Opto-Mechanical Characterization of Aspheric Lenses from the Hybrid Method

Aliouane Toufik, Hamdi Amine, Bouzid Djamel

***Abstract*—**Aspheric optical components are an alternative to the use of conventional lenses in the implementation of imaging systems for the visible range. Spherical lenses are capable of producing aberrations. Therefore, they are not able to focus all the light into a single point. Instead, aspherical lenses correct aberrations and provide better resolution even with compact lenses incorporating a small number of lenses.

Metrology of these components is very difficult especially when the resolution requirements increase and insufficient or complexity of conventional tools requires the development of specific approaches to characterization.

This work is part of the problem existed because the objectives are the study and comparison of different methods used to measure surface rays hybrid aspherical lenses.

***Keywords*—**Aspherical surface, Manufacture of lenses, precision molding, radius of curvature, roughness.

I. Introduction

THE aspherical lenses are differentiated by their conventional complex surface whose radius of curvature changes according to the distance from the axis of the light beam.

Spherical lenses are likely to produce aberrations. Therefore, they are not able to focus all the light at a single point. Instead, the aspheric lenses correct aberrations and provide better resolution even with compact lenses incorporating a small number of lenses.

The hybrid aspherical lenses are increasingly used in high precision compact optical systems, such as digital cameras and projectors to improve system performance and reduce product size and cost [1].

However the need for instruments more efficient in terms of field, resolution and spectral range, as well as the stress of congestion and weight increasingly reduced (under the impetus of military needs or space and professional instruments phones) has required control implementation process of aspheric surfaces, for example for the realization of space telescopes with compactness and presenting important deformations compared to the sphere [2]-[4].

There exist various types of manufacturing of the aspheric lenses, such as the moulded lenses [5], lenses out of ground glass, lenses manufactured by the hybrid method [6]. Among these types of manufacturing, the hybrid method is regarded as one of most suitable. The lens carried out by the hybrid method is manufactured by depositing a layer of monomer between the lens out of spherical glass and the aspheric metal mould [7].

A. T. is with the Institute of Optics and Precision Mechanics, Setif1 University 19000 Algeria (phone: 21300662146974; fax: 213036611158; e-mail: aliouane.toufik@ gmail.com).

H. A. and B. D. are with the Institute of Optics and Precision Mechanics, Setif1 University 19000 Algeria (e-mail: hamdi_amine@ymail.com, ja_bouzid@yahoo.fr).

II. Experimental Procedure

The optical glass used is a crown refractive index n = 1.48 and the glass transition temperature greater than 570 ° C. The manufacture of spherical lens of diameter 40mm, involves a sequence of operation generally classified into cutting, turning, grinding, lapping and polishing. For the lapping step, it was used by several successive steps of alumina fractions F30, F15 and F9, and the agent polishing is cerium oxide suspension of grain size 300 nm and a polyurethane polishing pad [8]. For coating, we used a resin refractive index n = 1.48 is very sensitive to ultraviolet radiation and polyvinyl buturale PVB very reputed to be used to make laminated glass. The realization of the aspherical surface by the hybrid method is as follows:

Once the convex lens carried out, a resin is injected between the lens out of spherical glass and the aspheric mould, then irradiated with a radiation UV in order to shape a hybrid lens (see Fig. 1) [9].

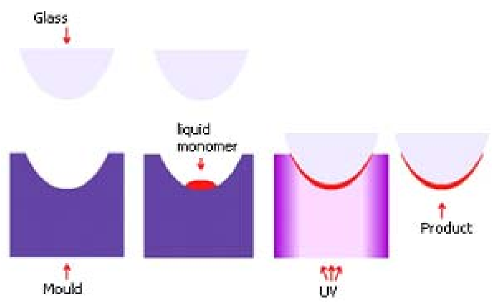

Fig. 1 Technique of manufacturing of the aspheric lenses by hybrid method

III. Control of Curvature Radius

A. Spherical Lens

The spherical lens that one carried out in our laboratory is a lens of diameter 40mm and radius of curvature rp=49,23mm

To control the profile of spherical surface, one used an optical measuring equipment which is the profile projector with an enlargement of ×10. Once the profile is projected onto the screen, a line is fixed as a reference, the ordinate and measuring (x, y) for 20 selected points on the lens, then the profile is obtained according to Fig. 2.

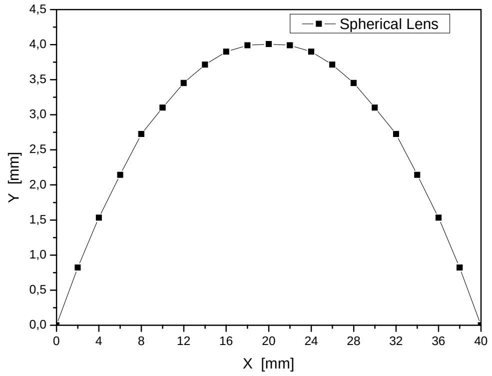

Fig. 2 Shape of the spherical lens

The radius of curvature of the lens is obtained by the following (1)

$$g(i) = \sqrt{((20 - x(i))^2 + (45{,}23 + y(i))^2)} \qquad (1)$$

The median value of the radius of curvature: R = 49,3631mm measured with a precision of ± 0,0704mm.

According to these results, we find that the spherical lens carried out in our laboratory is canonical in the field of manufacturing because the relative error is very low (<0.5%) in all measured points. These errors are attributed to measurement errors and perhaps manufacturing [10]-[11].

B. Aspherical Lens with Resin

Fig. 3 shows the shape of the aspherical lens made of the combination of ultra-violet flexographic resin.

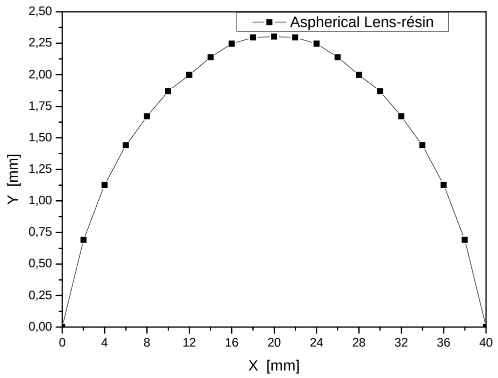

Fig. 3 Lens aspheric shape with the resin

It is difficult to measure the radius of curvature by classical techniques. What led us to seek techniques able to estimate the radius of curvature of aspheric surface. One measured the radius of curvature on the optical axis, which corresponds to the distance [OM], then with the software Matlab, one measured the distances [OMi], which represent Ri, such as Ri the radius of curvature for each point of surface (see Fig. 4) [12].

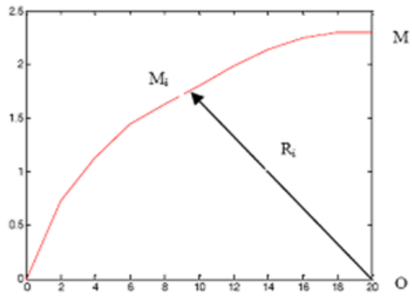

Fig. 4 Measurement principle radius of curvature Ri

The measurement of radius of curvature of the aspheric lens was done by the following (2):

$$f(i) = \sqrt{((20 - x(i))^2 + (47{,}2 + y(i))^2)} \qquad (2)$$

The values of radius of curvature Ri according to step of measurement i obtained from the aspheric lens carried out in combination of the resin (see Fig. 5).

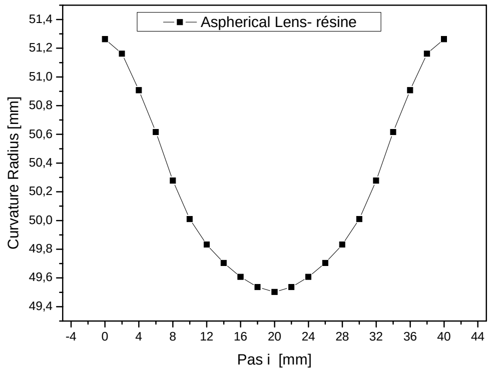

Fig. 5 Radius of curvature Ri according to step of measurement i of the aspheric lens

C. Aspheric Lens With PVB

The Fig. 6 shows the shape of the aspherical lens made in combination with Polyvinyl buturale.

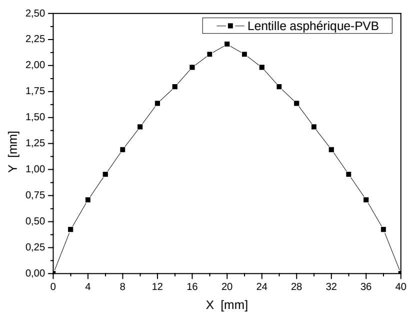

Fig. 6 Aspheric shape of the lens made by the PVB

The values of radius of curvature Ri according to step of measurement i obtained from the aspheric lens carried out in combination with the PVB (see Fig. 7).

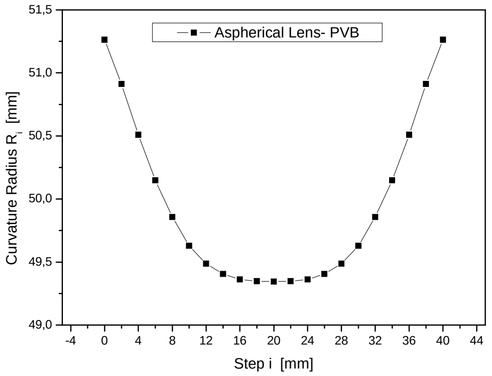

Fig. 7 Radius of curvature Ri according to step of measurement i of the aspheric lens carried out by the PVB

Fig. 8 compares the radius of curvature of the mould used, the aspheric lens carried out by the PVB and of the aspheric lens carried out by the resin.

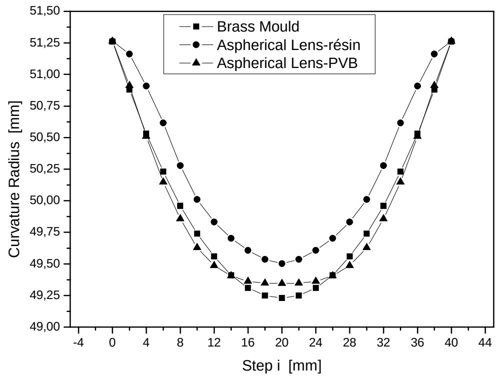

Fig. 8 Comparison of the various radii of curvature

The comparison of the results (see Fig. 8) between the rays of the mold used and different radii aspheric lenses with either flexographic resin or polyvinyl of buturale showed that the manufacturing process of the aspherical hybrid method makes it possible to obtain radii very near to the radius of curvature of the mold used. It is observed that the aspheric-PVB lens is better compared to the lens aspheric-resin on the other hand the withdrawal is more important at the flexographic resin with the ultra-violet than the polyvinyl of buturale.

IV. Surface Roughness

Roughness was measured at the top of the lens spherical and aspherical (carried by the resin and the PVB) by an atomic force microscope AFM. The Fig. 9 shows the surface topography of three lenses.

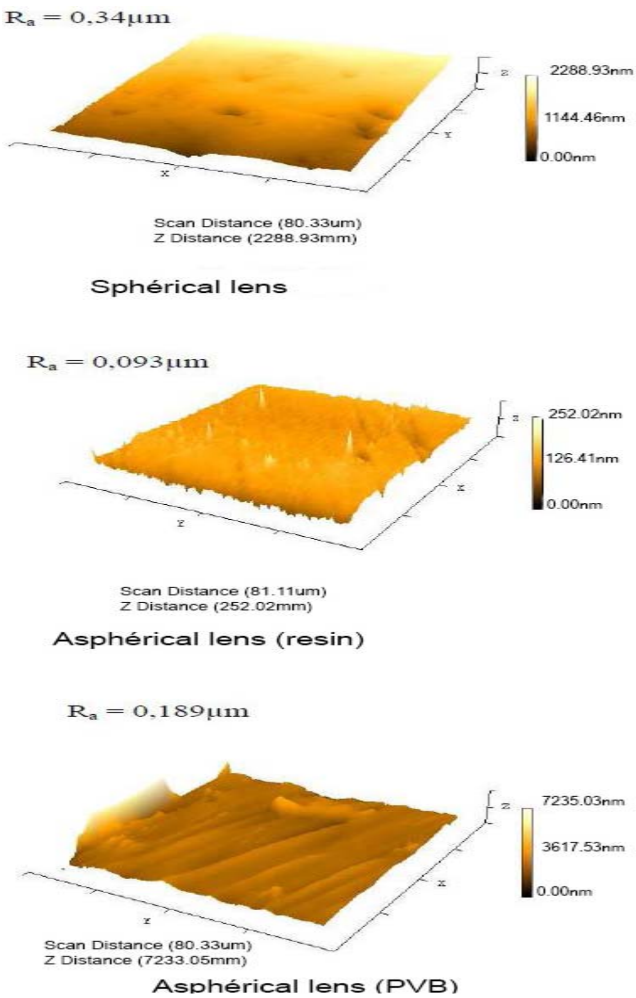

Fig. 9 Surface Topography of three types of lenses

Fig. 9 shows that the surface roughness improves in both cases (PVB and resin) compared to the initial state (spherical lens) and we also note that the roughness of aspherical lens made by resin is better compared to the roughness of the aspheric lens surface carried by PVB, this improvement in roughness may be due to a combination of brass (mold material) and resin and physico-chemical properties of coatings on the one hand and the instability of polyvinyl buturale which normally requires a SiO_2 layer to secure it [13].

V. Measurement of Optical Transmission

We have measured the optical transmission for the three lenses: spherical, aspherical-resin, PVB-aspherical with micro-densitometer in three positions A, B and C (see Fig. 10).

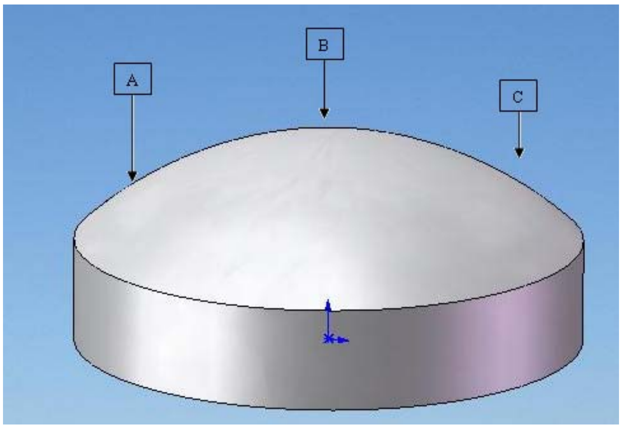

Fig. 10 The positions of optical transmission measurement

The results of optical transmission are shown (see Table I)

TABLE I
OPTICAL TRANSMISSION FOR THREE LENSES

Lenses	A	B	C
Spherical lens	70%	83%	75%
Aspherical lens-resin	80%	90%	84%
Aspherical lens -PVB	79%	88%	81%

From this results, we notice that the lenses developed in our laboratory transmit more or less light especially in the middle of the lenses; whereas edge, although the improvement is significant but insufficient to cause release problems we encountered during our work, it is recommended that, in future work, using calcium carbonate before casting to prevent lenses from sticking.

VI. LENSES ABERRATIONS

Using the Oslo software, we calculated the aberration of spherical and aspherical lenses (see Fig. 11).

From the results obtained, we draw the following conclusions:

- The longitudinal chromatic aberration is almost the same for spherical and aspherical lenses.
- The lateral chromatic aberration is lower for the spherical lens than aspherical lens
- For coma, its value is low for both types of lenses used.
- The astigmatism is low for all lenses used.
- Distortion increases much more for spherical lenses but corrected aspherical lens.

VII. CONCLUSION

This work showcased the manufacturing process of the aspherical hybrid method in general and to explore the possibility of applying this method in practice with the study of the influence of various process parameters (mold material, mold aspherical design, material of the aspheric lens material monomer layer (resin, PVB ... etc). From the experimental results, it was concluded that the manufacturing technology with aspherical hybrid method remains to this day and empirically very difficult especially for the demoulding of the lenses by against it can be easily used for organic lenses.

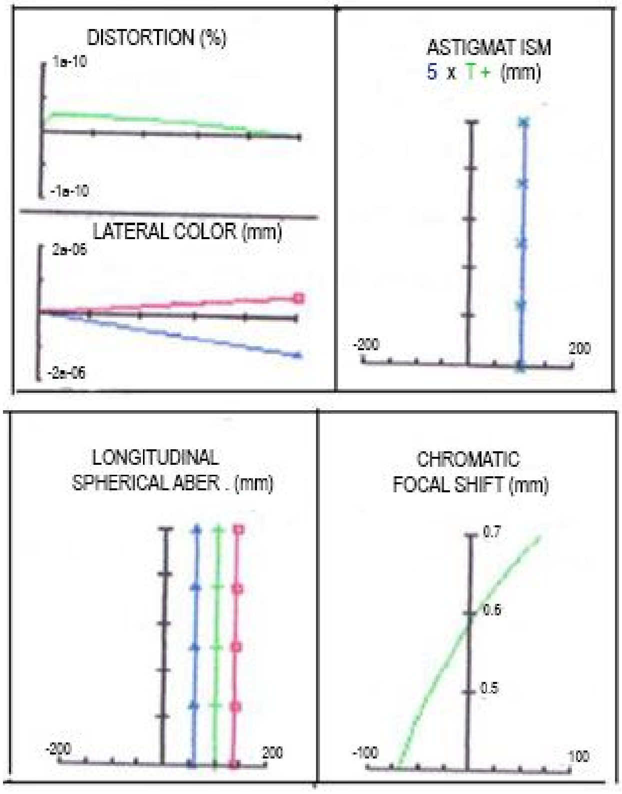

Fig. 11 Aspherical lens aberrations

REFERENCES

[1] T. Aliouane ; Hamdi Amine ; D. Bouzid. Evolution of opto-mechanical characteristics of hybrid aspherical lenses .ISITES 2013 1st International Symposium on Innovative Technologies in Enginneering and Science Sakarya University Congress and Culture Center. Sakarya – Turkey

[2] H. H Karow. Fabrication methods for precision optics. Wiley-interscience, ISBN 0-471-70379-6 USA; 2004.

[3] J. P. Marioge Surfaces optiques, Méthodes de fabrication et de contrôle, recherche EDP science ISBN 2-86883-486-8, France, 2000.

[4] T Aliouane., Bouzid D., Caractérisation de la sub surface durant le doucissage des verres optiques, 1er colloque international de la céramique. Safi, Maroc, 2010.

[5] M Loghrab. Etude comparative des méthodes de fabrication des surfaces asphériques, thèse de magister, IOMP, 2012.

[6] J. M Othoniel. Technologie des objectifs, 8ème édition, France, 2006.

[7] D. Bouzid., N. Belkhir., T. Aliouane , Optical glass surfaces polishing by cerium oxide particles iop, Conf. Series, Materials Science and. Engineering 2012: 28 , 012007.

[8] T Aliouane, D Bouzid. Caractérisation des polissoirs en polyuréthane durant le processus de polissage du verre optiques. 1er colloque international de la céramique. Safi , Maroc, 2010.

[9] T. Aliouane, D. Bouzid. Effect of the variation of the contact surface between polishing pad and glass on surface polished shape. ICG J. 2007, xxième congrès mondial du verre , strasbourg , France, 2007.

[10] V.Herold, O Schmelzer. R..Pechmann In process measurement in the polishing of optical glass, Proceedings of the9th international. precision engineering seminar braunschweig, 1997, s.636-639.

[11] H. C. Chuang, P.L. Tso, An investigation of lapping characteristics for improving the form error of an aspheric lens.Journal of materials processing technology 2006: 176 , 183–190.

[12] C..Wyant Advanced interferometric surface measurement in the technology frontier, optical sciences center, University of Arizona, Tucson, az 85721.
[13] K. Khoudour. Correction de défauts de sablage par déposition de couches minces transparentes. Thèse de magister, IOMP, 2012.