Optical Field/Pupil Rotator With A Novel Compact K-Mirror For MagAO-X

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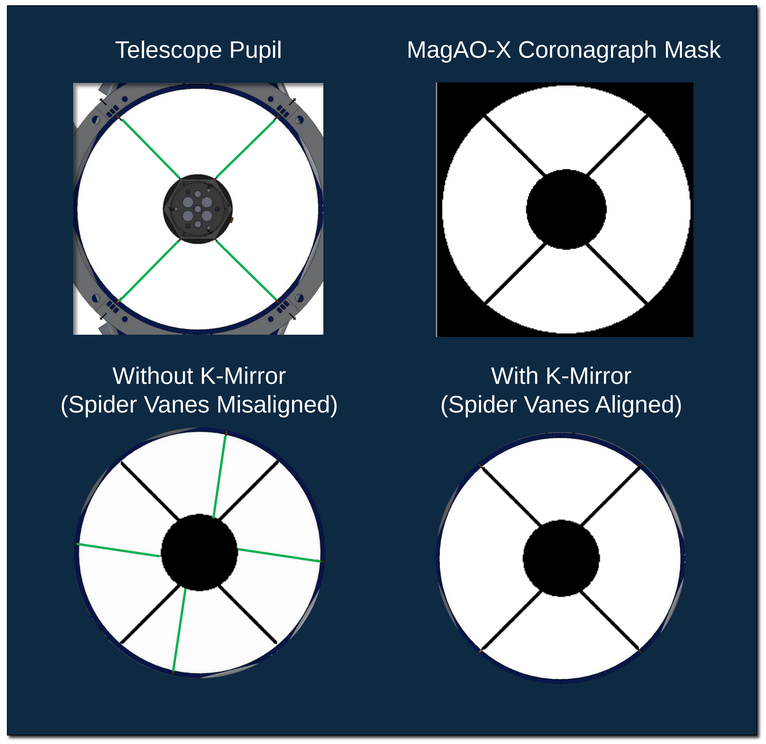
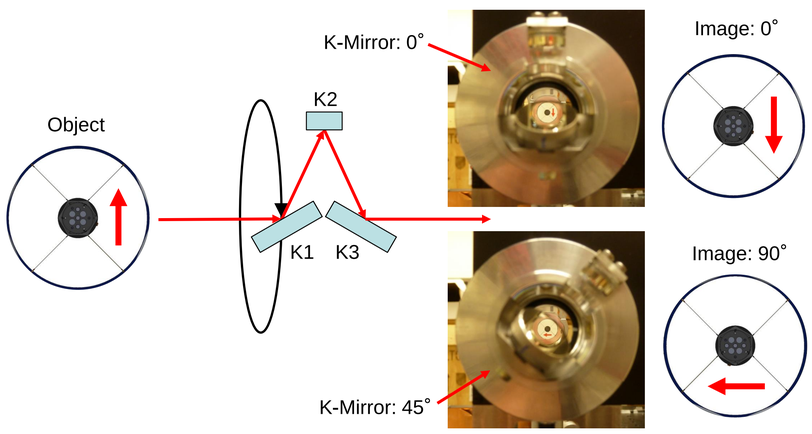
INTRODUCTION

Magellan Extreme Adaptive Optics (MagAO-X) is a visible-wavelength adaptive optics instrument optimized for visible light coronagraphy and exoplanet imaging with the 6.5-m Magellan Clay Telescope. A crucial component to MagAO-X is the **K-Mirror**, a 3-mirror system designed to de-rotate the optical image as the telescope tracks the sky.

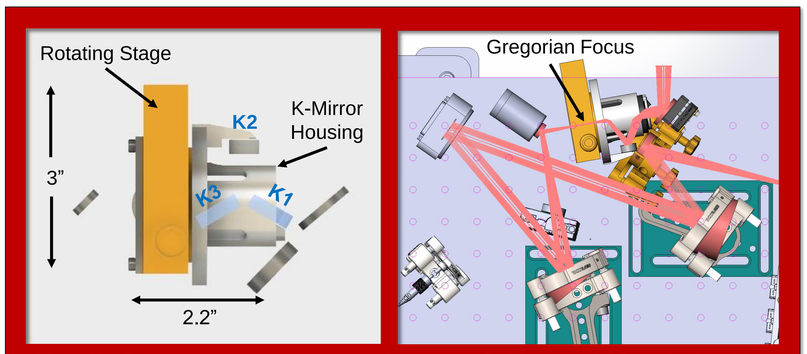


The Magellan Clay optical design produces a pupil that is asymmetric (top-left) and requires a vector aperture phase plate (vAPP; Otten et al. 2017) coronagraphic mask (top-right; Males et al. 2018). As the telescope rotates, the mask is misaligned with the pupil's spider arms (bottom-left). **A K-Mirror is therefore needed to de-rotate the pupil as the telescope tracks the sky and keep the vAPP mask aligned (bottom-right)** with the pupil.

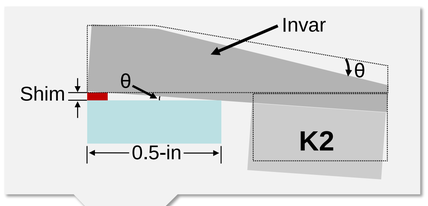


The K-Mirror creates an image inversion and rotates the image 2x per K-Mirror rotation

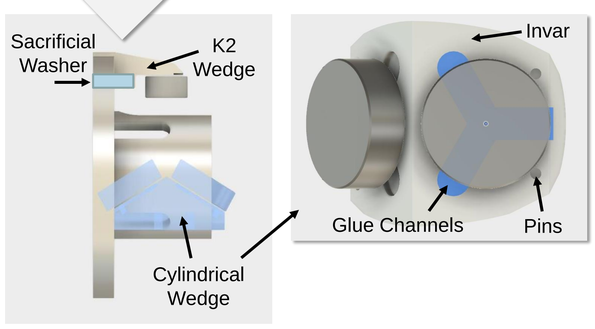
K-MIRROR DESIGN



The K-Mirror was designed in Autodesk® Fusion 360™ (left). The MagAO-X SolidWorks® model (right) shows the space in which the K-Mirror is inserted. **Due to the complexity of the MagAO-X design (Close et al. 2018), the K-Mirror must be placed here, requiring a compact design of 50mm in size**. The surrounding mirrors make it difficult to fit the K-Mirror inside this cavity and impossible to use the usual kinematic adjustable mounts, so **glue was the only solution to mounting these mirrors.**

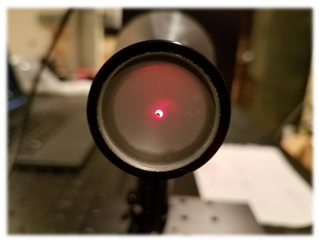


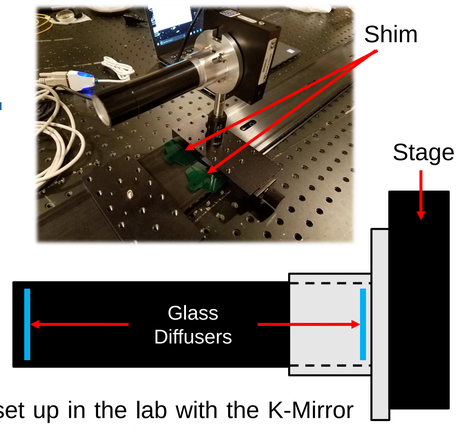
K2 has a “sacrificial washer” that allows us to change the height and tilt of K2



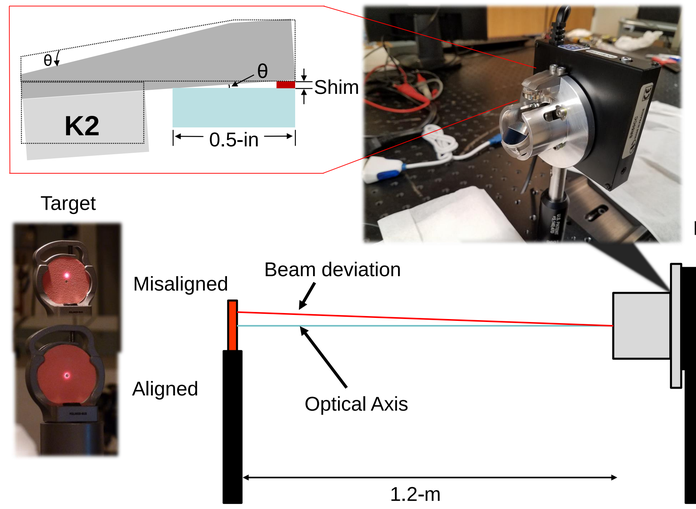
The Mirrors were glued onto “wedges” made of invar using a fast-drying epoxy, where glue channels allowed any excess glue to run free, and pins helped keep the mirrors in place.

ALIGNMENT





A collimated 1mm beam was set up in the lab with the K-Mirror housing mounted on an optical rail. To eliminate any pitch or yaw misalignment with the rotating stage, a 4-in long tube with 2 glass diffusers was inserted into the K-Mirror housing. By spinning the K-Mirror and using shim stock, the beam was aligned with the glass diffusers to align the stage.



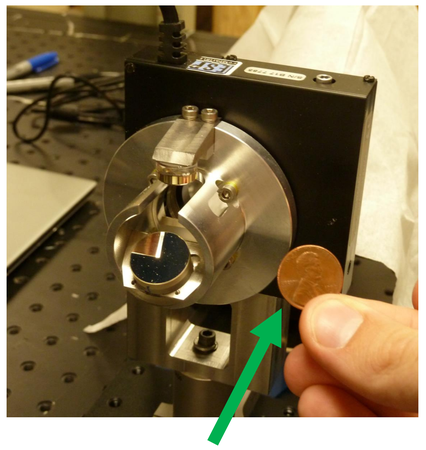
The K-Mirror was aligned by measuring the beam offset on a distant target and adjusting K2. The goal was to have the input and output light aligned as the K-Mirror makes one full rotation. The K1, K2, and K3 flats are λ/40 super-polished, silver coated and have very high surface quality over the illumined footprint even after gluing.

CONCLUSIONS

The K-Mirror is now aligned in the lab with < 1 arcminute of wobble over 360° of rotation (well within the internal 6 arcminute pupil alignment system of MagAO-X; Close et al. 2018). So the K-Mirror meets MagAO-X's specs. Future work for this project will include simulating a telescope with the K-Mirror and using two CCD's to image the pupil and the source. This way, we can measure the K-Mirror's performance more directly by observing how the image of the pupil and source rotate. Finally, the K-Mirror will be mounted onto the MagAO-X bench and aligned with the system.

THE SMALLEST K-MIRROR EVER BUILT!

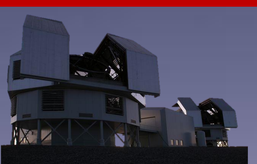
- Under 60mm (2.3”) in size
- No Actuators
- < 1 arcminute of wobble over 360° of rotation



PENNY FOR SCALE

REFERENCES

1. Otten, G. et al., “On-Sky Performance Analysis Of The Vector Apodizing Phase Plate Coronagraph On MagAO/Clio2,” Astrophysical Journal (2017)
2. Males, J. et al., Proc. SPIE 10703 (2018).
3. Close, L. et al., “The Optomechanical Design of MagAO-X”, Proc. SPIE 10703 (2018)



Acknowledgments

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PI: Jared Males

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Project Title: The First Census of Accreting Proto-Planets Inside the Gaps of Transitional Dust Disks
PI: Laird Close