Adaptive mirror design for European XFEL

European XFEL

Fan Yang, Harald Sinn, Antje Trapp, European XFEL, Albert-Einstein-Ring 19, 22761 Hamburg, Germany
Riccardo Signorato, Bruker-ASC, Köln Dellbrück, Geramny
Tino Noll, Helmholtz Zentrum Berlin, BESSY-II, Institute for Nanometre Optics, Berlin, Germany

In the beam transport system of the European XFEL, an offset and distribution mirror scheme is designed using adaptive piezoelectric bimorph technology. There are all together eleven mirrors planned over all the 3 beamlines, e.g. SASE1, 2 and 3. For the first and second mirrors in these three beamlines, specially in SASE 3, the spontaneous radiation is considered as critical heat load on the mirrors. Moreover, the different experiments require that the shape error of the mirror should be at the unprecedented level of below 2 nm peak-to-valley level over 700 mm optical length, with the focusing curvature continuously tunable between an ideal flat and 50 km spherical radius [see CDR for X-ray optics and beam transport, xfel.eu, 2012, Harald Sinn et al.]. To fulfill all these extremely stringent requirements under the expected heat load, a bimorph mirror based on a novel concept and including provisions for cooling has been designed in the length of 930 mm, with four rows of PZT actuators attached on the four corners of the silicon substrate. Using the finite element tool ANSYS®, static thermal and mechanical performance of this innovative bimorph mirror are simulated. Besides, the mirrors will operate in a vibration-optimized UHV chamber based on parallel kinematics, to meet the requirements on pointing stability dictated by the long distance to the experimental setups.

1

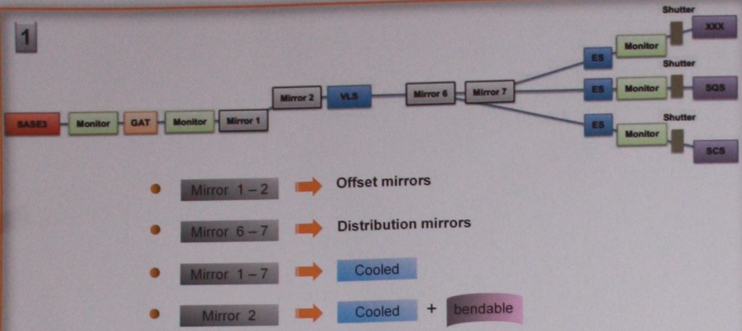


Figure 1: Layout the the SASE3 beamline in European XFEL. All these mirrors need to be cooled, specially the 1st offset mirror (Mirror 1), which is exposed to the spontaneous radiation of 10 – 100 W. The 2nd offset mirror (Mirror 2) needs to be bendable from flat to about 50 km, to compensate the thermal deformation of Mirror 1, and to create an intermediate focus for branch beamlines.

2

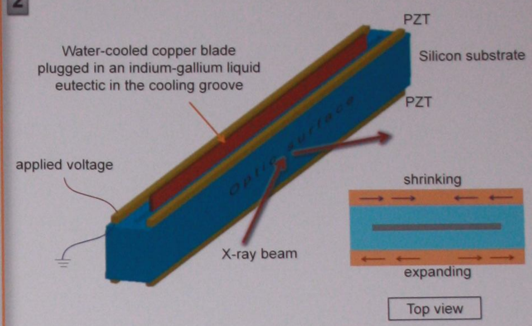
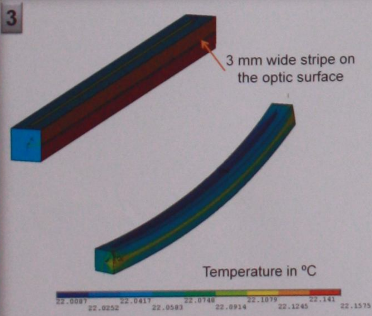


Figure 2: Initial design of the 2nd offset mirror, including cooling scheme and piezo actuators with individual electrodes covering the surfaces. The PZT actuators near the optic surface are inversely polarized from the actuators near to the back side, therefore applying the same electrical potential, the inverse deformation of the piezo actuators will cause the total bending of the mirror substrate.

3



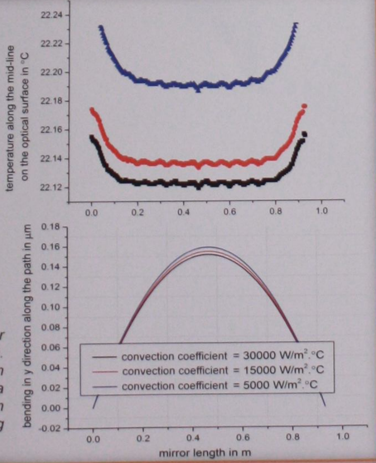


Figure 3: Temperature distribution of the 1st offset mirror (Mirror 1) with heat load from spontaneous radiation. The substrate is 930 mm long, with a cooling groove on the top. A 10 W heat load is applied as surface load on a 3 mm wide stripe on the optic surface. The figures on the right show the temperature profile and the bending with different convection coefficients.

4

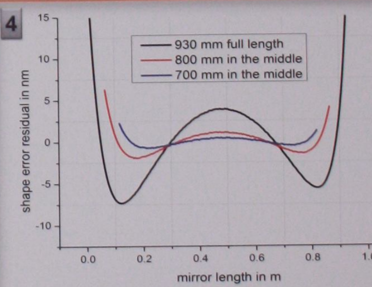
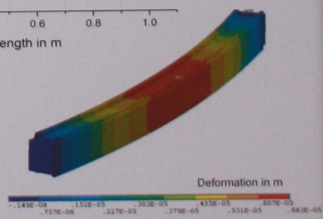


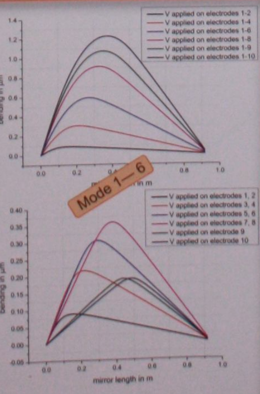
Figure 4: Bending of the 2nd offset mirror under 315 V applied voltage.

The shape error plot above shows the end effect because of the mounting and supporting. In the case of fitting a polynomial over 700 mm in the middle region, the shape error PV is less than 2 nm, which fulfills the technical specifications.



5

mode	Electrodes 1-18 on each row of piezo actuator																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	V	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	V	V	V	V	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	V	V	V	V	V	V	0	0	0	0	0	0	0	0	0	0	0	0
4	V	V	V	V	V	V	V	V	0	0	0	0	0	0	0	0	0	0
5	V	V	V	V	V	V	V	V	V	0	0	0	0	0	0	0	0	0
6	V	V	V	V	V	V	V	V	V	V	0	0	0	0	0	0	0	0
7	+V	-V	+V	-V	+V	-V	+V	-V	+V	-V	+V	-V	+V	-V	+V	-V	+V	-V



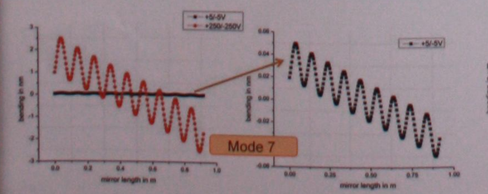


Figure 5: Pulse function demonstrating the adaptive zonal control capability of the mirror substrate. The plots of Modes 1-6 show the local bending capability with 315 V voltage applied on all the 18 electrodes sequentially. If the voltage is applied alternately on the electrodes, the high frequency oscillation is plotted as Mode 7, which shows the minimum limit of local bending capacity of the active mirror.

6

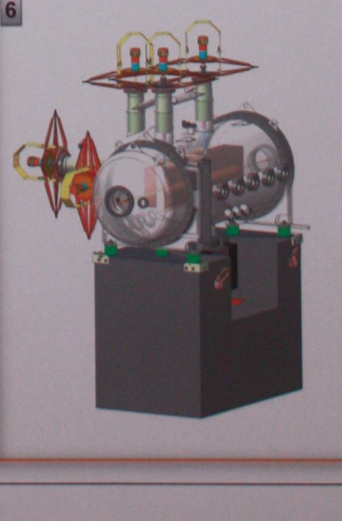


Figure 6: Mirror chamber design based on parallel kinematics. By means of FEA simulation the shape and the structure was optimized so that the eigenfrequencies of the chamber are above 90 Hz. The deformation due to the vacuum force are up to 100 micrometers. For the final design, a support of granite was chosen to optimize the vibration properties.