The development of ultra-thin backside reflecting mirror panel

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Abstract

This paper presents the development of the ultra-thin, ultra-light mirror back reflected panel for the application in a high energy gamma ray Air Cherenkov Telescopes. The goal of the project is to develop lightweight lard are mirror with reasonable surface and reflected quality lasting decades under the environmental condition.

Keywords: Ultra-light, gamma rys, mirrors

1. The gamma ray ground imaging telescopes

The detection of high energy gamma photons is usually realized by a use of the Imaging Atmospheric Cherenkov Telescope (IACT) on the ground level represented by a current project H.E.S.S [1], MAGIC [2], VERITAS [3] and CTA [4]. The technique use the collection of the gamma ray produced by the primary high energy gamma photons in the atmosphere and offers the best angular and energy resolution comparing to the ground and space particle detector INTEGRAL [5], AGILE [6], FERMI[7], HAWC [8], LHAASO [9], ARGO [10]. As the technique is based on the optical detection of the UV light produced in the atmosphere, the quality of the optical elements of the telescope is crucial. The most important parts of the optical system of the telescopes are the mirror parameters, optical filters, optical detectors the light-guards of the detectors. The field of view, optical PSF of the telescope and the camera pixel size define the angular resolution of the system in the first approximation. As for the mirror parameters, the PSF of individual mirrors defined by the mirror shape and the surface roughness and spectral reflectance of the coating are the main important imaging parameters of the reflected part of the IACT. The quality of the parameters could degraded during the lifetime of the telescope and need to be known and monitored. The current IACT are mainly composed by the solid glass mirror segments. The usage of the solid glass structure guarantees rigid mechanical and thermal stability guaranteeing stable mirror surface shape - PSF. The main disadvantage is the weigh of the segments which defines the telescope dish structure and the kinetics of the telescope movement. The weight of segments could be reduced by using different material of the segmented type mirror substrate e.q. MAGIC, CTA [11]. This paper presents a development of the light segmented mirror substrate and goes further using more stable and durable coating using the back side reflected surface of the mirror facets.

2. The backside reflected ultra-thin mirrors concept

Dusan, Jurek, Jacek

The main idea of the ultra-thin backside reflected mirror combines two extraordinary advantages. The main idea already used in the field of IACT is to reduce the weight of the mirror segment with optimizes mechanical stability and long term durability of the segments and extend the required optical property of the reflected layer. The goal of the research is to produce a mirror with required parameters lasting the designed lifetime of the project without or with limited maintenance. Both advantages guarantee the reduction of the cost of the telescope (due to the weight reduction) and maintenance time during the operation.

2.1. CTA mirrors for MST telescope

Jurek, Jacek

3. The mirror parts

DUsan, Jurek

3.1. Back side panel

Jurek

Figure 1: The author of the concept of the ultra-light mirror with the new generation back-coated with AI + Cr, mirror.

3.2. The front reflected panel

Dusan, Mira The front reflected panel is based on a thin UV light transparent glass coated with the aluminum and chromium layers. Two different manufacturer of the substrate were selected :

- SCHOTT Borofloat® 33
- NSG glanova ™

with different thickness. The selected list of glass parameters represents the Table 1

3.3. Reflection coating of the thin glass

Reflection of the mirror was achieved by a thin optical layer made of 100 nm thick aluminum covered by a protection layer of chromium (approximately 150 nm thick). Aluminum has a flat reflection profile (even in the optical interface with the soda lime glass) over wide range of wavelengths

glass	C.T.E. $[K^{-1}]$	n	D $[g/cm^3]$	E $[kN/mm^2]$	T [%]
SHOTT BG 33	3.3	1.47	2.23	67	90
NSG glanova	9.2	1.51	2.48	75.4	≥91

Table 1: Selected parametres of the Schott BF 33 and NGS glass taken from the producer sheets. The C.T.E. is Coefficient of Linear Thermal Expansion $10^{-6}K^{-1}$, n - refractive index at 587.6 nm, D - density $[g/cm^3]$, E - Young's Modulus $[kN/mm^2]$, T / optical transmittance [%]

in the near ultraviolet (UV) and the visible (VIS) region. Starting from the thickness of 80 nm, the reflection of this interface decreases from 90% at 300 nm to 87% at 600 nm (here, losses due to the glass transmission are not counted). The extra chromium layer is added thanks to its higher adhesion to the glue used to assembly the thin mirror and the back support. Besides this, it protects the aluminum from oxidation right after the deposition process.

Both materials were deposited by means of the PVD (Physical Vapour Deposition) technology at the pressure $5 \cdot 10^{-4}$ Pa and at the room temperature (as deposited) to prevent the reflectivity deterioration of the aluminum in the UV region. The fragile thin glass substrate was carefully cleaned before its insertion to the PVD chamber and further treated by a 10 minutes long Argon discharge prior to the deposition itself to improve adhesion. Aluminum was deposited by a thermal evaporation on tungsten boats (a fast process). The chromium was deposited by means of an electron gun (slow process).

4. Mechanical parameters and test

Jurek

5. Optical performance and test

Dusan , Mira The quality of the mirror facets depends on the shape of the substrate, micro roughness and the optical transmittance and reflectance of the used materials. The overall shape defines the PSF of the mirror facets. The micro roughness defines the ration between the secular reflection and the scattering component of the light. The used material and it's property defined the overall reflectance of the facets composed by the transmittance and reflectance of the thin front panel and coated layers. The mentioned contributor to the PSF are measured separately or for the whole surface using dedicated measurement methods. The shape of the surface are measured by contact or non-contact methods. The micro roughness is obtained by using optical non-contact instruments like spectrometers. Also the reflectance is measured locally on the surface or using the non contact spectrophoto meters. By combining the parameters the final PSF can be simulated and calculated. All these steps can be measured in once and the PSF and reflectance of the mirror facet obtained. The method use the light source in the distance of $2f$ (twice distance of the radius of curvature) and a screen observed by the optical spatial detector or the detector could be illuminated directly.

5.1. PSF and encyrcled energy

The size of PSF is an important parameter. To quntify the size of the PSF the encycled energy within a certain angle or circle with the center in the center of the gravity needs to be define.

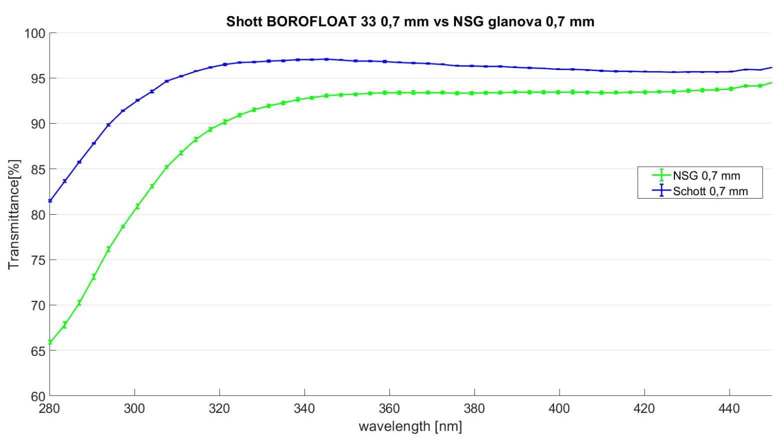

Figure 2: The comparison of spectral transmittance for the UV light of Shott BOROSILICATE 33 0.7 mm thick glass and NSG glanova 0.7 mm thick.

The front thin glass sheet used for the prototypes was the

6. Conclusion

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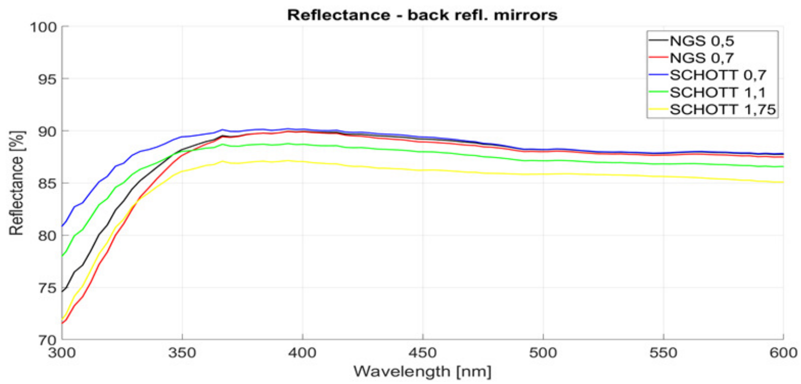

Figure 3: The spectral reflectance of a coated samples of thin glasses Shott and NGS.

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