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# MULTI FEL LINES WITH COMPACT UNDULATOR LAYOUT

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*Abstract*

The X-ray Free Electron Lasers based on superconducting radiofrequency technologies [1, 2] can operate at very high repetition rates at up to MHz level. Such a facility is capable of serving many FEL photon beamlines simultaneously with each of which has large flexibilities in selecting wavelength, intensity, polarization, coherence and other properties through independent tuning of the undulator magnets. In reality the space needed to accommodate many undulator lines could be a limiting factor of user capacity, especially for the XFELs built in the underground tunnels. In this paper we present a practical option to provide multi FEL lines in limited spaces like underground tunnels with the stackable multi-layer undulator. The comparison with the two-in-one type undulator is also presented.

## INTRODUCTION

Shanghai Coherent Light Facility (SCLF) is a newly approved X-ray Free Electron Laser based on superconducting radiofrequency technologies [3]. The superconducting electron accelerator and undulators as well as photon beamlines/endstations are all installed in underground tunnels with an overall length of more than 3 km. The electron beams are distributed in the switchyard shaft to different undulator lines. The current design assumes single tunnel for main accelerator and three tunnels for undulators and beamlines, all with an inner diameter of 5.9 m.

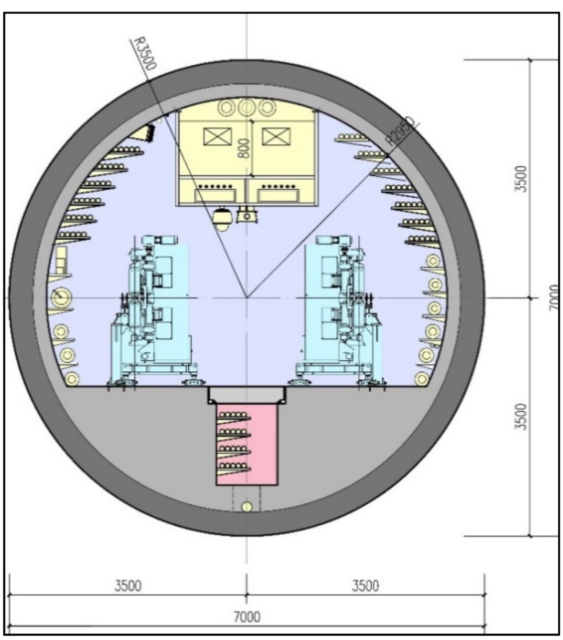


Figure 1: Cross section of undulator tunnel of SCLF.

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The dimension of cross section of tunnels designed to install two conventional undulator lines. See figure 1.

In the first phase of the project there are three undulator lines planned for producing bright FEL beams in hard and soft X-ray regimes. The FEL-I and FEL-II will be located at the central tunnel in parallel using conventional out-vacuum undulator technology. The FEL-III is going to adopt the superconducting undulator concept for achieving stronger magnetic field strength with small undulator period hence the higher photon energies with relatively moderate electron beam energy. Currently SCLF is designed to cover the wide range of photon energy from soft to hard x-ray with 8 GeV electron beam and three undulator lines. In future it is crucial for this kind of facility to maximize its ultimate capabilities of providing photon beamlines for scientific users.

## STACKABLE HORIZONTAL GAP UNDULATORS

The vertical polarization undulators with horizontal gaps have been adopted in different FEL facilities [4][5]. Here we present a multi-layer layout of this kind of undulator [6] shown in Figure 2.

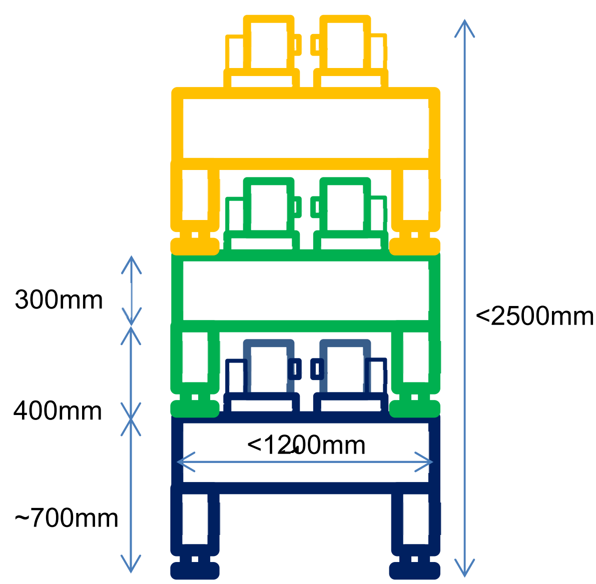


Figure 2: Scheme of stackable horizontal gap undulator.

The main features are,

- The transverse dimensions for a three-layer layout are no more than 1.2m wide and 2.5m high.
- A quite compact design is needed to arrange all the components in limited spaces. In particular, the widths of strongback must be under control to

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leave enough spacing for the supports of upper layer undulator.

- To address above issue the magnetic compensation scheme is adopted in the current design.
- The stackable structures have an obvious advantage over the one-frame structure, i.e., FEL lines could be built up as staged project. However the one-frame option could be more stable and would be constructed at a time. See Figure 3.

Figure 3: Layout of multi-layer horizontal gap undulators, Left, Stackable type; Right, One-frame type.

There are enough spaces between undulator lines for transport and installation work near the tunnel walls, The space of 1.5 m width between undulator lines is available for transporting undulators and 0.9 m between tunnel wall and outer undulator magnet for component installations.

With this type of undulator each tunnel with 5.9m-diameter may accommodate up to 6 independent FEL undulator lines. See Fig.4.

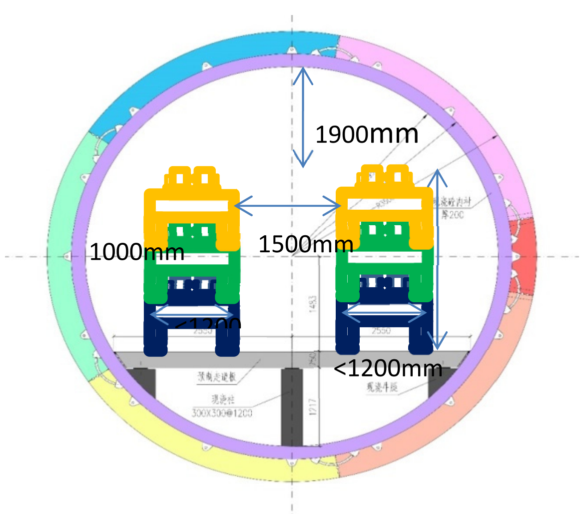


Figure 4: Proposed installations of up to six horizontal gap undulators in the SCLF tunnel with two rows of three-layer layout.

In order to verify the mechanical performance of this type of concept three 4-meter-long full size prototype undulator frames have been constructed. See Figure 5. The measurements of stabilities of the three layers of frame are carried out. It is planned to install novel magnetic structures with compensation schemes.

Figure 5: Three frames of stackable horizontal gap undulator.

Figure 6 shows three different undulators in same picture, from left to right,

- conventional undulator with a typical frame structure that supports only one pair of strongback.
- Two-in-one type undulator[7] in which two pairs of strongback share a common frame hence save a lot of spaces and components
- Multilayer(shown has three layers) and stackable undulators

Each type of undulator comes with very similar transverse dimensions, say, about 1.2 m wide and 2.5 m high. This means newly proposed undulators could increase the capacity of FEL lines per tunnel by a factor of 2 and 3, respectively.

Figure 6: Three kinds of undulator are showing here, red one is a conventional undulator, two-in-one type undulator is in the middle(unpainted) and multi-color stackable undulator frame.

## CONCLUSION

A concept of stackable horizontal gap undulator magnet is proposed to better utilize the space in tunnel to provide independently tuning flexibilities of three different FEL photon beams within spaces comparable to a conventional undulator line. The prototype of frames of stackable undulator is constructed and being tested.

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