# Computing the Influence Functions of an Adaptive Optics Large Deformable Mirror: The Numerical Method and the Experimental Data

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## Abstract

Many large telescopes are equipped with Adaptive Optics (AO) units, that allow to obtain diffraction limited astronomical images by compensating the effects of the atmospheric turbulence. The design of the control system of the Deformable Mirror (DM) - the key component of the AO unit - includes a feed-forward block, the so called stiffness matrix, aimed for increasing the efficiency of the control loop. Such stiffness matrix is determined by computing the force to be applied by an actuator to displace the mirror shell - the influence function - when all the other actuators are kept at their nominal position (0 displacement). This paper discusses the computation method adopted to calculate the influence functions of the concave DM of the Large Binocular Telescope (LBT) and of the convex DM of the Very Large Telescope (VLT). The capabilities of the COMSOL Multiphysics®/MATLAB® interactions are greatly used in order to implement the static computations.

Based on the optical parameters of the thin mirrors and on the geometrical layouts of the actuators, a first script builds the geometry, applies the physics required to solve the problem and constructs the mesh. The complexity of the actuator geometry (the LBT and the VLT DM's have 672 and 1170 actuators, respectively) and the accuracy required by the optics when modelling the geometry of the actual glass shell makes the COMSOL Multiphysics® GUI ineffective.

Instead of the explicit definition of an auxiliary coordinate system for each actuator - in principle the natural manner to define the constraints -, with a consequent awkward increasing of the COMSOL Multiphysics® nodes, because of the large number of actuators, the application of the constraints is implemented via a user-defined interpolation function, whose input is defined by a proper MATLAB® algorithm.

Finally, the computational loop runs are performed via a solving function, which performs also the post-processing of the results.

The LBT DM underwent several tests in the optical test tower. In particular, the displacement of

the thin shell are known via interferometric analyses, and the force applied by the actuators are acquired from electrical measures. Comparing these experimental data with the COMSOL Multiphysics® results shows a good agreement. A very similar matching is obtained for the VLT glass shell. As some of the VLT DM influence functions cannot be measured, because of the shadow of the spider mounted in the test tower to support the convex mirror, we can conclude that the simulations give correct results. The COMSOL Multiphysics®/MATLAB® computational method discussed in this paper is suitable for accurately predicting the delicate optomechanics of the AO DM's.

## Reference


[1] R. Biasi et al, VLT deformable secondary mirror: integration and electromechanical tests results, Proc. SPIE, 8447 (2012)
[2] A. Riccrdi et al.,The adaptive secondary mirror for the Large Binocular Telescope: optical acceptance test and preliminary on-sky commissioning results, Proc. SPIE, 7736 (2010)


## Figures used in the abstract

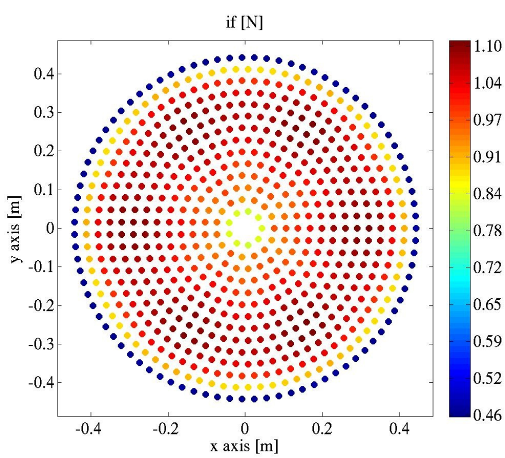


**Figure 1**: The LBT DM influence functions

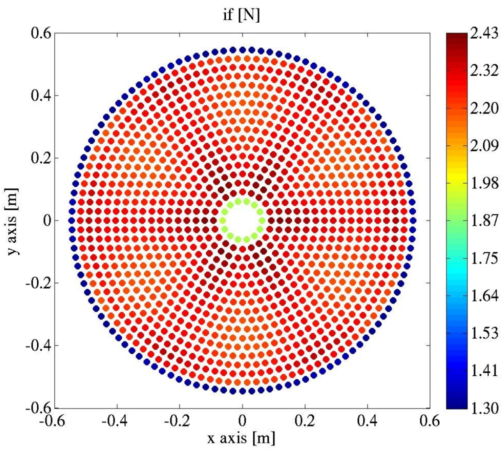


**Figure 2**: The VLT DM influence functions

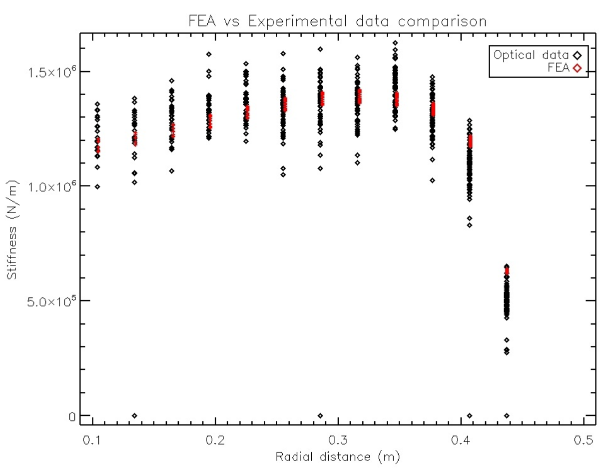


**Figure 3**: The LBT DM influence functions: comparison of numerical results with experimental data