LATEST DEVELOPMENTS OF INSERTION DEVICES AT ACCEL INSTRUMENTS

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Abstract

ACCEL Instruments GmbH [1] has designed, manufactured, assembled, and tested several insertion devices for many synchrotron light sources and free electron lasers around the world. Besides the superconducting (sc) wavelength shifters, sc-wigglers and sc-undulators, ACCEL has entered the pure permanent magnet based insertion device market.

The latest progress of the insertion device (ID) group was the production of 6 identical PPM undulators for the SPARC Free Electron Laser (FEL) project in Frascati (Italy), the production of a prototype undulator and an industrial study on large scale undulator production for the European X-FEL project in Hamburg (Germany).

ACCEL has signed a know-how and license agreement with the ID group at the ESRF in order to be able to supply customers with high quality insertion devices in short delivery times. Therefore ACCEL has setup a standard ESRF 7 m granite measuring bench.

Design issues, measurement techniques, and measurement results will be presented.

INTRODUCTION

ACCEL has produced and delivered one 50 - and one 100 - period superconducting undulator (SCU) for SSLS (Singapore Synchrotron Light Source, National University of Singapore) [2] and for the ANKA storage ring at ISS at FZK (Institut für Synchrotronstrahlung, Forschungszentrum Karlsruhe, Germany) [3], respectively. Furthermore a design study for reducing phase errors and handling higher heat loads for SCUs for the ESRF has been made.

ACCEL has signed a know-how and license agreement with the ID-group of the ESRF [4] concerning several types of insertion devices like out-of-vacuum undulators, wigglers and APPLE II, in-vacuum IDs, cryogen-in-vacuum IDs and also measurement benches.

ACCEL has set up a 7-m long ESRF newest standard granite measuring bench including a flip-coil and a hall probe measurement system. The data acquisition and analysis software is optimized for an efficient field, field integral, angle, trajectory, and phase error optimisation.

Six identical pure permanent magnet (PPM) undulators for the SPARC FEL project and a 2-m hybrid prototype for the PETRAIII / European X-FEL projects have been delivered recently. An industrial study for the large series production of undulators for the X-FEL is underway.

Further design solutions are under construction for in-vacuum undulators, APPLE II devices and superconducting high field wigglers.

ACCEL is now able to offer all types of highly engineered insertion devices to customers worldwide.

CRYOGENFREE SUPERCONDUCTING UNDULATORS

Figs. 1 and 2 show the undulators produced for the SSLS and ANKA. The ANKA team showed [4] the compatibility of the SCU in terms of heat load, electron beam interaction, ultra high vacuum conditions and cryogenics. Both devices provide a solid base for further production and development of such devices.

Figure 1: SSLS SCU with power supply.

Figure 2: ANKA SCU installed into the storage ring.

The measured magnetic fields and integrals for both devices are shown in Tab. 1. The phase error of the SSLS device is in the order of 6° r.m.s., whereas the undulator for ANKA shows a larger phase error. Technological issues will be improved for future projects as described later.

Table 1: Measurement Results and Design Values for SCUs

		SSLS SCU	ANKA SCU	ESRF design	ANKA SCU 2 (offered)
λ	(mm)	14.0	14.0	15.0	15.0
gap	(mm)	4 - 12	8 - 16	5	8 (5)
N λ		50	100	89	100
length	(mm)	1400	2200	2300	design
field	(T)	1.4	0.7	0.9	design
phase error	°r.m.s.	5.6	12	n.a.	measure
1. integrals	(Gcm)	10	10	n.a.	measure
2. integrals	(Gcm^2)	500	500	n.a.	measure
vacuum	(mbar)	10^{-9}	10^{-10}	n.a.	measure

Improvements

Intensive design studies have been carried out in the framework of an ESRF design study in order to improve:

- the assembly steps (simplified assembly, and maintenance, welding procedures)
- the compensation of heat loads from the electron beam and radiation from the up-stream bending magnet by the introduction of high quality Cu-foil
- the phase error by applying electrical shimming procedures

using ANSYS [6], RADIA [7] and OPERA / TOSCA [8].

Electrical shimming procedures are evaluated using the measured SSLS SCU data and applying specific wiring schemes allowing to correct local distributed phase error jumps. This method allows reducing the phase error of 6° r.m.s. down to 2° r.m.s. The result of this optimisation is shown in Fig. 3.

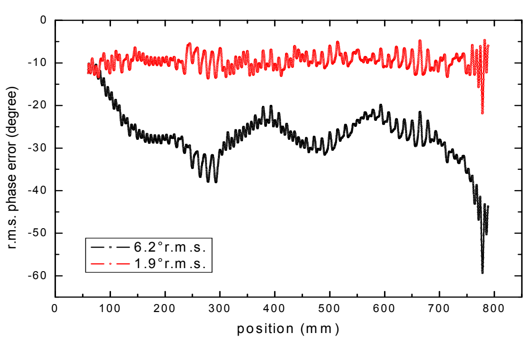

Figure 3: phase error optimisation results.

MEASUREMENT BENCH

In 2004 ACCEL has performed a major step to supply customers with high quality insertion devices by setting up an ESRF standard measurement bench comprising a flip coil and a 3D hall probe. The major advantage of this bench is the stroke length of 6.5 m and the highly automated shimming procedure implemented in the software, calculating directly the angles and trajectories of the electron beam as well as the field integrals and phase errors. Online report generation can easily be done. Figure 4 shows the large granite measuring bench. Table 2 lists the main parameters of the measurement bench.

Figure 4: 7-m granite measurement bench equipped with a flip coil and a 3D hall probe.

The magnet array assembly is done after pre-sorting the magnet blocks and on the results of the Helmholtz coil, mechanical and north/south effect measurements, followed by the characterisation of the magnet pre-assembled modules with a stretched wire setup and mounting the magnet modules on the magnetic array with the computer assisted assembly software.

Table 2: Main Parameters of Measuring Bench

Hall probe calibration / operation	+/- 1.8 T
Hall probe accuracy	1 x 10^{-4} T
Resolution of the flip coil	2 Gcm
Reproducibility of the 6.5 m travel	0.7 µm
Resolution of X and Y axes	0.5 µm
Roll	+/- 15 µrad
Pitch	+/- 10 µrad
Yaw	+/- 10 µrad
Flatness	20 µm

PPM AND HYBRID UNDULATORS

Figure 5 shows the undulator produced for the SPARC project.

Figure 5: 6 identical PPM undulators for the SPARC project.

The electron orbit is shown in Fig. 6, Fig. 7 shows the phase error and Tab. 3 lists the integrals and integrated multipoles calculated from the measured magnetic field at a minimum gap of 6 mm.

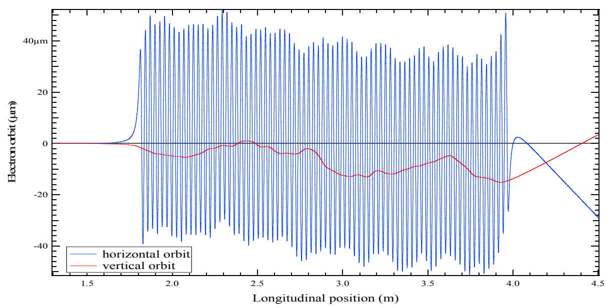

Figure 6: electron orbit at 6 mm gap of one SPARC PPM undulator.

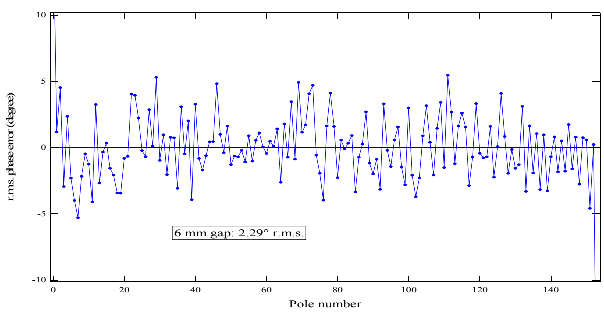

Figure 7: phase error at 6 mm gap of one SPARC PPM undulator .

Table 3: Measurement Results of All 6 SPARC Undulators

ENEA	**1**	**2**	**3**	**4**	**5**	**6**
B (T)	1.10	1.12	1.10	1.12	1.07	1.11
K value	2.90	2.94	2.90	2.95	2.81	2.91
Phase error	2.51	2.58	2.55	2.35	2.29	2.44
∫ normal (Gcm)	31	25	8	21	21	24
∫ skew (Gcm)	38	17	70	97	54	184
∫∫ normal (Gcm^2)	2361	2660	2240	3580	4332	3935
∫∫ skew (Gcm^2)	<1e^3	3360	7660	4460	9854	1.7e^4
n. quad. (G)	45	25	35	22	7	42
s. quad. (G)	250	24	24	98	46	45
n. sext. (G/cm)	118	21	17	16	60	73
s. sext. (G/cm)	26	15	28	227	77	386
n. octu. (G/cm^2)	37	8	16	19	19	21
s. octu. (G/cm^2)	102	9	2	72	63	55

An important effect of the production of 6 identical undulators is the enormous learning factor achieved, including only ten working days for characterising, assembling, aligning and shimming the magnetic arrays of the last undulator.

Figure 8 shows the prototype undulator produced for the PETRA III and the X-FEL project. The scope of work included the implementation of design changes in order to allow a series production based on the DESY design. The high precision of the gap positioning and synchronised movement of the 4 servo motor gap controllers is better than 1µm.

Figure 8: 2-m prototype for the PETRA III / X-FEL project.

FUTURE DEVICES

On the basis of all produced insertion devices, design studies are underway in order to supply customers worldwide with highly engineered IDs like APPLE II, IVUs or cryogen IVUs using the extensive experience from the ESRF ID group.

The combination of our know-how in cryogenics, UHV, and insertion device technologies makes ACCEL Instruments a reliable and potential supplier also for the cryogen IVUs.

REFERENCES

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