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Segmented glass optics for next generation X-ray telescopes

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Abstract. The realization of X-Ray Optical Units, based on the use of slumped thin glass segments to form densely packed modules of mirrors in a Wolter type I optical design, is under investigation since some years at the Astronomical Observatory of Brera (INAF-OAB) in collaboration with the Max Planck institute for Extraterrestrial physics (MPE) and the European Space Agency (ESA). In order to reach the challenging requirements posed by next-generation X-ray telescopes, an innovative assembly approach to align and mount the IXO-like mirror segments has been developed, based on the use of glass reinforcing ribs that connect the plates to each-other. One of the most interesting features of this integration scheme is that it guarantees an active correction for existing figure errors: since the glasses are bonded into the optical unit while kept trough vacuum suction on the integration mould surface, they assume the exact shape of the mould itself. The status of the development is reviewed in this paper, from the basic idea to the latest results obtained with prototypes.

Key words. hot slumping, segmented optic, thin glass foil, grazing incidence optic

1. Introduction

Future X-ray telescopes will be characterized by large collecting area ($\sim 3m^2$) and high angular resolution ($\leq 5arcsec$) in order to offer scientists new high quality data to reveal the still hidden secrets of the Universe. Because of the excessive resulting weight of the optics or the limited image resolution, traditional production methods (i.e. direct polishing, Nickel electroforming, Aluminum foils) cannot be considered and new technologies need to be treated. Because of the large diameters ($\geq 3m$) the segmentation of mirror shells is a must. Since 2007, INAF-OAB is involved in the assessment and development of a candidate technology to manufacture X-ray telescopes: the slumping technology, based on the thermal shaping of glass mirror segments and their integration into basic X-ray Optical Units (XOU) composed by stacks of plates and spacers, called ribs. The research is financed by ESA and relies on the support from a pool of small Italian companies including ADS International, BCV Progetti, Media Lario Technologies, and Stazione Sperimentale del Vetro and from the German institute MPE. The study has been so far performed in the frame of the IXO mission which has to be considered as a case study since the technology can be applied also to other missions.

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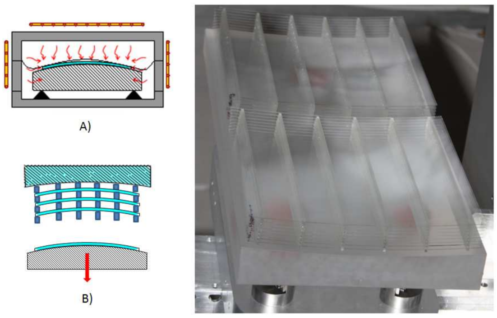

Fig. 1. Schematic representation of the hot slumping (A) and of the integration procedure (B). Close view of the prototype under development.

2. Slumping technology

The slumping technology consists in a thermal shaping of a glass foil that is flat in origin and is bent applying a suitable thermal cycle: the glass is positioned over a mould, having the shape desired for the final mirror, and is heated until its viscosity is such that it slumps against the mould, replicating its shape within certain accuracies (Proserpio et al. 2011). The entire process takes place inside a stainless steel muffle that guarantees better T uniformity, dust control and the possibility of pressure application to help the glass-mould contact. The original surface finishing of the glass can be maintained during the process through the optimization of process parameters, mainly maximum temperature of the cycle and applied pressure. The ongoing activities are performed using glass type D263 by Schott with dimension of 200x200x0.4 mm and a zerodur K20 convex mould having Radius of Curvature of 1000 mm. The slumping mould has a cylindrical shape despite the Wolter I design of the IXO telescope since the right shape is imparted to the mirror segment after the hot slumping following a particular approach for its integration into the basic optical element (Parodi et al. 2011). Through the use of vacuum suction, the slumped mirror segment is forced to adhere to the Wolter I shape of a suitable porous integration mould, modifying in this way its shape. Low frequency deformations eventually present inside the glass after the slumping, can also be corrected with this method, named Partial Cold Shaping Phase (PCSP). The shape of the integration mould is frozen inside the mirror, except for spring back effect that can be controlled, by gluing it into the XOU through the use of glass ribs. Two stiff glass planes close the stack at both ends giving more rigidity to the entire structure. The assembly of the parabola and hyperbola segments in the XOU is performed simultaneously to control their mutual alignment using an ad-hoc designed Integration Machine (IMA) (Civitani et al. 2011).

3. Present results and conclusions

Following the described technology, one prototype has already been realized and a second one is at an intermediate stage of assembly at the time of writing: the Proof of Concept (PoC) demonstrator and the X-ray Optical Unit Breadboard (*XOU_BB*). The first one is composed by a stack of two mirror segment pairs and was assembled to test the IMA functionality. The second one, presently composed by 8 segment pairs, will ultimately be composed by a stack of 20 layers and will be measured at the Panter X-ray facility by the end of the year to verify the expected Half Energy Width (HEW) through X-ray calibration. The simulations realized on the measured profiles data of the last thermally shaped segments (Ghigo et al. 2012) suggest in fact that, after their integration into a stack, they have the potentiality of delivering an HEW of around 15-20 arcsec. Further improvements to the whole process chain are under investigation and development in order to reach the goal of 5 arcsec posed by next generation X-ray telescopes.

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