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STATUS OF HEPS INSERTION DEVICES DESIGN

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Abstract

HEPS is a 4th generation light source with the energy of 6 GeV and ultralow emittance of 34 pm.rad. A total of 14 beamlines with 19 insertion devices has been planned in the first phase, including 6 cryogenic undulators, 5 in-vacuum undulators, and two special non-planar IDs. The schemes and parameters of all the IDs are planned to be determined in this year. We report on the status of the design of these IDs and their effects on beam dynamics.

INTRODUCTION

The first phase of HEPS is planned to be completed in 2025 [1]. A total of 14 ID-based beamlines are required in the first phase of HEPS. The photon energy range is targeted at hard-X ray (>10 KeV) regime for most beamlines except one for the research of the high resolution nanoelectronic structures which the interest energy range is at 100-2000 eV.

PARAMETERS AND PERFORMANCE

Type selection and parameter designs of all these IDs have undergone three times of major changes since the HEPS project has been approved. The first change was at the beginning of the preliminary design. During this change, the total number of "performance" beamlines are limited to seven because of too many CPMUs [2] or IVUs were chosen before by users which lead to too large electron energy loss per turn and hence some concerns on related effects, e.g., dynamic vacuum. The second modification was made correspondingly with the update of the main ring lattice design in 2018 and 2019. In this new lattice design, the storage ring comprises 48 7BA cells that are grouped in 24 super-periods. There are a low-beta straight section and a high-beta straight section on each side of one 7BA cell [3]. Base on this design, the minimum acceptance physical aperture at the low-beta straight section is determined to be 5 mm according to the beam loss simulation. It restricts the minimum magnetic gap of all IDs to 5.2 mm (0.2 mm is for the twice of thickness of conducting foils). The modification of beta functions and acceptable minimum gap leads to the second round of update of all ID parameter designs. During the period of HEPS international advisory committee in Nov. 2019, this version of ID type selection and parameter design were discussed thoroughly. According to the advices of the committee, we have made some additional adjustments according to needs of different users. The main change is in the ID type selection for two "performance" beamlines. A 4-meters long IVU was used to replace the previous scheme of double two meters long CPMU in tandem. Two of special types of PPM IDs are planned. The one is a special type of 4-rows APPLE-Knot undulator [4, 5] has been adopted by PES beamline users in order to produce polarization tunable soft X-ray with the photon energy range of 100-2000 eV and low on-axis power heat load. In order to satisfy the requirement of large vertical field range for X-ray phase contrast imaging, a special Delta type PPM wiggler called Mango wiggler has been designed for the other.

After several years of iteration and consultation with beamline users, schemes of ID type selection and parameters have frozen in Oct. 2020 as shown in Table 1.

Table 1: Types and Parameters of all IDs for 14 Beamlines Planned in the First Phase of HEPS

Beamline	Type	λ_u (mm)	Periods	K
ID07	CPMU×2	16.7	117	1.19
ID19	IVU SmCo	22.6	174	2.3
ID23	CPMU	12	164	0.9
	CPMU	14.2	138	1.3
ID09	IVU SmCo	19.9	199	1.8
ID33	IVU NdFeB	18.6	213	1.8
ID31	IVU SmCo	18.6	213	1.8
ID21	CPMU	18.8	104	2.4
	wiggler	73	13	11.2
	Mango-W	51/50	18	4.8
ID05	IVU SmCo	22.6	174	2.3
ID42	CPMU	22.8	85	2.5
	IAW	73	13	11.2
ID46	IAU	35	141	2.9
ID02	IAU	32.7	151	2.4
ID08	IAU	25	199	1.3
ID30	IAU	32.7	141	2.4
ID06	APPLE-Knot	256.8	18	H.L: y/x 6.4/7.9 V.L: y/x 4.9/6.2 C.: y/x 5.8/4.4

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Design performances of the photon sources were also derived after ID parameters are frozen. We present the on-axis brightness of all beamlines except APPLE-Knot beamline at the high brightness mode [6] of the storage ring as shown in Fig. 1. In the calculation, we used "zero-current" beam parameters of HEPS without the consideration of ID effects including radiation damping quantum excitation and linear optics distortion. And a Gaussian-Schell approximation [7] was applied in the calculation.

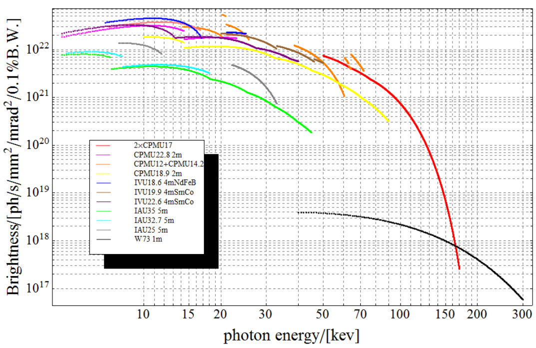

Figure 1: Brightness of all IDs for 13 beamlines at high-brilliance mode.

CRYOGENIC PERMANENT MAGNET UNDULATOR

Based on the development of the HEPS test facility, a 2-m long CPMU with the period length of 12 mm has been developed first for the fabrication process certification of all the remain standard CPMUs. It consists of PrFeB magnets and alternatively arranged poles with the material of FeCoV and operated at the temperature of 80 K, as shown in Fig. 2.

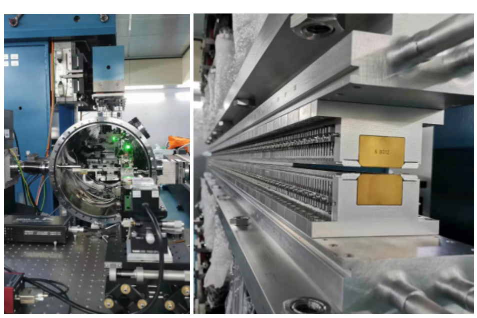

Figure 2: Photograph of CPMU12(left) and its magnetic rows(right).

It was constructed for the source of the structural dynamics beamline which is able to produce radiation photon with the fundamental energy of over 20 keV and the on-axis maximum brilliance of approximately 5×10^{22} ph/(s.mm^2.mrad^2.0.1%B.W.) when operating concurrently with another CPMU14.2 in tandem at the high brightness mode. Commissioning work of CPMU in the lab was basically completed in April this year. The hall-probe measurement results show the phase error could be less than 3.2 degree in the operating gap range and the temperature of 80 K, with the results as shown in Fig. 3. The adjustment of multipole integral error is still in progress. Figure 4 presents the stretched wire measurement status of the field integral distributions.

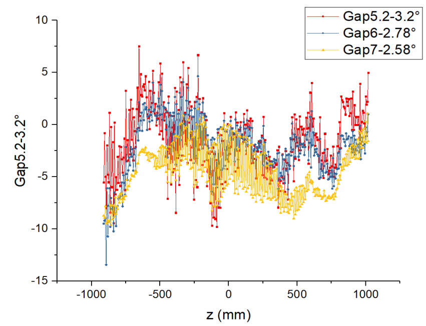

Figure 3: Phase errors@80 K.

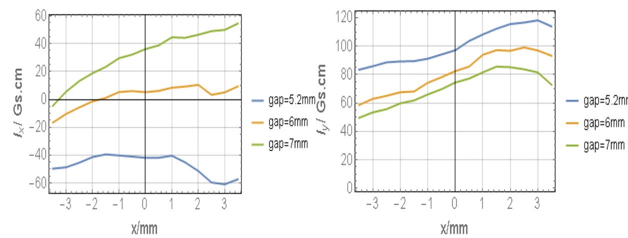

Figure 4: Field integral error distribution in the good field region@80 K.

SPECIAL POLARIZATION INSERTION DEVICE

In the first phase of the HEPS, there are two special non-planar insertion devices planned to be built. The first is the APPLE-Knot undulator which is planned to be applied on the PES beamline. It will be the first attempt to construct a four rows APPLE-Knot [8, 9] by using amount of merge magnetization magnets. The requisite technology of high accuracy magnetization for magnets has been validated on an existing 10-periods prototype of Delta-Knot undulator [10]. Furthermore, a two-period prototype of the APPLE-Knot undulator is planned to test the mechanical design.

The second is the Mango wiggler which is a demand-driven conception from XPCI users. It was developed for the goal of expanding vertical photon field region and named by the profile of the radiation power transverse distribution as shown in Fig. 5 (left). A Delta type of PPM Halbach structure with a small period length deviation in two perpendicular directions has been designed to meet this goal as shown in Fig. 5 (right).

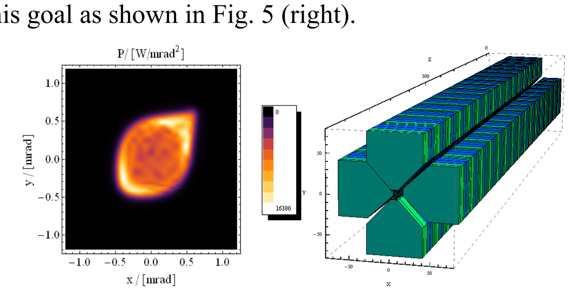

Figure 5: Power distribution of Mango wiggler (left) magnetic structure of Mango wiggler (right).

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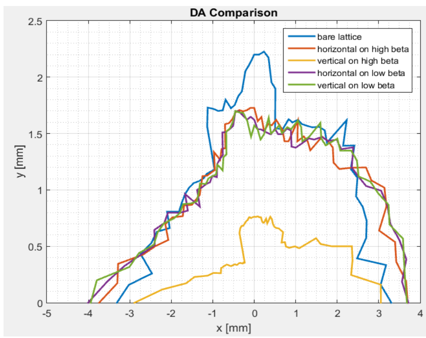
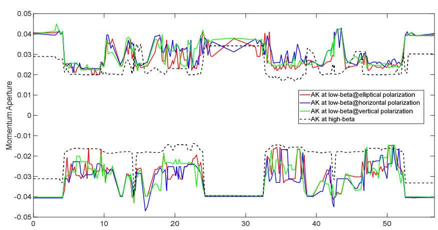
DYNAMIC EFFECTS

The linear optics is matched to the ID by seven pairs of quadrupoles besides ID [11]. It is able to match the tune shift, dispersion and Twiss parameter simultaneously. Dynamic aperture as well as beam life-time are calculated by tracking with AT program. During last Nov., we have changed the planned location of APPLE-Knot ID from the high beta straight section to the low beta straight section to increase the DA and LMA as shown in Fig. 6. We finally ensure the beam life time over 1.6 hour (with all IDs but without errors) for the high-bunch-charge mode at 200 mA. All ID pass-methods are modelled by kick-maps [12, 13].



(a)



(b)

Figure 6: DA comparison (a) LMA comparison (b).

SUMMARY

Up to now, all types and parameters of most of the IDs are chosen after the long-term iteration design between the accelerator and the beamline experts. However, physical designs of two special non-planar IDs are still in progress. Nevertheless, development of the first CPMU has not yet been completed that means the fabrication process of standard CPMU is still need time to be explored. Fabrication of the first 4 meters long IVU is planned to start in 2021.

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