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DEVELOPMENT OF A REVOLVER TYPE UNDULATOR

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Abstract

A revolver-type undulator is developed for the SASE section of the FLASH Free-Electron Laser (FEL) at DESY. Currently, a 1.2 GeV linear accelerator injects electrons into two undulator lines to provide fully coherent VUV light to different experimental stations in two experimental halls. The more recently built FLASH2 branch consists of 12 planar undulators with a fixed magnet structure of 32 mm period length.

Within plans for refurbishment of the original FLASH1 undulator section and also to open up new operation schemes with an extended photon energy range, an undulator development was started that allows for a change of different magnet structures. Once installed, it will be possible to change the wavelength range or the FEL operation scheme within a short period of time. Magnet structures can then be switched at any time without any observable effect on the electron beam orbit or the photon beam position.

The single design steps are described in the following article: profile of requirements, choice of an applicable changing mechanism, development of a new magnet structure, the position of the bearing points, a new floor assembly and improvement of the cantilever arm.

INTRODUCTION

The motivation for the development of a magnet structure changing undulator is to open up the photon energy range for the users within a short period of time without manpower-intensive hardware exchange in the tunnel or impact on the beamline. This development is still ongoing; the paper reflects the present status of design.

PROFILE OF REQUIREMENTS

The magnet structure changing undulator should be based upon the currently installed planar insertion devices with a length of 2.5 m. Its new dimension should neither exceed the available space nor result in changing a lot of assemblies in the surroundings. Another requirement for the construction is to switch between as many as possible magnet structures automatically within a short period of time. Effects on the electron beam are undesirable. The currently installed magnet structure shall possibly be used further on and also be part of the new ones. The changing mechanism is to be mounted on the currently used base frame of the FLASH2 insertion device (ID) with all its installed components. The length of the new ID should still be 2.5m and the whole assembly shouldn't pass the existing limits. The shutdown-time for exchanging the undulators with another magnet structure and the necessary manpower has to be minimized.

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SELECTION OF THE CHANGING-MECHANISM

There are at least four different concepts how an exchangeable magnet structure has been realized in the past. Generally it is required to open the gap before changing the magnet arrays.

The first type has been built at DESY already in the early days of undulators and has a rotating cylinder pivot-mounted and electrically driven at the outer ends (see Fig. 1). The advantages are that you are free at the number of installed magnet structures and only restricted by their magnitude. Also, there are no disturbing influences on the magnetic field along the magnet structure. However, the cylinders, not pivot-pointed at the "Bessel-points", causing a large bending in the middle of the ID, which varies with gap and also from one to the other magnet structure [1].

The second version is similar to the first one with the difference that the pivot-points are positioned at the calculated "Bessel-points" or at the four optimum points in case of two further links. Both, upper and lower cylinder can carry three structures at maximum because the other space is preserved for bow bearings. This is the most common way of design and has been built at several labs [2, 3].

In the third solution the magnet structures are mounted side by side on an intermediate plate which can be moved transversally on a stiff magnet girder in order to change the structure. It has the advantage that a rotating mechanism with inevitable angular and phase errors can be avoided. On the other hand, the full magnetic force of all three structures is always present. In principle, the magnetic attraction of the girders can be canceled e.g. by compensation magnets beside the actual magnets which of course holds for any of the four discussed schemes. Besides, large and exact linear guides and adjustments are required [4, 5].

The fourth solution is an ID with a rotation mechanism based on multiple strap hinges which connect the movable with the fixed part of the girder. This is an innovative, compact and rigid design. Drawbacks of this concept are the limitation to only two magnet structures and in particular a complex and expensive fabrication of the strap hinge as a bearing [3].

The four alternatives have been investigated in detail and assessed under consideration of various boundary conditions with different impact, among those: an integration of possibly three magnet structures, compatibility with the existing magnet structure, keeping the 2.5 m girder length, minimization of girder bending, small overall size, reuse of the well-proven undulator frame, further use of the existing vacuum chamber, and finally costs.

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Figure 1: Former DESY revolver undulator.

Finally, decision was made for a rotating cylinder with distributed support points. The changing mechanism of the new undulator is a revolver-like and loaded with up to three magnet structures per rotating cylinder (see Fig. 2). The present Flash2-structure can be integrated. The bearings of the strongback have been positioned at the optimum points. The whole length of the ID can be used for the magnet structure. Without regard to a few small changes, the current frame and power unit will also be used as is. Only a few minor changes of neighbored components will be necessary with this concept. Though, a change of the vacuum chamber and its holders is required due to the larger cross-section of the rotating structures. Also affected is the width of the ID and therefore the transport space for other assemblies behind it.

THE NEW MAGNET STRUCTURE

The development of a new magnet structure is caused by the restricted space between the different structures. The new structure has to achieve the same functions as the old structure, but in a minimized space. Positioning the magnets and adjusting the poles in height and angle must still be possible. Beneficial is a mounting of the poles and magnets from the upper side of the structure, because there is not much space for tools between them.

Finally there are three variants of new magnet structures, which must be tested under real conditions with small prototypes. The first structure is similar to the actual one, but with a transverse moving wedge instead of two counter screws for adjusting the poles. The screws for holding the magnets and poles are positioned more vertically beside the magnets and poles. The whole structure becomes smaller with another clamping mechanism on the rotating cylinder. The second structure has square magnets to find the best of four positions for a well-directed magnet field. The magnets are positioned with clamps from the top. The poles are mounted in two lateral pushers, which can be moved and adjusted with screws parallel or with a small difference (that effects the rotating of the poles). The third structure moves the poles with two independent screws equipped with an eccentric orbiting bolt. The right position is fixed with counter nuts on the screws. The vertical moving height in this version depends on the eccentricity of the small pins and is therefore strongly limited. The vertical adjustment is not permanent in relation to the rotating angle of the screw. If the counter nut is unfastened, the force of the pole is effective and affects its position. So readjusting the poles seems to be difficult. Small tests will show, which variant is more effective to be implemented onto the revolver cylinder.

A further requirement for the new undulator is to reuse the actual Flash2 magnet structure. That means to sink this structure with an equivalent nut into the rotating cylinder. The aim is to keep the poles on the same rotating radius. It is possible, if this structure is clamped from besides or with long screws from the bottom through the rotating cylinder. A discussion point for all three structures is, whether it is still necessary to fasten the poles with counter screws or other means from the bottom side. Tests will be made to find out whether the pole position is still stable without those screws. If the result is positive the counter screws could be left out and problems with space for tools are not present anymore.

THE POSITION OF THE BEARING POINTS

The main topic for an undulator is to have a strong and homogenous magnetic field over the whole length of the structure. So the magnet girders and the supporting frame have to be built stable to provide these demands. After it came to the decision to develop a revolver undulator, first step was to find the right positions for the bearings, carrying and rotating the cylinder with the magnet structures. Finding the four bearing points only for the rotating cylinder and the magnet force was influenced by space for the rotating mechanism, the weight of the structures and of the cylinder and of the cylinder's diameter. Experience of FE-analysis has shown that it is a great difference to carry only the cylinder or to look at the whole structure. A sinusoidal form of the cylinder results in a parabolic arc, when hanging at the frame. After the four bearing points were found for a structure, mounted at the frame with minimum and constant bending, the result of the FEA-calculations shows a reduced spacing between the main side-parts of the undulator. The difference for each part was 65 mm. That is why another requirement could not be kept: the exchangeability between the actual FLASH-ID and the new Revolver-ID on the same floor assembly. As a minimum only the anchor rods could remain at their positions.

THE NEW FLOOR ASSEMBLY

Adapting the floor assembly also included rearranging the three feet of the ID. The disadvantage of the old arrangement was the danger of overturning in several stages of production. The base, resulting from those three feet, was small and sharp and needed particular care when adapting the support mechanics for other geometric requirements. The new arrangement has two feet under the rotating mechanism

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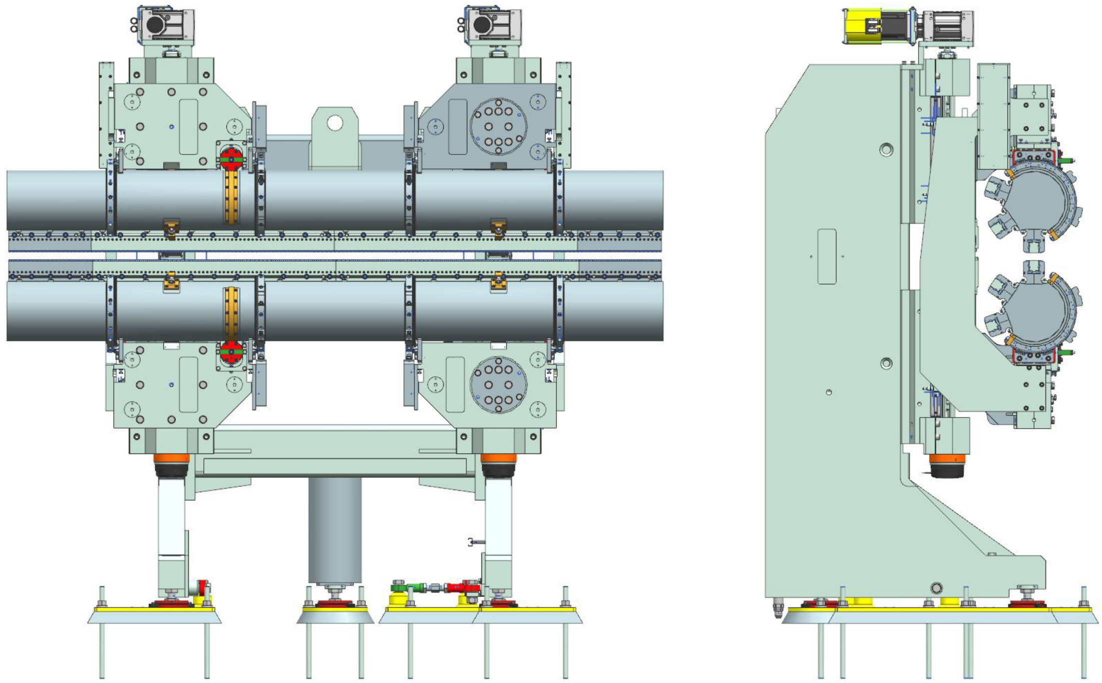

Figure 2: New DESY revolver undulator.

and the third foot on the backside of the frame. This base is much bigger than the old one and the centre of mass is secure in the near of the middle of this triangle.

THE IMPROVEMENT OF THE CANTILEVER ARM

This cantilever arm replaces the primary support plate, which carries the flat magnet girders together with the magnet structures and moved them vertically. The diameter of the rotating space for the three structures instead of the current slim outline requires a long connection to the drive train. It should be stable against bending moments and torque and lightweight. Different models came up to solve this problem: a full iron cantilever arm, a welding construction with an included thick tube (difficult to weld), another weldment with stiff plates and at least a full aluminum milled part. The final decision on this ongoing work will be made after FEA-simulations. The remaining final steps will be

- Prototyping and testing of the various magnet structures
- Construction of a hard stop for the middle structure
- Recheck the drive chain
- Recheck the whole ID-assembly with a FE-analysis to confirm the new distance of the bearing points and the minimum sinusoidal bending of the magnet girder.

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