UNDULATORS FOR FREE ELECTRON LASERS

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Abstract

Danfysik has produced insertion devices for the FEL community for almost 10 years. In this paper, we describe two recent undulator deliveries: a 2.8 m undulator for the FELIX free electron laser, and a 4.5 m device for the FLARE project, both at Radboud University in Nijmegen, in the Netherlands.

The device for FELIX is a 2.8 m PPM device, with a peak field of 0.483 T, and a minimum gap of 22 mm. The device for FLARE, is a 4.5 m hybrid device, with special poles, which allow for double focusing.

For both devices,we describe the magnetic modelling, and the magnetic performance.

INTRODUCTION

Danfysik[1] has the ability to deliver all types of insertion devices, including in-vacuum devices, out of vacuum devices, and Apple-II type devices[2,3]. In this short paper, we describe the latest FEL undulators deliveries, this time to Radboud University, in Nijmegen, where 2 undulators have been delivered.

FLARE PROJECT

The FLARE facility[4] is a new light source capable of generating powerful pulsed light in the THz range, between 300 GHz, and 3 THz.

Danfysik received the order to design and build a 110 mm period double-focussing undulator. The main specifications are summarized in Table 1.

Table 1: FLARE Undulator Specifications

Period length	**110 mm**
Number of full-size periods	40
# poles, including end poles	80+2
K_{RMS}	3.45
Effective field	0.475 T
Minimum clear gap	24 mm
Field flatness (x<10 mm)	+1.0 %
Undulator type	Hybrid
Magnet block type	SmCo

Magnetic Design

The undulator was modeled both in RADIA[5] and in Vectorfields OPERA. RADIA was used to get the end termination correct, whereas Vectorfields OPERA was used to double-check central field performance, and demagnetization losses. To achieve the specified double focusing action, we designed a small groove into all of the pole. In this way, we achieved a field increase of 1.0 % at 10 mm.

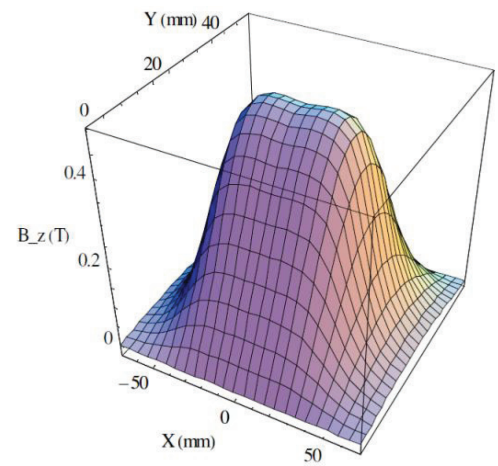

Figure 1: Magnetic field profile on the median plane of the undulator.

Magnetic Results and Shimming

The magnet blocks were delivered by Vacuumschmelze and were well within the limits specified by Danfysik. In particular, the spread in the magnitude of the magnetic moment was mostly within ± 0.5%. This minimized the time necessary for shimming.

The field integral contributions of the horizontally magnetized magnets were all measured individually with the flip coil. The magnets were then installed on the girders, in a sequence determined by the field integral, thus minimizing different accumulated field errors, using a competitive cost-function scheme.

The device was shimmed mostly by magnetic pole displacements, to optimize the electron orbit at all gaps.

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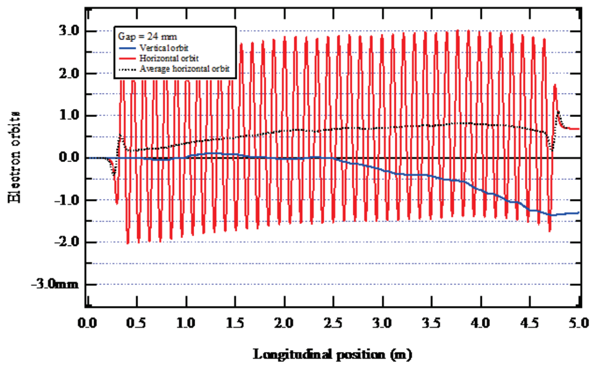

Figure 2: Simulated electron trajectory based on Hall measurements.

FELIX PROJECT

Danfysik also received the order to design and build a U65, PPM undulator for the FELIX facility[6], which has been moved to Radboud. The FELIX beamlines can produce coherent radiation in the wavelength range of 3 to 250 µm.

Table 2: FELIX Undulator Specifications

Period length	**65 mm**
Number of full-size periods	42
# poles, including end poles	84+2
K_{RMS}	2.08
Effective field	0.485 T
Minimum clear gap	22 mm
Undulator type	PPM
Magnet block type	SmCo

Magnetic Design

The undulator was modeled in RADIA[5] and in Vectorfields OPERA. The central and end sections were largely determined from RADIA, and OPERA was used to verify the center design, and check for demagnetization losses. The end design was optimized to minimize the gap variation of the electron orbit, both in terms of first and second field integral.

Magnetic Results and Shimming

The magnet blocks were delivered by Arnold Magnetics and were within the limits specified by Danfysik. The spread in the magnetic moment was ± 1.5%.

As for the U110 hybrid undulator, we chose to measure the field integral contributions of all the magnets prior to mounting the magnets, with a stretched-wire system. As this is a pure-permanent device, we measured the horizontal magnets individually, and paired the vertical magnets, in antisymmetric pairs, according to the Helmholz coil measurements.

The magnets were installed on the girder, in a sequence determined by the field integral, and Helmholz contributions.

Once mounted, the first and second integrals were minimized by using block swapping, based on the field integral signatures of the sub-blocks. Finally, the peak field ripple was minimized by pair-wise shimming of the vertical magnet blocks.

The gap variation of beam-walk specification was quite tight for this device, as it was limited to 0.5 times the wiggle amplitude at all gaps.

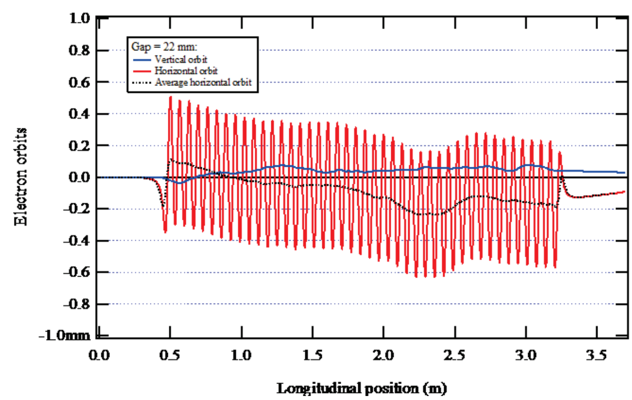

Figure 3: Simulated electron trajectory based on Hall measurements.

CONCLUSION

We have presented 2 different undulators which have been delivered to FLARE and FELIX, both at Radboud University. For the FLARE device, we found that it was possible to design a groove in the poles, to achieve the required focusing. For the FELIX device, extra shimming was required to fulfill the magnetic specifications at all gaps.

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