Further techniques for LGS tilt recovery: the perspective and the predictive approach

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ABSTRACT

The recovery of the absolute tip—tilt of a Laser Guide Star (LGS) is a crucial one in the Laser assisted Adaptive Optics programs, especially in the visible wavelengths where the natural sky coverage is poor. A number of techniques has been proposed to achieve this goal: the multicolour LGS by Foy, the use of auxiliary telescopes, the use of auxiliary laser projector, the use of the propagation delay, by our group. In this paper two more possible solutions are presented. These techniques are partly speculative or requires a strong technological development and are here reported in the hope that the dissemination of new and unconventional ideas on this problem will leads to some efficient solution.

Keywords: adaptive optics, laser guide stars, tilt measurement.

1. INTRODUCTION

Laser Guide Stars (LGSs) tilt indetermination problem is recognised as a fundamental problem1,2 to be overcome in order to realise for any type of seeing condition, full adaptive optics correction. While full adaptive optic correction with an LGS is still a complex task, most of the problems other than tilt recovery are essentially of a technological nature. As a very first approach we think that one should imagine to have unlimited technological support and to work out techniques for the tilt recovery regardless of their technical difficulty.

The techniques proposed in the literature ranges from the multicolor LGS3, the tristatic configuration4, the use of Natural Guide Stars (NGSs) well outside the isokinetich patch of the observed object, thanks to at least two auxiliary small telescopes5 and the adoption of the delay between the firing of the LGS from the telescope and its observation after the journey disturbing layer—mesospheric Sodium layer—disturbing layer6. Moreover one should point out some modification of the multicolour LGS pointed out by Belenkii7.

A detailed investigation of the ultimate limits for all of these techniques is still missing and, due to the speculative nature of the ideas covered in this paper, we do not explore this last area.

In the following we discuss briefly two novel (to the best of our knowledge) ideas for the tilt recovery. We are aware that these ideas lacks to a certain extent of a solid background. We propose them here in the hope that
this could contribute to the discovery of a technique (or to a combination of different techniques) really able to solve routinely the problem in the next generation of LGSs–based adaptive optics systems.

2. THE PERSPECTIVE TECHNIQUE

Let us assume that the LGS is generated by projection of the proper laser beam from the cage of the secondary mirror of a concentric two mirrors telescope (see Fig.1). Due to the finite thickness of the mesospheric Sodium layer where the resonant back-scattering occurs, one can observe the LGS at two well defined different heights. This can be easily obtained using pulsed lasers. It has been independently claimed that the technology for the realization of such laser already exists.

The two spots (Spot 1 and 2 in the figure) will be seen from the main telescope slightly separated of the angle $\epsilon$ (take into account that $\epsilon$ is probably much lower than the intrinsic size of the single spots; this means that it is unfeasible to determine $\epsilon$ from the elongation of the full spot produced, for example, by a CW laser). Said $h_{Na1}$ and $h_{Na2}$ the altitudes of the two spots and $h_T$ the average height of the turbulent layers producing the tilt, it is easy to recognize that, at least for small angles:

$$\varphi \approx \epsilon \frac{h_{Na1} + h_{Na2}}{2 h_{Na2} - h_{Na1}}$$

The angle $\epsilon$ can be estimated measuring the differential position of the two spots (the two spots will jitter coherently due to the wandering of the light beam in the ground to layer and back journey) because it is easy to recognize that $\epsilon$ is always much less than the isoplanatic patch of the main telescope.

As possible problems that could turn out to be serious drawback to the described approach one can enumerate the uncertainty in the height position of the two spots, the time–varying $h_T$ affecting the final result and the different distribution of the scattered light in the Sodium layer that could affect $\epsilon$ for reasons other than the perspective effect here described. Finally one should also point out that using a bistatic configuration the elongation effect, being larger than the LGS apparent size, could be used for tilt indetermination problem, at least along the axis orthogonal to the apparent LGS elongation.

3. THE ANNULAR–KNOWLEDGE BASED PREDICTION TECHNIQUE

This second technique is even much more speculative than the preceding one and it is based upon the predictability of a small portion of the wavefront, given the knowledge of the surrounding annular region to the small portion. Actually the prediction can be limited to the overall wavefront tilt only rather than on its detailed shape.

As it is sketched in Fig.2 using the tilt information as seen from the same small pupil area used for the LGS firing one apparently see the LGS as fixed in such small pupil area. The recovered wavefront will evolve from $t_0$ to the following instants retaining the central pupil area flat, at least in the averaged sense and likely as it is pointed out by the solid lines in the left column of Fig.2.

Let us suppose that one is able to predict the tilt evolution in the central portion of the pupil. This can be done using the knowledge of the wavefront in the annular region of the pupil. It is worthwhile to point out that such a task is apparently much more simple than the full predictive approach attempted by several authors.
Figure 1: The perspective approach for the absolute LGS tilt recovery.
Figure 2: The predictive approach for the absolute tilt LGS recovery.
Under this condition one can imagine to recover in a differential manner the evolution of the true tilt. However the unavoidable error will accumulates along with time. However a nearby NGS can be used to re-lock the tilt loop, provided that the described technique is able to give enough accuracy for a time significantly larger than the tilt evolution characteristic time. This last consideration is the same adopted in the laser propagation delay technique; the interested reader should refer to this last work for further details on this point. Here it is only pointed out that, at least in principle, full sky coverage can be obtained with this combination of LGS and faint NGS observed on a longer than the usual time scale.

4. CONCLUSION

Two further techniques for absolute tilt recovery of an LGS has been outlined. Further work is required in order to establish the effectiveness and the limits of this and other techniques. In spite of the speculative nature we hope that our work could be useful to point out that several techniques can be used in order to figure out the precious tilt information. Being that the first-order effect (the apparent tilt of the LGS) cannot be used as a source of information for the absolute tilt knowledge, one must explore the area of the second order effects. We believe that this area has not still be explored with enough deep and that one should expect in the near future that further techniques, or the modification of the proposed ones, will be discovered leading in a near future to full sky—coverage, full—correction, adaptive optics system for the very large ground based telescopes planned for the beginning of the next millennium.

5. REFERENCES