DIFFRACTION ANALYSIS OF LAMOST — TWO SEGMENTED MIRRORS INCLUDED

WENLI XU
Nanjing Astronomical Instrument Research Center, Chinese Academy of Sciences

ABSTRACT

LAMOST is a special reflecting Schmidt telescope. Both the reflecting Schmidt plate \( M_A \) and the spherical primary mirror \( M_B \) are segmented mirrors. These two co-focus but not co-phase. The diffraction of the optical system is decided by the shape overlapping of \( M_A \) and \( M_B \). This paper describes the diffraction calculating results with different declination and different field angle. The diffraction influence to the image quality is acceptable in the error budget of optical system. It also proves that the size selection of the sub-mirror is reasonable.

I. BASIC PRINCIPLE

The optical system of LAMOST is composed of two segmented mirrors \( M_A \) and \( M_B \). Reflecting Schmidt plate \( M_A \) consists of 24 hexagonal sub-mirrors. Each segmented is 1.1m long in diagonal.

Because the sub-mirror's distribution of \( M_A \) is different from that of \( M_B \), when they overlap more sub-areas will be produced (See Fig. 1). Otherwise, rays of center object of FOV incident \( M_A \) with a angle \( \theta \), we consider the overlapping shape of \( M_A \) and \( M_B \) in the perpendicular plane to incident ray (See Fig. 2). Because \( M_A \) does the tracking and the main optical axis is fixed, obviously, \( \theta \) varies with different sky area observed, so the overlapping shape of \( M_A \) and \( M_B \) is different. When the shape of \( M_A \) and \( M_B \) overlap with off-axis field there is also a relative movement between their center. So diffraction of the optical system of LAMOST varies with the overlapping of \( M_A \) and \( M_B \).

(a) Diffraction of One Sub-Area

If we ignore the aberration of the optical system, the sub-area equal to a diffraction plate which aperture function is \( P(x_1, y_1) \) and the focal length is \( f \). With the parallel rays of unit amplitude incident vertically, the amplitude in the focal plane is given by

\[
U_S(x, y) = \frac{1}{f} \exp \left( jk \frac{x^2 + y^2}{2f} \right) \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} P(x_1, y_1) \exp \left[ -j 2\pi \left( \frac{x_1}{f} x + \frac{y_1}{f} y \right) \right] dx_1 dy_1.
\]

The intensity is \( I_S(x, y) = |U_S(x, y)|^2 \).

(b) Diffraction of System

Because LAMOST is almost used to get spectral data, each sub-mirror is required only co-focus not co-phase, the diffraction of system is the sum of all intensity contributions \( I_S(x, y) \) from each sub-area. We assume the \( i \)-th segment of \( M_A \) is divided into \( N \) sub-area, \( M_A \) consists of 24 sub-mirrors, so the result is

\[
I(x, y) = \sum_{i=1}^{24} \sum_{n=1}^{N} I_S(x, y).
\]

(c) Encircled Energy

In our occasion, what we concern most is the encircled energy. Discussed in polar coordinate, the total diffraction energy is

\[
I_A = \int_0^\infty \int_0^{2\pi} |I(\rho, \theta)|^2 \rho d\rho d\theta.
\]

Assuming \( \rho_0 \)

\[
\int_0^\infty \int_0^{2\pi} |I(\rho, \theta)|^2 \rho d\rho d\theta = 80\% \cdot I_A.
\]

II. THE RESULTS AND CONCLUSION

The most difficulty is giving out the correct aperture function of all the sub-area. The author does carefully with them and programs strictly according to them. Till now, four kinds of diffraction energy distribution of LAMOST have been calculated when the star is in meridian \( \delta \) is zenith of the observing sky area. \( \theta \) is incident angle of center object of FOV. \( W \) is the field angle.

1) \( \delta = -10^\circ(\theta = 7.3^\circ) \), \( W = 0^\circ \), 80% diffraction energy spreads in 0.49 arcsecond.

2) \( \delta = 30^\circ(\theta = 27.3^\circ) \), \( W = 0^\circ \), 80% diffraction energy spreads in 0.53 arcsecond.

3) \( \delta = 90^\circ(\theta = 57.3^\circ) \), \( W = 0^\circ \), 80% diffraction energy spreads in 0.51 arcsecond.

4) \( \delta = 90^\circ(\theta = 57.3^\circ) \). Field is in the plane decided by center object and main optical axis (meridional plane), \( W_X = 0.75^\circ \). It is estimated to be the worst case. Not only the meridional size of \( M_A \) is compressed, but also there are relative movement between the centers of \( M_A \) and \( M_B \) 80% diffraction energy spreads in 0.47 arcsecond.

According to above calculations, we can obtain such a conclusion: even if how \( M_A \) and \( M_B \) overlap, except a few individual cases the diffraction spread is less when each sub-mirror of \( M_A \) coincides with sub-mirror of \( M_B \), 80% diffraction energy of the optical system of LAMOST spreads in about 0.8 arcsecond. The diffraction influence to the image quality is acceptable in the error budget of optical system.
Fig. 1.— The overlapping of the segmented mirrors $M_A$ and $M_B$ ($\delta = -10^\circ$, $W = 0^\circ$)

Fig. 2.— The illustration of the overlapping of $M_A$ and $M_B$

Otherwise, diffraction is calculated when $M_-$ and $M_-$ are other two segmented shapes.

I. $M_A$ is a segmented mirror with 1.1m hexagonal sub-mirror in diagonal. $M_B$ is a single 6m mirror. Thus the diffraction of optical system is the same as the diffraction of a sub-mirror. $\delta = -10^\circ$, 80

II. Each sub-mirror of $M_A$ and $M_B$ is 1.5m hexagonal in diagonal. 80energy spreads in about 0.42 arcsecond.

The author thanks Prof. Su Dingjiang and Prof. Wang Yanan a lot for their beneficial discussions.

REFERENCES