Introduction to Off-Axis Parabola Alignment

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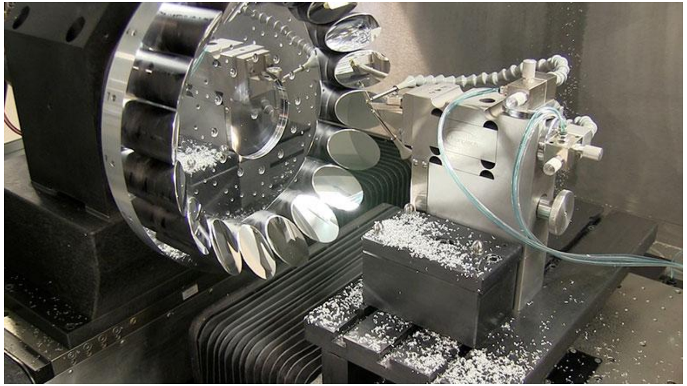
Off-Axis Parabolic Mirror (OAP)

- **OAPs** are used in optics in general, but also astronomy, optical microscopy, optical communications, biomedical imaging and, as in our case, **laser beam steering and focusing**.
- They require **precise machining**, and their **cost can vary from 100s to some 10000s €**, depending on size, surface quality and coating.
- **OAPs are essential devices** to focus ultrashort laser pulses up to relativistic (≳10^{17} W⁄cm2) intensities without nonlinear and dispersive effects induced by transmissive focusing optics.

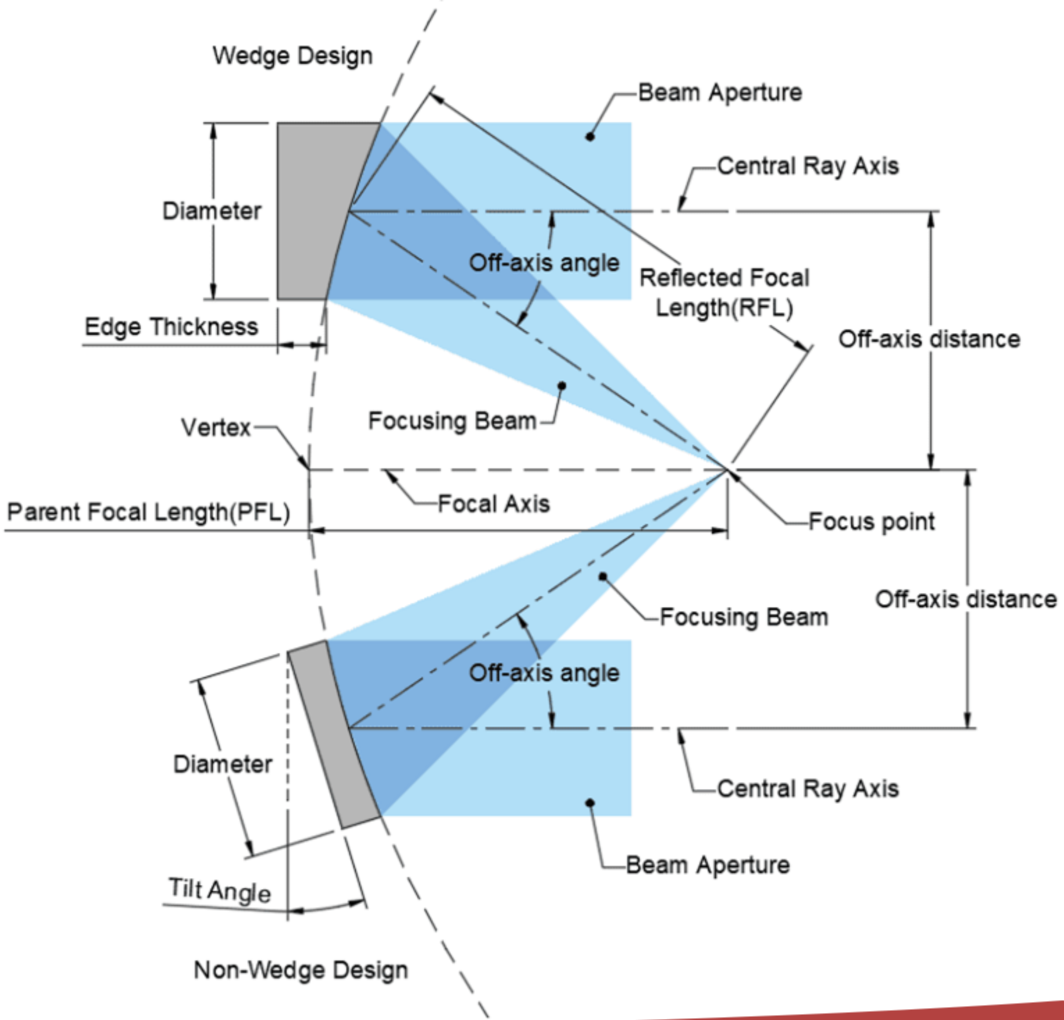


Off-Axis Parabolic Mirror

OAPs are **sections of a parent paraboloid**, used off-axis so that the input/output beam paths don't physically intersect the mirror's axis.

This is great for avoiding central obstructions (like in telescope secondary mirrors), but it also makes the system:

- Highly **non-symmetric**
- More **sensitive to input beam angle and position**
- Very **alignment-critical**



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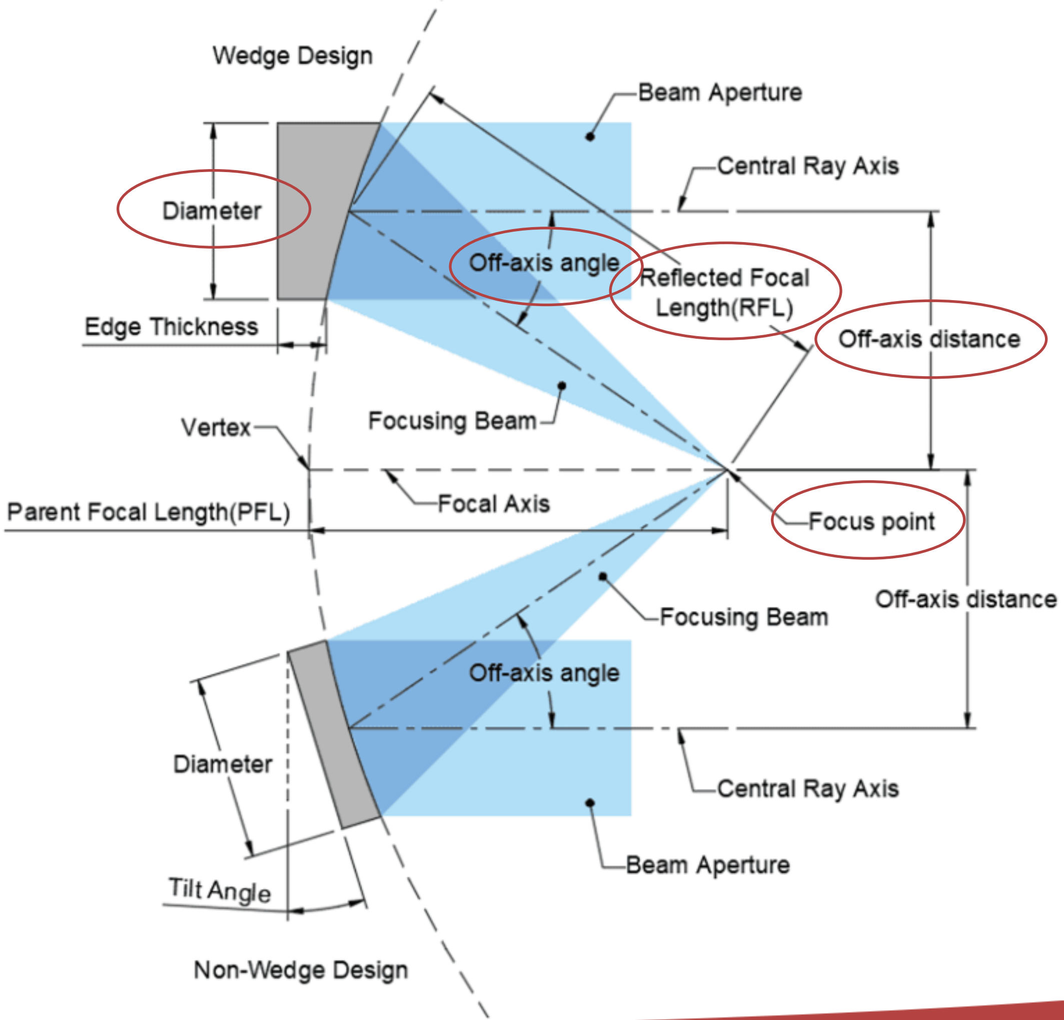

Aberrations in OAPs

Aberration	OAPs?	Description
Chromatic aberration	NO	**Dispersion in refractive elements**, not present in mirrors, for instance variation in focal length with wavelength
Spherical aberration	Not in ideal paraboloids	**Spherical shape instead of parabolic**, not present in ideal OAPs for common f-numbers in our field, peripheral rays focus on a different point than central rays
Coma	YES	**Variation in magnification over the clear aperture**, rays at different heights on the mirror don’t converge perfectly, leading to asymmetric blurring of the focus spot
Astigmatism	YES	Off-axis geometry introduces different curvatures in orthogonal planes, especially with large off-axis angles or wide beams; **rays in the vertical and horizontal planes focus at different distances**, focus appears elliptical or as a line rather than a point

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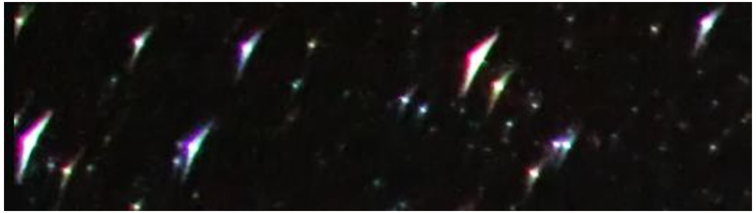

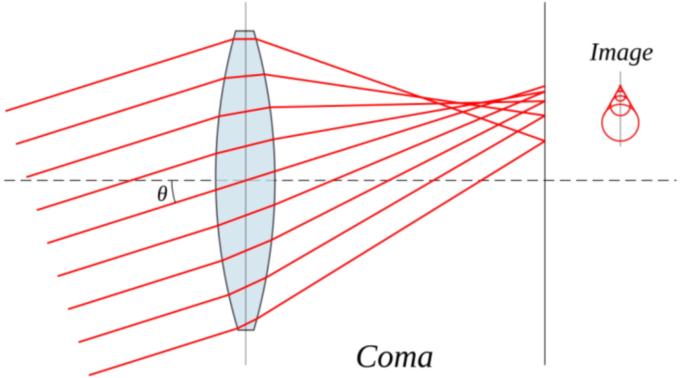

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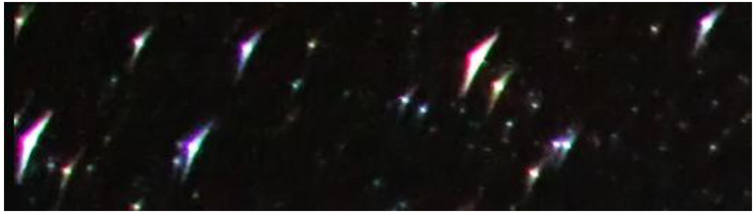

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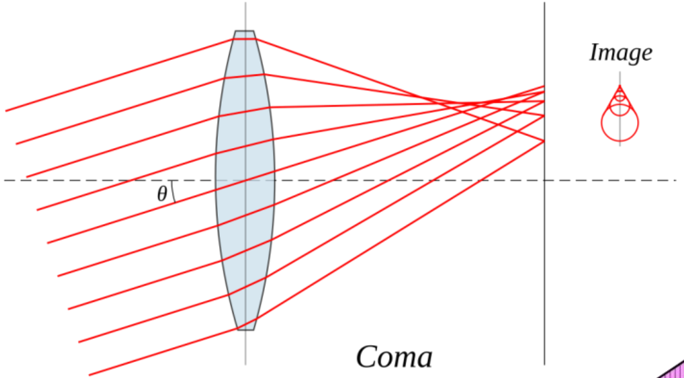

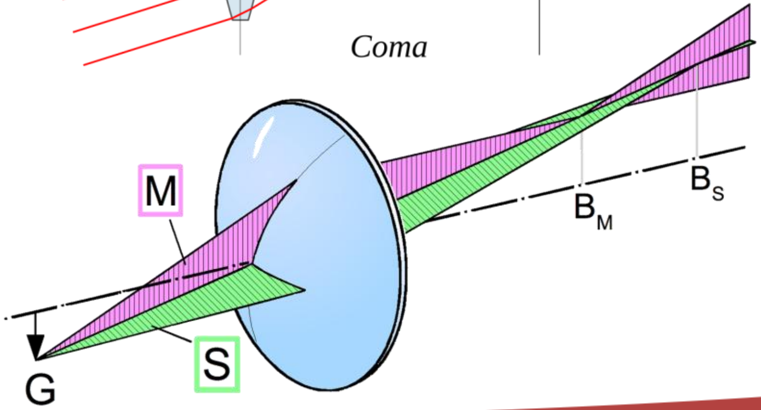

Theoretical background

6506 Vol. 55, No. 23 / August 10 2016 / *Applied Optics* Research Article

applied optics

Effects of small misalignments on the intensity and Strehl ratio for a laser beam focused by an off-axis parabola

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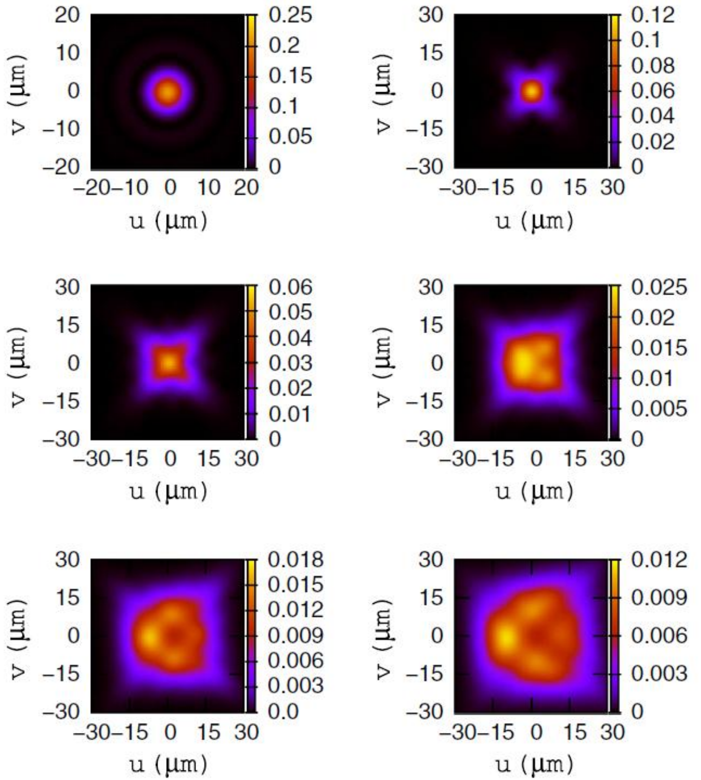
Corresponding author: luca.labate@ino.it

Theoretical framework for the **calculation of the intensity distribution** of a super-Gaussian laser beam focused by an OAP in the presence of **possible misalignments**, with attention on the effects induced on the maximum intensity and the energy encircled in the main focal spot.



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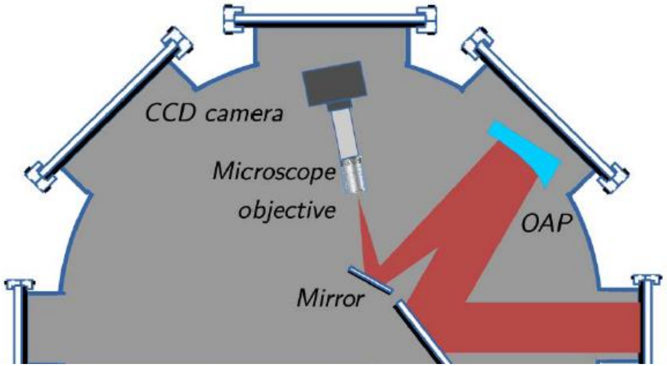

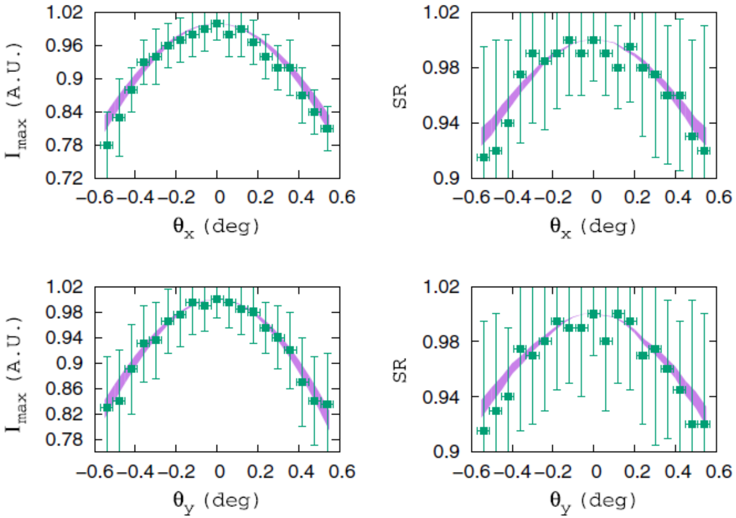

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Alignment procedure for off-axis-parabolic telescopes in the context of high-intensity laser beam transport

J. B. OHLAND,[1,2,*] Y. ZOBUS,[1,2] U. EISENBARTH,[1] B. ZIELBAUER,[1] D. REEMTS,[1] AND V. BAGNOUD[1,3]

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Null test of an off-axis parabolic mirror. I. Configuration with spherical reference wave and flat return surface

Jan Burke,[*,1] Kai Wang,[2] and Adam Bramble[2]

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[2]Centre for Lasers and Applications, Department of Physics, Macquarie University, NSW 2109, Australia
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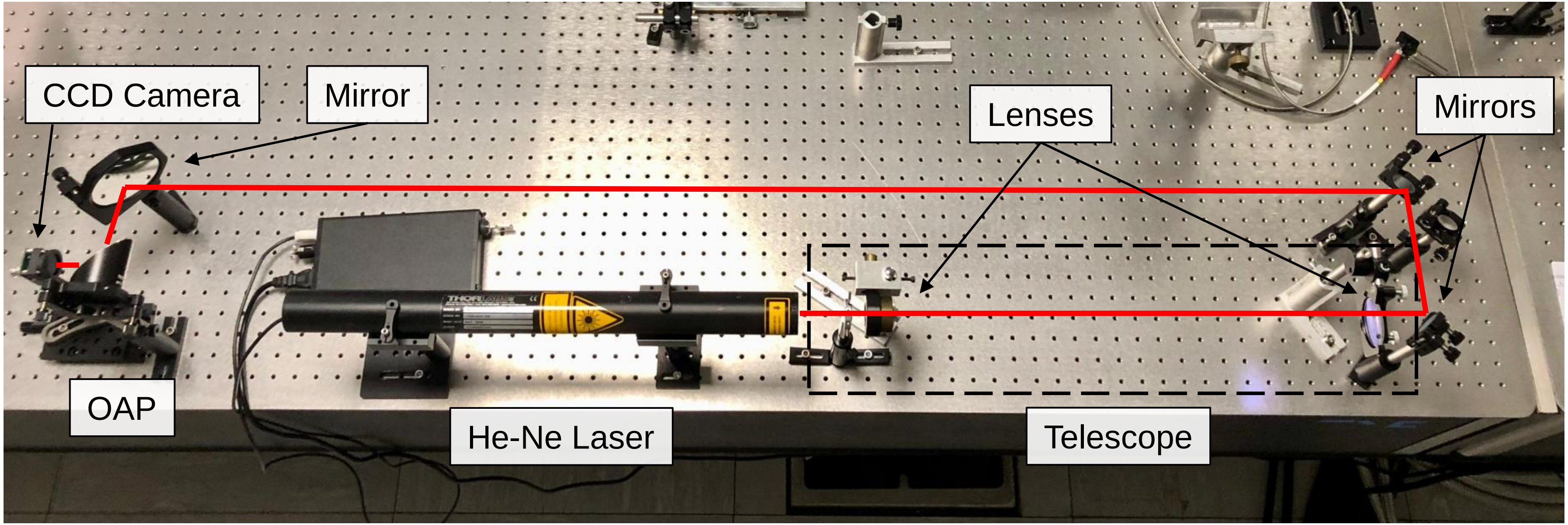
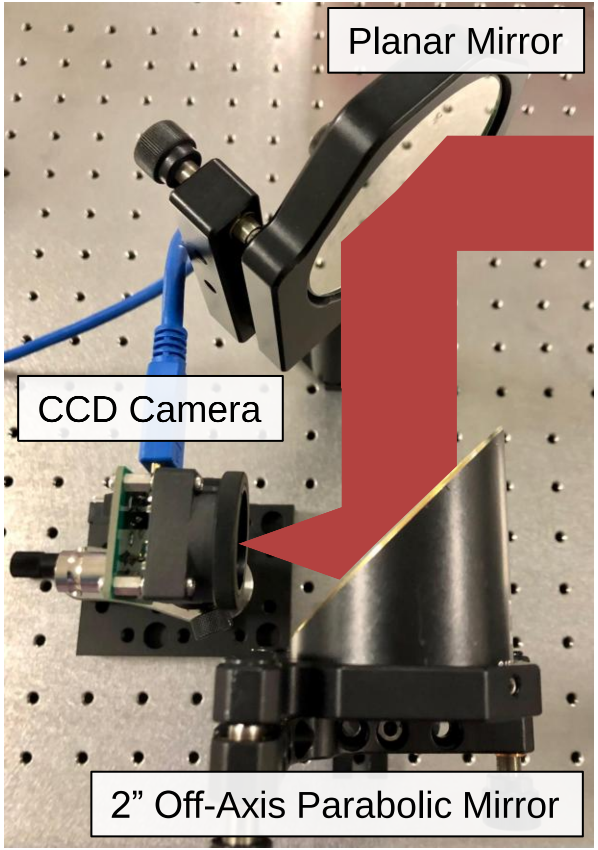
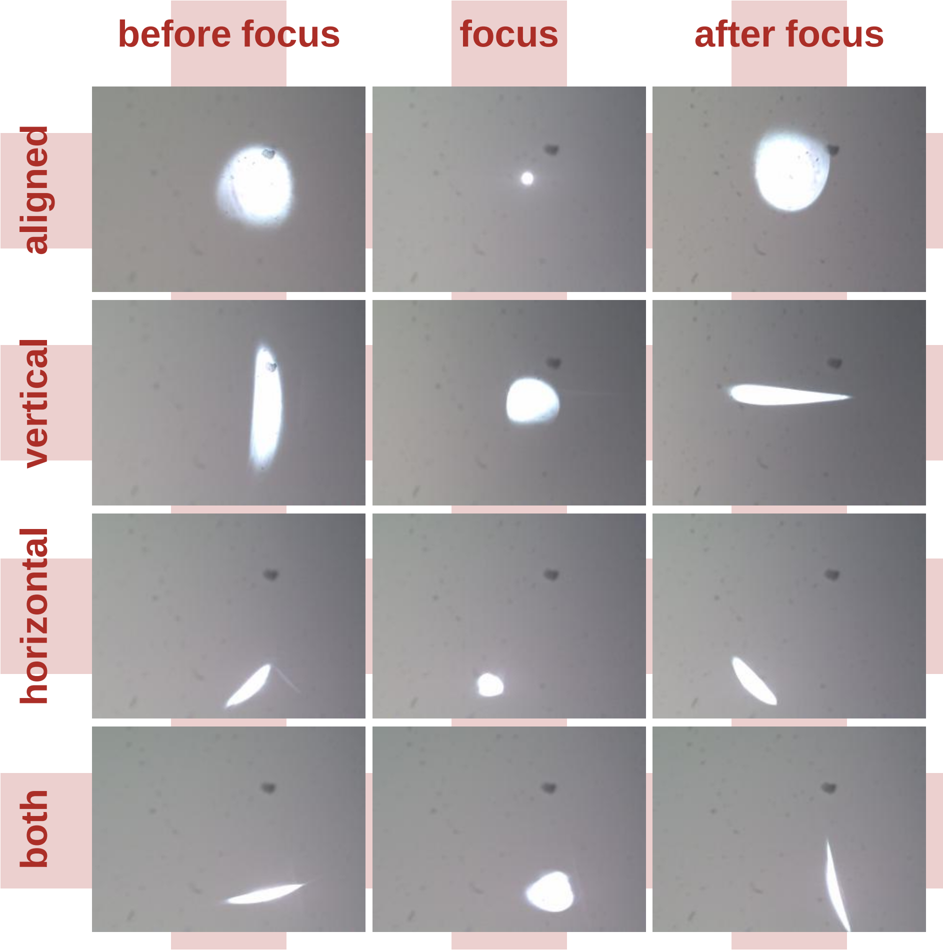
Hands on activity: the experimental setup

Telescope setting and lenses normalization → **General OAP alignment** → **OAP alignment with specific direction and focal point**




Planar Mirror
CCD Camera
2” Off-Axis Parabolic Mirror


before focus
focus
after focus
aligned
vertical
horizontal
both

Links and References

- https://www.thorlabs.com/newgrouppage9.cfm?objectgroup_id=9980
- https://www.youtube.com/watch?v=l8v8RyCi4HU&ab_channel=Thorlabs
- https://avantierinc.com/resources/knowledge-center/mastering-off-axis-parabolic-mirrors/
- Jan Burke, Kai Wang, and Adam Bramble, "Null test of an off-axis parabolic mirror. I. Configuration with spherical reference wave and flat return surface," Opt. Express 17, 3196-3210 (2009)
- J. B. Ohland, Y. Zobus, U. Eisenbarth, B. Zielbauer, D. Reemts, and V. Bagnoud, "Alignment procedure for off-axis-parabolic telescopes in the context of high-intensity laser beam transport," Opt. Express 29, 34378-34393 (2021)
- Luca Labate, Paolo Ferrara, Lorenzo Fulgentini, and Leonida A. Gizzi, "Effects of small misalignments on the intensity and Strehl ratio for a laser beam focused by an off-axis parabola," Appl. Opt. 55, 6506-6515 (2016)

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