Actuation time optimization in the Advanced Virgo mirror thermo-elastic correction

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Abstract

Heating elements surrounding the core optics of Gravitational Wave interferometers are used to correct the radius of curvature of the high reflectivity surface that can deviate from their nominal value because of manufacturing defects and the non-zero absorption of the laser power in the substrate and coatings. These actuators (usually referred to as Ring Heaters, RH) require about 10 hours to reach the steady state; this long transient makes a significant impact on the commissioning time of the interferometer. In this work a new strategy aiming at the reduction of the actuation time of the ring heaters is presented together with the experimental results of the tests performed on the TeTiS facility in the Virgo laboratory of Roma Tor Vergata. It is found that by applying a time varying voltage on the ring heater, the steady state can be reached in less than an hour.

The output function

A challenging goal was chosen for the mirror response, that is the following output of the system:

\[ r_{\text{goal}} = 4 \times 10^{-8} \times \text{cos}(2 \pi t / 10) \times 10^{-5} \text{ cm} \]  

where \( t \) is the time.

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The input function

• Knowing \( t_f \) and \( r_{\text{goal}} \), the input function \( P(t) \) was computed (shown in fig. 3).

• The computation was done sampling at \( t_f \) in order to obtain the goal response in fig. 3.

The transfer function

The transfer function of the mirror is obtained by fitting the simulated curvature response to 1 W step input applied to the RH (fig. 2). A good fit can be found as a sum of sinusoids and exponentials:

\[ F(t) = a_1 \sin (c_1 t + b_1) + a_2 e^{b_2 t} + a_3 e^{b_3 t} + c e^{0 t} \]  

The experimental setup

• The thermal lensing effect was measured on-axis with double passage and using a Hartmann wavefront sensor that has the same sensitivity as the one used in Virgo.

• The RH power supply is remotely controlled (\( \Delta t = 4.875 \) s).

Experimental results

The thermal behaviour of the glass rings by applying \( P(t) \) is in figure 7. The curvature response shown in figure 6 agrees with the model, and the 95% of the steady state is reached in about \( \sim 15 \) min.

Conclusions

• The obtained power curves \( P_{1W} \) and \( P_{2W} \) bring the system to the steady state in less than 30 min.

• The curvatures measured at \( P_{1W} \) and \( P_{2W} \) are in a very good agreement with the analytical model, allowing a fair reduction of the settling time of the RH.

• A deeper investigation is needed to check the behaviour at higher power where non-linear effects related to the thermal radiation are likely to become relevant.

References


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