DESIGN ASPECTS OF FELICE, THE FREE ELECTRON LASER FOR INTRA-CAVITY EXPERIMENTS

B.L. Militsyn, A.F.G. van der Meer, FOM Institute of Plasma Physics "Rijnhuizen",
P.O. Box 1207, 3430 BE Nieuwegein, The Netherlands

Abstract

At the FOM Institute "Rijnhuizen" a new Free Electron Laser for Intra-Cavity Experiments (FELICE) is under development. In this article we describe the accelerator aspects of the project as it is seen at the moment.

1 INTRODUCTION

The FELICE project [1] is developed as a third stage of the IR user facility FELIX [2] and dedicated to fundamental research of the structure and dynamics of (bio)molecules, clusters, and nano-particles which demands extremely high luminosity.

FELICE will generate pulsed infrared radiation tunable in the region of 3-100 μm, which is often referred to as the 'molecular fingerprint' region. It should allow intra-cavity experiments with optical beam energies in the interaction point of some 10 J, which is a factor 100 higher than what is currently available for the users. The optical beam will have a temporal structure consisting of a few-microsecond long, 1 GHz train of ps-micropulses, that is repeated at 10 Hz.

2 THE SOURCE OF DRIVING ELECTRON BEAM

According to the present conceptual design the FELICE user facility will be installed in a separate vault, which is located some 50 m away from the existing facility FELIX. The driving electron beam is going to be obtained from FELIX. General layout of the FELICE facility is shown in Fig. 1.

In order to provide highly efficient and simultaneous usage of the existing facility and new facility the following schematic was chosen: the driving beam is extracted from the FELIX beam line at the point, which is located after the second acceleration section with a 188° U-turn. For sake of transportation, the beam energy will be fixed at 45 MeV, which is the highest energy that can be routinely obtained at this point. The parameters of the FELIX beam are shown in Table 1.

Table 1: Parameters of the FELIX beam.

Output beam energy, *MeV*	45
Duration of the micropulses, *ps*	1.0
Charge of the micropulses, *nC*	0.2
Repetition rate of the micropulses, *GHz*	1
Duration of the macropulse, *μs*	0.2-10
Repetition rate of the macropulse, *Hz*	20
Normalized beam emittance, $\pi \cdot mm \cdot mrad$	94

The extracted beam is transported into the FELICE vault via a 50 m long beam line.

In order to provide energy variation from 20 to 65 MeV, which is necessary to cover the λ-range of the FEL, an acceleration section is installed after the transport line. For injection of the beam at a given energy into the undulator an S-bend will be used.

After the FEL interaction, the beam is dumped with a section, which comprises a 45° bending magnet, a high energy acceptance beam line, and a beam dump.

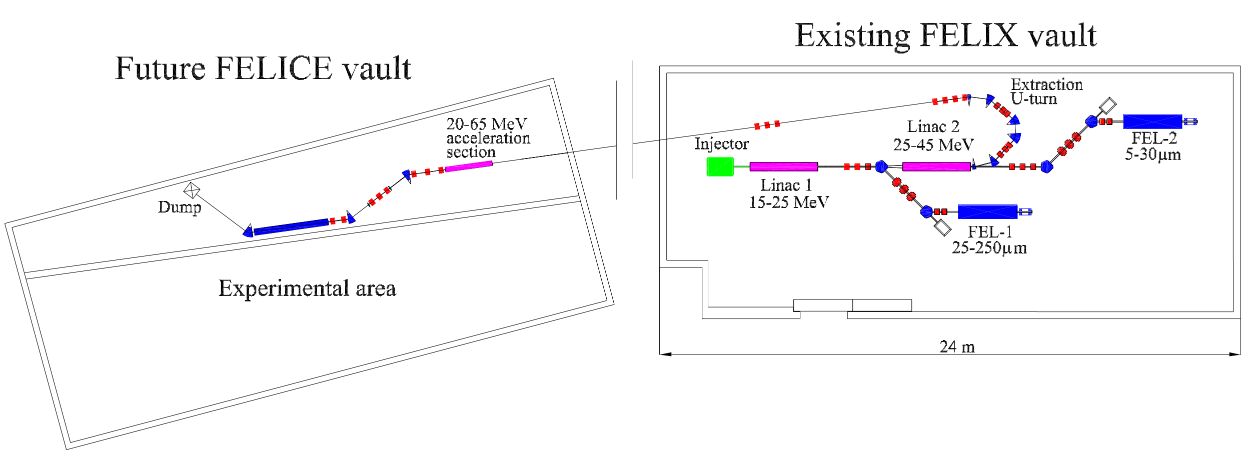

Figure 1: General layout of the FELICE free electron laser facility.

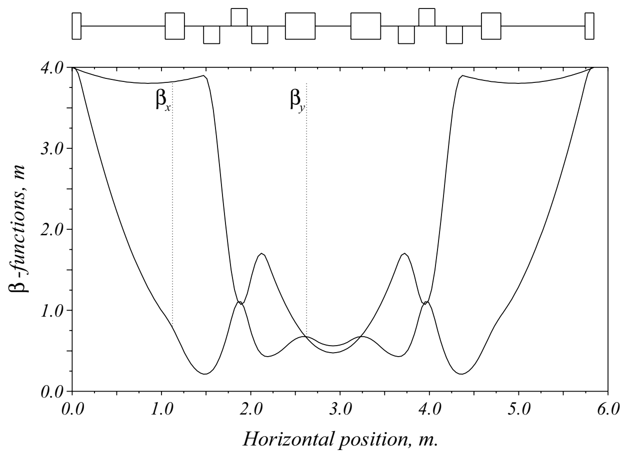

Figure 2: Optical functions in the beam extraction section for the zero chromaticity and chronicity as calculated with the MAD code.

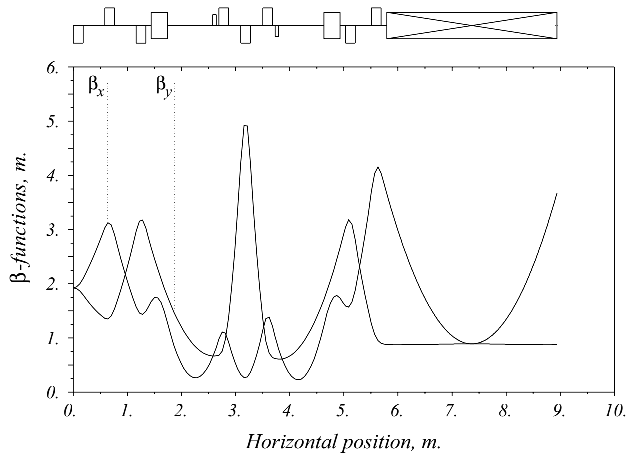

Figure 3: Optical functions in the undulator and in the S-bend as calculated with the MAD code at an energy of 45 MeV and an undulator strength K_{rms}=1.0.

2.1 Beam extraction section

The beam will be extracted from the FELIX beam line with a pulsed 15° shunting-yard magnet, switching the beam at a frequency of 10 Hz. This allows simultaneous operation of one of the existing beam lines of FELIX and FELICE. Further the beam will be deflected by means of a 158° dispersion-free U-turn and directed into the beam line, which will transport the beam to a new experimental hall with a pulsed 15° deflecting magnet. For stable extraction this magnet identical to the shunting-yard magnet and will be fed in series with the extracting magnet.

The U-turn consists of two mirror-symmetrical sections with a drift space in between, similar to [3]. Every section comprises a 32° and 47° DC bending magnet. Focusing and correction of chromaticity is provided by a quadrupole triplet, installed in between the bending magnets. As the beam travels a long distance between the U-turn and the additional acceleration section, debunching of the beam due to its space charge is possible. In order to compensate this effect the U-turn is designed with adjustable chronicity. Variation of the chronicity in the range ±1 mm/pm can be obtained. A distortion of the optical functions, which appears in the process of cronicity variation is compensated with a first matching section in the beam line (see 2.2). Second order chromaticity of the U-turn is corrected with a couple of sextuples, which surrounds the quadrupole triplet. Optical functions of the extraction section as calculated with the MAD code are shown in Fig 2.

2.2 Transport beam line

The driving beam is delivered to the FEL section, which is installed in a new experimental area 50 m away from the existing FELIX facility with a transport beam line. This beam line will consist of six identical units with a drift space of some 10 m between them. Each unit comprises a focusing triplet, that provides focusing in both horizontal and vertical directions, and a set of bi-directional steering coils. Units from second to fifth provide identical focusing in both vertical and horizontal directions and form a periodical focusing structure. In order to provide stable transport, the focal distance is chosen to fulfill the stability criterion for periodic focusing $0<S<4f$ [4], where S is the period of the focusing system, and f is the focal distance of the unit.

The first section matches the optical function of the beam at the output of U-turn to the ones of the periodic structure. The last section in turn matches the optical functions of the periodic structure to the ones required at the entrance of the acceleration section.

Following the transport beam line an accelerator section will be installed that will boost or reduce the beam in the energy range from 20 to 65 MeV.

2.3 S-bend and injection into the undulator.

Injection of the driving beam into the undulator is performed with a standard injection beam line, based on an S-bend, consisting of two 30° bending magnets and a quadrupole triplet in between. Matching of the beam to the undulator is provided with a quadrupole triplet, which is installed between the acceleration section and the S-band and a doublet between the S-band and the undulator. This scheme allows to match the beam to the undulator over the full energy range (20–65 MeV) and an undulator strength K_{rms} of 0.5–2. Second order chromatism of the horizontal dispersion, which leads to the ‘coma’ chromatic aberration in the undulator, is compensated with two sextupoles, which surround the quadrupole triplet in the S-bend. Typical optical functions in the injection line and in the undulator as calculated with the MAD code are shown in Fig. 3.

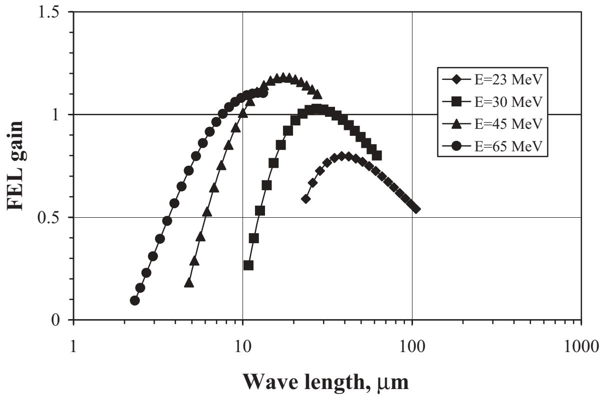

Figure 4: FEL gain for different energies of the driving electron beam as calculated with the code [5].

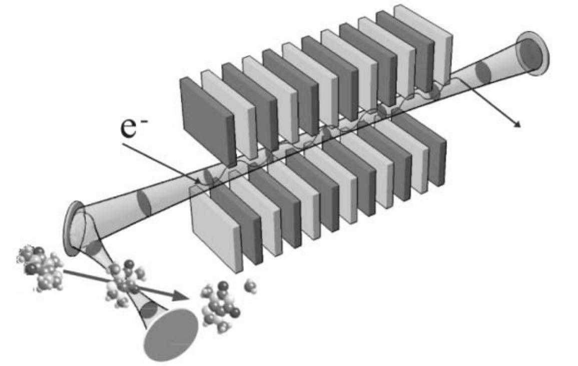

Figure 5: The L-shaped optical resonator and a typical layout of an intra-cavity experiment.

3 UNDULATOR

The FEL will make use of a Halbach-type tunable-gap, permanent-magnet (SmCo) undulator with a spatial period of 65 mm. The minimum gap will be 22 mm, which should allow tuning of the wavelength over at least a factor of three (see Fig. 4). In order to obtain a single-pass small-signal gain of more than 50%, the number of periods should be 50. In order to avoid wavelength filtering inside the resonator, the undulator will be shimmed to suppress the harmonic content.

Wavelength tuning of FELICE by a factor 10 can be achieved by varying the beam energy. Another factor of three will be achieved by changing the undulator gap, providing fast and convenient tuning that can easily be brought under user control.

4 OPTICAL CAVITY

The L-shaped optical resonator (Fig. 5) will consist of three, broad-band, copper mirrors providing two waists: one half-way down the undulator to optimize the overlap of the optical beam and the electron beam, and one in the center of the Fourier Transform Ion Cyclotron Resonance mass spectrometer (FT-ICR) and/or IR – Resonance Enhanced Multiphoton Ionization (IR-EMPI) setup to provide a high fluence at the sample. In view of the minimum undulator gap of 22 mm, a retractable two-plate waveguide will be inserted for lasing at wavelengths beyond 35 micron, in order to keep the diffraction losses at a minimum. As the curvature of the wavefront of the optical beam will depend on the wavelength in this case, a few, interchangeable sets of mirrors with appropriate curvatures will be used to cover the spectral range up to 100 micron.

5 CONCLUSION

If funding is obtained, construction of the FELICE will start in the fall of 2002 and is estimated to take about three years to be completed. However, in order not to frustrate the current user programs, the downtime of the existing beam lines of the facility will be kept to a minimum.

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6 REFERENCES

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