

The Free-Electron-Laser experiment FELICITA I, set up at the DELTA storage ring, is designed for the wavelength regime from 500 down to about 200 nm. With the flexible electromagnetic undulator FEL and optical klystron operation is possible. Besides some preliminary experiments started in parallel to the commissioning of DELTA [1] the commissioning of FELICITA I started late in 97. The start up wavelength was chosen to be 470 nm, corresponding to an electron energy of 450 MeV. Up to now electron beam currents of
24-30 mA in single and 4 bunch operation, respectively, have been stored with a bunch length below 120 ps (FWHM). Losses of the optical cavity as low as 1.5 % per pass have already been demonstrated. This paper will report the actual results of the experiment.

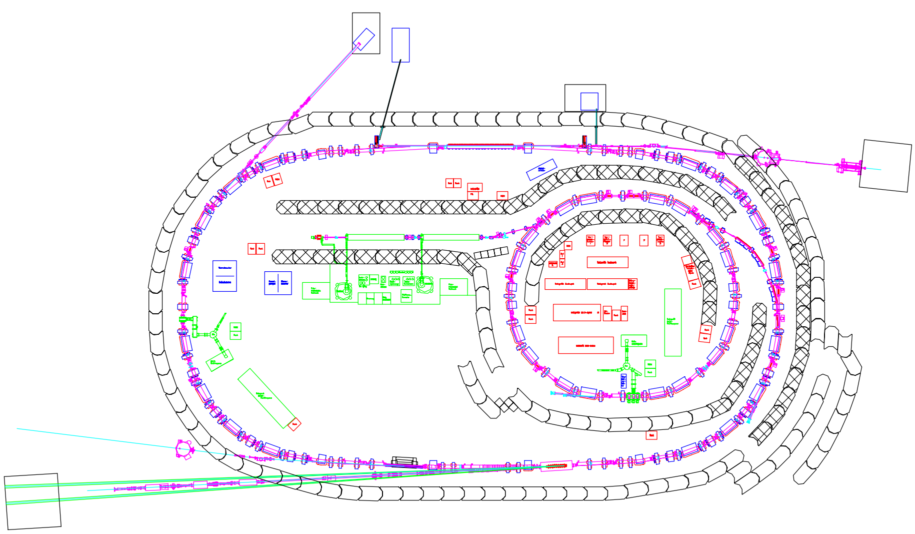

Fig. 1: Layout of the DELTA. FELICITA I is located in the northern superstraight. Two FEL beamlines are available to probe the radiation coupled out through upstream and downsteam mirror.

1 INTRODUCTION

Free-Electron-Lasers (FEL) have been one of the main goals of the DELTA facility just from the start of the project. This idea had a serious impact on the design of the storage ring. The racetrack shape of the lattice allows for the installation of undulators up to 14 m length, to provide the possibility to operate high gain devices, as needed to reach the VUV regime. To guarantee a low impedance the vacuum system was designed under the prerequisite to avoid all changes of the cross section of the vacuum chamber. This implied the design of new kicker magnets [2] and other low impedance vacuum components [3]. Due to the combination of all these measures, the overall impedance of the vacuum system was calculated to be Z/n = 0.4 Ω [4].

In order to start a long term FEL program aiming for operation within the regime of 100 nm, a first milestone was defined with the FELICITA I project addressing the visible and near UV [5].

2 SETUP OF THE FELICITA I EXPERIMENT

The first FEL designed for the DELTA facility is called FELICITA I. With a undulator period of 25 cm and a K value below 3, it is possible to operate this FEL in the

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visible part of the spectrum. Due to the long period length the undulator is constructed as an electromagnetic device, featuring two operation modes. The magnet can either be operated as a conventional FEL or in the optical klystron configuration usual for storage ring FELs.

In order to shorten the optical cavity additional bending magnets were introduced into the superstraights of the DELTA ring. The last bendings of the arcs were altered from 10° to 7° bending angle, adding additional 3 ° bends to the straight to split it into 3 parts.

As shown in Fig. 1 this design allows for an optical cavity of 14.4 m mirror distance, corresponding to 4 bunch operation of DELTA. As a consequence, the complete experimental setup is located inside the shielding of the accelerator facility. Especially for the mirror system this had serious impact on the design of the optical cavity. Everything has to be remote controlled. Another condition was the required use of the spontaneous radiation by a downstream beamline[6]. This yields a design of the mirror vessels, that allows to remove the mirrors from the optical axis of the cavity. Furthermore, a system is available to change the FEL mirrors without breaking the vacuum. A sketch of the mirror vessel is shown in Fig. 2.

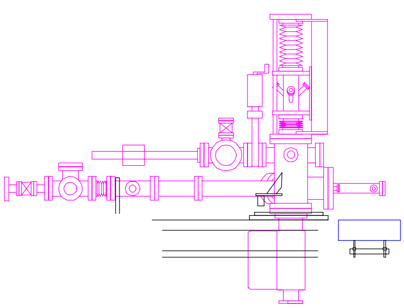

Fig. 2: Sketch of the FEL mirror vessel. The beam is entering the vessel through the beam pipe, coming from the left. The mirror can be pulled up by about 10 cm, and then be manipulated or changed through a gate system

3 STATUS OF THE COMMISSIONING

The assembly of the FELICITA I experiment was done inparallel to the assembly of the main ring. Thus, the undulator was already installed during the commissioning of the ring. Therefore, first tests of the undulator could be performed just with the first electron beams stored in DELTA.

During fall 97, the storage ring was characterised at different energies, especially in the low energy regime, in order to figure out the best energy for FEL operation. It was decided to start the commissioning of FELICITA I at 450 MeV. This energy was chosen as a compromise between machine stability and FEL gain. Furthermore, the measurements indicate a minimum of the emittance at this energy.

The commissioning wavelength is fixed to 470 nm, to stay well in the visible. At 450 MeV this wavelength corresponds to an undulator K of 1.98. Furthermore, it was decided to start using the optical klystron configuration with the strongest possible dispersive section, in order to work at the highest possible gain. Fig 3. shows the spectrum of the FELICITA I undulator in the optical klystron mode.

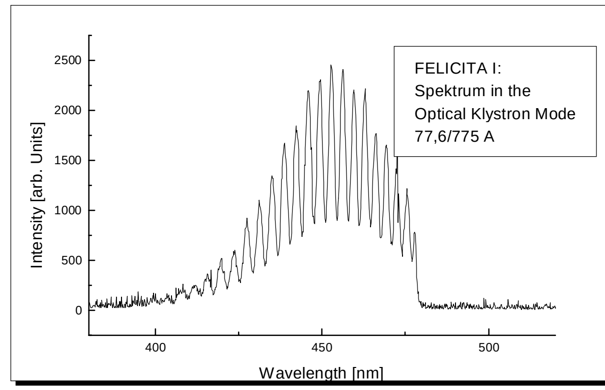

Fig. 3: Spectrum of the FELICITA I undulator in the optical klystron mode. The quality of this spectrum is reduced due to unsufficient alignment of the pinhole.

During the 450 MeV runs currents up to 24 mA in single bunch mode and 30 mA in 4 bunch operation have been achieved. At prensent, the 4 bunch operation cannot be used for the FEL, as strong synchrotron oscillations disturb the accuracy of the spacing between the 4 bunches. For single bunch operation a simple feedback system, acting on the RF phase of the transmitter, was used to suppress the longitudinal oscillations in the RF bucket. Fig. 4 shows the bunch length and peak current of DELTA, measured with a fast photodiode and a streak camera, respectively[3].

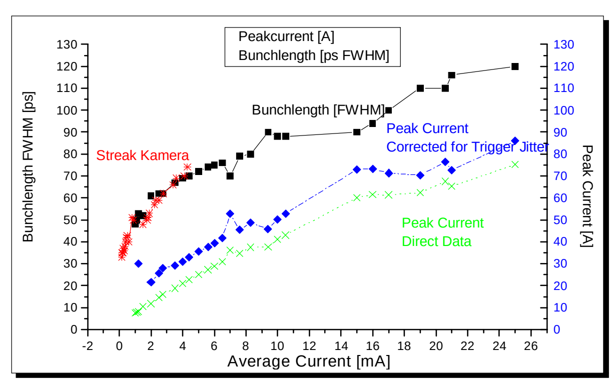

Fig. 4: Measurement of bunch length and peak current with a fast photodiode and a streak camera, respectively.

[3] The measurements with the streak camera have be recorded during a demonstration of Hamamatsu, Germany at DELTA.

The optical cavity could be tuned to losses as low as 1.5 % per pass, resulting in about 5 % losses per electron pass for single bunch operation (Fig. 5)

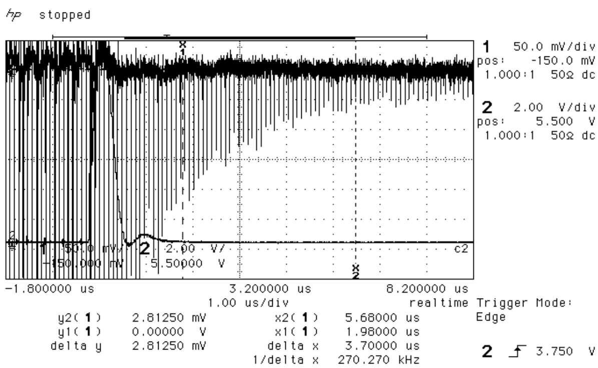

Fig 5: Ring down of the stored emission in the optical cavity. The electron beam was killed using a kicker magnet.

Collecting all data taken from the ring and from the optical cavity, the expected threshold current for lasing can calculated (Table 1). The resulting threshold current is about 7 mA for single bunch operation. This is well in the operation regime of DELTA.

Up to now two periods of dedicated FEL runs have been performed. During the first period in winter 97/98 the electron beam had the required performance, but the alignment of the optical cavity and the matching of the electron beam to the optical cavity was not sufficient. This could be improved in a second run period during spring 98, but due to a shortcut in an internal sextupole magnet, DELTA could not provide currents high enough to reach the threshold. The next beam time is scheduled for July 98.

4 CONCLUSION

The FELICITA I experiment at DELTA is under commissioning. Both the required electron beam quality as well as the operation of the undulator and the optical cavity have been demonstrated. Therefore, the successful operation of this device is expected in the near future.

ACKNOWLEDGEMENT

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e^- Beam Parameter		FEL	Op. Klyst.
Typical Average Current	mA	15	15
Number of Bunches		1	1
Bunchlength (FWHM)	ps	90	90
Bunchlength	mm	11,5	11,5
Peak Current	A	60	60
Energy Spread		7,500E-04	7,500E-04
natural Emittance	m rad	1,940E-08	1,940E-08
Beam Energy	MeV	456	453
Undulatorparameter			
K--Value		2,000	1,980
total Length	m	4,750	4,750
Periodlength	mm	250	250
Number of Periods		19	7
Slippage Parameter Nd			1,138E+02
Optical Cavity			
Wavelength	nm	470	470
Mirror Refl. per Pass		98,676%	98,676%
Mirror Refl. per e- Pass		94,806%	94,806%
Cavity Length	m	14,4	14,4
Radius of Curvature	m	8,0	8,0
Beam Waist	m	5,992E-04	5,992E-04
Raileigh Length	m	2,40	2,40
FEL Performance Data			
JJ Faktor		6,529E-01	6,553E-01
Filling Factor		2,784E-01	3,755E-01
Current Density * FF	A/m^2	7,669E+07	6,615E+07
Colson Current per mA	1/mA	1,6030E-02	8,046E-04
1 + Nd/Nu			1,726E+01
Energy Spread Gain Deg.			5,229E-01
Gain and Currents			
Gain per mA	1/mA	0,22%	0,73%
Laser Threshold	%	5,19%	5,19%
Theshold Current	mA	24,00	7,15

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