An innovative alt-alt telescope for small observatories and amateur astronomers

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ABSTRACT

This paper want to show an innovative amateur oriented telescope with an unconventional alt-alt configuration. The goal is to make a telescope with good optical quality reducing production costs by adopting a gimbal based mounting to develop an alt-alt configuration suitable for a telescope. Reduce costs while preserving the optical quality is a necessary condition to allow small groups of amateur astronomers, schools and cultural clubs, with reduced economic resources, to acquire an astronomical instrument that encourages learning and advancing astrophysical knowledge. This unconventional mechanism for the realization of a telescope alt-alt provides significant advantages. The traditional rotary motors coupled with expensive precision bearings are replaced with two simple linear actuators coupled to a properly preloaded gimbal joint and the cell becomes the primary structure of the telescope. A second advantage would be secured by mechanical simplicity evident in the easy portability of the instrument. The frame alt-alt has some limitations on the horizon pointing but does not show the zenith blind spot of the alt-az mount. A dedicated alt-alt pointing and tracking model is under development to be compatible with commercial telescope softwares and with the proposed new mounting.

1. INTRODUCTION

Medium size alt alt telescopes have almost entirely replaced equatorial mounts in recent years due to their greater versatility, the presence of Nasmith gravity "invariant" foci and the possibility of being placed in various locations with a simple GPS GEO-location and reconfiguration of pointing model.

On the other hand this configuration exploit some disadvantage, like increased mass and costs due to heavy mechanics and electronics; moreover the required field derotation impose a mechanical blind spot at the zenith due to the high rotation speed (ideally infinite right at the zenith). This is often considered a problem for astronomical observations, since they are precluded in an area where astronomical events and atmospheric transmission are characterized by superior quality. An alt-alt configuration overcomes the problem transferring the criticality of the zenith point to the horizon where the astronomical observations are relatively less interesting relatively lose interest.[1]

INAF Brera has recently completed a feasibility study for a fast pointing 3-meter telescope[2,3] the alt alt configuration was really considered as a technically viable solution. Despite the promising results derived from the studies, the wide adoption of these configuration in astronomy is currently limited by the lack of an engineering development and prototyping. Thus the increased costs do not justify for the moment the quite better performances.

The amateur and professional telescopes markets have historically been separated by a large gap in costs and technology. Over the last ten years scientific cases like follow-up transient, long-term monitoring of variables, etc.., difficult to implement in large professional telescopes but adequately covered by an intermediate class of telescopes (60 cm 1.2 m) have been established. They are managed either by amateur groups or professional entities. Among these we can advise REM at La Silla, STELLA in the Canary Islands and SONG the multiple spectroscopic telescopes project funded by the European Union.

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Although the unit price still very high (from 300 to 800k according to size and performance) many telescopes of this size have been sold and installed over the last ten years by a few producers in the market. In addition several public small observatories in the Italian territory are now under procurement (Astronomy of Madonie Park, Antola Regional Observatory, etc..).

An expansion of this class of telescopes is desired at the international level (see "The Alt-Az Initiative" U.S.[4]) to increase their observational skills in astronomy in general and in the scientific cases mentioned above in detail. However the main obstacle to huge diffusion is still the cost.

This paper wants do describe an INAF funded project that proposes to cover a possible way to reduce costs through a radical simplification of the telescope mounting by developing the alt alt configuration.

2. OVERALL DESCRIPTION

The project baseline is an alt-alt amateur telescope with a 600mm diameter main mirror, the mounting key point is a gimbal joint that enable the required motion keeping an high pointing precision with reduced costs. The optical design currently almost frozen is a parabolic mirror coupled to a spherical one. This require a double lens corrector but allow the procurement of a relatively cheap main mirror considering the massive scale production of this elements. The development of a software pointing that takes account the alt alt motion is under development starting from a previously well tested alt-az based one.

Summary of Main technical characteristic:

- ALt alt mounting
- Parabolid Primary Mirror
- Pointing and tracking (60min) precision 1 arcsec
- Angular speed $5^o/sec$
- Minimum declination angle 15^o

The proposed mounting is sketched in Figure 1 and was patented by the company in Italy TOMELLERI*.

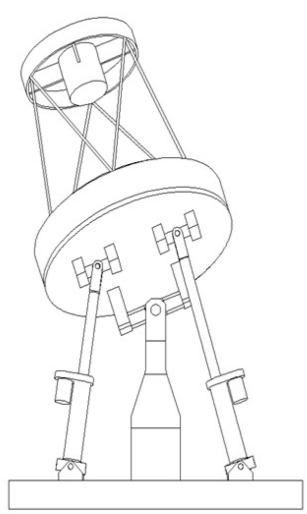

Figure 1. Conceptual view of the alt alt telescope.

*Patent No. VR2010A000170 deposited in Verona on 03/09/2010

2.1 Support and drive.

The support of the cell of the primary mirror is made by means of three parts consisting in a gimbal joint and two linear actuators. The drivers are fixed nearly to the vertexes of an equilateral triangle disposed at the center of the lower surface of the mirror holder cell. The gimbal joint constraints four degrees of freedom of the cell: the three translations and the rotation along the vertical axis, while the two remaining degrees of freedom are constrained by two linear actuators. The motion of the two linear actuators allows to point the cell in all the orientations within the solid angle of a cone with the symmetry axis coincident with the telescope axis and an amplitude of approximatively 75^o.

2.2 Mirror's orientation measurement

The gimbal joint is made by of three parts, the base of the main shaft which is fixed to a column welded to the base plate of the frame, the orthogonal shaft which is fixed to the cell, and the intermediate body that is interposed between the other two. The intermediate body of the cardan shaft is free to rotate according to a declination axis whose angle of rotation can be measured directly with a precision rotary encoder (Figure 2); the second shaft rotation can be measured in the same way with a similar encoder (Heidenhain). The set of this two measurements provides uniquely the orientation of the cell, related directly to the direction of the axis of the mirror, and is not affected by any structural deformation of telescope support.

Figure 2. Precision angular encoder.

2.3 Mirror support

The mirror's cell support will be made adopting the concept of a whiffletree.[5] This solution keeps the basic principle of the kinematic three-point support system, but spread the load supported by each of the three points over a larger number of points on the mirror. To preserve the kinematic nature of the system, support points on the back of the mirror are grouped by twos or threes and mounted on pivots.

The three main constraints points are located near the cardan shaft and the two linear actuators in order to directly download the weight from the whiffle tree to the basement. The lateral support of the mirror is formed by three rods fixed tangentially to the lateral surface of the mirror in this way the mirror is constrained so isostatic by three axial constraints and by three lateral restraints.

A preliminary tree optimization has been done with a dedicated software called Plop. The best compromise obtained in terms of connection point Vs mirror weight for a $60cm$ consider a mirror thickness of $1/10 = 60mm$. The tree includes 18 connection point (Figure 3): 6 are located in an inner ring with $134mm$ radius and 9 in an outer with $252mm$ radius. The connection point are grouped in six triangle, one vertex is a inner connection point while the other are two outer connection points. Each pair of triangles is linked by a connecting bar. The baricenters of the three connecting bar are the three main connection points of the tree to the rest of the cell and are located an a radius of $180mm$.

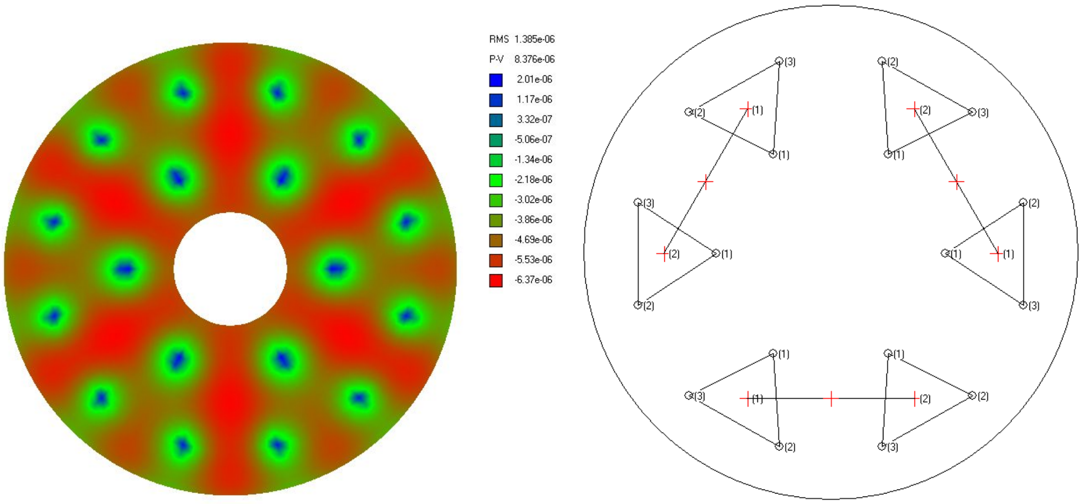

Figure 3. M1 gravity deformation (left) with 18 connection point whiffle three (right).

3. OPTICAL LAYOUT

The cost of each optical element strongly depends on the required surface quality and the complexity of its form as a result the demonstrator will be a compromise between quality optical image and the total cost of the optics. The optical layout has been then tailored to minimize cost through the adoption as much as possible of off-the-shelf components. Where this is not possible, the acquisition of raw optics with surfaces as close as possible to the nominal ones is foreseen; by means of the ion Beam Figuring which is a technology already developed at INAF-Brera the breadboard optics will be modified to get the desired shape.

In particular M1 will be a commercial[6] parabolic $600mm$ mirror with a focal length of $2400mm$ and a thickness of $6cm$. M2 is designed to be a spheric convex Mirror with a diameter of $250mm$ and a curvature radius of $5082mm$, the manufacturing of this mirror can take advantage of off-the-shelf spheric concave reference blank.[7] The field correction can be made through two S-BSL7 Ohara spheric lenses with a clear aperture of $125mm$. Finally M3 can be a simple flat elliptic mirror easy to found on the market.[6]

Summary of optical Constraints and assumptions:

- $600mm$ diameter parabolic primary mirror to Orion.uk
- Secondary mirror diameter 125 spherical radius (master to Edmund)
- field Correction: two elements in S-BSL7 Ohara useful diameter 125mm + mirror plane
- Distance between the corrector and M1 $< 450mm$
- Focal extraction of $350mm$ and $135mm$ from the top of the primary
- FOV 0.5^o over $400 - 700nm$

4. PRELIMINARY FEM

In order to dimension and optimize the telescope structure a simplified Finite Element Model has been set up. The whole model is done through 2D elements for the plate and 1D element for the truss rods. The optical element has been modeled through semi-rigid element with proper mass and inertia characteristics. The gravity displacement under X, Y and Z direction has been evaluated and introduced via a Matlab routine into the optical model to obtain the image displacement and quality degradation. Considering that within a certain amplitude the flexure can be directly compensated by the pointing model the optimization has been mainly driven by the optical quality. The model is made by 23268 elements and 23318 nodes.

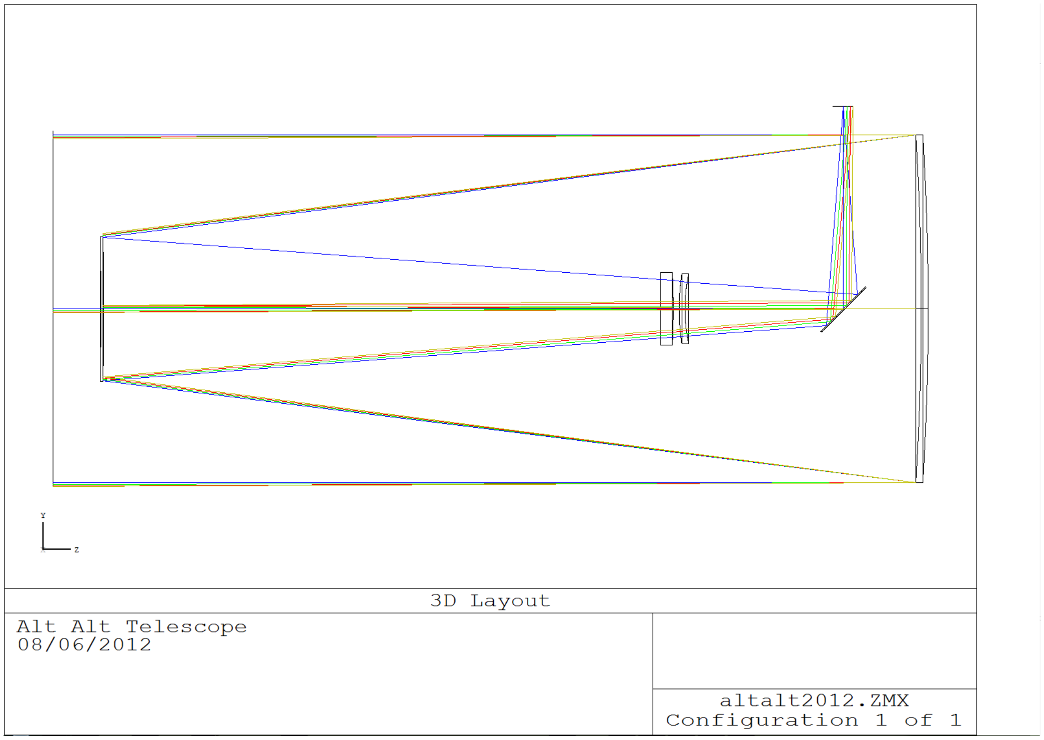

Figure 4. Telescope Optical Layout.

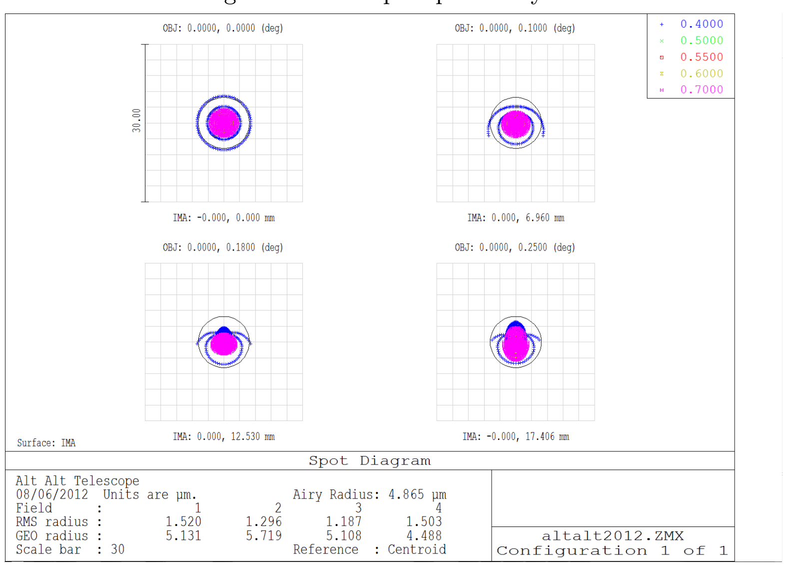

Figure 5. Telescope Optical quality.

5. POINTING AND TRACKING SOWFTWARE

The variation of parallactic angle combined with the physical behavior of the mountings, , induces a field rotation during observation that must be compensated to keep the star in the desired position on the focal plane of the instrument. Of course this rotation depends on a number of parameters: the latitude of the observer, the coordinates of the object and the focal position where the instrument is mounted. Different corrections are required if the telescope has an alt azimuth motion or an alt alt one as can be seen from Figure 7

We note that the meridian passage for an object at the zenith corresponds to a velocity of ∞. A comparison of the alt cases zenith at low speed (field) and even when observing the celestial equator this velocity vanishes

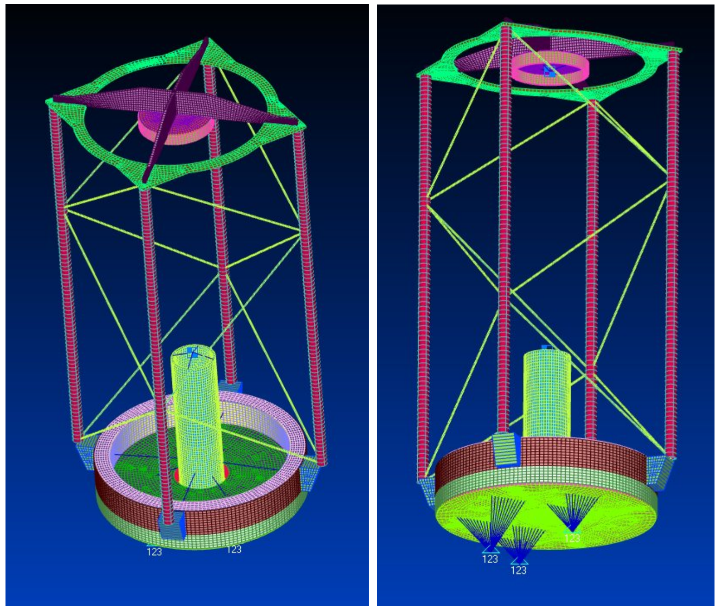

Figure 6. Telescope Finite Element model overall views.

because having an axis parallel to the axis of the earth acts as a matter of fact creating a pseudo-equatorial configuration. The following table shows the different behavior for an alt az telescope (above) and alt (below). On the left is shown the parallattic angle Vs the corner zone to the right while the speed of rotation of the field vs. the angle of azimuth.

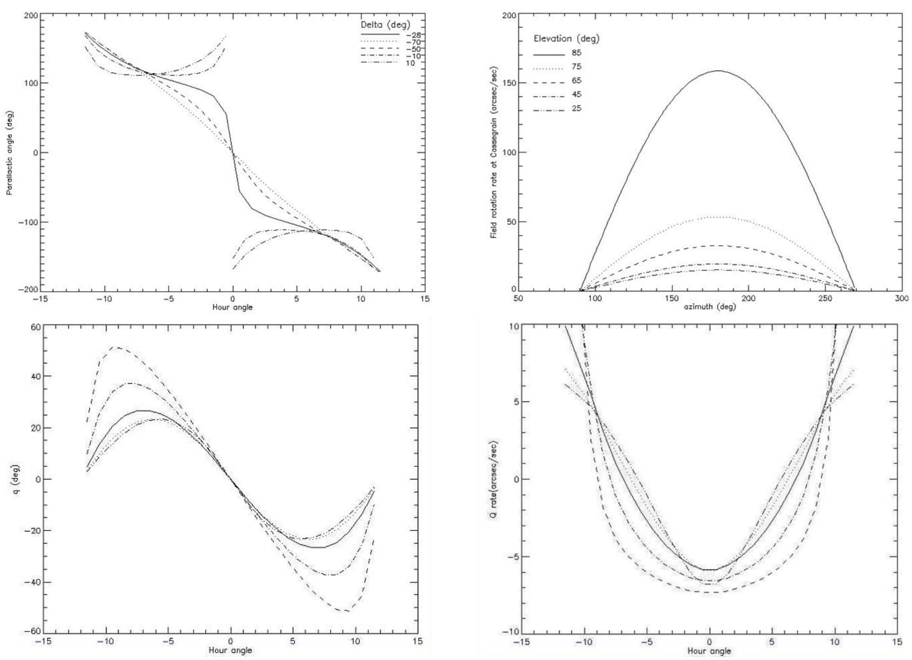

Figure 7. Field rotation in alt az configuration (left) or alt alt (right).

6. CONCLUSIONS

The weight of the gimbal mount structures is very low and the actuation systems are particularly simple since the movement is driven by the linear actuators worm. This particular notation keeps the overall complexity and cost quite reduced. Furthermore, considering the needs of amateur and small groups to conduct observations from different "viewpoints", portability is a major strength of the proposed system. The bred board under development is also conceived to demonstrate the scalability of these technologies to larger telescopes offering further developments and applications (even scientific type).

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