# Ultra-lightweight, large aperture, deployable telescope for space applications: a technology demonstrator

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In the frame of an ESA contract for use of LIDARs in space, a technology demonstrator for large aperture, lightweight, active and deployable mirror for space telescopes has been manufactured and tested, in order to cover two critical areas: the functionality of the actuators and the demonstration of mirror survivability during launch.

## 1 Introduction

This work shortly presents the latest results of new technological concepts for large aperture, lightweight telescopes using thin deployable active mirrors. The study is originally addressed to a spaceborne DIAL (DIfferential Absorption Lidar) at 935.5nm for the measurement of water vapour profile in atmosphere, as an output of an ESA contract (whose preliminary results were presented at ICSO 2006 [1]). The technology of active mirrors is already widely in use on ground for compensating slowly varying effects [2]. The high versatility of these concepts allows exploiting the presented technology for any project willing to consider such kind of space telescopes. For the case of space DIAL technique, since laser power transmission is inversely proportional to the aperture size, retrieving the signal emitted by moderate power laser transmitter is done by means of a large telescope collecting area. The key features of this design are: large optics (total available primary mirror surface ~10 $m^2$); lightweight and deployable primary mirror with areal density ~15 $Kg/m^2$; high wavefront quality (<$\lambda$/3). The last condition is assured by a closed-loop active control system which involves a set of actuators connected with the thin mirror shell and a wavefront sensing system. The shape error sources are deployment, mirror manufacturing and thermal deformation.

The innovative approach for the primary mirror is based on the coupling of a 1-mm thick Zerodur mirror optical surface with a lightweight CFRP (Carbon Fiber Reinforced Plastic) back-plane and supporting structure. A major problem is how to preserve the integrity of the glass shell in the harsh environment of the launch. The use of electrostatic force is here proposed for attracting the glass toward the back plane. This method is particularly promising especially due to the low power consumption.

A technology demonstrator has been manufactured and tested in order to investigate two critical areas identified during the preliminary design: the performances of the long-stroke actuators for the mirror active control and the mirror survivability to launch. It has been demonstrated that the mirror actuators are able to adequately control the surface shape and to recover a deployment error with a minimum amount of power; the mirror survivability is achieved with an electrostatic locking between mirror and back-plane able to withstand a vibration test representative of the launch environment.

## 2 Actuator design description

The actuators are based on voice-coil actuation concept; they are placed on a 250x250 $mm^2$ pattern on all the primary mirror backplane (Fig. 1).

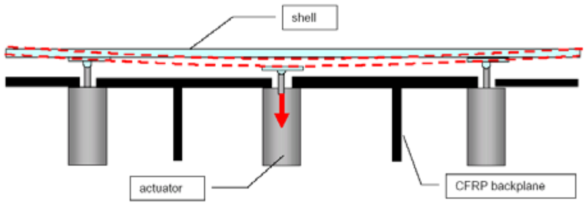


***Fig. 1*** *Actuator concept for mirror motion.*

Each actuator is ~25 mm Ø and ~80 mm long, made of aluminium. The mobile part is in ceramic material and is guided by two axial steel bearings carrying a pair of permanent magnets. The coil is winded on the stator and the magnetic circuit is closed by iron polar expansions. The position is measured by a capacitive sensor with cylindrical aluminium armatures. The interface between actuator head and mirror is made by a magnetic joint

(Fig. 2). Actuator current design is consistent with an overall power dissipation of the order of 200 mW/act.

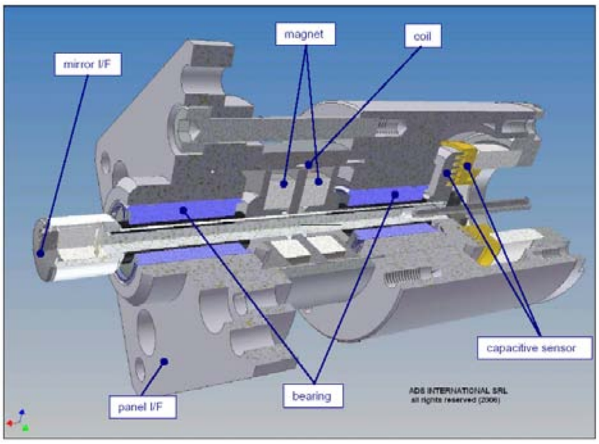


***Fig. 2*** *Active mirror control actuator: details.*

## 3 Electrostatic locking

In order to assure the glass integrity after launch, the electrostatic force is used to hold the glass to the back-plane. The glass back face is silver coated and the back-plane is covered with two layers of material, the first being conductive, while the second is an insulator with high ε (Mylar). This configuration gives a capacitor with large capacitance (Fig. 3). Applying 300 V, the attractive force is >6000 N/m$^2$, which would allow an (axial) detach only with a static equivalent acceleration of ~100 g.

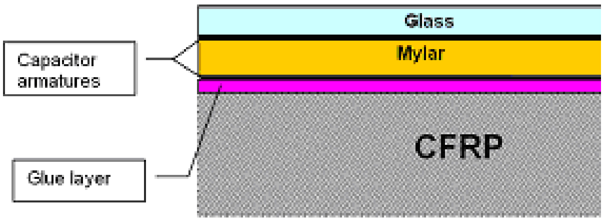


***Fig. 3*** *Scheme of Electrostatic Locking.*

## 4 Ground demonstrator

The Electrostatic Locking Back-plane (ELB) ground demonstrator is composed of the CFRP panel with a voice coil actuator (Fig. 4). To be representative of the final mirror performance, the breadboard has an areal density <20 Kg/m$^2$, a suitable thermal stability and it is tested at the 1$^{st}$ frequency of (150 ± 50) Hz. The following tests have been performed:

- Sine vibrations with 10g peak in each axis;
- Random vibrations;
- Shock tests between 125g and -60g for 0.5msec each, in the perpendicular direction;
- Actuator functional test (Tab. 1).

The mirror did not detach from the back-plane surface and the actuator test showed the goodness of its performance through the vibration tests.

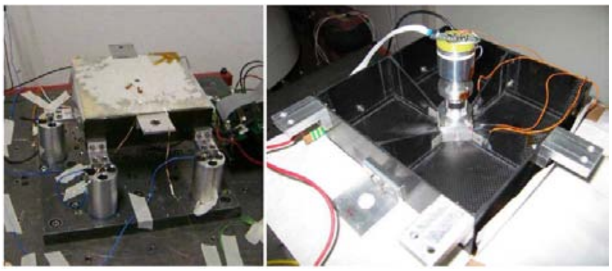

***Fig. 4*** *Tested ground demonstrator (top & bottom view).*

| Actuator performance | Requirement | Measured value | Achievable value |
|---|---|---|---|
| Actuator stroke | >1mm | 1.27mm | >1.27mm |
| Accuracy | < 200nm | 25nm | 10nm |
| CL Actuator bandwidth | >1Hz | 100Hz | 50Hz (for 10nm accur.) |
| Efficiency | >0.45 $N/\sqrt{W}$ | 0.45 $N/\sqrt{W}$ | 1.5 $N/\sqrt{W}$ |
| Mass | | 0.15Kg | 0.1Kg |

***Tab. 1*** *Voice Coil actuator performances.*

## 5 Applications

The advancement of this technology could be the key for the improvement of the next generation space telescopes. The potential application range is wide, for instance for Earth observation missions, high Resolution astronomy. In particular, it can be thought for Super-EUSO (Super-Extreme Universe Space Observatory), an international mission whose aim is to study Ultra High Energy Cosmic Particles, with a telescope using a 11-m mirror.

## 6 Conclusion

The built breadboard was successfully tested on a flat geometry with a general vibration environment that simulates a typical launch environment independent from the specific application. The Electrostatic Locking concept has demonstrated its high efficiency, providing a retention force that largely satisfies the requirements. Additional margins exist to improve the actuator efficiency and to optimize the actuator density. In conclusion, these techniques are promising, and can positively affect the development of future space-based observatories.

## References

[1] P. Mazzinghi, *et al.*, „An ultra-lightweight large aperture deployable telescope for Advanced LIDAR Applications“ in *Proc. of the 6$^{th}$ International Conference in Space Optics*, ESTEC, The Netherlands, 2006.

[2] A. Riccardi, *et al*, „Adaptive secondary mirrors for the Large binocular telescope“ in *Astronomical Adaptive Optics Systems and Applications,* Tyson, Robert (ed) Proc. SPIE, 5169, pp. 159-168, 2003.