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INSERTION DEVICES AT THE MAX IV 3 GeV RING

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Abstract

Currently there are 8 Insertion Devices (ID) installed and in operation and 2 new ones to be installed end of 2021 at the MAX IV 3 GeV storage ring. In this paper, the first commissioning results of the three newly installed ID's in 2020 will be described. The new ID's are one APPLE II for SoftiMAX beamline and two In-vacuum Undulators (IVU) for the DanMAX and CoSAXS beamlines. The mitigation scheme adopted to reduce undulator-like radiation from BALDER in-vacuum wiggler will be discussed.

Two new IVU's with period length of 17 mm and 18 mm for the ForMAX and MicroMAX beamlines will be installed during winter shutdown of 2021-2022. Both ID's have 3 m length and a minimum gap of 4 mm. In this paper, the magnetic measurement results will be presented in terms of the achieved field quality and phase error.

INTRODUCTION

The beamlines at the MAX IV 3 GeV storage ring rely on insertion devices as a source of synchrotron radiation. Today there are 8 beamlines receiving light and 2 new ones are under construction. The first 5 ID's of phase I beamlines were covered in ref [1]. Recently 3 beamlines were commissioned and the sources are based on APPLE II for SoftiMAX beamline and IVU's for CoSAXS and DanMAX beamlines. Table 1 summarizes the main parameters of the 3 ID's and also the 2 new ones of ForMAX and MicroMAX beamlines.

Table 1: Parameters of Phase II IDs at 3 GeV Ring

ID	L [m]	λ [mm]	Keff
SoftiMAX	4.0	48.0	3.33
CoSAXS	2.0	19.3	2.20
DanMAX	3.0	16.0	1.66
ForMAX	3.0	17.0	2.00
MicroMAX	3.0	18.0	2.20

SOFTIMAX APPLE II

The SoftiMAX is a soft X-ray beamline dedicated to spectromicroscopy and coherent imaging. The photon energy range is 275 – 2500 eV with full polarization control as the ID is based on the APPLE II structure, see Fig. 1. The ID was built and characterized in-house to meet the tight requirements of the low emittance 3 GeV ring. Figure 2 shows the residual field integrals in both planes as measured 'magnetically' by the e-beam in the helical modes. Similar measurements were carried out for the so-called inclined mode. The beamline started to receive light on March 2020 and as shown in Fig. 3, one of the first spectra at gap of 20 mm after conditioning time of beamline components and preliminary photon beam based alignment.

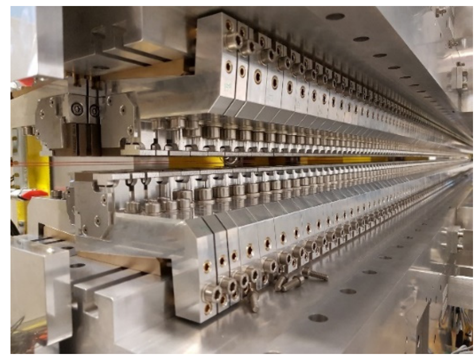

Figure 1: SoftiMAX APPLE II during magnetic characterisation at ID laboratory.

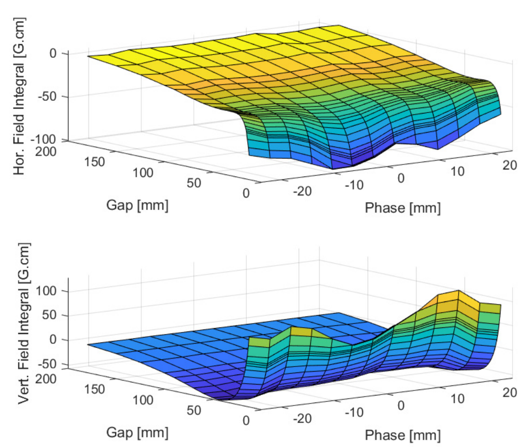

Figure 2: Residual field integrals in both planes of SoftiMAX ID as a function of gap and phase in helical mode.

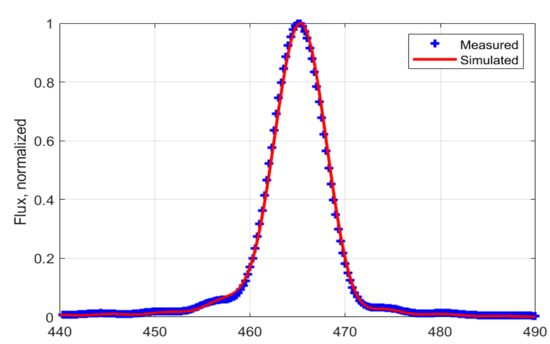

Figure 3: Comparison of simulated and measured SoftiMAX ID spectra at 20 mm gap and zero phase.

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The motion control of gap and phase for the SoftiMAX ID is based on closed loop. As an example, each of the 4 motors dedicated for the gap movement is connected to linear encoder of its respective axis. Such configuration improves step and continuous scanning of the photon energy, improves operational safety as it prevents unintentional tapering and increases speed of gap adjustment and gap precision. Figure 4 shows upper and lower girders of the ID's gap and gap tapering while moving the gap from 150 mm to 20 mm and back to 150 mm.

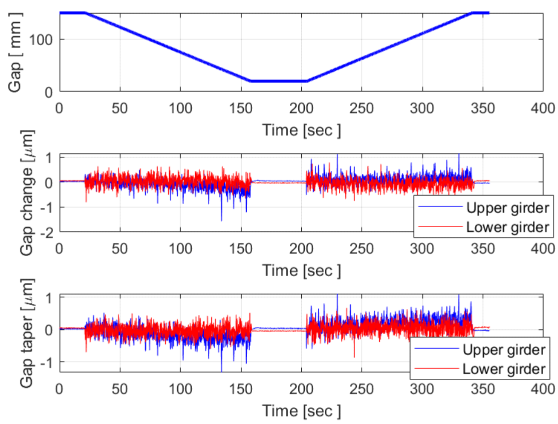

Figure 4: Read-outs of SoftiMAX ID gap and gap tapering while gap movement.

BALDER IN-VACUUM WIGGLER

The low emittance and low energy spread of the 3 GeV ring leads to an undesirable undulator-like spectra from the BALDER in-vacuum wiggler [1]. The ripples or large variation in the photon flux during energy scanning were predicted at the design stage and the wiggler was built with gap tapering feature of maximum 2 mm, see Fig. 5. In addition to gap tapering, the e-beam could be tilted vertically to collect photons off-axis to smoothen the ripples to an acceptable level. Figures 6 and 7 show two spectra at 5 mm gap with zero and 0.5 mm tapering at different vertical tilt angles of the e-beam that are affordable by orbit correction system. The engagement of the 8 ID's to minimum gap lead to an emittance reduction of 17% as expected and measured. Further optimisation is currently under study to shift the front-end fixed mask vertically.

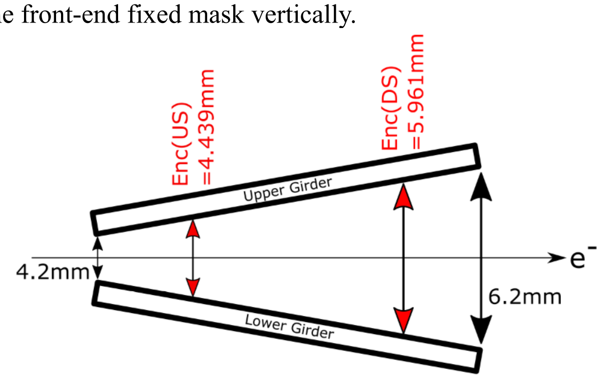

Figure 5: BALDER wiggler taper configuration at minimum gap and maximum tapering with encoders read-outs.

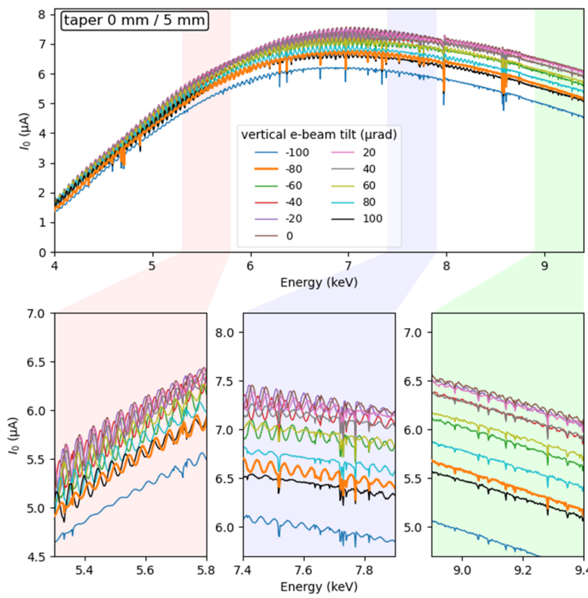

Figure 6: BALDER wiggler spectra at 5 mm gap with zero tapering and different vertical tilt angles of e-beam.

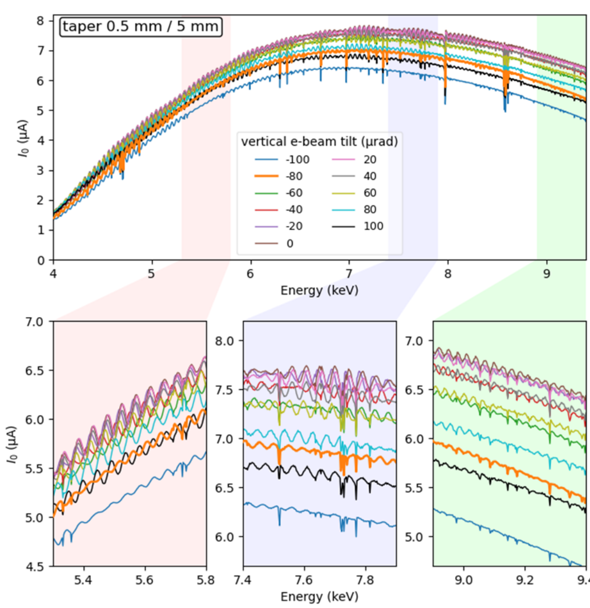

Figure 7: BALDER wiggler spectra at 5 mm gap with 0.5 mm tapering and different vertical tilt angles of e-beam.

DANMAX & COSAXS IVU'S

The DanMAX and CoSAXS ID's are based on room temperature in-vacuum undulator with hybrid structure. The 2 ID's were specified to have RMS phase error of <2.5 degrees, which was achieved as shown in Fig. 8. The CoSAXS IVU's influence on the beam as a residual kick is measured with 3 mA beam as in Fig. 9.

Figure 10 shows a collected spectra from the DanMAX during commissioning phase of the same photon energy from two distant harmonics, the 7th and the 15th, at two different gaps and hence, two different RMS phase errors. This is a way to judge the effect of the energy spread of the

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e-beam and the phase error on the line width and hence the brilliance. The two spectra were collected at 250 mA and energy spread of 0.08%. The difference of total radiated power between the two gaps is around a factor of 11 higher for the low gap case.

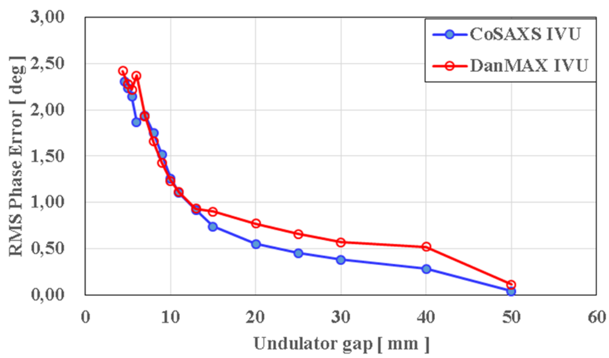

Figure 8: Measured RMS phase error of DanMAX and CoSAXS IVU's prior installation.

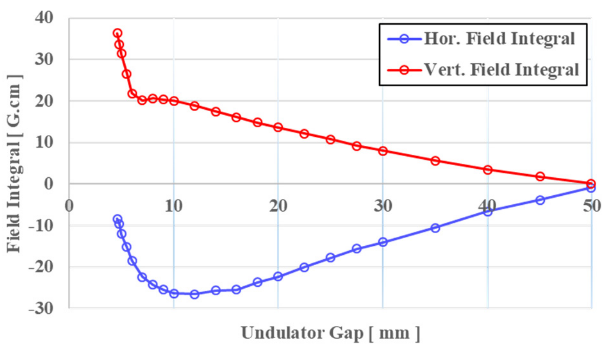

Figure 9: CoSAXS IVU field integrals as seen by the 3 GeV e-beam.

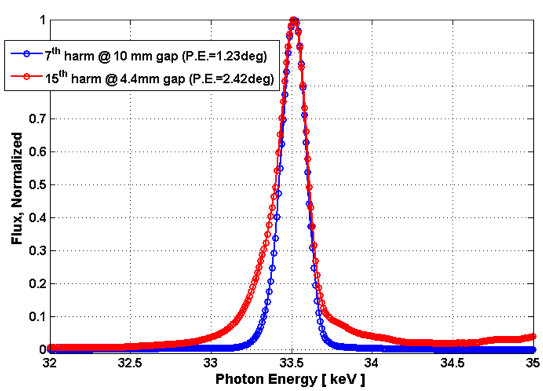

Figure 10: DanMAX spectra of same photon energy from the 7th & 15th harmonics at 250 mA.

NEW IN-VAUUM UNDULATORS

The installation of the two new IVU's for the ForMAX and MicroMAX beamlines was delayed to winter 2021-2022 due to Covid-19 restrictions. The magnetic measurements demonstrated an achieved effective K values and RMS phase errors of both ID's as shown in Fig. 11. The commissioning of both ID's will start early 2022 as planned. Figure 12 shows the expected brilliance estimate of both ID's at 500 mA design beam current.

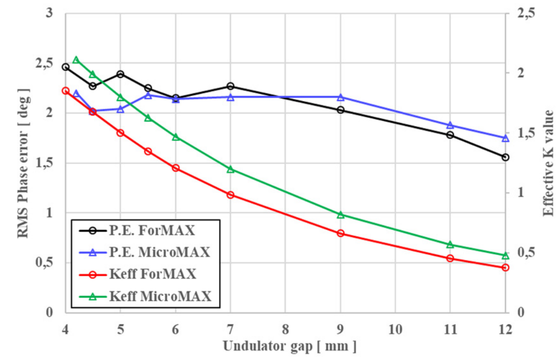

Figure 11: Measured RMS Phase Error (P.E.) and effective K value (Keff) for ForMAX and MicroMAX undulators.

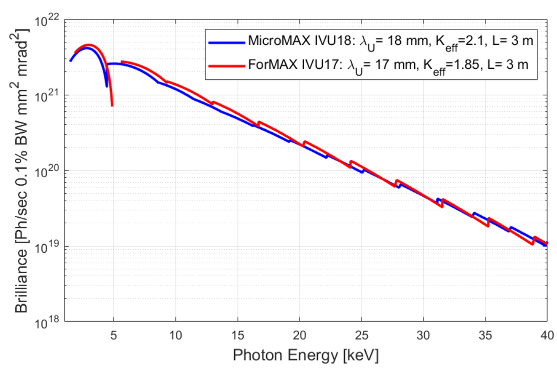

Figure 12: Brilliance estimate of the ForMAX and MicroMAX IVU's at 500 mA beam current.

CONCLUSION

The commissioning of the SoftiMAX, CoSAXS and DanMAX ID's were successful in terms of the influence on the e-beam and related photon beam based alignment to meet the expected performance. Gap tapering and manipulation of the e-beam inside the BALDER wiggler proved to be the proper scheme to reduce the undulator-like radiation. The 2 new IVU's of ForMAX and MicroMAX are planned for installation end of 2021.

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REFERENCES

[1] H. Tarawneh *et al.*, "First Commissioning Results of Phase I Insertion Devices at MAX IV Laboratory", *AIP Conference Proceedings*, vol. 2054, p. 030023, Jan. 2019. doi:10.1063/1.5084586