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 1.2GeV 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 ~32mm 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.

Flash2-ID; 2.5m; U32; 12.4kN maximum magnet force

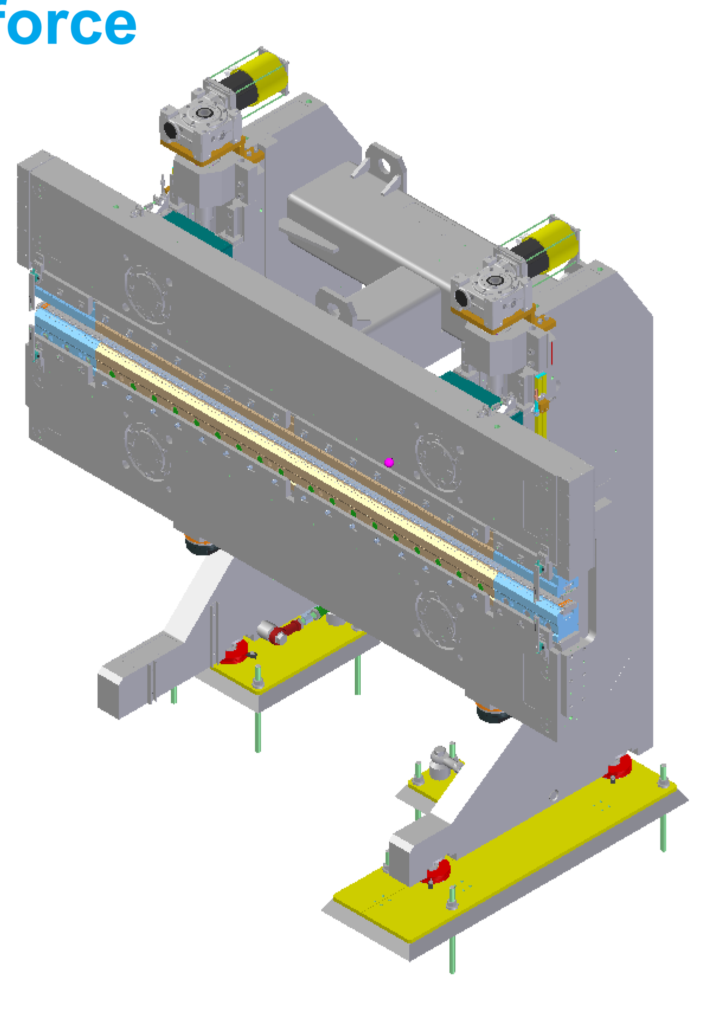

Figure 1: current FLASH2-ID (DESY)

Selection and evaluation of various exchange mechanisms

Figure 2

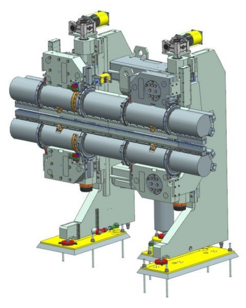

Figure 3

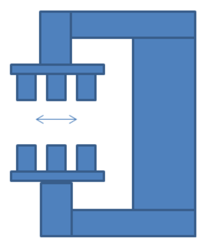

Figure 4

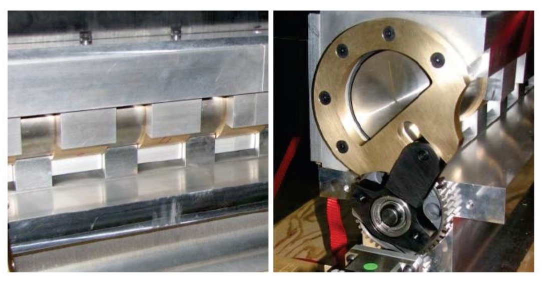

Figure 5

A rotating cylinder pivot-mounted and electric driven at the outer ends [1], (see Figure 2)

Advantages: the number of magnet structures is restricted by their magnitude. The repeatability is given by a locking mechanism. There are no disturbing magnet field influences among each other.
Disadvantages: the cylinders are not pivot-pointed at the "Bessel-points". The bending is big in the middle; it varies with gap and also from one to the other magnet structure. The minimum bending is only valid for one magnet structure.

A rotating cylinder pivot-mounted at the "Bessel-points", divided at four points, with three magnet structures maximum [2], [3], (see Figure 3)

Advantages: a constant and minimum bending over the whole length; a small cross section; the space for a full length magnet structure is given; the influence between the magnet structures is neglectable small.
Disadvantages: the restricted number of magnet structures; the marginal smaller cross-section; a lever arm to the rotating cylinder with higher forces and moments on the linear drive chain.

A horizontal changing mechanism on a desk or with the whole ID [4], [5], (see Figure 4)

Advantages: the rotating mechanism with angular and phase errors does not apply; a short way to change the magnet structure; the full magnet force can be compensated with compensation magnets, with springs or with moving a half phase in beam direction.
Disadvantages: all structures are engaged the whole time; the magnet force of all structures is always effective; moving longitudinal requires additional and precise adjustments; a broad table with a long lever arm.

A retractable mechanism based on a strap hinge [3], (see Figure 5)

Advantages: the stiffness/flatness is not caused by the main cylinder but the supporting magnet girders; the space must be free for a 180-degrees about-turn of a magnet-structure; a small cross-section.
Disadvantages: restricted number of magnet structures; complex and expansive fabrication of a strap hinge as a bearing; space for a worm-gear beside the structures is necessary; the full length of a girder cannot be used for the magnet structure.

Flash2R-ID; 2.5m; U36; 18.5kN maximum magnet force

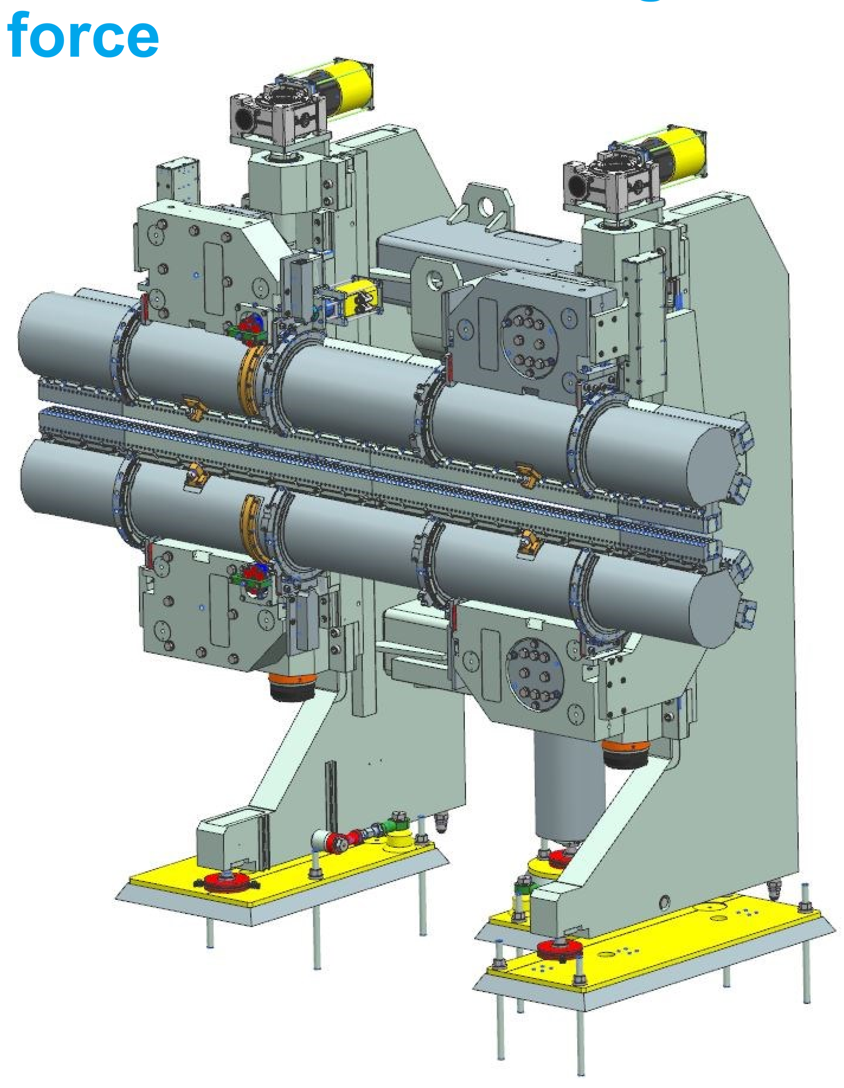

Figure 6: new revolver-ID (DESY)

The position of the bearing points

The main topic for an undulator is to have a strong and homogenous magnet 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.

The first chart shows the bending of the cylinder, when it is fixed at the motion links. The effective forces are the own weight, the maximum magnet forces, and the magnet forces between the "third" structure and the frame.

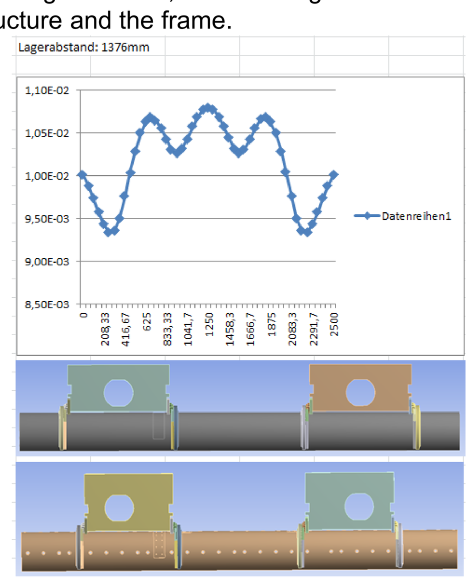

Figure 7

The distances of the bearing points are scaled down from the DESY-5m-ID. This solution quits, because of the missing space for the revolving cylinder engine (see Figure 7).

The second chart shows the bending of the same rotating cylinder, when it is fixed with the motion links on the frame (see Figure 8).

Next step was to decrease the distance between the motion links and main side parts (see right side).

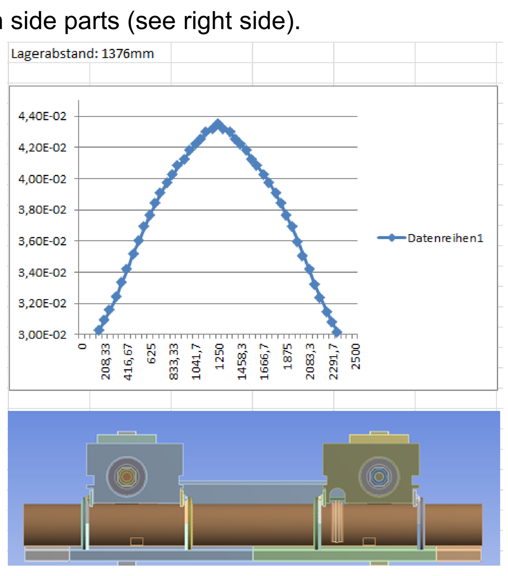

Figure 8

Weighting criteria for the four alternatives (Chart 1):

weighting criteria :

a. perpetuation of the 2.5m magnet structure
b. exchange of as much as possible structures
c. constant and slight bending
d. small required space
e. reuse of approved undulator frame
f. reuse of existing vacuum chamber
g. reuse of existing magnet structures
h. costs

criteria	variant 1	variant 2	variant 3	variant 4
a	0	4	4	4
b	4	3	4	3
c	1	4	4	4
d	1	3	2	3
e	1	2	1	2
f	1	2	1	2
g	1	2	1	1
h	4	4	3	3

Chart 1

Development of a new magnet structure (Fig. 9-10):

requirements to the magnet structure

1. divided side parts caused by manufacturing
2. mounting the magnets to the floor
3. positioning the poles in the height and angular
4. side parts mounted and adjusted by screws and bolts
5. plugs to be mounted independently along the magnet structure
6. slots for shimming the structures should be preserved

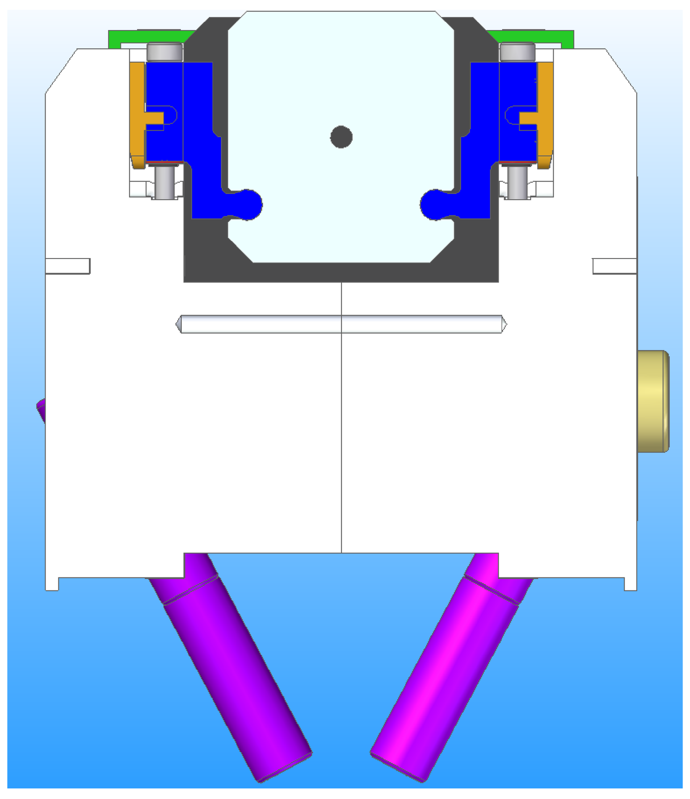

Figure 9: new magnet structure; first version

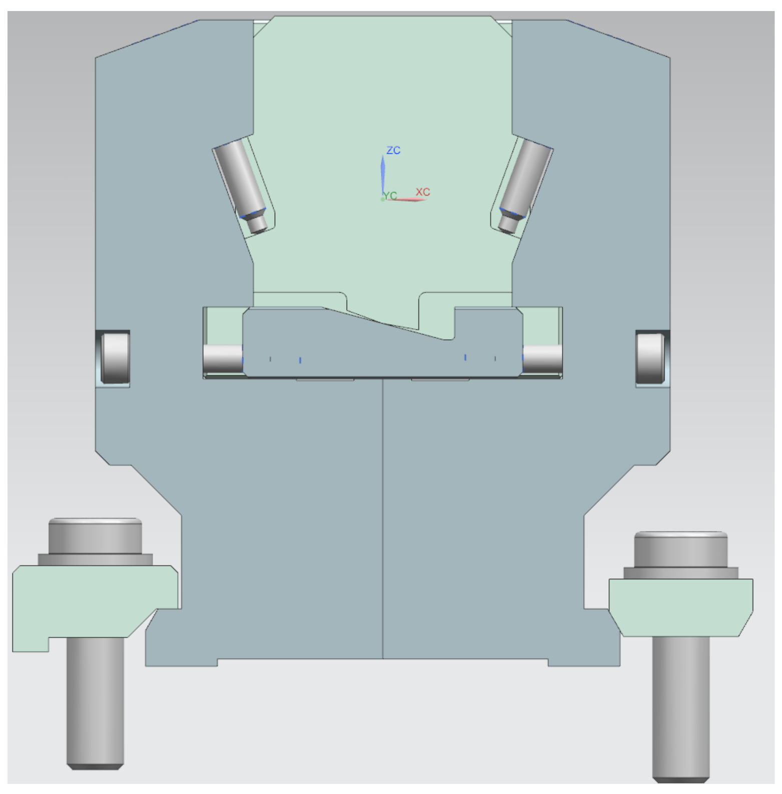

Figure 10: new magnet structure; second version

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 FEM-analysis to confirm the new distance of the bearing points and the minimum sinusoidal bending of the magnet girder

The final position of the bearing points (Chart 2)

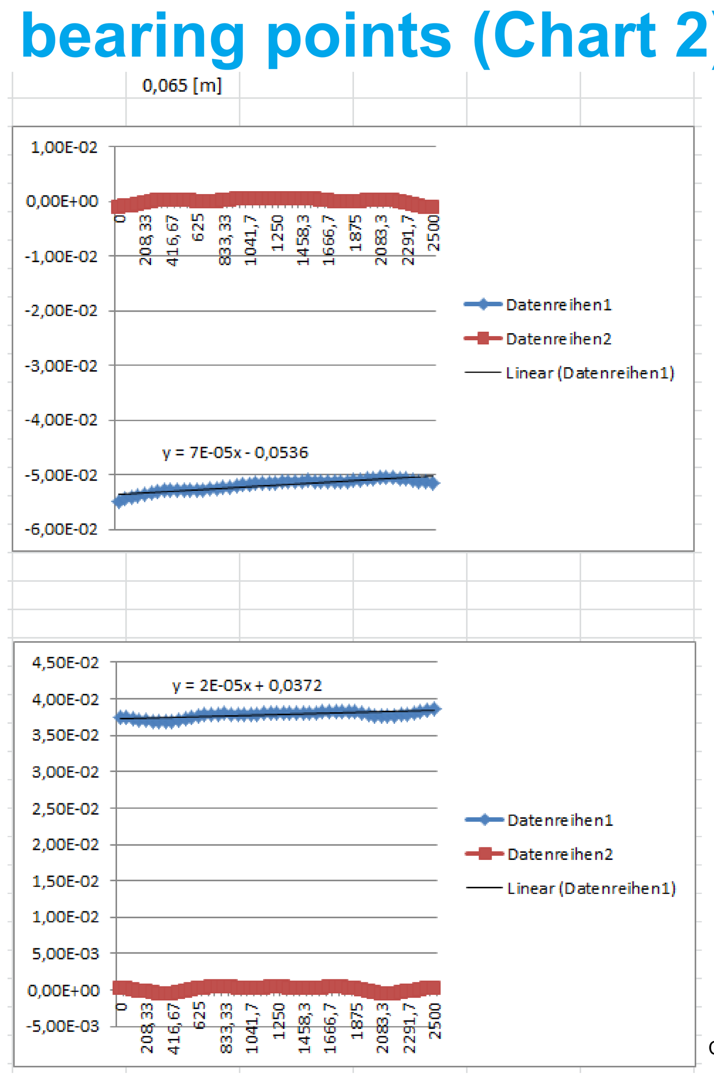

Chart 2

The conclusion is to move the motion links eccentric to the inner side or both of the main side parts.
The third chart shows the solution after the movement of both side parts about 65mm.

Comparison of the current and new floor assembly

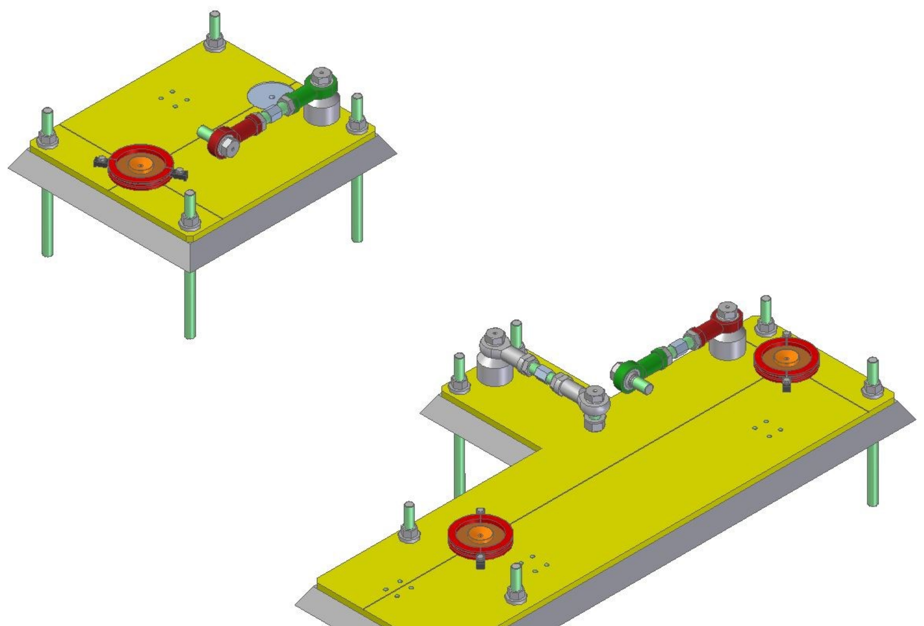

Figure 11: current floor assembly

The new floor assembly

Adapting the floor assembly also included rearranging the three feet of the ID. The disadvantage of the old arrangement (see Figure 11) 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 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 (see Figure 12).

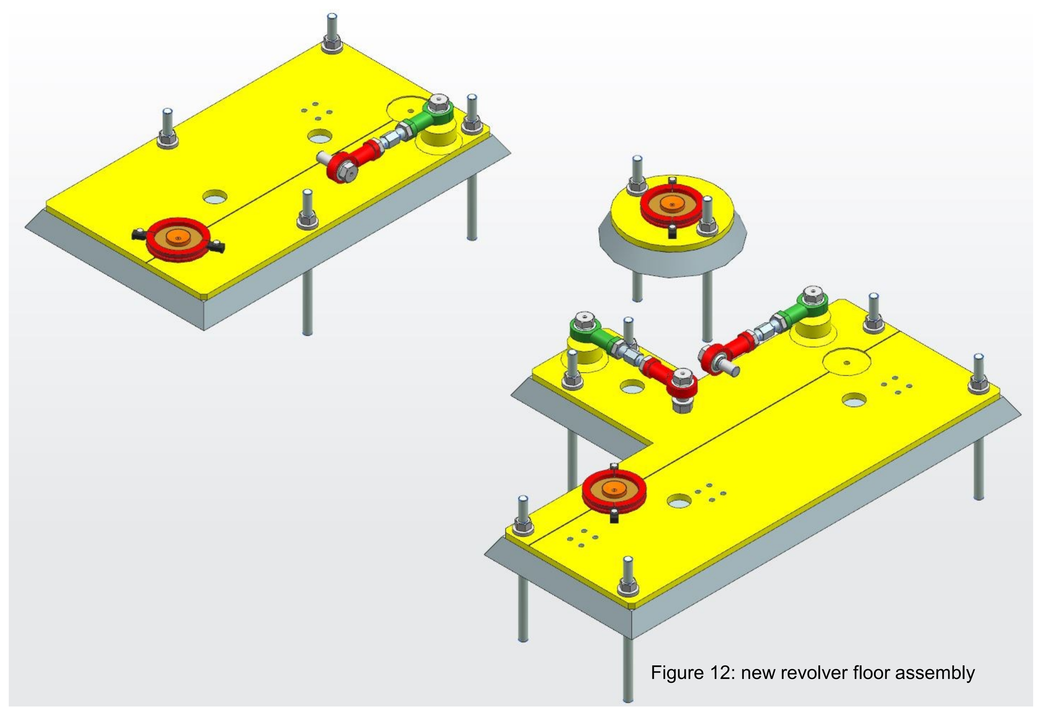

Figure 12: new revolver floor assembly

References:
Figure 5: B. Stillwell, J. H. Grimmer, D. Pasholk, E. Trakhtenberg in Proceedings of IPAC2012, New Orleans, Louisiana, USA, pp. 750-752;
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[4] R. Z. Bachrach et al. The SSRL insertion device beamline `Wunder'. SPIE, 582:251267, 1985;
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