WARM BEAMLINES AND INFRASTRUCTURE IN THE EUROPEAN XFEL

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Abstract

The European XFEL is driven by a superconducting linear accelerator. In the main accelerator tunnel the accelerator modules will be suspended from the tunnel ceiling. The warm sections like bunch compressors will be installed on girders supported from the floor. The accelerator infrastructure like klystrons and electronic racks will be installed in the accelerator tunnel in close proximity to the electron beam line.

INTRODUCTION

The layout of the European XFEL [1] is depicted in figure 1. There are two injector linacs, each consisting of a normalconducting RF gun, one accelerating module with 8 superconducting cavities, one 3rd harmonic module with 8 superconducting cavities as well, and a warm beam line with laser heater and extensive beam diagnostics.

Two dogleg chicanes guide the beam onto the axis of the main linac. To transport the beam with relatively large energy spread, the chicanes consist of a large number of narrowly spaced dipoles, quadrupoles and sextupoles. At the entrance of the main linac tunnel follows the first bunch compressor chicane (B0). The chicane is C-shaped and deflects vertically. Subsequently the beam is matched into a string of four accelerator modules (L1) which is followed by the second bunch compressor (B1) and a diagnostic section for transverse and longitudinal beam diagnostics. This scheme is repeated once (L2, B2) before the beam is boosted to the final energy in the main linac. There is space reserved for an extension of the main linac. Still in the main linac tunnel the collimation section is located to limit the energy deviation and the maximum transverse excursions the beam might develop coming out of the main linac. Afterwards the beam is distributed to the undulator beam lines necessary for the SASE process.

COLD LINAC SECTIONS

The superconducting RF cryo modules in the main linac are suspended from the ceiling of the tunnel. This provides the shortest connection between the cavity axes and the fixture on the tunnel wall. The specifications for the tunnel straightness were comparatively relaxed, so that the ceiling frames have to allow for ±50 mm adjustment both horizontally and vertically. This is achieved by making them out of two parts which are cut to length and shifted against each other before they are welded together in situ. The whole setup is welded to steel bands which were cast in the tubbings of the tunnel wall at the time of manufacture. Including the suspension frames and the modules inner structure the beam axis is located 2.2 m from the tunnel ceiling.

Under the modules there is room for klystrons, high voltage pulse transformers, pumps, electronic racks, and other equipment. To protect the electronics from radiation caused by beam loss or dark current in the cavities the racks are shielded by concrete blocks. Two blocks are located in front of and behind the racks along the direction of the beam. A layer of blocks is put on top of the racks. The maximum top load on the racks needed to be increased to support the weight of the concrete. There is no shielding to the sides where the electronics are accessed. An assessment of the expected dose rate was done and a sideways shielding appeared unnecessary. The radiation dose in the racks however is monitored and should additional shielding be required additional shielding plates can be attached.

Short distance cable connections within one RF section comprised of 4 cryo modules are made on a cable tray on top of the shielding. Long distance connections are reduced to the absolute minimum and consist of fibre cables wherever possible. These connections are traced in a compartment below the tunnel floor.

The room under the tunnel floor is used for water supply lines, high voltage pulse cables for the klystrons, main lines of the electric supplies, and fibre cables.

BUNCH COMPRESSOR SECTIONS

The bunch compressor sections comprise of the actual bunch compressor chicane and a diagnostic sections for

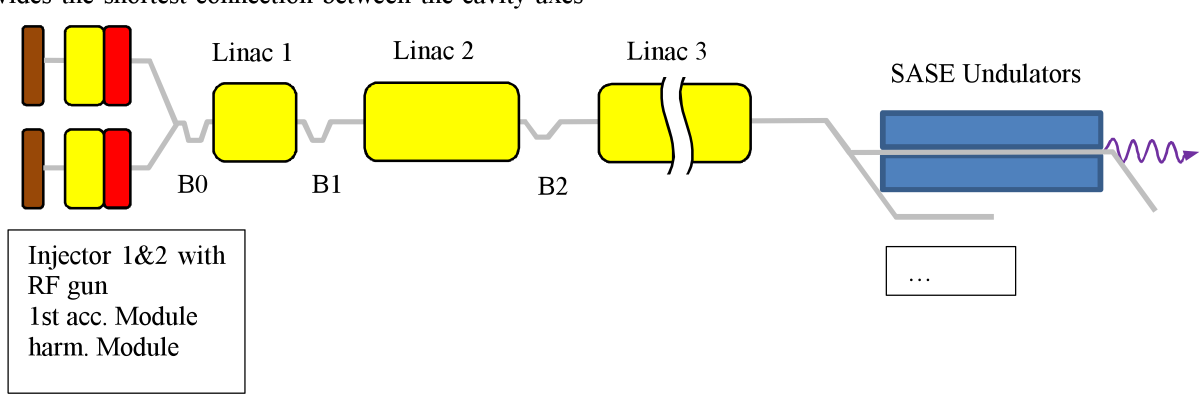

Figure 1: Layout of the European XFEL.

transverse and longitudinal beam diagnostics. In contrast to the cold sections in the warm sections beam line elements are supported from the floor. Due to the short distance of the beam axis to the ceiling, the distance from the floor is comparatively large, namely 2.2 m from the floor and even 3.5 m from the lower tunnel walls.

The larger parts of the bunch compressor sections are erected on girders. This reduces the number of installation and alignment steps at the inconvenient height and the number of bellows is dramatically reduced. The girders come in lengths of 3.2 m and 4.6 m. They are made as a sandwich-structure of steel and concrete. Aluminium plates are fixed to the upper side and machined for precise flatness and provided with grooves for easy and precise mounting of the elements (see figure 4). The girders are supported by two concrete pillars fixed to the tunnel floor. Studies were made to minimize the susceptibility of the whole setup to vibrations given the unfavourable conditions [4]. It was possible to increase the lowest resonance of the setup above 35 Hz. A test setup is in preparation in the main tunnel to verify these assessments.

Between the concrete pillars electronic racks are placed. The pillars and the girder provide a limited amount of radiation shielding. Additional shielding is provided by concrete blocks on top of the racks in analogy to the setup in the cold linac sections. To reduce the detrimental influence of the shielding on the vibrational behaviour of the setup, the shielding blocks on top of the racks are decoupled from the pillars. Like in the cold section this results in increased specs for the maximum load on the roof of the racks. Figure 2 depicts the 3D model of the setup.

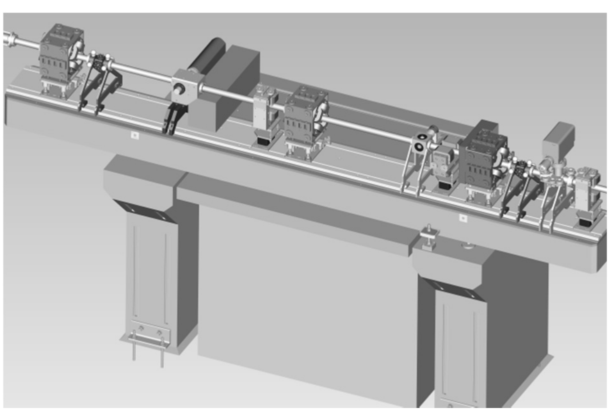

Figure 2: Bunch compressor girder setup with support columns, racks, and rack shielding.

DOGLEG SECTION

There are two injectors foreseen for the European XFEL. They are located in two storeys of the underground injector building. The floors are symmetrically shifted upwards respectively downwards against the main tunnel floor. The injected beam has to pass a dogleg chicane to enter the main tunnel. The dogleg crosses the main cavern of the main entrance shaft. The distance to bridge is 18 m, the height difference 2.5 m. The largest distances are 4.8 m from the cavern floor, 7.9 m from the ceiling, 5.5 m from the side walls.

The bunch compression scheme is such that the first compression chicane is located right at the entrance of the main tunnel. The beam is accelerated with an off-crest phase in the injector to provide the energy chirp for the bunch compression. Third harmonic modules are placed in the injectors to linearize the energy modulation. Extreme care has to be taken to transport the beam with large energy spread to avoid emittance degradation [2]. This is achieved by splitting the deflection into many undulating kicks along this section.

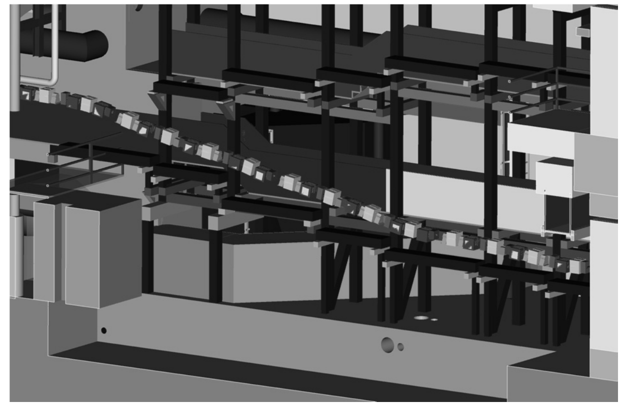

Figure 3: Dogleg support structure.

This means that the section is filled with 16 dipoles, 17 quadrupoles, and 16 sextupoles. Between the magnets diagnostic elements and vacuum equipment need to be supported. This is accomplished by putting the beam line on girders which in turn are supported by a large steel frame. The frame consists of two rows of columns made from I-beams. The girders are attached to protruding beams welded to two one column of each row. Diagonal struts help stiffening the structure [3]. By this the lowest resonance frequency of this structure was raised to 14 Hz. Figure 3 shows a 3D model of this structure.

Since the beam is inclined for the larger part of this section, most of the components have to be installed with a slope against the girder underneath. Moreover the

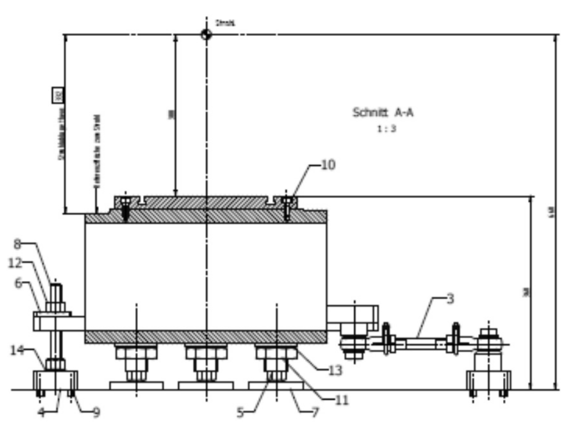

Figure 4: Cross-section of the bunch compressor girder.

slope changes many times. To accommodate this, the fixtures for the beam line elements allow for easy inclination.

INJECTOR SECTION

The injectors are each located in a separate enclosure so that they can be operated independently from each other and from the main accelerator. Here all beam line elements are supported from the floor, the beam axis is 1.4 m from the floor. Originally it was intended to locate all electronics outside the tunnel in a higher floor. Meanwhile the demands on beam diagnostics and RF control tightened and essential parts of the electronics had to be put near the beam line. Eleven racks are placed under the first accelerator module. Because of the restricted space the racks only have half height. In the close vicinity of the RF gun a high level of radiation from dark current is expected, therefore the racks are shielded all around. The shielding is made from a sandwich of aluminium, lead, boron and polyethylene. This is expected to be more powerful than a shielding made out of concrete.

The warm beam line is tightly packed with elements and therefore put on girders. The girders are of the same kind as in the bunch compressors. The room below the girders however is too small to place racks there. The electronics that does not fit under the modules is placed into shielded racks besides the beam line. The detailing is on-going with respect to accessibility of the machine elements behind the racks.

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