DESIGN OF THE SWISSFEL SWITCHYARD

N. Milas* and C. Gough, PSI, Villigen 5232, Switzerland

Abstract

The SwissFEL facility will produce coherent, ultra-bright, and ultra-short photon pulses covering a wavelength range from 0.1 nm to 7 nm, requiring an emittance between 0.18 to 0.43 mm mrad. In order to provide electrons to the soft X-ray beam line of SwissFEL a switchyard is necessary, which will divert the electron beam, with an energy of 3.4 GeV, after the first set of accelerating structures. This switchyard has to be designed in such a way to guarantee that beam properties like low emittance, high peak charge and small bunch length will not be spoiled. In this paper we present two possible schematics for the switchyard and also discuss the constraints on the kicker-septum set, on misalignments and on charge fluctuation.

SWITCHYARD DESCRIPTION

The switchyard for SwissFEL [1] diverts the beam coming from Linac 2, with an energy of 3.4 GeV, to the long wavelength undulator (Athos beamline). At the switchyard entrance a fast kicker followed by a septum magnet deviates the second of the two bunches accelerated in the Linac 2. This second bunch will then be further deviated towards the Athos beamline while the first bunch continues straight towards Aramis. In the present set-up of the switchyard, its total length is 77 m and the separation between the Athos and Aramis beamlines is about 4 m, with a net bending angle equal to zero, making the two beamlines parallel to each other, as shown in Figure 1. In the transport line, the central section has 9 m which should allow for the transport of heavy equipment to the Linac area and there is also enough space for collimators in between the quadrupoles all along the switchyard. This design has two almost identical double-bend achromatic (DBA) sections and each section has a total bending angle of about 4°. A central dipole is inserted in the center of each double bend, a ”micro-bend”, and is used only to adjust the value of $R_{56}$ in order to make the sector also isochronous. The next section shows the two possible designs for the switchyard regarding how the bunch separation is performed. Since the two lattices share the same type of symmetry and also its main characteristics a more general discussion about both lattices is given later on.

Kicker and Septum

SwissFEL will work in double bunch mode with a bunch time separation of 50 ns and a repetition rate of 100 Hz. The first bunch will feed the hard X-ray beamline (Aramis) while the second one will go through the switchyard to the soft X-ray line (Athos). In order to separate the beam for the soft x-ray beamline a resonant kicker [2] will be used together with either a septum pulsed magnet or a Lambertson magnet. The set horizontal kicker and septum has the advantage of not creating any vertical dispersion, however the constraints on the septum shot-to-shot jitter may create technical difficulties for its manufacture. Another possibility is to use resonant kickers to deflect the beam in the vertical direction and use a DC Lambertson magnet to separate it horizontally [3], this setup has the advantage of introducing much less noise on the beam but on the other hand creates vertical dispersion that must be taken care of in the switchyard.

Horizontal Deflection

In the case of horizontal separation, a set of 3 kickers are placed at an average distance of 10 m from a pulsed septa. The lattice functions are shown in Figure 2. In this case there is only horizontal dispersion and the switchyard lattice is quasi-symmetric. The Septum and the first dipole bending angles are -1.97° and the second set of dipoles bending angles are 1.92° and the ”micro-bending” angles are 0.18 and -0.08, respectively.

Vertical Deflection

In the case of vertical separation, a set of 3 kickers are placed at a distance of 14 m from a DC Lambertson magnet. The lattice functions are shown in Figure 3. In this case the Lambertson is rotated by an angle of 1.6° with respect to the longitudinal axis, so that the switchyard is parallel to the horizontal plane. The lattice functions are symmetric and mirrored with respect to the center of the switchyard and the vertical dispersion is maximum at a point of...
zero horizontal dispersion. The Lambertson and all three dipole horizontal bending angles are ±2° and the “micro-bending” angles are ±0.08°.

**Common Lattice Design**

For both lattices studied the Twiss functions in the two bend sets are approximately the same, so that kicks due to coherent synchrotron radiation (CSR) act in opposite directions and, by adjusting the phase advance between them, we can compensate for the emittance dilution caused by CSR. The maximum dispersion is 0.15 m in the double-bend sections and, considering a total energy spread in the beam of 0.1%, the maximum beam size in the switchyard is 160 µm (1 sigma rms) in the horizontal plane, and is 56 µm (1 sigma rms) in the vertical plane, and is about 0.15 m in the double-bend sections. Therefore, the maximum emittance is negligible, being much smaller than distortions caused by the lattice. For the case with CSR, the amount of projected emittance growth was suppressed by carefully choosing the phase advance between the two bending sets. Although the projected emittance can be very sensitive to the phase advances, the sliced emittance is conserved along the whole switchyard, as shown in Figure 5.

**Table 1:** Twiss Functions at the End on LINAC2 and at the Entrance of the Switchyard

<table>
<thead>
<tr>
<th>Twiss Function</th>
<th>LINAC2</th>
<th>Switchyard</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_x$</td>
<td>29.6 m</td>
<td>5 m</td>
</tr>
<tr>
<td>$\alpha_x$</td>
<td>-1.93</td>
<td>0.0</td>
</tr>
<tr>
<td>$\beta_y$</td>
<td>8.6 m</td>
<td>46</td>
</tr>
<tr>
<td>$\alpha_y$</td>
<td>0.55</td>
<td>6</td>
</tr>
</tbody>
</table>

**KICKER SEPTUM CONSTRAINTS**

Given the requirements of the undulators the maximum orbit jitter acceptable at their entrance is 0.1$\sigma_{x,y}$ and, for the Athos beamline, a maximum acceptable emittance growth of 5%. Converting this requirements to shot-to-shot jitter for the kicker and septum setup, and given that the resonant kicker is able to provide a shot-to-shot jitter < 36 ppm or $4 \times 10^{-5}$ we found that the Septum jitter should be
beamline, foresees a set of transverse collimators at the horizontal dispersion free section of the switchyard and a dispersive energy collimator in the second set of DBAs, as shown in Figure 6. For each transverse plane a set of two collimators are separated by a phase advance of 90° and the apertures are 12 mm and 8 mm for the vertical and horizontal collimators, respectively. Those apertures give an acceptance of \( A_x = 1.4 \text{ mm.mrad} \) and \( A_y = 1.3 \text{ mm.mrad} \) which is smaller then the limitation of 1.6 mm.mrad at the undulators. For the energy collimation an aperture of 6 mm will give a total momentum acceptance of 1.7 %. Further studies including dark current and halo formation are necessary to optimize the collimators design.

Figure 6: Initial position of the collimation system. Example of the position of the collimation system together with the twiss functions for the case with horizontal deflection (kicker and septum).

**CONCLUSION**

We have presented two possible schematics for the switchyard, including vertical or horizontal separation. Studies on misalignments, charge fluctuation and on the kicker-septum constraints were also carried out. A preliminary study on the collimation and protection system was initiated and possible locations for the transverse and energy collimators were chosen. Further studies on non-linearities, chromatic effects and a more detailed study on the collimation setup are under way.
ACKNOWLEDGMENTS

We would like to thank Bolko Beutner, Sven Reiche, Masamitsu Aiba and Andreas Streun for the very fruitful discussions.

REFERENCES