Atmospheric dispersion corrector for the Large Sky Area Multi-Object Fibre Spectroscopic Telescope

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ABSTRACT

The Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST) is the largest, wide field-of-view (FOV) telescope (with an aperture of 4 m), and it is equipped with the highest number (4000) of optical fibres in the world. For the LAMOST North and the LAMOST South, the FOVs are 5° and 3.5°, respectively, and the linear diameters are 1.75 m and 1.22 m, respectively. A new type of atmospheric dispersion corrector (ADC) is put forward and designed for LAMOST. It is a segmented lens, which consists of many lens–prism strips. Although it is very large, its thickness is only 12 mm. Thus, the difficulty of obtaining a large optical glass is avoided, and the aberration caused by the ADC is small. By moving this segmented lens along the optical axis, different dispersions can be obtained. We discuss the effects of ADC’s slits on the diffraction energy distribution and on the obstruction of light. We calculate and discuss the aberration caused by the ADC. All these results are acceptable. Such an ADC could also be used for other optical fibre spectroscopic telescopes, especially those which a have very large FOV.

Key words: atmospheric effects – instrumentation: spectrographs – techniques: spectroscopic – telescopes – surveys.

1 INTRODUCTION

The Large Sky Area Multi-Object Fibre Spectroscopic Telescope (LAMOST) is a new type of telescope (Wang et al. 1996; Cui, Su & Wang 2000; Su & Cui 2004). The main parameters of LAMOST are the following: a clear aperture of 4 m (average), an f-ratio of 5 and a field of view (FOV) of 5°. The linear diameter of the FOV is 1.75 m. There are 4000 optical fibres (Xing et al. 1998), which introduce the light of different celestial objects to 16 spectrographs (Zhu et al. 2006). These optical fibres are positioned on a large focal surface. The dedication ceremony for LAMOST was held on 2008 October 16. We call this LAMOST North. At present, another telescope of this type, LAMOST South, which is intended to survey the Southern sky, is under consideration by China and other countries, with a view to international cooperation (Cui et al. 2010). The clear aperture and f-ratio of LAMOST South will still be 4 m and 5, but its FOV will be reduced to 3.5°. The linear diameter of the FOV of this telescope is 1.22 m. Many years ago, some atmospheric dispersion correctors for a small FOV were designed and used. Since the 1980s, some atmospheric dispersion correctors for larger FOVs have been designed (Epps, Angel & Anderson 1984; Su 1986; Su & Liang 1986; Wynne 1986, 1988; Willstrop 1987; Liang & Su 1988; Su, Wang & Yi 1988; Bingham 1988; Wang & Su 1990). In these correctors, there is a pair of prisms or lens–prisms (lensms), each of which is a cemented lens with a tilted cemented surface and each consists of two different glasses. By rotating these two lens–prisms, we can obtain different dispersions. Using this method with LAMOST would require very large lens–prisms, and it is difficult to obtain optical glass of such large size and to support the large lens–prisms. Liu & Yuan (2005) have designed several types of small corrector, each for an optical fibre. However, it is difficult to install and move these for 4000 optical fibres. In this paper, as an example, we propose and discuss a detailed design of this ADC for LAMOST South. It is a large but thin segmented lens, which consists of many lens–prism strips. Thus, the difficulty of obtaining a large optical glass is avoided, and because it is thin, the aberration introduced is small. By moving this segmented lens along the optical axis, we can obtain different dispersions. The entire design of this ADC could also be used for LAMOST North – we only need to extend its diameter to about 1.78 m. In this ADC, the clear aperture of a portion of celestial objects is divided into two parts (i.e. a slit is added to it). Here, the word ‘slit’ means slit plus chamfer at the edge of each lens–prism strip. These are covered with black paint, so in this paper a ‘slit’ is a light-obstructing black belt with a width of 1 mm. In this case, the diffraction spot is enlarged. However, in LAMOST, as the following discussion shows, this is not a serious problem, and it is acceptable. Apart from this, there is some loss because of light obstruction by...
the slit. For different celestial objects, the loss is different in the whole FOV, and it is also different when the ADC is at different positions. For these two reasons, such a segmented ADC is not suitable for diffraction-limited high-resolution telescopes and high-accuracy photometry. Such a segmented ADC is mainly used for optical fibre spectroscopic telescopes, especially if these telescopes have a very large FOV.

2 A BRIEF INTRODUCTION TO LAMOST

LAMOST is shown in Fig. 1. It lies on the ground in a south–north direction. Mb is a spherical mirror. Ma is an aspherical reflecting plate, which corrects the spherical aberration of Mb and reflects the light of celestial objects to the Mb. Ma and Mb consist of 24 and 37 hexagonal mirrors, respectively, and each mirror has diagonal of 1.1 m. In a segmented mirror telescope, the point spread function (PSF) is enlarged, especially when a segmented ADC is added. At a good astronomical site, if we do not use adaptive optics, atmospheric seeing only allows a telescope with an aperture of less than 30 cm to obtain the diffraction-limited image. Because adaptive optics cannot be used for a large FOV telescope, in this case, for a segmented mirror telescope, a subarea of a diameter of 50–60 cm is enough. The other reason that LAMOST North uses two segmented mirrors is to save costs. Incidentally, it is possible that LAMOST South will use one segmented mirror consisting of 1.1-m hexagonal submirrors. However, in many optical fibre spectroscopic telescopes, the diameter of the optical fibre is more than 1.5 arcsec. Compared with the seeing and diameter of the optical fibre, the effect of an enlarged PSF in LAMOST including a segmented ADC is minor and acceptable. During the observation, for a particular observation direction (a particular sky area), LAMOST is a reflecting Schmidt telescope. However, when observing in different directions (i.e. different celestial objects or the same celestial objects at different times), LAMOST should be a different reflecting Schmidt telescope. This means that the shape of Ma should be different for correcting the spherical aberration. Traditionally, such an optical system cannot be realized. Active optics is a key technology for correcting telescope errors, such as gravitation deformation and thermal deformation. This technology was developed mainly by Wilson (1999) and Lemaitre (2009) for the thin mirror, and by (Nelson 1980) and Mast & Nelson (1980, 1982) for the segmented mirror. Chinese experts have creatively applied active optics technology to Ma to make such a telescope possible and they have developed thin-mirror and segmented-mirror combined active optics (Su, Cao & Liang 1986; Su et al. 1998; Cui, Su & Wang 2000; Su & Cui 2004; Cui 2008). LAMOST is a wide FOV telescope, and it has the largest aperture and the strongest capability for obtaining fibre spectra in the world. The observing sky area of LAMOST is $-10^\circ \leq \delta \leq +90^\circ$. The celestial objects are observed for an average of 1.5 h before and after they pass through the meridian. During observations, only the mounting of Ma does the tracking and the focal surface does the rotation. LAMOST North was set up at Xing Long Station (latitude 40.4° N, at a height above sea level of 900 m), National Astronomical Observatories, Chinese Academy of Sciences. The largest zenith distance (with the celestial object in the meridian, as in the following text) is 50.4°. For a waveband of 380–1000 nm, the atmospheric dispersion is 2.2 arcsec. At Xing Long Station, the FWHM of seeing is about 2 arcsec. The largest spread of aberration is 1.84 arcsec. The diameter of the optical fibre adopted is 3.3 arcsec. In this situation, although it is better to correct the atmospheric dispersion, leaving it uncorrected will not present a serious problem. Through the development of LAMOST North, Chinese experts found that the size of each optical fibre positioner could be significantly reduced. So, for LAMOST South, the FOV will be reduced to 3.5°, its linear diameter will be 1.22 m, and 6000 optical fibres could be put on this focal surface. The observing sky area of LAMOST South will be $0^\circ \geq \delta \geq -90^\circ$. LAMOST South might be installed at the Las Campanas Observatory of the National Optical Astronomy Observatory (NOAO) or the Paranal Observatory of the European Southern Observatory (ESO). The NOAO Las Campanas Observatory is situated at latitude 29.9° S, at an altitude of 2400 m above sea level, and the largest zenith distance observed is 60.1°. The ESO Paranal Observatory is situated at latitude 24.6° S, at an altitude of 2635 m above sea level, and the largest zenith distance observed is 65.4°. For a waveband of 380–1000 nm, the corresponding atmospheric dispersions at these two observatories
are 2.75 arcsec and 3.35 arcsec, respectively. Because the image quality (because of the reduction of the FOV to 3.5°) and the seeing at the two observatories are better than those of LAMOST North, the diameter of the optical fibre used will be 1.6 arcsec. For LAMOST South, the atmospheric dispersion should be corrected. Because the largest atmospheric dispersion is bigger at the ESO Paranal Observatory, it is chosen as an example in this paper.

3 STRUCTURE OF THIS ADC

The layout and specification of this ADC are shown in Figs 2 and 3 and in Table 1. Each lens–prism strip consists of Schott glass PSK3 and LLF1. The refractive indices of PSK3 and LLF1 are given in Table 2. In $\lambda = 441.8$ nm, the refractive indices of the two types of glass are the same. In LAMOST, the Mb and the focal surface are concentric. The radius of the focal surface is 20 m. When the ADC is at the farthest position, we take its two outside surfaces and the focal surface to be concentric (i.e. the radius of the outside surface equals $20 \text{ m} + 250 \text{ mm}$). In this position for the waveband of 380–1000 nm, we need this ADC to produce a dispersion of 3.35 arcsec. From this, the tilt angle of the lens–prism strip can be obtained, which is 6.89°. We set the width of each lens–prism strip to be 50 mm.

![Figure 2](image1.png)

*Figure 2.* A sectional drawing of the ADC and the focal surface. In this figure, the radii of the ADC and the focal surface have been reduced (i.e. bent more), and the thickness of the ADC has been enlarged.

![Figure 3](image2.png)

*Figure 3.* (a) The light-beam area of the object is at the middle of a lens–prism strip. (b) The slit of two lens–prism strips is at the centre of the light-beam area of the object.

| Surface | Radius (mm) | Separation (mm) | Glass | Tilt angle (°) |
|---------|-------------|-----------------|-------|---------------|
| 1       | 20 250      | 6               | LLF1  | 6.89          |
| 2       | 20 244      | 6               | PSK3  |               |
| 3       | 20 238      | 238             |       |               |

| Focal surface | 20 000 |

Table 1. Structural parameters of the ADC.

| $\lambda$ (nm) | 380 | 441.8 | 500 | 587.6 | 656.3 | 1000 |
|----------------|-----|-------|-----|-------|-------|------|
| LLF1           | 1.574977 | 1.562383 | 1.555066 | 1.548138 | 1.544564 | 1.535632 |
| PSK3           | 1.570682 | 1.562383 | 1.557313 | 1.552320 | 1.549650 | 1.542388 |

which equals the light beam diameter of each celestial object on this ADC. Thus, in this position, only one slit is added for each object. Because the thickness difference of one lens of the lens–prism strip is 6.04 mm, the total thickness of the ADC is 12 mm. Because the $f$-ratio of LAMOST is 5, the diameter of the ADC should equal the linear FOV diameter plus 50 mm ($250/5 = 50$; i.e. 1.27 m for LAMOST South). So, the maximum length of the strip is also 1.27 m for LAMOST South. A similar result for LAMOST North is 1.78 m. If it is felt that some lens–prism strips are too long in LAMOST North, those strips longer than 1 m could be divided into two parts. In this case, only about 1/20 celestial objects will meet two slits when the ADC is at the farthest position. Although such an ADC is very large, it is very thin and only includes one segmented lens. As it is moved along the optical axis, its dispersion is changed. Thus, the atmospheric dispersion for $z < 65.4^\circ$ celestial objects can be compensated. The dispersion produced by this ADC is in direct proportion to the distance from it to the focal surface. In these situations, only one slit is met for some of the celestial objects. When the atmospheric dispersion is small enough that it does not need to be compensated, this ADC can be moved out easily. With regard to the manufacturing of the ADC, we plan to glue these lens–prism stripes together (with removable glue) to form a disc, and then to grind and polish it. We have already had some experience with such a method. Because the maximum light beam of each celestial object on the ADC is only 50 mm, the figure tolerance of the lens–prism strip is loose. On the whole, for this ADC, the tolerances of position, tip and tilts are loose. All lens–prism strips are fixed on
to the edge of the frame. As long as each lens–prism strip is well fixed, its tip and tilts will be small. Liquid glue can be used for the cemented surface to reduce the reflecting loss. Nevertheless, there are moderate difficulties in the manufacturing and mounting of the ADC, and thus it is still necessary to conduct more research and testing in this respect.

4 SOME DISCUSSIONS ON SPECIAL TOPICS

4.1 Effect of ADC slit on diffraction energy distribution

In LAMOST, both Ma and Mb consist of hexagonal mirrors, each with a diagonal of 1.1 m. The surface area of such a hexagonal mirror equals a circular area with a diameter of 1 m. For different celestial objects, these submirrors of Ma and Mb are covered by each other in the clear aperture with different states. Because, in LAMOST, all submirrors only co-focus, the light from different subareas is non-coherent and these shapes of the subareas divided by the edges of the hexagonal mirrors are complex. First, we discuss the case when both Ma and Mb are approximately perpendicular to the optical axis (i.e. the angle between the light of the celestial object and the optical axis pointing to Mb is small). It can be found that each hexagonal submirror is mainly divided into three or four subareas. If we assume four subareas, an important conclusion can be obtained: the average surface area of a subarea equals a circular area with a diameter of 0.5 m. As a rough estimate, we think that the diffraction energy distribution of LAMOST in this case is like a circular hole with a diameter of 0.5 m (i.e. 84 per cent of the light energy spreads in an area of about 0.5 arcsec; Airy disc). Xu (1997) made a detailed calculation for four special situations, and a similar conclusion was obtained. Because LAMOST’s clear aperture is 4 m, its surface area is 64 times that of a 0.5-m circular area. We think that about 64 subareas can be included in LAMOST’s clear aperture. For a particular celestial object in the worst situation, its clear aperture is divided by an ADC’s slit along the diameter direction, and thus about eight subareas are divided. As an average result, the diffraction energy of the eight subareas will distribute in two times its original length in a perpendicular direction to the slit (i.e. 84 per cent diffraction energy will spread in an area 0.5 arcsec wide and 1 arcsec long, and half of the energy will disperse beyond the 0.5-arcsec area). Thus, in the 0.5-arcsec area, the light energy will reduce by 4/64 (i.e. about 6 per cent). The energy loss is small and it still distributes in a 1-arcsec area. Given that the diameter of the optical fibre is 1.6 arcsec, the energy loss is acceptable.

Secondly, we discuss the situation where the celestial objects observed are near the celestial pole. In this case, in a plane perpendicular to the optical axis, the projective width of the submirrors of Ma will reduce to about a half, but the projective width of submirrors of Mb is unchanged. Considering these two factors and using a method of analysis similar to that above, we obtain the following conclusion. In this case, in LAMOST, 84 per cent of the light energy spreads in an area about 0.5 arcsec wide and 0.75 arcsec long, and in this area the light energy reduces by about 4.5 per cent because of an ADC’s slit. The energy loss is small and it distributes in a 1.5-arcsec area. Given that the diameter of the optical fibre is 1.6 arcsec, the energy loss is acceptable. In LAMOST South, either Ma or Mb might adopt a non-segmented (monolithic) mirror. It is easy to find whether either Ma or Mb is a non-segmented mirror or consists of larger submirrors, because with such a segmented ADC, the total diffraction energy distribution will be more concentrated than in the above situation.

4.2 Probability of objects meeting a slit

In the largest zenith distance $z = 65.4\degree$, each object will meet a slit of strips. When $z < 65.4\degree$ (i.e. the distance between the ADC and the focal surface is less than 250 mm), only some of the objects meet a slit of lens-prism strips. For example, if the distance between the ADC and the focal surface is 100 mm (according to $z = 39.6\degree$; see Section 5 and Table 3), only 2/5 of the objects meet a slit. If the distance between the ADC and the focal surface is 50 mm (according to $z = 20.6\degree$), only 1/5 of the objects meet a slit.

4.3 Light obstructed by ADC slits

According to a technical requirement, the edge of strips of the ADC should be chamfered to a projective width of 0.5 mm. In order to reduce the scattered light, all chamfers and slits of the ADC should be covered with black paint. Thus, all slits will become black belts with a width of 1 mm between two strips. These slits will obstruct light. The width of each strip is 50 mm. The approximate average obstructed ratio equals $1/50 = 2$ per cent. The thickness of the ADC is 12 mm. The $f$-ratio of LAMOST is 5 and the maximum inclination angle of ray is 1/10 to the ADC’s surface. Considering these situations, we find that about an average of 2.5 per cent of light will be obstructed. This is the average light loss. For a specific celestial object, this loss might be zero when the object does not meet a slit, and it might be several times the average loss when the ADC is near the focal surface and the object meets a slit. Although the loss of light due to the obstruction of a slit is uneven, this loss can be calculated and corrected for any one specific celestial object. Therefore, such a segmented ADC telescope can be used for photometry though it is not suitable for high-accuracy photometry.

4.4 Orientation of the ADC

Both the atmospheric dispersion and the ADC’s dispersion are vectors. The compensating error equals the ADC dispersion vector plus the atmospheric dispersion vector. For compensation, not only should the amounts of the two vectors be equal but also their directions should be opposite to each other. In a telescope, the ADC should be rotated to make its dispersion direction opposite to the atmospheric dispersion direction. From spherical astronomy, the ADC’s orientation formula can be derived easily. The tolerance of the ADC’s orientational angle is loose.

4.5 Aberrations

First, we ignore the tilt of the cemented surface of the ADC. Because the radii of the ADC are very large, the ADC can be considered as a parallel glass plate. From the third-order aberration formula, the smallest circle of spherical aberration is only 0.01 arcsec, and this can be corrected by active optics. From the chromatic aberration formula, the spread circle of chromatic aberration is 0.17 arcsec.

| Table 3. Distance from the first surface of the ADC to the focal surface, corresponding to the object’s zenith distance at the Paranal Observatory and the diameter of the light-beam area of the object on the ADC. |
|--------------------|--------|--------|------|--------|
| Distance from the first surface of ADC to the focal surface (mm) | 250    | 200    | 150  | 100    | 50    |
| Object’s zenith distance at Paranal Observatory (°) | 65.4   | 59.9   | 51.9 | 39.6   | 20.6  |
| Diameter of the light-beam area of the object on the ADC (mm) | 50     | 40     | 30   | 20     | 10    |

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at the extreme wavelengths of 380 and 1000 nm. For a glass parallel plate, the spherical aberration and chromatic aberration are unchanged when the ADC moves along the optical axis. When the tilt of the ADC’s cemented surface is considered, the coma will be added. It increases with the increasing difference of the refractive index of the two glasses (i.e. it is maximum at two extreme wavelengths). Also, this aberration is in direct proportion to the distance from the ADC to the focal surface. Here, we do not use a formula to calculate it. In Section 5, using ZEMAX software, all aberrations, which are indicated by spot diagrams, are given, including this aberration.

4.6 Compensation error of atmospheric dispersion

Because of the difference between the atmosphere and the glass dispersion, the compensation error does exist. It is just like a secondary spectrum in an achromatic optical system. Apparently, it is in direct proportion to the amount of compensated atmospheric dispersion.

5 CALCULATION AND DISCUSSION

The ZEMAX software is used for the following calculations.

In this paper, only the aberrations caused by the ADC are analysed (i.e. the aberrations of the original optical system are ignored).

We take the two outside surfaces of the ADC to be concentric with the focal surface when this ADC is at the farthest position. In this situation, if we ignore the structure of the strip in the whole FOV, the images are the same. We only need to calculate and discuss the case where the object is at the centre of the FOV, but with different relations to the strips. For central objects, we take two states: (i) the light-beam area of the object is at the middle of a lens–prism strip; (ii) a slit of two lens–prism strips is at the centre of the light-beam area of this object (i.e. the light of this object is half in one strip and half in another strip). In this section, all spot diagrams are calculated for these two states. For state (i) we adjust the tilt angle of the cemented surface of the lens–prism strip to make the image centroids of \( \lambda = 380 \) nm and \( \lambda = 1000 \) nm coincide at \( z = 65.4^\circ \) (i.e. to remove the atmospheric
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Figure 6. The spot diagram when the distance from the first surface of the ADC to the focal surface is 150 mm. The rest of the explanation is the same as in Fig. 4.

Figure 7. The spot diagram when the distance from the first surface of the ADC to the focal surface is 100 mm. The rest of the explanation is the same as in Fig. 4.

These main calculation results are shown in Figs 4–8 and Table 3–5. It is clear that the predictions in Sections 4.5 and 4.6 are proved and some specific values are obtained. The largest monochromatic image at an extreme wavelength is about 0.18 arcsec, which is mainly chromatic aberration. This figure shows no apparent change as the ADC moves along the optical axis. From Figs 4–8, we can find some coma induced by the tilt-cemented surface, and this reduces when the ADC moves towards the focal surface. The maximum compensation error of the atmospheric dispersion is 0.29 arcsec for the atmospheric dispersion 3.35 arcsec (i.e. the compensation error is about 1/12 of the atmospheric dispersion). The total spread in the waveband between \( \lambda = 380 \) nm and \( \lambda = 1000 \) nm is about 0.4 arcsec. In Figs 4–8, the same wavelength images are separated about 0.04 arcsec because the light of this object is half in one strip and half in the other strip. These two tilt-cemented surfaces have different distances to the focal surface. They produce different dispersions, one larger and the other smaller than the average dispersion. Incidentally, the largest part of one semi-circle of the lens–prism strip is LLF1 and the other largest part is PSK3. Together, they produce the difference chromatic aberration, so the sizes of the chromatic spread are different. Even though a 0.4-arcsec geometrical aberration is created, it is worth using such a simple ADC to...
Figure 8. The spot diagram when the distance from the first surface of the ADC to the focal surface is 50 mm. The rest of the explanation is the same as in Fig. 4.

Table 4. The correction results of the ADC when the light-beam area of the object is at the middle of a lens–prism strip. The largest spread of the spot diagram and the compensation error are in arcsec.

| Distance from the first surface of the ADC to the focal surface (mm) | 250 | 200 | 150 | 100 | 50 |
|---------------------------------------------------------------|-----|-----|-----|-----|-----|
| Largest spread of spot diagram \( \lambda = 380 \text{ nm} \) | 0.180 | 0.180 | 0.182 | 0.183 | 0.185 |
| Largest spread of spot diagram \( \lambda = 500 \text{ nm} \) | 0.033 | 0.029 | 0.027 | 0.024 | 0.021 |
| Largest spread of spot diagram \( \lambda = 1000 \text{ nm} \) | 0.172 | 0.168 | 0.165 | 0.162 | 0.160 |
| Largest spread of spot diagram of the whole waveband \( \lambda = 380–1000 \text{ nm} \) | 0.401 | 0.343 | 0.279 | 0.215 | 0.185 |
| Compensation error | 0.289 | 0.227 | 0.175 | 0.113 | 0.041 |

Table 5. The correction results of the ADC when a slit of two lens–prism strips is at the centre of the light-beam area of the object. The largest spread of the spot diagram and the compensation error are in arcsec.

| Distance from the first surface of the ADC to the focal surface (mm) | 250 | 200 | 150 | 100 | 50 |
|---------------------------------------------------------------|-----|-----|-----|-----|-----|
| Largest spread of spot diagram \( \lambda = 380 \text{ nm} \) | 0.192 | 0.193 | 0.194 | 0.196 | 0.200 |
| Largest spread of spot diagram \( \lambda = 500 \text{ nm} \) | 0.028 | 0.025 | 0.023 | 0.026 | 0.027 |
| Largest spread of spot diagram \( \lambda = 1000 \text{ nm} \) | 0.188 | 0.187 | 0.185 | 0.183 | 0.184 |
| Largest spread of spot diagram of the whole waveband \( \lambda = 380–1000 \text{ nm} \) | 0.397 | 0.339 | 0.276 | 0.212 | 0.200 |
| Compensation error | 0.289 | 0.227 | 0.175 | 0.108 | 0.046 |

6 CONCLUSION

In this paper, we propose a new type of ADC. It is a segmented lens, which consists of many lens–prism strips. As an example, we design and discuss such an ADC for LAMOST South. Its linear diameter of the FOV is 1.22 m and its \( f \)-ratio is 5. Although the diameter of this ADC is 1.27 m, its thickness is only 12 mm. Thus, we avoid the difficulty of obtaining large optical glass, and the aberration caused by the ADC is small. When we move this segmented lens along the optical axis, different dispersions can be obtained. These ADC slits will produce about 2.5 per cent average obstruction loss of light. In the largest zenith distance, each celestial object’s light only meets one slit of this ADC, and at another zenith distance only part of an object’s light meets a slit. We discuss the effects of the ADC slits on the diffraction energy distribution. Because LAMOST is used for optical fibre spectroscopic observations and the diameters of the optical fibres are 1.6 arcsec (LAMOST South) and 3.3 arcsec (LAMOST North), these effects are acceptable. From the waveband \( \lambda = 380–1000 \text{ nm} \), a total spread of aberration of 0.4 arcsec, which mainly is the compensation error of dispersions and achromatic aberration, is found when we use such an ADC for compensating 3.35-arcsec atmospheric dispersion. In this segmented ADC, the diffraction spot is enlarged and the loss of light obstruction by the slit is uneven. For these two reasons, such a segmented ADC is not suitable for diffraction-limited high-resolution telescopes and high-accuracy photometry. It is mainly used for optical fibre spectroscopic telescopes. Because this ADC is thin, the aberration caused is small, there is no difficulty in obtaining its glass, its thickness does not increase with the enlarged FOV, and it has almost the same image quality for the centre and off-axis FOV. Such an ADC is especially suitable for optical fibre spectroscopic telescopes with very large FOVs.

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