Design Analysis of Future Deformable Mirrors

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Abstract

Adaptive optics systems are essential in ground-based astronomical observatories and in laser communication through free space. In particular, turbulence in the atmosphere causes wavefront aberrations that set a limit on the achievable image quality. Adaptive optics systems allow to actively compensate the atmospheric disturbances which leads to a significantly enhanced image quality. A crucial element in adaptive optics systems is the deformable mirror, see Figure 1, which contains many actuators to explicitly control the shape of the mirror.

Stringent demands regarding performance in adaptive optics systems require a change in the design of deformable mirrors, in particular an increased number of actuators, and an increased mirror diameter which results in an increased mass of the support structure. As a consequence, the flexible dynamic behavior of the support structure predominantly occurs at lower frequencies which limits the achievable correction bandwidth. For this reason, the flexible dynamic behavior should be addressed explicitly in next-generation deformable mirror design and motion control.

The aim of this paper is to develop an approach for the analysis and identification of mechanical models of deformable mirrors from experimental data. To facilitate accurate and fast experimentation, a unified approach is developed using the local rational method (LRM) [1] and Maxwell's reciprocal theorem [2, Chapter 9]. The unified approach allows for the identification of dynamic modal models with which the flexible dynamic behavior of both the reflective surface and the support structure can be identified. Specifically, dynamic modal models of the form

$$G_{\text{mod}} = \sum_{i=1}^{N_m} \Phi_{s,i} \frac{1}{s^2 + 2\beta_i \omega_i s + \omega_i^2} \Phi_{a,i}^{\top}$$

are estimated. These modal models allow for the visualization of mode shapes of both the mirror surface and the support structure which allows for new insights in the design and control of deformable mirrors.

The proposed approach is applied in a case study. The case study encompasses an experimental deformable mirror with 57 actuators which has been developed by TNO. The case study confirms that the local rational method allows for accurate and fast frequency response measurements. Specifically, the 18x57 system is identified with approximately 1 minute of experimentation time. Also, a mechanical model is identified and analyzed, see Figure 3. The analysis of the mode shapes reveals unexpected flexible dynamics of the support structure which confirms the effectiveness of the proposed approach, see Figure 2. The insights from the analysis will be used to improve the design of the deformable mirror.

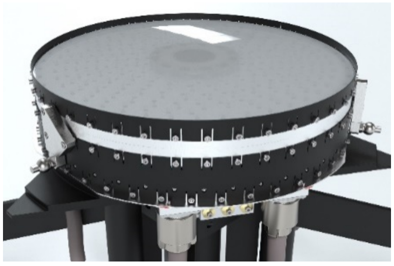

Figure 1: Deformable mirror developed by TNO. Image courtesy of TNO

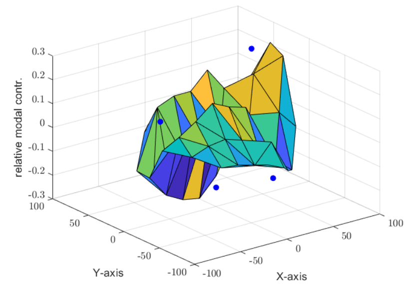

Figure 2: Mode shape of the support structure by employing Maxwell's reciprocal theorem.

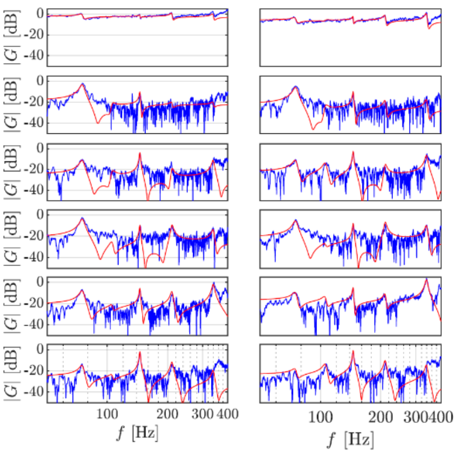

Figure 3: 6x2 Subset of the frequency response function (blue) and mechanical model (red).

References:

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