THE MIRROR MOUNTING OF A FAST SWITCHING MIRROR UNIT AT FLASH

F. Perlick, M. Sachwitz, A. Donat, R. Heller, L.V. Vu, J. Nagler, DESY, Zeuthen, Germany

Abstract

Mirrors used for the deflection of a laser beam are always a potential source for unwanted beam deviations. These deviations may be caused by an insufficient surface quality, by deformation or undesired motion of the mirror in its mounting. Especially a tilting of the mirror towards the laser beam leads to a major horizontal beam deviation, which increases with increasing distance to the deflecting point [1]. This study compares the original mirror mounting design with a modified one, showing the great impact of the holder geometry on the beam deviation at the test sites.

FAST SWITCHING MIRROR UNIT

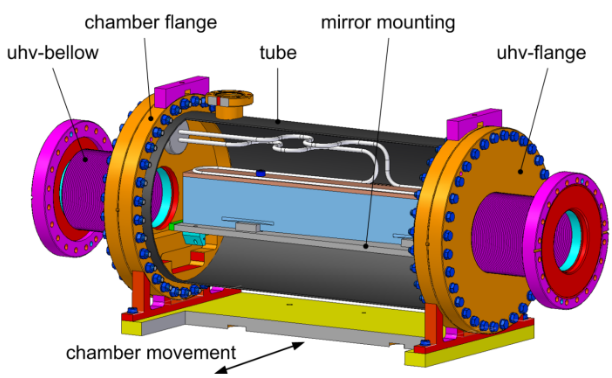

Figure 1: Fast Switching Mirror Unit.

The Free Electron Laser Hamburg (FLASH) is a linear accelerator producing brilliant laser light from four to sixty nanometre wavelengths. The laser light is diverted towards the test sites by massive silicon mirrors, which are firmly mounted into holder plates and attached to the mirror chambers. These chambers are moved (see Figure 1), so the mirror can reside in two different states of use. When the chamber is moved out of the beam, the laser goes into the beam line straight ahead without diversion, while it is diverted with an angle of six degrees into a diverging beam line when the chamber is moved into the beam (see Figure 2). Recently, a “Fast Switching Mirror Unit” was developed and successfully installed at FLASH, whose linear motor allows permanent switching with amplitudes up to thirty millimetres and switching frequencies up to five Hertz. The operation of the chamber in permanent switching mode doubles the number of test sites which can be simultaneously supplied with synchrotron light, but also leads to strong forces acting on the components during the chamber acceleration. Therefore the challenge lies in assuring a firm mounting without significant deformation of the mirror. The overall laser beam deviation at the test sites resulting from the mirror deformation should not exceed ten microns.

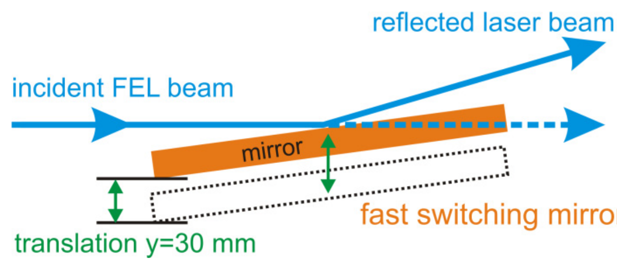

Figure 2: Course of the laser beam.

MOUNTING CONCEPT

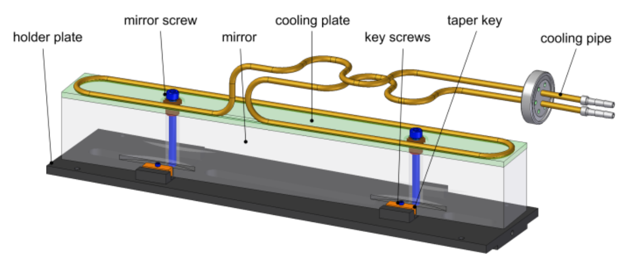

Figure 3: Mirror mounting components.

The mirror mounting is installed in the middle of the Fast Switching Mirror Unit, where it is attached to the chamber flanges with four screws. It consists of the single components holder, mirror, keys and cooling components, which are supposed to ensure a fast heat transport from the mirror to the outside of the chamber if it should be necessary (see Figure 3). The cooling plate, which is arranged on top of the mirror, serves as a heat conductor from the mirror towards the cooling pipe. The cooling plate and the mirror are attached to the holder plate with two screws sized M8, which assure the vertical fastening. The torque for these screws is ten Newton metres. On the upper side of the holder plate there are four elevations, which assure the horizontal fastening of the mirror. On the reverse side of the reflecting surface there are two keys, which are pushed down towards the holder plate by one screw each. The screws are M3 in size and torqued with 0.6 Newton metres. While the mirror-sided face of the key is rectangular to the top face, the opposite side is manufactured with an angle of eighty degrees to the top face. Since the corresponding plane at the bracket offers a one hundred degree angle, the vertical force inserted into the key by the screws is converted into a horizontal force on the mirror. Consequently the mirror is pushed towards the elevations of the holder plate.

ORIGINAL HOLDER PLATE

Features

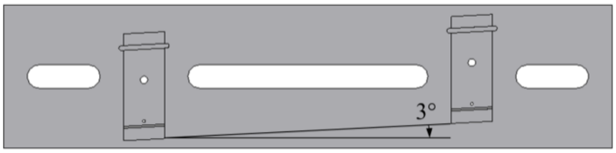

Figure 4: Original holder plate (top view).

The original holder plate is 520 millimetres in length and 122 millimetres in width. It is made of aluminium alloy (AlMg4.5Mn0.7). This material is only one third in weight compared to steel; furthermore its strength is less than silicon, so the risk of damage to the mirror at the assembly can be reduced. The long side is parallel to the chamber axis. In order to achieve a mirror beam deflection of six degrees the mirror is adjusted in a three degrees angle to the edge (see Figure 4). The maximum thickness of the holder plate is fifteen millimetres (see Figure 5). The elevations are ten millimetres in height and about ten millimetres thick; their outer planes are rectangular to the holder plate. In order to reduce its weight the holder plate is provided with cutouts in areas with little tension.

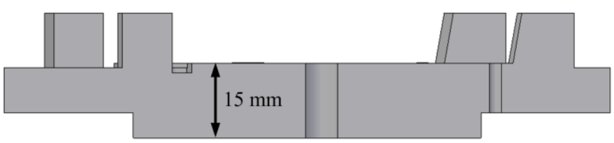

Figure 5: Original holder plate (section).

Simulation of the Deformation

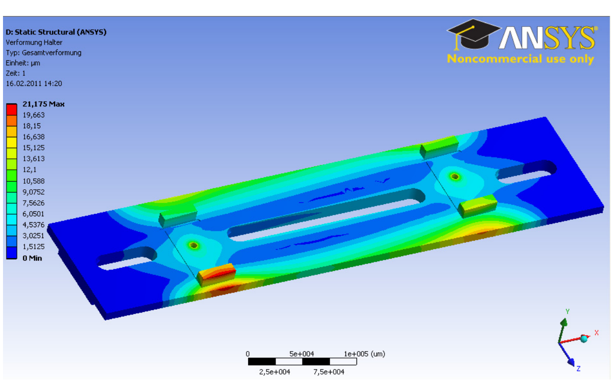

Figure 6: Deformation of the original holder plate.

The results of the simulated deformation can be seen in Figure 6. The colours specify areas of identical deformation and reach from minor deformation (blue) to major deformation (red). Due to the pressure forces applied to the elevations the holder plate is bent up in this area. The maximum deformation of twenty-one microns can be found at the side where the keys touch the holder plate. It is evident that the deformation is not symmetric; the deformation in the area of the left key exceeds the right one by about six microns. This deformation behaviour can be explained with differences concerning the section modulus at these areas as the material strength at the left elevation is only eleven millimetres, while at the right elevation it is fifteen millimetres. The bending of the holder plate leads to a tilting of the mirror towards the laser beam (see Figure 7), which is irregular over the length of the mirror due to the asymmetric deformation of the elevations. The maximum displacement at the upper edge of the mirror is about fifteen microns; the minimum displacement at the lower edge is about five microns. This leads to a laser beam deviation at the test sites of approximately 250 microns, which exceeds the maximum deviation target by the factor twenty five.

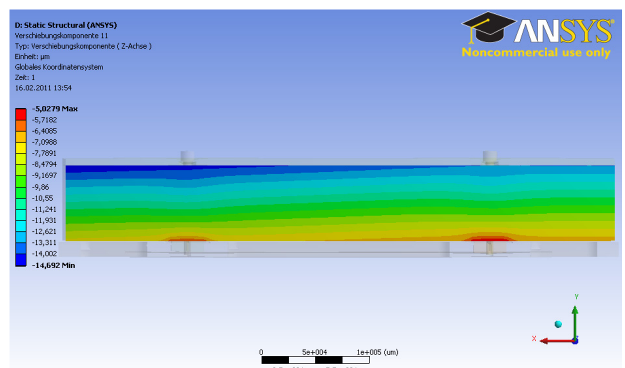

Figure 7: Deformation of the mirror (original).

MODIFIED HOLDER PLATE

Features

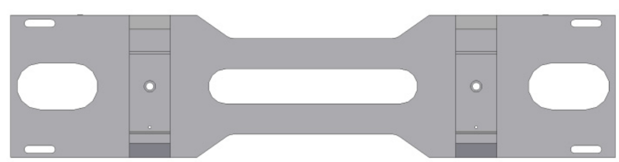

Figure 8: Modified holder plate (top view).

The target of the holder plate modification is to achieve a constant and reduced overall tilting of the mirror. The overall dimensions of the plate remain constant. The mirror is adjusted parallel to the edge of the holder plate (see Figure 8), which means that the holder plate is now installed in the chamber with an angle of three degrees. In the region of the elevations the thickness of the holder plate is increased from fifteen to forty millimetres (see Figures 9 and 10). Since these measures increase the weight of the holder plate, the cutouts in the middle of the holder plate are enlarged and further cutouts are added in order to reduce the weight. The angle between the outer elevation planes and the holder plate is reduced from ninety degrees to forty-five degrees in order to ameliorate force distribution.

Figure 9: Modified holder plate (side view).

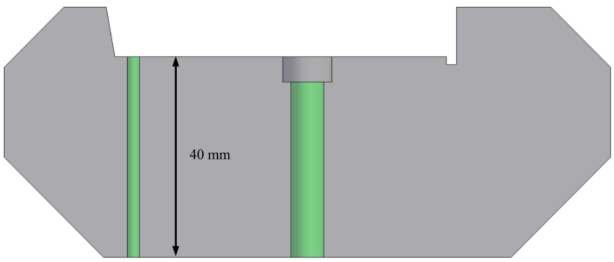

Figure 10: Modified holder plate (section).

Simulation of the Deformation

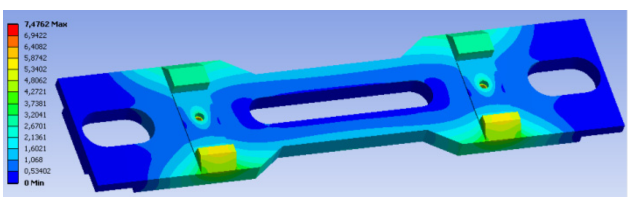

Figure 11: Deformation of the modified holder plate.

As can be seen in Figure 11, the deformation of the modified holder plate is significantly smaller than the original one. The holder is still bent up, but the maximum deformation at the elevations is reduced from twenty-one to six microns. As the mirror is adjusted parallel to the holder's edge, the holder deformation is symmetric. This leads to an almost constant tilting of the mirror in the holder plate (see Figure 12). The maximum displacement at the upper edge of the mirror is reduced from fifteen to four microns; the minimum displacement at the lower edge is reduced from five to two microns. This results in a laser beam deviation at the test sites of about twenty-five microns, which means that the deviation is reduced to one tenth compared to the original holder plate.

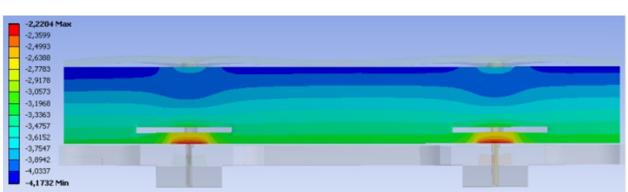

Figure 12: Deformation of the mirror (modified).

CONCLUSION

Table 1: Comparison of Original and Modified Holder Plate

Holder plate	Original	Modified
Maximum deformation of the elevations	21 µm	6 µm
Maximum displacement of the mirror	15 µm	4 µm
Deviation of the laser beam at the test sites (estimate)	250 µm	25 µm

The original holder plate shows a major asymmetric deformation at its elevations, which leads to a strong tilting of the mirror towards the laser beam. The resulting deviation of the beam at the test sites is twenty-five times bigger than the requested deviation. Through modifications of the holder plate, especially the adjustment of the mirror parallel to the holder's edge and the increase of thickness in the region of the elevations, the deformation of the holder plate can be reduced to about one forth; furthermore it becomes symmetric. As a result the laser beam deviation can be reduced to one tenth in comparison with the original holder plate.

REFERENCES

[1] Hahn, U. et al., "A Fast Switching Mirror Unit for FLASH", internal report, Hamburg 2007, A. Donat et al., "A Fast Switching Mirror Unit at FLASH", PAC09, Vancouver BC, Canada, TU5RFP061