Design of Off-axial Objective for High-NA EUVL Using Free-form Surface Mirrors

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The next generation of optical system for extreme ultraviolet lithography (EUVL) will focus primarily on 16nm node and beyond. With decreasing of feature size, higher numerical aperture (NA) EUVL projection objective (PO) will be required. To avoid the obscuration of the light path caused by large NA, we propose a design method for EUVL objective with tilted and decentered reflective elements. Free-form surface mirrors are used to enable the well correction of aberration of the off-axial objective. The enlarged NA design can be obtained by modifying the traditional co-axial EUVL objective without adding extra mirrors. Many outstanding off-axial 6-mirror projection objectives have been presented in patent by the Carl Zeiss designer Mann[1]. The NA of these objectives may achieve 0.4~0.7. However, the design method of their gorgeous works was not mentioned in detail. The grouping design method proposed by Fei Liu can calculate many co-axial systems as the start point of EUVL PO efficiently[2] . But it cannot be used to design complicated off-axis EUVL objective.

In this article, we propose a tilted method to design off-axial high-NA EUVL PO. The design method starts with a co-axial EUVL PO design, which can be got with existing design methods[3]. When increasing the NA of a co-axial EUVL PO, the ray beam will be obscured by some mirrors so that the system cannot achieve high-resolution. We tilt the mirrors to avoid obstruction. The tilted angles can be calculated based on extended non-obscuration. The extended non-obstruction condition suggests that the tilted angle can be expressed as the clear space between the light path and the used mirror area nearby. Furthermore, for the co-axial central obscured system, this idea can also help us to decrease central obscuration. The mirrors can be tilted to change the obscured position for decreasing the central obscuration. For keeping the properties such as magnification and image side teleconcentricity of the original EUVL PO unchanged, the sum of the tilted angles should be equal to zero. After these simple steps, we can achieve an original off-axial high-NA EUVL PO. To meet the requirement of aberration correction, free-form surface mirrors will be used. Using this method, NA 0.4 and NA 0.5 off-axial 6-mirror EUVL objectives are designed respectively, and both of the systems have high imaging performance.

Figure 1 shows the design of a non-obscuration EUVL PO with NA 0.4.
Figure 2 shows the design of a central obscured EUVL PO with NA 0.5.

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[1] Hans-Jurgen mann. Imaging optical system, US 8018650,B2, Sep. 13 2011.
[2] Fei Liu and Yanqiu Li, OPTICAL REVIEW, VOL.20, No.2 (2013) 1-7
[3] M. F. Bal: Dr. Thesis, Technique University Delft, Delft (2006).

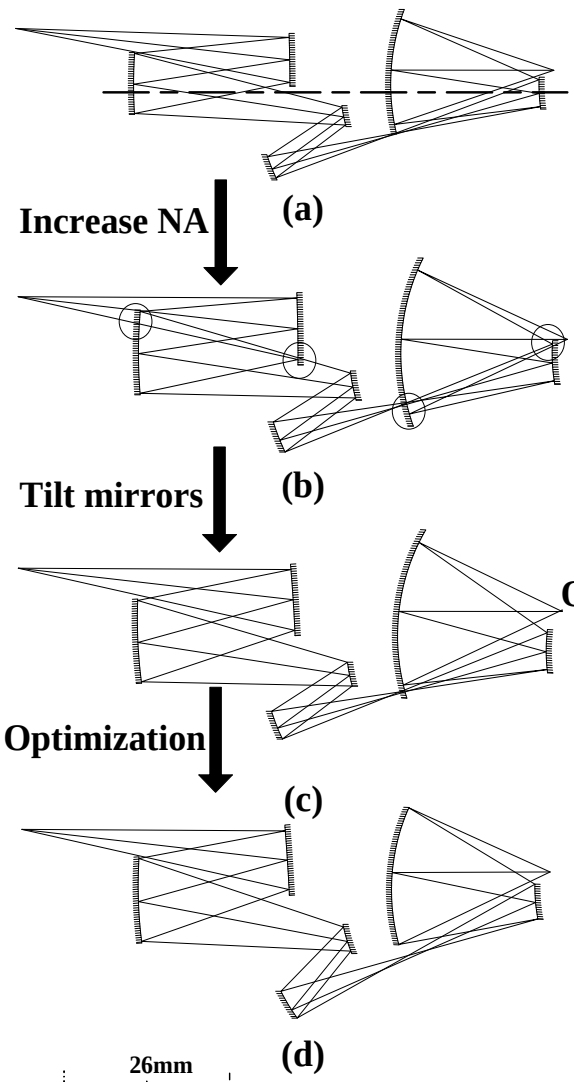

FIGURE 1: the process of designing non-obscuration EUVL PO with NA 0.4. (a) An original 1/4 reduced co-axial projective with NA 0.3; (b) NA is increased to 0.4 with obscuration; (c) The mirrors are tilted to achieve non-obscuration PO; (d) The optimized PO; (e) The image side field; (f) Corresponding MTF plot.

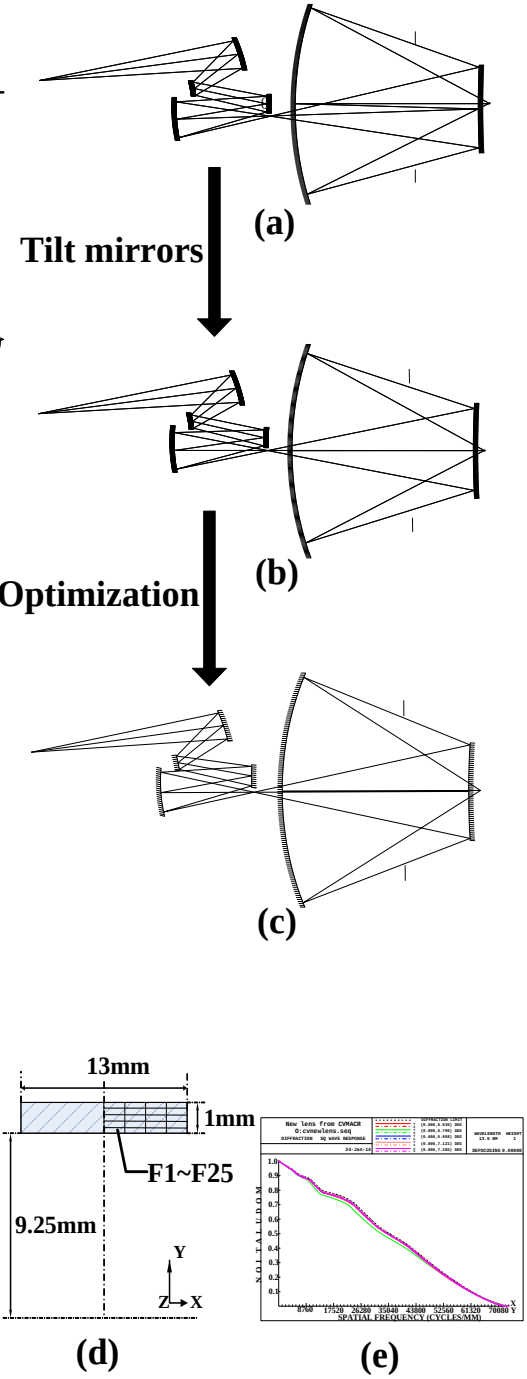

FIGURE 2: the process of designing central obscured EUVL PO with NA 0.5.(a) An original 1/8 reduced co-axial projective with NA 0.5 and the central obscured ratio is 22%; (b) The mirrors are tilted to achieve the PO with central obscured ratio is 13%; (c) The optimized PO; (d) The image side field; (e) Corresponding MTF plot.