# Using a wavefront sensor to optimise the alignment of beamline optics

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The last section of a typical synchrotron radiation beamline is a mirror which images the exit slit of the monochromator onto the measurement spot in the experimental chamber. Often this focal spot is not readily accessible for characterization because it is in the centre of the experimental chamber and often also too small for direct imaging with a pixel-sensor. A further hurdle for a direct investigation is the high power density directly in the focal spot. Well established methods like knife-edge scans which are used to overcome these issues are very time consuming, particularly if the focal properties must be iteratively characterized to optimise the alignment of the focussing optics. A measurement approach which works from a distant location is therefore very useful.

Wavefront analysis using Hartmann and Shack-Hartmann sensor is well established for applications in the visible spectral range. For shorter wavelengths the micro-lenses are not usable anymore and the basic Hartmann sensor approach has been adapted recently for wavefront measurement at free electron lasers like FLASH [1]. We used this instrument to optimise and control the alignment of beamline focussing mirrors. The measured wavefront can be expressed by means of the well-known Zernike polynomials. The lower order Zernike polynomials can be directly linked to the main degrees of freedom for the alignment of a mirror: the defocus term is correlated to a shift of the mirror position along the optical axis, the $0^\circ$ astigmatism is correlated to misalignment of the angle of incidence with respect to the mirror surface, while the $45^\circ$ astigmatism is correlated to misalignment of the symmetry plane of the mirror and the plane of reflection. We will show the sensitivity of the method and demonstrate one-to-one correlation of the three Zernike components and the respective mirror alignments.

## References

[1] B. Keitel, E. Ploenjes, S. Kreis, M. Kuhlmann, K. Tiedtke, T. Mey, B. Schaefer and K. Mann: "Hartmann wavefront sensors and their application at FLASH", J. Synchrotron Rad. (2016). **23**, 43–49