Wavefront-based Optical Alignment of Confocal Off-Axis Freeform Reflective System

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Abstract: As the wavefront-based Zernike coefficients provide systematic information about optical aberrations, it can be utilized for optical alignment. Therefore, we introduce the sensitivity table alignment method to a two-mirror confocal off-axis system (tel: +82 10.7763.0431, e-mail: lsw@khu.ac.kr).

1. Introduction

Off-axis freeform reflective optical systems have been developed for various applications that require unobscured scattering-free (due to the secondary mirror and its spiders) configurations. Nowadays, a confocal off-axis optical configuration is being featured as it eliminates linear astigmatism which is the most performance-limiting aberration in the conventional off-axis designs. In this confocal design, the mirrors share their focal points without obscuration of the secondary mirror [1]. As the linear astigmatism becomes more critical for large field of view-angles, the confocal off-axis optical design has advantages especially for wide field of view imaging system applications.

We present the wavefront-based optical alignment method for the two-mirror confocal off-axis optical system including freeform optical surfaces (i.e., mirrors). The alignment of the two-mirror optical system usually performed for one mirror while the other is fixed. In this case of two-mirror systems, the sensitivity table alignment method can be a direct and convenient tool [2].

The sensitivity table method is based on the wavefront measurement analyzing the change of Zernike coefficients via misalignment. As the measured wavefront contains the systematic optical performance degradation, the exact misalignment effect can be verified if the optical surfaces of the system are well understood. Especially, a Zernike polynomial-based wavefront analysis is appropriate for the alignment because it numerically represents the presence of each low-order misalignment induced optical aberration [3].

2. Sensitivity table analysis for wavefront-based alignment process

The sensitivity table method calculates the response signal due to misalignments of the optical system under the following two assumptions. One is that Zernike coefficients and misalignment have linear correlation as shown in Figure 1. The second is that the difference between measured and nominal Zernike coefficients only comes from the misalignment of the optical components.

In our investigation, the Zernike coefficient differences are obtained from wavefront measurements and the CODE V optical design software modeling simulations. The first derivatives of the Zernike coefficients through the misalignment degrees of freedom (alpha-tilt, beta-tilt, x-decenter, y-decenter and inter distance between the mirrors) are simulated using CODE V and the results are presented in Figure 1. With these parameters, the sensitivity table method estimates the misalignment of the two-mirror confocal off-axis optical system.

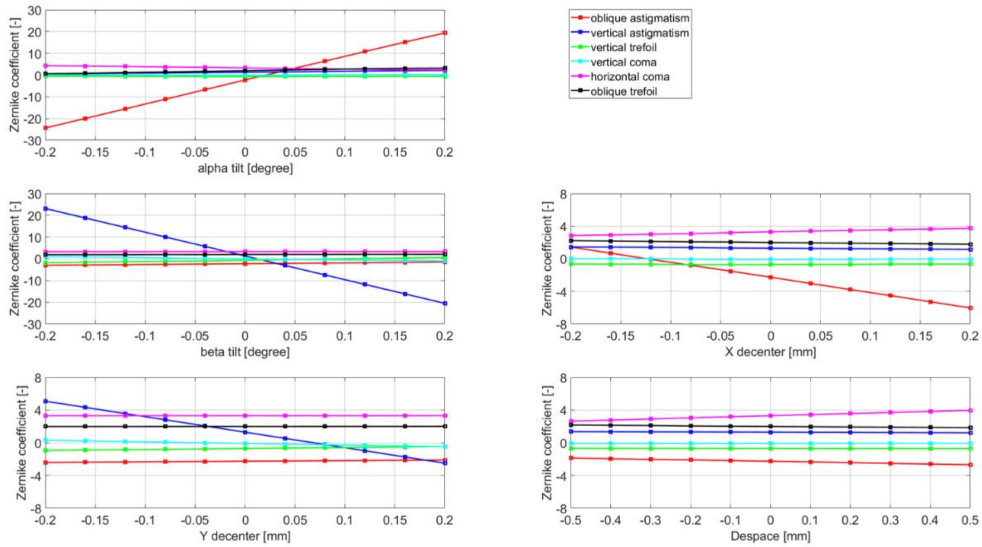

Fig. 1. Simulated Zernike coefficients change in wavefront due to misalignments.

3. Wavefront-based alignment simulation study

We verified the matrix algorithm for the sensitivity table method using nominal freeform mirror surfaces and imitating misalignment errors of the secondary mirror. The test wavefronts are generated from CODE V whose misalignment errors of 0.5 mm for decenter and distance between the mirrors (i.e., despace), and 0.5° for tilt are applied. Then, the sensitivity table method calculates misalignment errors from the test wavefronts which are theoretically 0.5 mm and 0.5° for decenter, despace, and tilt. Calculated misalignment errors are applied to the optical design for the next iteration trial of the alignment process, and this sequence iterates. The misalignment errors during the iterations are plotted in Figure 2. The errors converge to acceptable scale after iterations and the reliability of the sensitivity table method has been verified for the two-mirror confocal off-axis system.

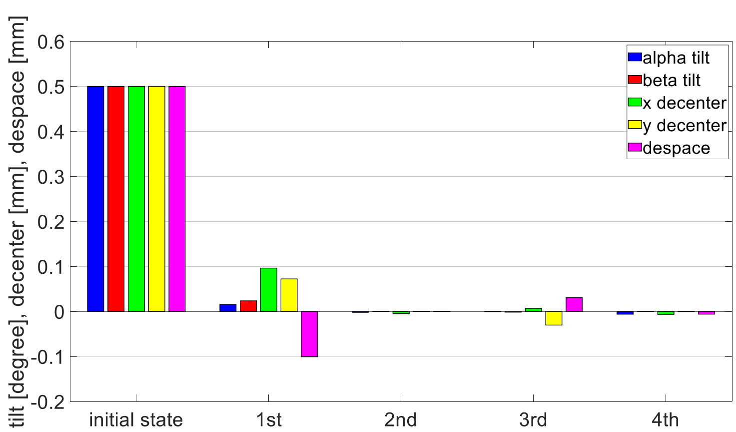

Fig. 2. Alignment simulation showing the misalignment error change through iterations.

Reference

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