Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Analysis of the Parameters of Korea-4GSR

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1. Introduction

As the 4th generation synchrotron radiation based on a storage ring (4GSR) is widely spread over the world, the Korean accelerator community has begun to design and construct a 4GSR facility, called tentatively as Korea-4GSR. 4GSR intends to establish the ultimate light source based on a storage ring, a synchrotron radiation source the electron beam-emittance of which is limited only by nature (diffraction of light), not by limitations of machines. Once the diffraction limited electron emittance is achieved, it would not be necessary to reduce the electron emittance any further. The radiation from a diffraction limited synchrotron light source would be not only extremely bright but also spatially coherent. The practical method for achieving 4GSR is the multi-bend achromatic (MBA) magnet lattice. In reality, most 4th generation light sources based on MBA are diffraction limited only vertically for hard X-ray radiation, except few large machines such as APS-U [1] or PETRA-IV [2].

The Korea-4GSR has finished its lattice design and fixed many relevant physics parameters [3]. Using many techniques developed so far after the advent of the first 4GSR, MAX-IV [4], the Korea-4GSR has been able to achieve a very low electron emittance and good relevant parameters. This paper aims to overview and analyze such key parameters of Korrea-4GSR as electron beam energy, beam emittance, bunch length, and understand its status in the 4th generation light sources of the world.

2. Parameters of Korea-4GSR

The main parameters of Korea-4GSR is shown below in Table 1, and the magnet lattice is shown in Fig. 1.

Table I: Parameters of Korea-4GSR

Parameter	Value	Unit
Energy	4.0	[GeV]
Current	400.0	[mA]
Circumference	799.29698	[m]
No. of bunches	1065	[-]
Bunch length (No HC /HC)	4.058 / 16.232	[mm]
Natural emittance	62.23950131	[pm]
Coupling Constant	0.1	[-]
Energy Spread	0.001263788	[-]
RF frequency	499.877	MHz
Beam lifetime	4.54	Hour

2.1 4 GeV Electron Energy

The first notable thing is that its beam energy is 4 GeV, while the 4GSR beam energies around the world are either 3 GeV for general purpose machines or 6 GeV for hard X-ray users. 4 GeV beam energy is a unique choice. Of course, one of the reasons for the choice was to focus on hard X-ray spectrum.

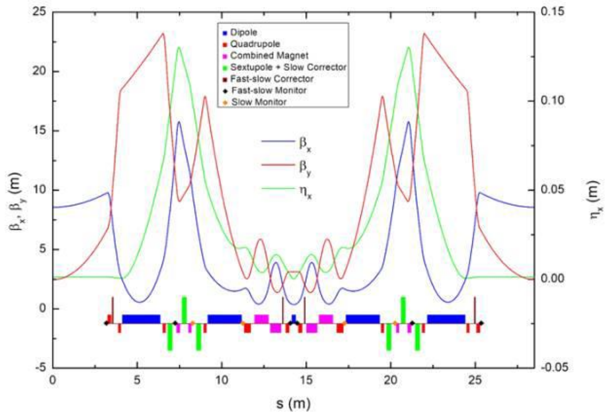

Fig.1 Korea-4GSR lattice.

Another reason for choosing the 4 GeV electron energy for Korea-4GSR was probably to be more prepared for possible instabilities in the storage ring. For example, the MAX-IV commissioning and operation showed the danger of coupled bunch instabilities coming from RF cavities. The radiation damping time of a 4-GeV beam is smaller by 0.42 times than that of a 3-GeV electron beam. Without a superconducting RF cavity system, this shorter damping time may be greatly helpful in fighting against beam instabilities.

2.2 MBA Lattice and Magnets

Another remarkable thing about the Korea-4GSR parameters is that it has a relatively lower beam emittance (62 pm rad) compared to other 4th generation light sources of similar sizes, as can be seen from Fig. 2. In other words, it is competitive in beam emittance. The reason for this low emittance is that the Korea-4GSR design team has made use of a number of techniques developed by many laboratories after the advent of

MAX-IV. Korea-4GSR has been designed by using many different types of magnets, including longitudinal gradient bending magnets, transverse gradient bending magnets, quad bending magnets, quad reverse bending magnets, and reverse bend magnets in addition to center bending magnets. As a result, Korea-4GSR has a design emittance one order of magnitude lower than the MAX-IV emittance. This emittance can be lowered further by installing damping wigglers additionally. Damping wigglers will not be installed initially but may be installed later after a few years of operation.

Note that the condition of being diffraction limited is that the beam emittance is smaller than $\lambda/4\pi$, where λ is the wavelength of target radiations. For the 0.1 nm wavelength hard X-ray, which is widely used, $\lambda/4\pi$ is smaller than 10 pm, a much smaller number than 62 pm. Therefore, Korea-4GSR's hard X-ray radiation will be fully coherent vertically, but not horizontally.

2.3 RF System and Beam Lifetime

Korea-4GSR will install 10 normal conducting HOM (high order modes)-damped RF cavities and 6 third harmonic cavities. HOM-damped cavities are expected to suppress HOMs sufficiently so that coupled bunch instabilities will not occur. Third harmonic cavities are necessary to elongate electron bunches to increase beam lifetime. The installation of third harmonic cavities can increase the beam lifetime from 4.5 hour to around 16 hour. Long enough beam lifetime is required for stable operation, and making sufficiently long beam lifetime is particularly difficult in 4GSR.

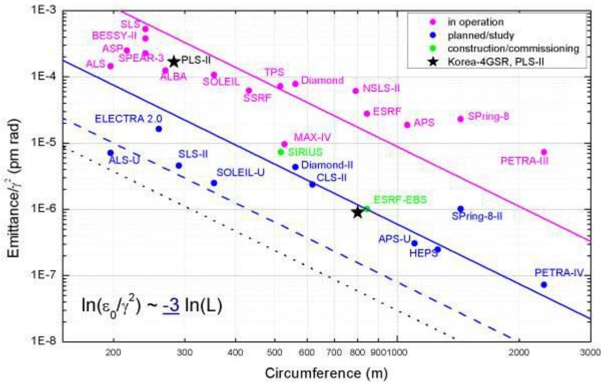

Fig. 2. Emittance/γ^2 as a function of the storage ring circumference. Here, $\gamma = E/mc^2$.

3. Comparison of 4GSR with X-ray FEL

A storage ring based 4th generation light source (4GSR) and a linear accelerator based X-ray free-electron laser (XFEL) both provide extremely bright radiation. In general, an XFEL has higher peak brightness, whereas a 4GSR has higher average brightness. In radiation quality, both facilities provide spatially coherent radiation, but the XFEL radiation is also partially coherent temporally. In radiation stability, a 4GSR is better. An XFEL may have fluctuations shot to shot.

4. Conclusion

Korea-4GSR will be a unique 4th generation light source with an exceptionally low emittance. Its radiation will be fully coherent vertically and partially coherent horizontally. With third harmonic cavities, it will have sufficiently long beam lifetime. With HOM-damped cavities and the relatively higher 4 GeV beam energy, it will be a stably operated machine.

REFERENCES

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