

second possible solution to this problem of high amplitudes is to use the active surface at another position than at the first surface of the system. By using a static optical element on the object side which produces a large change of direction to rays, a small angular deviation on the active surface could be amplified to a larger angular deviation in the object space. This would then require smaller amplitudes for a given RoM. This solution also includes placing the active surface far from the stop near the image plane instead of near the front lens. The drawbacks of this method are increased aberrations and more complex calculations for the active surface shape.

Because of the non-linear relation between RoM and Z'' in Eq. (6) and 7, another limit of the deformable surface is on the achievable precision of the desired shape. A given error on the surface curvature produces a non-linear error on RoM. From Eq. (6), given a relative error $\Delta(L_0 Z'')$ on the product of Z'' and L_0 , the relative error ΔRoM is given by Eq. (14). With a numerical example, a relative error of 1% ($\Delta(L_0 Z'') = 0.01$) will produce relative RoM errors of respectively 0.10%, 1.01% and 4.17% with RoM of 1.1, 2 and 5, meaning that the larger the RoM is, the more impact on the desired magnification is caused by a given relative error on the surface curvature or the distance L_0 . It was not possible to measure it in our experiment because of the limited amplitude that can be measured by the Shack-Hartmann.

$$\Delta RoM = \frac{1}{1 + (1 - RoM) \Delta(L_0 Z'')} - 1 \quad (14)$$

As for the limit on the entrance pupil diameter, which controls the beam diameter or the F/# of the imager, it is restrictive too. A closer look at Eq. (13) shows that larger values of D and/or lower values of H and f decrease the requirement on the minimum F/#, meaning that large FFOV lenses could be less limited by aberrations produced by the deformable surface. This is a consequence of the tendency of wide-angle lenses to have very small beam diameters compared to the front lens diameters because of the short focal length. Another solution is working with higher wavelengths so that the $\lambda/4$ criterion is less restrictive. However, when working with high F/# and increasing the wavelength as in the infrared, it must be remembered that the diffraction limited spot size scales linearly with λ and the F/# and that at high F/# as in this paper, diffraction already has a high impact on PSF and usable pixel size.

5. Conclusion

The locally magnifying imager presented here opens a new possibility in optical design, the use of real-time distortion to vary as needed the magnification of an image. This paper first presented the concept behind it and then followed with a mathematical description of the imager. This allowed obtaining Eq. (6), describing the achieved magnification change (RoM) in terms of surface amplitude and distance to entrance pupil. From this, it was found that the two major limits of this imager are the required amplitude for the active surface and the required F/# to keep additional aberrations created by the active surface under $\lambda/4$. With that in mind, an experimental prototype was assembled and results were presented for two cases, one with a constant magnification and one with magnification varying with field. In both cases, the results presented agreed with the theory.

Future work includes a deeper analysis of cases when the active surface is not the first of the system, better ways to counter the aberration problem and a closer look at some applications in distortion correction [17] and microscopy.

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