Report: adaptive optics closed loop system with photocontrolled deformable mirror

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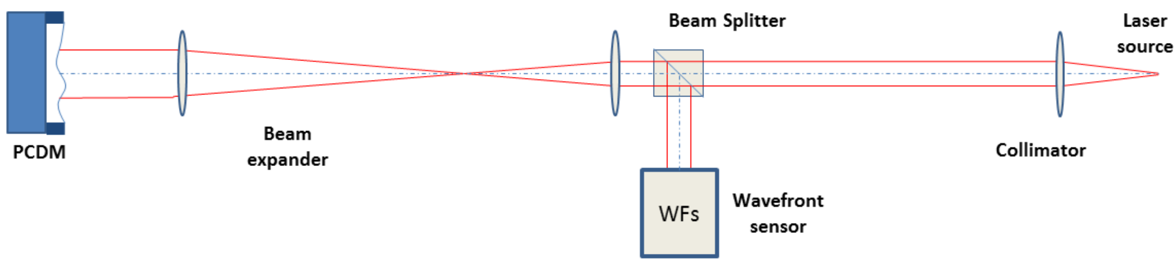
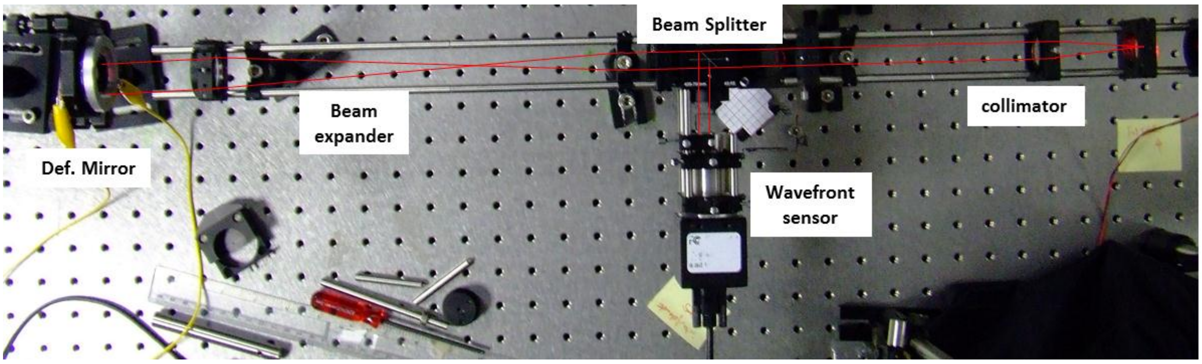
The photocontrolled deformable (PCDM) mirror was developed at the CNR-IFN LUXOR laboratory in Padova (U. Bortolozzo, S. Bonora, J. P. Huignard, and S. Residori, Continuous photocontrolled deformable membrane mirror Appl. Phys. Lett. 96, 251108 (2010)). The PCDM has the property of being controlled by the light intensity distribution which is projected on the back side of it where a photoconductor is placed. Therefore, with respect to other deformable mirrors, the PCDM does not have actuators, and high voltages amplifiers. The main advantages are: compactness, reduction of hardware complexity, high resolution. Because of this features the PCDM appears to be promising for the realization of big size deformable mirrors with many actuators for extreme astronomy. State of the art DMs have been realized by PZT with thousands of actuators but their cost and realization difficulties make them not appealing.

At present the PCDM has been designed, prototyped and characterized. With the collaboration with the National University of Ireland-Galway we used it for the first time in closed loop operation, which is the first development step for its use in applications such as astronomy and medical devices.

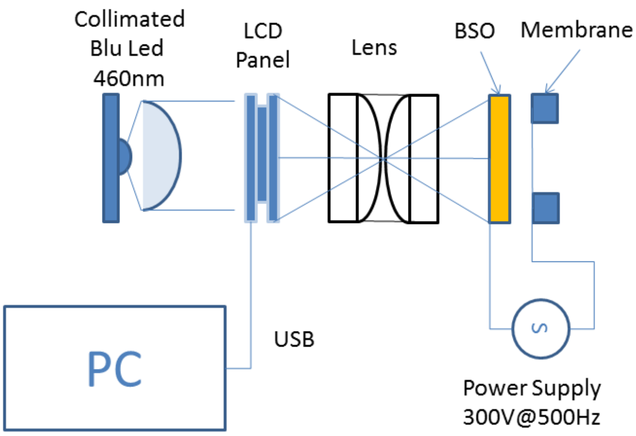
The experimental setup is depicted below:

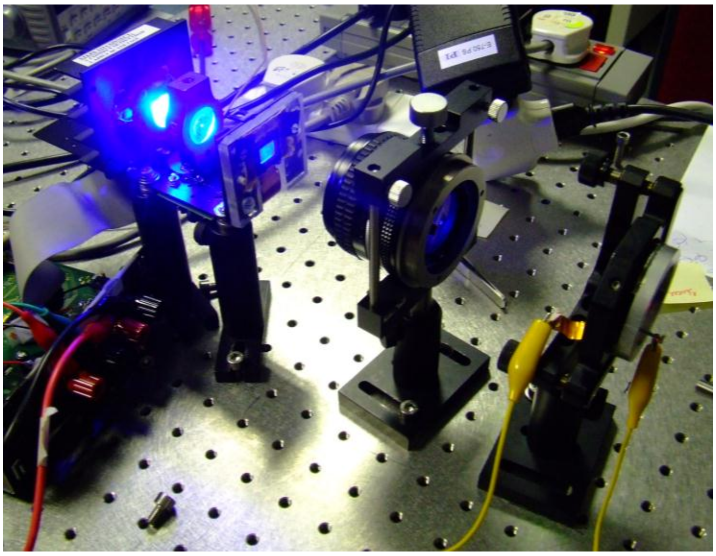


A photo of the apparatus mounted in Galway is in the next picture. The system is composed by a laser point source which is collimated and then expanded to match the active area of the PCDM which is of 10mm. In the second arm the beam reflected by the PCDM enters the a high resolution Shack-Hartmann wavefront sensor (f=6mm, pitch 200um) which has an optical aperture of 5mm.

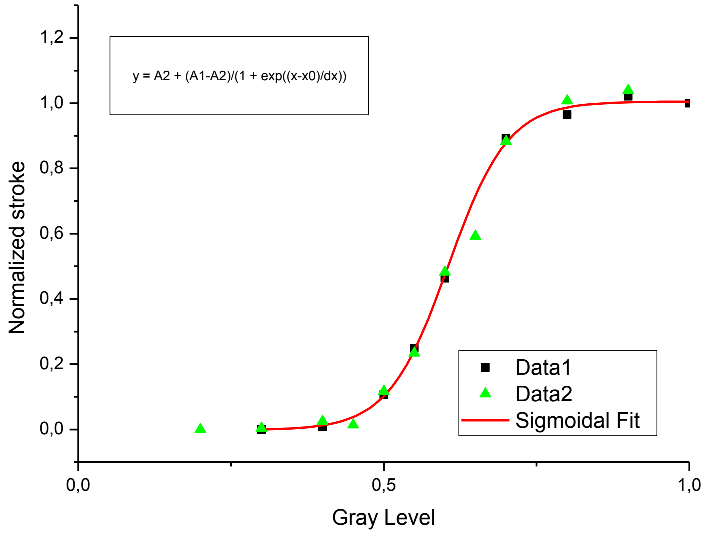


The PCDM is driven by a Liquid Crystal Display (LCD) 800x 600pixles which is illuminated with a high power blue LED. The LCD is imaged on the back of the PCD by the use of lens as illustrated in the figure and in the photo below.

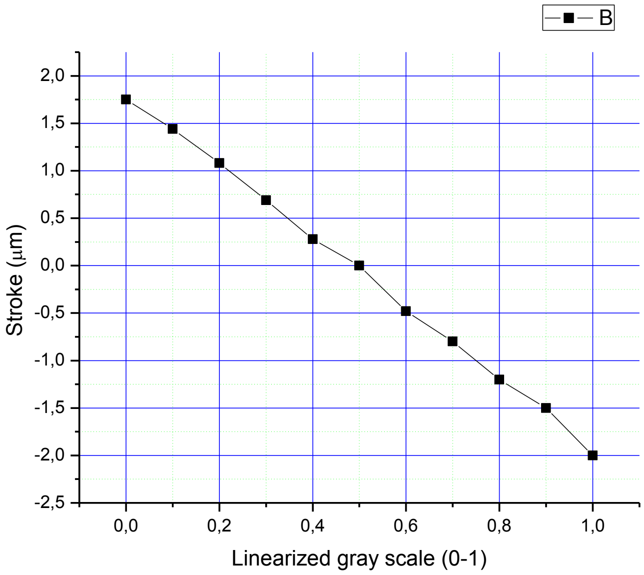




The LCD has been linearized both by the characterization of the wavefront acquired by the wavefront sensor and by a blue LED light intensity measurement. The figure below shows the sigmoidal modulation of the stroke of the deformable mirror in function of the blue gray level on the LCD. The function has been inverted to have a linear modulation necessary for the closed loop system.



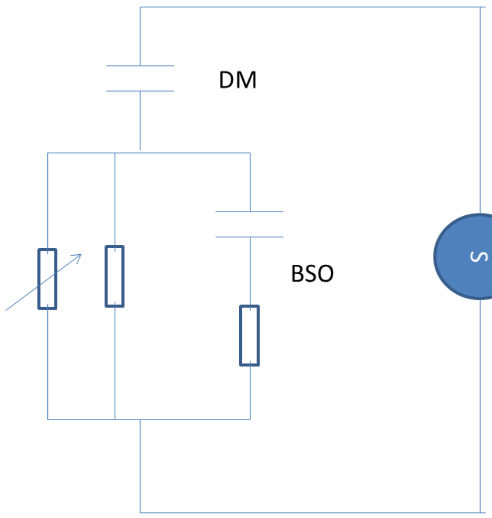
The measured DM stroke in function of the linearized gray level is reported in the graph below.



Exploiting the linearization we have been able to achieve the closed loop working.

Mathematical model:

The PCDM can be modeled with its electrical equivalent which is shown below:



The membrane forms a capacitor C_{DM} while the Bismuth Silicon Oxide (BSO) crystal is modeled as a parallel between the BSO dark resistor R_{dark}, the photoconductor resistor R_{PH} and the series between a capacitor C_{BSO} and a resistor R_{BSO}.

The electrical elements have the following values:

$$C_{DM} = \frac{\varepsilon_0 A}{t_{DM}} = 50pF$$

$$C_{BSO} = \frac{\varepsilon_0 \varepsilon_{BSO} A}{t_{BSO}} = 56pF$$

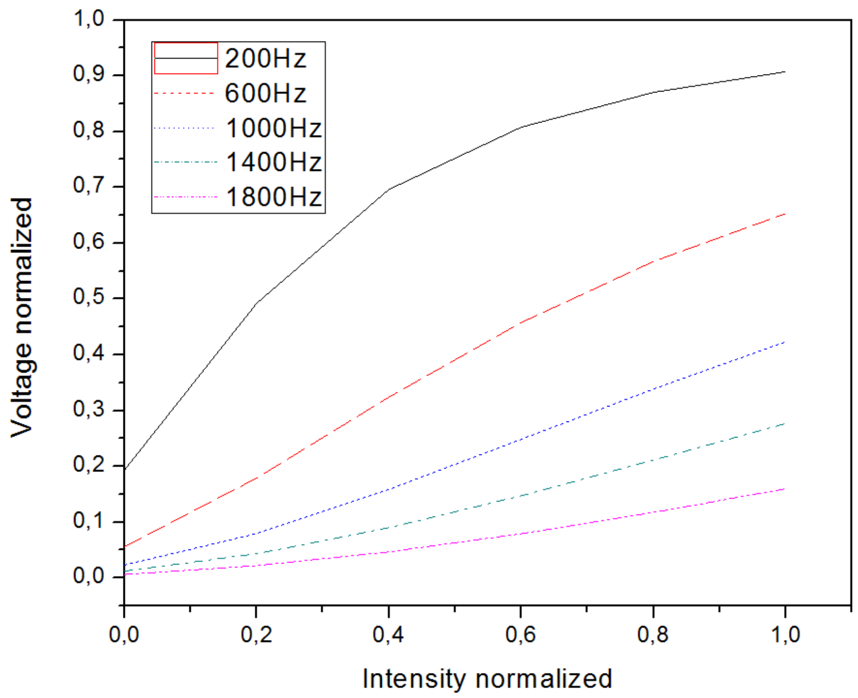
$$R_{dark} = \frac{t_{BSO}}{\sigma_{BSO} A}$$

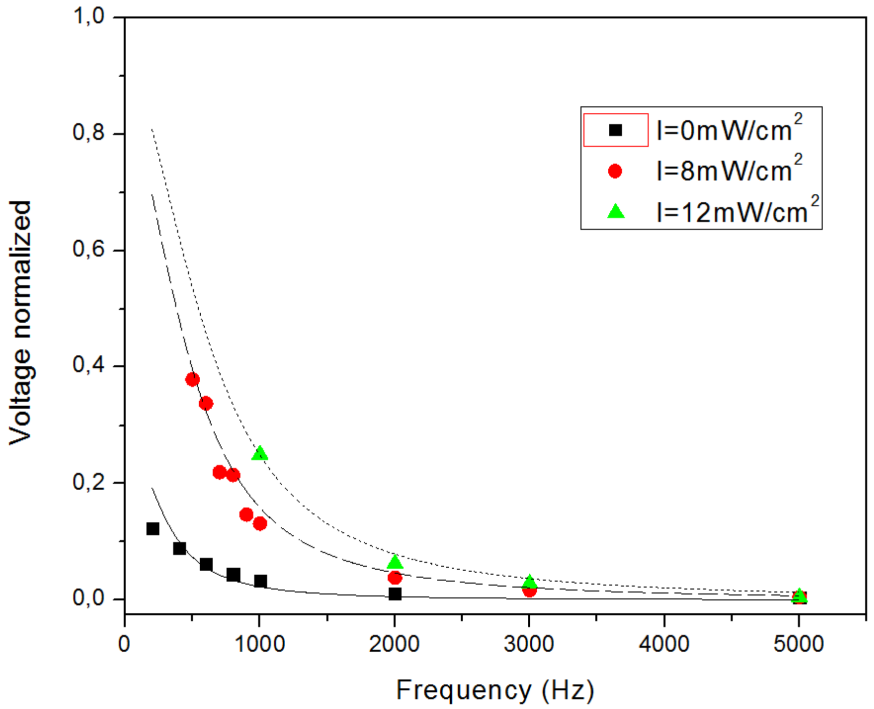
The resistor value R_{ph} changes linearly in function of the intensity according to:

$$R_{PH} = \alpha I$$

The value of R_{BSO} has been estimated from the data to be: R_{BSO}=20MΩ.

From the model we obtained the results below which show the normalized stroke on the DM in function of the blue intensity and in function of the frequency of the power supply voltage applied to the PCDM. Both results are in excellent agreement with experimental data.





Conclusions

The PCDM has been characterized and the experimental results have been used to determine the equivalent electrical model of the PCDM.

Moreover we demonstrated for the first time the use of the PCDM in closed loop for the correction of time variable aberrations.

Both LUXOR Lab and NUIG are interested in continue this collaboration and a new experimental session has been planned in August 2011 supported with NUIG funds for the acquisition of more data about the closed loop.

The experimental results will be submitted for publication on Optics Letters.