# Analytical designing of two-aspherical-mirror anastigmats permitting practical misalignments for soft-X-ray imaging

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With use of soft X-ray multilayer mirrors of several tens % reflection at normal incidence, practical microscopes with a laboratory source have been expected to be realized as an alternative to the conventional zone-plate microscope, which requires a narrow beam of synchrotron radiation available at limited location and machine-time. Historical Schwarzschild optics has also been demonstrated for imaging microscopes for soft X-rays.[1-2] However, the resolution still stays at a few micrometer range.

Although the Schwarzschild optics has good characteristics of small aberration, it has a practical drawback in high alignments accuracy required. As Horikawa[1] has pointed out, for imaging by a soft X-ray of 3.98 nm in wavelength, a permissible alignment error of the Schwarzschild mirrors falls within 300 nm for achieving diffraction limit imaging. Such a high sensitivity to misalignments can be the dominant difficulty for implementing the mirror optics of several cm in diameter and several tens cm apart at sufficient stability under various disturbances such as temperature drifts and mechanical vibrations.

The most promising solution to overcome this difficulty would be to seek for low alignment sensitivity configuration allowing larger misalignments by extending the spherical mirrors to aspherical, since such mirrors are now commercially available. For versatile designing to find new solution groups, an analytical method should be much more useful than a standard computer designing based on ray tracing and numerical optimization. Closed-form equations usable for this purpose to search for two-aspherical-mirror anastigmats have been previously treated.[3] The equations were found impractical however, because the solution groups were described by one variable indirect to practical design parameters. Therefore, the pupil obstruction needs to be calculated separately, which lacks insight to find practical solutions of high throughput essential in the soft X-ray optics composed of the partial reflection mirrors.

In this presentation we propose a new analytical method of designing based on new practical equations formulating aberrations for searching two-aspherical-mirror anastigmats in terms of the pupil obstruction of the optical systems. Then we introduce additional aberration terms caused by a slight misalignment to discuss the misalignment sensitivity of the solution groups. These formulations are then used for searching the anastigmats groups of soft X-ray microscopes respecting low sensitivity to misalignments and a large field of view.

*References*

1) Y. Horikawa et al., Proc. SPIE **1720** (1992) 217-225.
2) K. Murakami et al, Appl. Opt. **32** (1993) 7057.
3) D. Korsch: *Reflective Optics*, (Academic Press, 1991) pp. 155-161.