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DEVELOPMENT OF THE NEW UE38 UNDULATOR FOR THE ATHOS BEAMLINE IN SwissFEL

H. Joehri[†], M. Calvi, M. Hindermann, L. Huber, A. Keller, M. Locher, Th. Schmidt, X. Wang, A Zandonella, Paul Scherrer Institute, 5232 Villigen, Switzerland

Abstract

For Athos, the second beamline of SwissFEL, we profit from the experience of the U15 undulator development. The U15 undulator is in use at the Aramis-beamline in SwissFEL. But for Athos, there are new requirements, because it will be a polarized undulator with a period of 38mm. We developed a new arrangement of the drives in a X-arrangement. The magnet keepers are optimized for bigger forces also in the beam direction. A vacuum pipe with only 0.2mm of wall thickness is realized.

Currently, the undulator is in fabrication at MDC Max Daetwyler AG. All the main parts are manufactured and the assembly is close to be finished. For measurement and alignment, separate tools had to be designed.

For the vacuum pipe we have a prototype, which is close to the requirements. Some points of the fabrication process have to be optimized to realize a better straightness.

OVERVIEW

The general arrangement is an Apple II undulator, but the movements of the magnets are not in vertical direction. The opening of the gaps, is like an X (Figure 1).

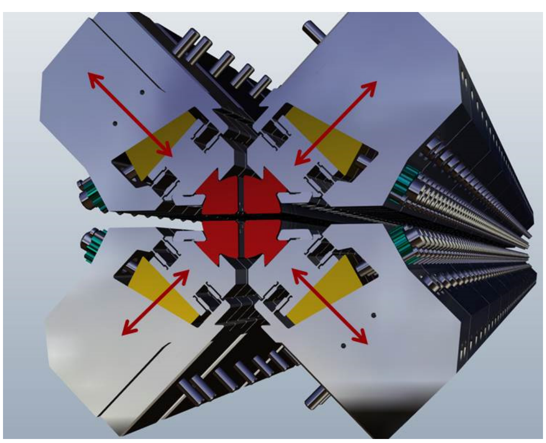

Figure 1: X – Arrangement.

Each magnet can be adjusted with a screw. The screw with two different threads moves a wedge. This wedge moves the magnet in the direction of the gap movement. This enables to use a robot system to adjust each magnet individually within a tolerance of 1.5 µm

† haimo.joehri@psi.ch

Main Specification

Length	: 2 m
Number of periods	: 52
Length of period	: 38 mm
Gap range	: 3 – 21 mm
Shiftrange	: +/- 21 mm
Magnetic force in X	: 1.6 tons
Magnetic force in Y	: 1.6 tons
Magnetic force in Z	: 2.0 tons

See figure 2 for the definition of gap and the direction of the forces

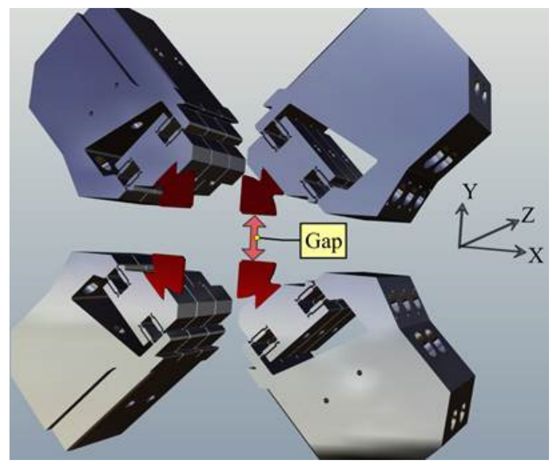

Figure 2: Definition of gap and the coordinates.

DRIVES AND ENCODERS

One goal of the development was to find an arrangement in a way, that the drives are independent of each other (see figure 3).

The gap is changed by a wedge drive. The wedge is driven by a servomotor and a spindle with a satellite roller screw. The slope of the spindle is 0.5 mm.

The shift drive is solved directly with a spindle and a servo-motor. Also here, a spindle with satellite roller screws is used. The slope is 1.0 mm.

To allow the baseplate with the keepers to move in both directions (gap and shift), a separate plate is positioned between the frame and the baseplate (violet plate in figure 3). This plate is connected to the frame with 7 linear guides to give the stiffness of the system.

All movements are controlled by linear encoders
Motors: Beckhoff AM8023-OE21
Encoders: Heidenhain LC 415-ML70

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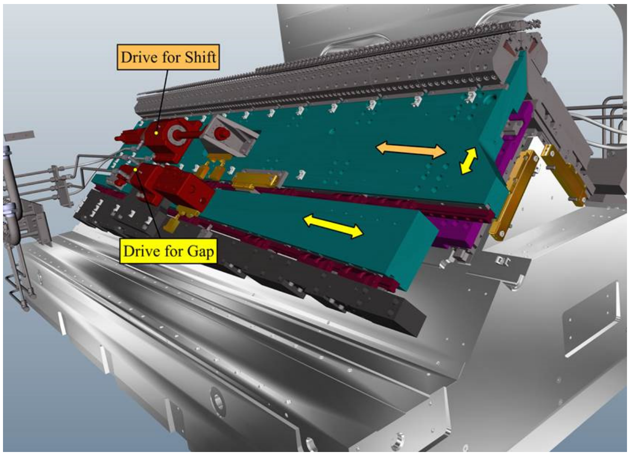

Figure 3: Drives.

FRAME

The frame has to fullfill different requirements

- Due to the big forces of the magnets, it has to be stiff.
- The production has to be cost-effective for a series of 20 units
- All parts should have the same thermal expansion, because the arrangement of the guides is very sensitive to differences in the expansion.
- For service of the components, the main parts should be accessable in case of failures

To fullfill these requirements, we chose a concept with two baseplates and two sidewalls, which gives a closed structure at the end. The two baseplates (upper and lower) are identical.

The sidewalls have openings to gain access to the drives.

We chose cast iron as material. This gives more freedom in the design than mineral cast and it can be milled. To prevent differences in thermal elongation, all parts that are shown in figure 4 are made in cast iron.

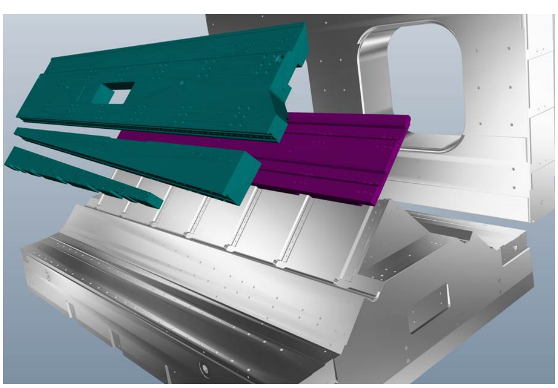

Figure 4: Parts in cast iron.

At the beginning of the design we tried tools with topological optimization. First result is shown in figure 5. As a first impression, the result looks a bit strange. Main finding was, that in the baseplates should be a rib over each linear guide from the gap movement. So we took that principle and designed the structure in the classical way with design rules for cast iron and optimized it with normal finite element analysis.

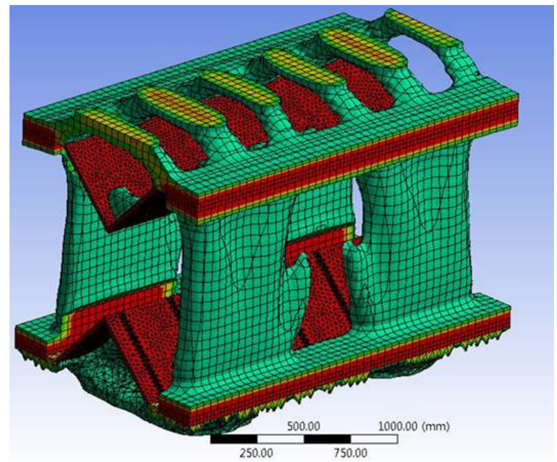

Figure 5: Result of topologic analyses.

KEEPER DESIGN

For U15 Undulator of Aramis (First beamline in SwissFEL), we developed a keeper, where each magnet can be adjusted by a screw [1]. This gives the possibility to use a robot screwdriver to automize the adjustment of the magnets.

For the UE38-Undulator, we wanted to profit from that experience. Some new requirements had to be taken into account.

- Forces from the magnets in each direction
- Limited space
- Bigger range for adjustment : +/- 0.1mm

To fullfill these requirements, we made two general changes:

The flexible part of the keeper is pulled to the wedge by a spring.

The screw to move the wedge is designed as a differential screw. One thread has a slope of 0.907mm, the second thread has a slope of 1.0mm. This gives a small movement of the wedge of only 0.093mm by one turn of the screw. The design is shown in figure 6.

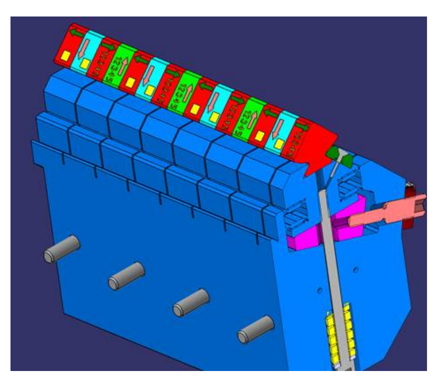

Figure 6: Keeper design.

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The keeper is made of aluminium. The wedge is made of bronze with dicronite coating to minimize the friction. The differential screw is made of stainless steel with dicronite coating.

For the assembling of the wedge and the screw, it is important that wedge is in the correct position. If both treads of the screw are in mesh during the positioning, it results in differences of 1mm depending of the starting point of the thread. To solve that problem, a separate part is used to define the second thread. The assembling procedure is shown in figures 7 to 9:

In a first step, the wedge is put to the neutral position and the screw is turned in the wedge (figure 7)

Then a special nut is turned until it is in contact with the keeper (figure 8)

In the last step, the nut is fixed with two screws (figure 9).

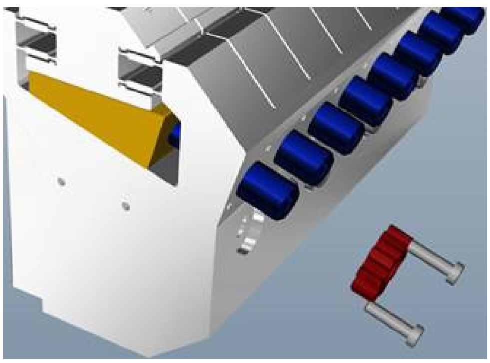

Figure 7: First step of assembling the keeper.

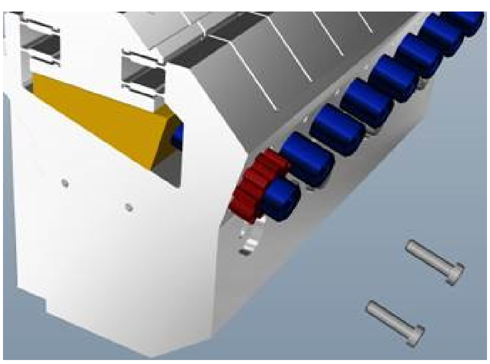

Figure 8: Second step of assembling the keeper.

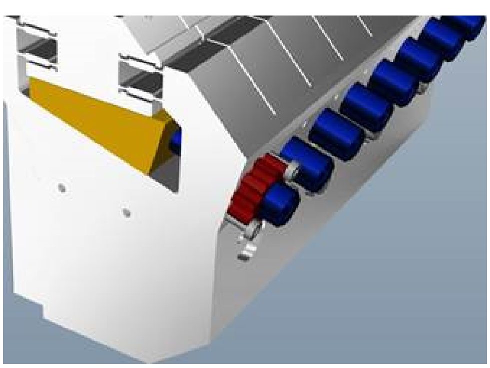

Figure 9: Third step of assembling the keeper.

The whole system has to withstand the forces of the magnets. The analysis with finite element tools showed, that the critical forces are in beam direction.

The stiffness is higher, when the magnet is adjusted to a higher position, because the flexor gives an additional pressure to wedge. Therefore it is less stiff in the lower position. The simulations showed, that the flexor should be as wear as possible and the force of the spring must be maximized.

Figure 10 shows one of the simulations

Figure 11 shows the details of the flexor

The spring has a load of 576 N. It is a spring with inner diameter of 6.3mm and an outer diameter of 12.5mm. The spring has a rectangular cross section and is mainly used in cutting tools.

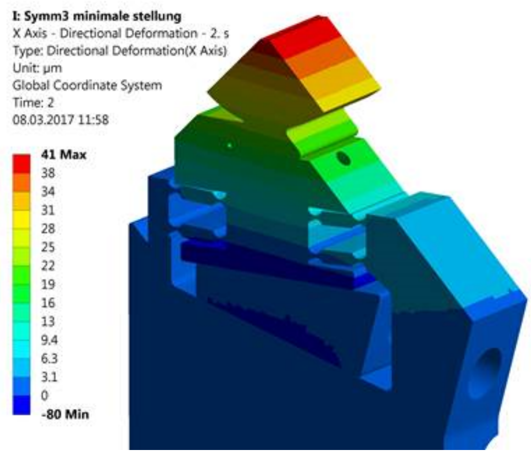

Figure 10: Simulation with force in beam direction.

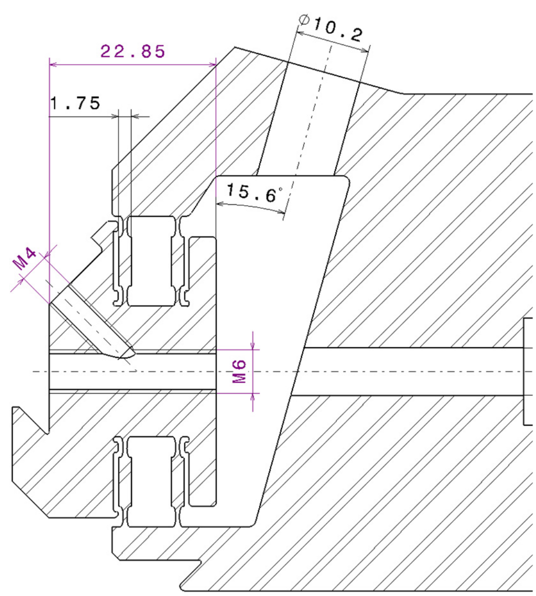

Figure 11: Detail of the flexor.

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VACUUM PIPE

The space between the magnets is very limited with a diameter of only 6mm. Therefore, we developed a pipe with an inner diameter of 5mm and a wall thickness of 0.2mm. The pipe is manufactured in copper by a galvanic process. The galvanic process is done by an external company: Galvano-T in Germany.

The pipe itself with its copper support and the external support, that places the vacuum chamber in the frame, is shown in figure 12. The process of manufacturing is explained step by step in the following figures:

Figure 13: The flanges are in stainless steel together with a conical interface, that will be enwrapped by copper. The flanges are put over a silicone wire. This wire has an internal steel wire to stretch it. It is coated with silver powder to enable electrical conductivity.

Figure 14: The flanges and the wire are fixed in a frame. All parts must be covered with an electrically insulation, except the parts that will be galvanized.

Figure 15: After the galvanizing, the silicone tube can be removed by pulling it out. After that step the result is a pipe with the flanges.

Figure 16: A copper support, that is manufactured separately is connected to the pipe also with a galvanic process. For that process, the pipe and the support are fixed in a frame. Everything except the interface from the pipe to the support is electrically insulated

Figure 12: Vacuum pipe with frame.

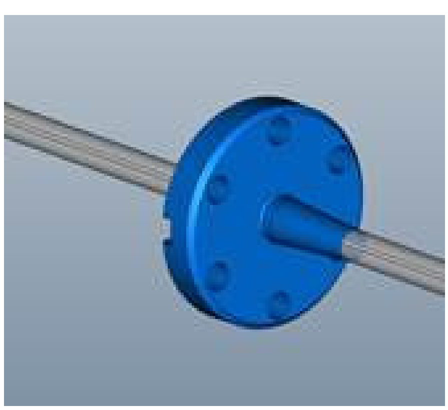

Figure 13: Flange with silicone wire.

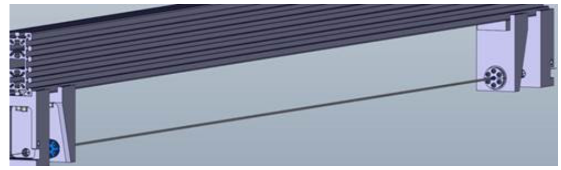

Figure 14: Streched wire before galvanizing.

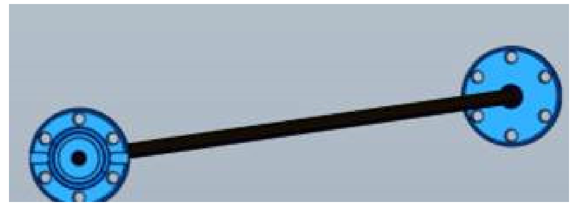

Figure 15: Pipe with flanges.

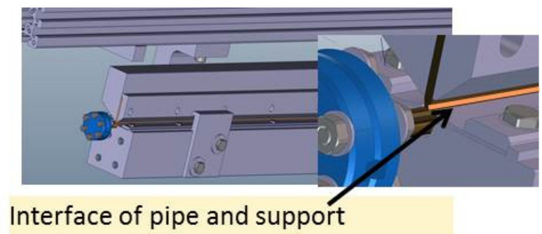

Figure 16: Galvanizing the support.

MEASUREMENT

For the precision of the whole system, the interface to the keepers has to be in a straight line at the correct position. During the assembling of the prototype, the upper line of the mounting plate (red chain dotted line in figure 17) is measured with gauches and lasertracker. After optimizing, we reached a straightness of 10µm

Figure 17: Measurement with laser tracker.

After optimizing the lower and upper mechanism, the frame can be completed with the sidewalls. To guarantee the position of the whole system, the system will again be optimized by lasertracker measurement. To avoid shimming with the sidewalls, the final height of the sidewalls is milled after the measurement of both mechanisms.

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ACTUAL SITUATION, NEXT STEPS

In June 2018, the assembling of the frames and the mechanics are short to the final step. We expect the delivery from MDC Max Daetwyler AG in July.

The keepers for the prototype are ready (Figure 18) for assembling with the magnets.

Next step will be the final assembly, that will be done at Paul Scherrer Institut by the Insertion Device Group.

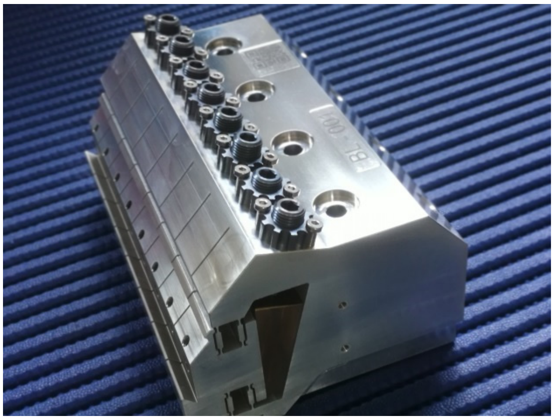

Figure 18: Keeper after assembling the wedges.

CONCLUSION

For the new Apple X Undulator (Figure 19) for Athos-Beamline at SwissFEL, we developed a new concept of frame and vacuum pipe.

For the keeper design we profit from the experience of the U15 Undulator.

At the moment, we are short to the final assembling. Whether everything works as planned will be revealed after an intensive testing with the magnets.

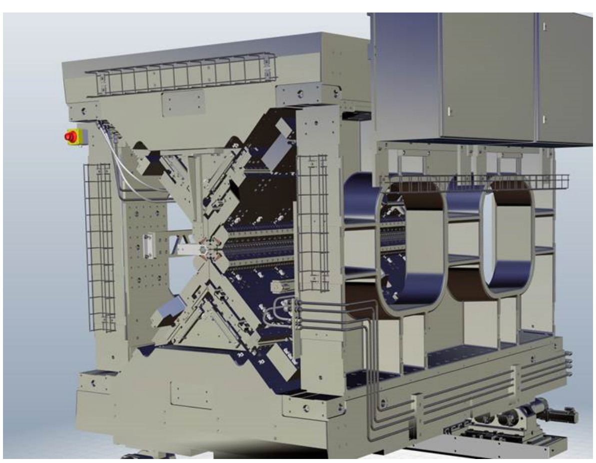

Figure 19: UE38 Undulator.

ACKNOWLEDGMENT

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