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Optical Design for the Off- axis Reflective Optics with Wide Field

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Abstract: Reflective optics with wide field of view has been applied more and more widely in EUVL or space optics, and also plays an important role in promoting scientific and technological research. Among the reflective optics, the off- axis reflective optics is the most hopeful solution to the ever- highest demands of these applications. This paper gives the requirements of both the above mentioned applications and the similarities and differences between these two kinds of optical systems. Finally, a design example of off- axis reflective optics with wide field of view is presented and described.

Key words: optical design; off-axis reflective optics; space optics; EUVL
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1 Introduction

High-resolution optics with wide field of view is always the target that the optical designers are pursuing. Because of the specialty of EUVL and space optics, reflective optics maybe is the solution but that the on- axis reflective optics has narrow FOV usually in recent years. On the other hand, because the technology of design, fabrication, alignment and so on have developed greatly, especially in off- axis optical system, the off- axis system with wide field of view is the focus to be researched, and eventually it has been used in practice more widely. The most representative system of such kind is TMA(three- mirror anastigmat).

Then why do we make our determination to draw upon TMA? Here we pick out a list of advantages of TMA as follows:

1. Its central obstruction is free.
2. It has enough freedom to correct aberrations.
3. It has compact package.
4. It has high resolution at the same time with wide FOV.
5. It has basic off- axis form.

From Fig. 1, we can see clearly that as time pass on, the short wavelength is used even widely and at the same time it reaches the transmission limit especially in EUVL. Subsequently, only the reflective optics can meet the demands of short wavelength system and as a result the reflective optics becomes necessary and popular.

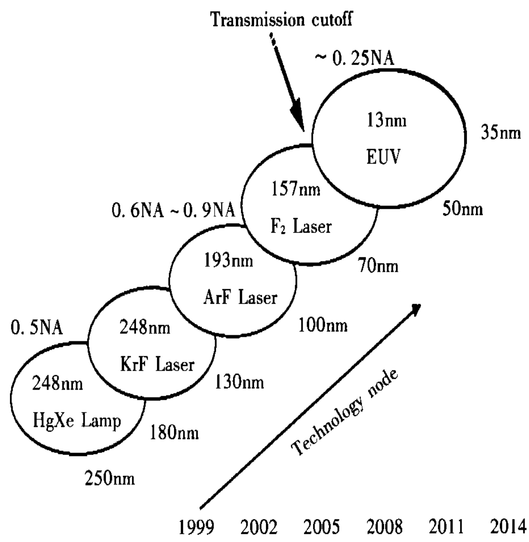

Fig. 1 Lithography tendency and optics form evolution

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Fig2. shows that the multi- mirror system will be used more widely in the future, especially in EUVL . Of course it will not be so easy to obtain, so pursuing the practical and suitable optics solution is a lasting and tough task for scientists. Next we will give you some multi- mirror systems and pick out its main specialties.

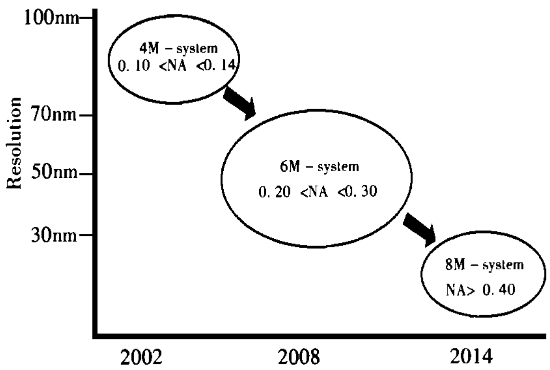

Fig. 2 FMA and the multi-mirror system

2 Summary of the reflective systems

2.1 Two - mirror system

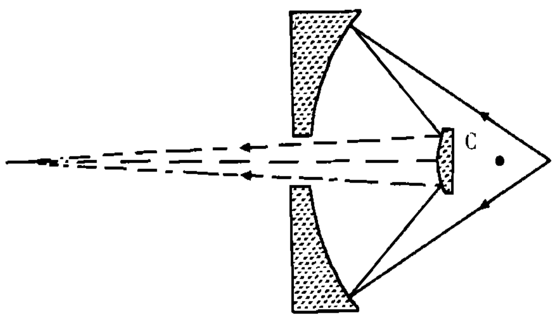

Fig. 3 a

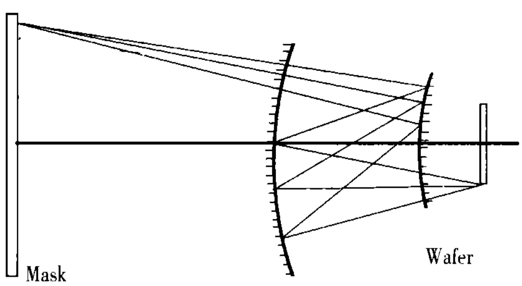

Fig. 3 b

Summary of the two- mirror system:

1. Its FOV is small.

2. There is no freedom to correct the distortion.

3. Distortion can cause image smear in scanning mode.

1) Although it has been used in 20x0. 04mm ring- field EUVL test, there are still problems in practical use.

2) This system is the basic form of the muti-mirror system. The muti- mirror system can be divided into several two- mirror system.

2.2 Three- mirror system (TMA)

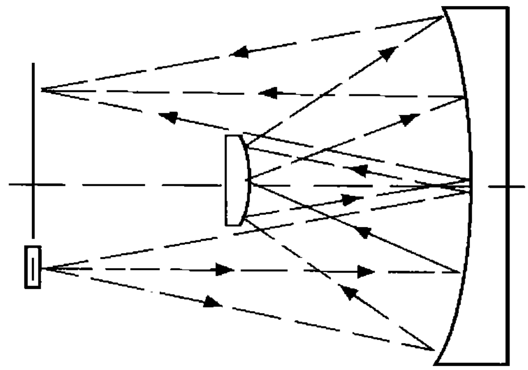

Fig. 4 a

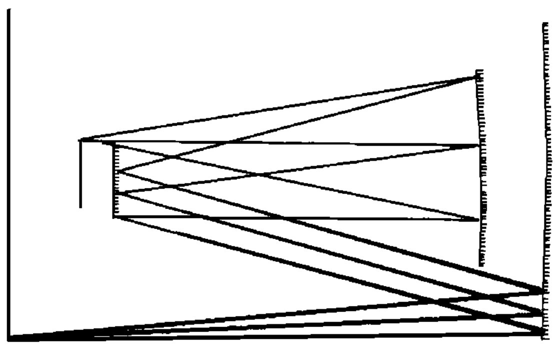

Fig. 4 b

Summary of the three- mirror system:

1. It has full freedom to correct the aberration.

2. There is no freedom to optimize AOI and its uniformity.

3. Odd number of reflections causes the same inconvenient object and image accessibility for scanning wafer and mask.

4. Lack of front- to - back symmetry from offered form causes aperture stop to be in an inaccessible location away from secondary , where beams are overlapping.

5. It has tight tolerances for compensation and alignment.

2.3 Four- mirror system (FMA)

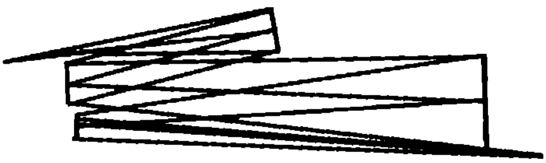

Fig. 5 a

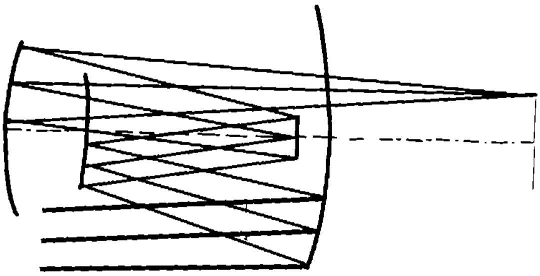

Fig. 5 b

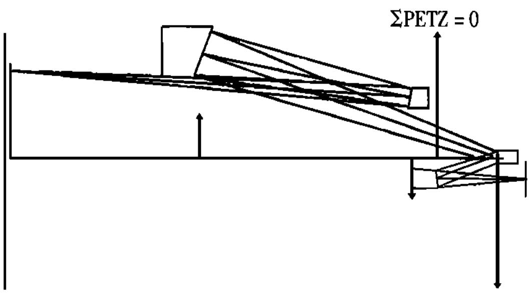

Fig. 5 c

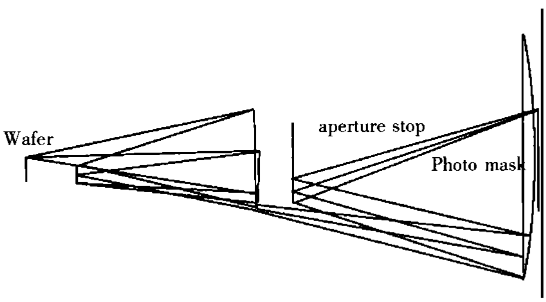

Fig. 5 d

Summary of the four- mirror system:

1. It applies most actively.

2. It has comparatively much more freedom to optimize AOI and it is easier to make stop at tertiary.

3. Even the number of reflections.

4. It is still difficult to lower the radial variation of astigmatism and distortion, which forces to be in the best position of stop separated from tertiary.

Next we can make a summary of EUVL optics:

1. Due to the ring - field requirement it prefers coaxial system .

2. FMA is good and realism solution on the base of TMA up to now.

3. The normal design ideas still make the FMA more perfect and practical.

4. Annular, torridal and even free surfaces may be needed to give additional design freedom.

3 Design consideration and example

Its wide FOV along with higher resolution is the greatest concern. The highest resolution is determined by the diffraction limit.

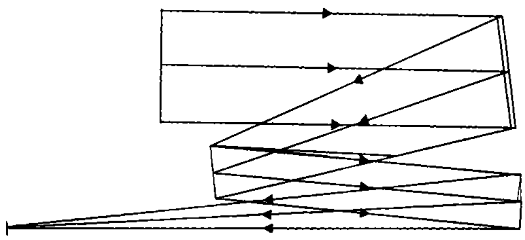

Fig. 6　System layout

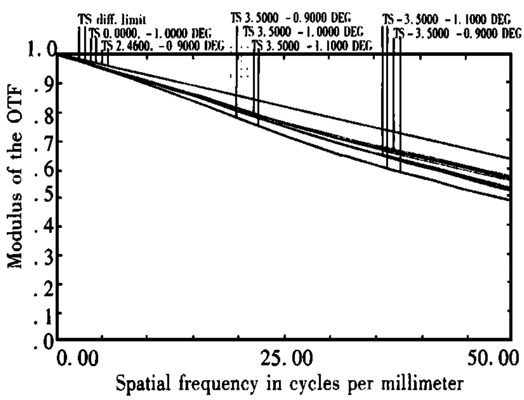

Fig. 7　MTF curve

Now here is a long EFL system for space application (swap scanning by TDI CCD), the system focal length is 10 meter and relative aperture is 1/10, total length is f/3– f/3, from Fig. 7 and Fig. 8. We can know its image quality is nearly limited by diffraction.

TMA's three mirrors are all aspherical surfaces, and the system has 8 variances:

1). Three radii

2). Two thickness

3). Three conic aspherical coefficients

Besides 5 primary aberrations need to correct, the focal length and working distance also need to be considered. Compact size is still another restriction.

$$H = n' NA \cdot f' \cdot \tan \omega$$

The information content capacity (ICC) is proportional to the square of Larguange invariant (H2), by comparison, EUVL TMA optics given 0.1 NA 24×0.5mm ring field has almost the same ICC as above relation calculated if perfect image is affected both by the same wavelength (13nm), the system layout is showed in Fig8. Both systems have similar difficulty to be conquered.

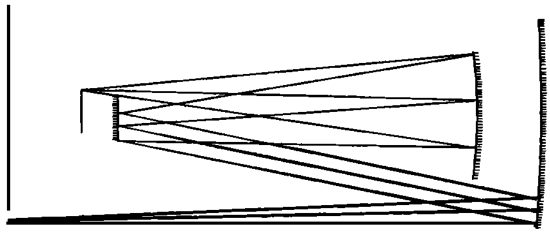

Fig.8 System layout of TMA for lithography

4 Conclusion

In the end we give some summary and discussions:

According to the content mentioned above, it's apparent that TMA plays an important role in the wide FOV reflective optics especially in the space optics. Space optics with rectangular FOV or full field prefers off– axis system (with real tilt or/and decenter elements) will be more difficult to be aligned. While EUVL optics prefers coaxial and off – axis ring– field aperture. On the other hand, EUVL optics has no stiff demand in the spectrum range while the space optics need a comparatively wider one. And EUVL often demands comparatively small package than space optics does. Besides, distortion may not be so stiff in space optics as EUVL because even a little distortion can cause image swear in scanning mode. While both require advanced design to meet these requirements.

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