EUROPEAN UNION

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Competitiveness Operational Programme (COP)

Extreme Light Infrastructure - Nuclear Physics (ELI-NP) – Phase II

OAP alignment training report

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Content

- Brief overview of the theory
- Setup description
- Alignment procedure

Theoretical background

Gaussian beams are focalized to a diffraction limited spot of radius w_0

$$w_0 \sim \frac{2}{\pi}\lambda f_{num},$$

$$f_{num} = \frac{f}{\Phi},$$

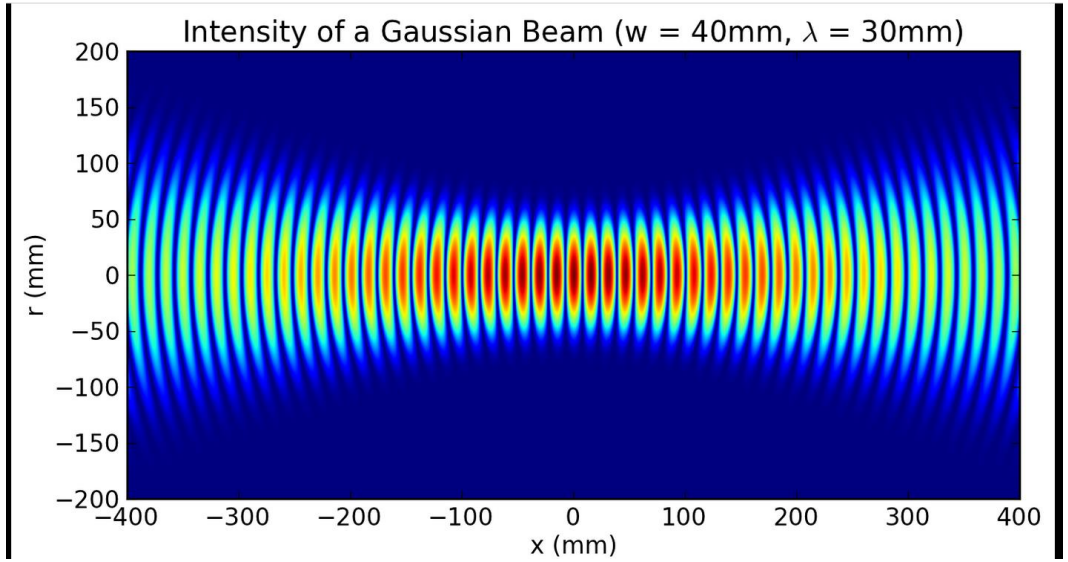


Fig 1. Intensity distribution and wave front curvature around the focus of a Gaussian beam.

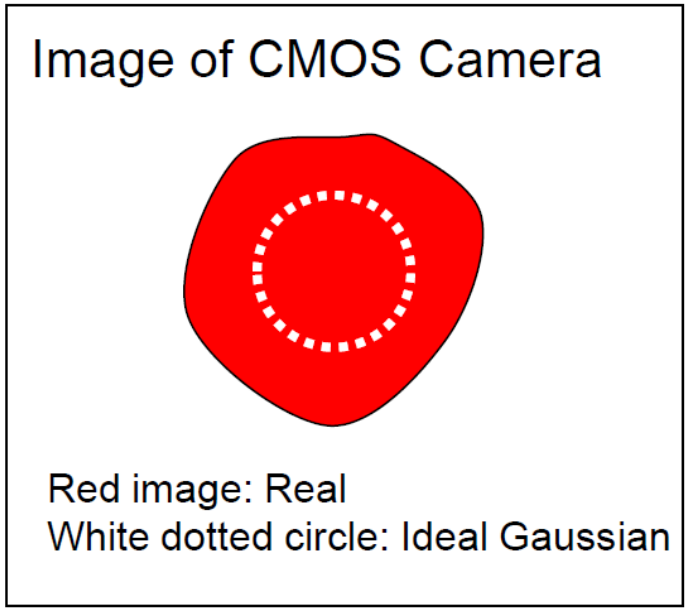


Fig 2. Comparison of an ideal and a real focal spot.

Experimental set-up

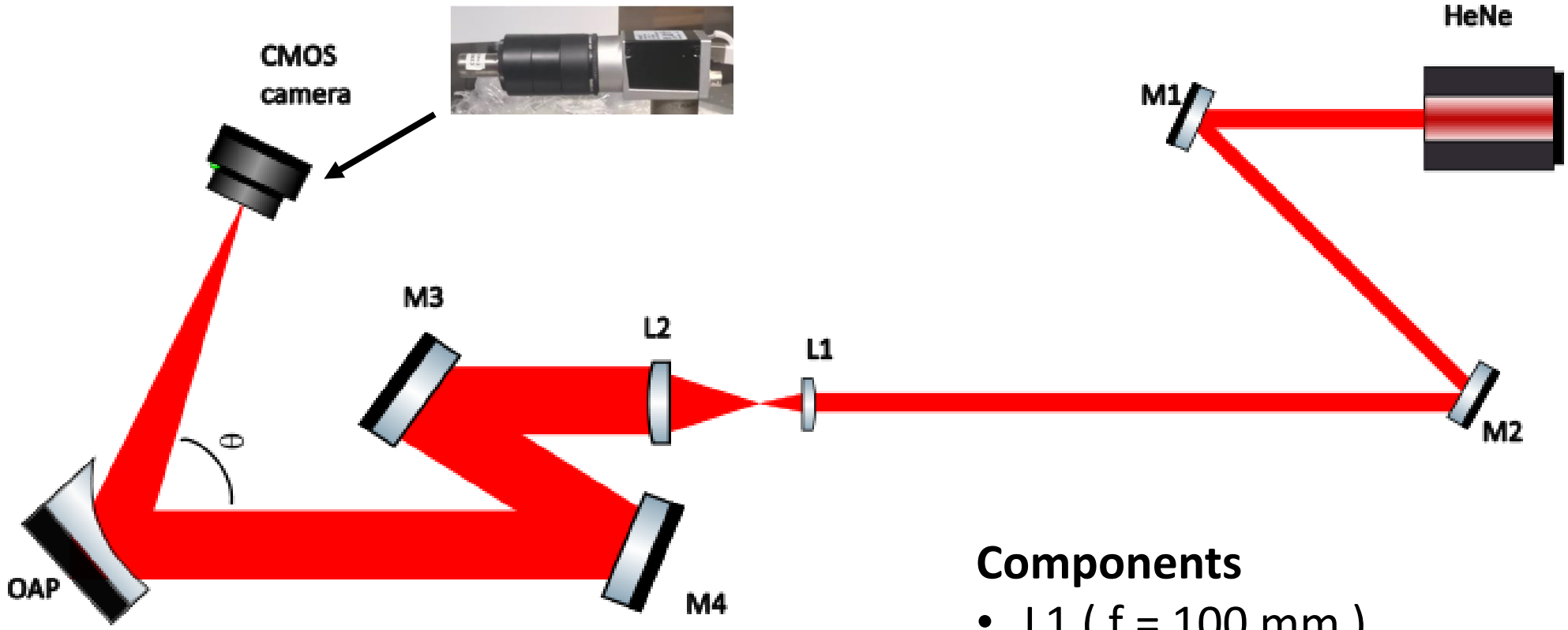


Fig. 3 Diagram of the experimental set-up. The HeNe beam is magnified by 10X and focalized by an OAP with EFL = 101.6 mm on the chip of a CMOS camera.

Components

- L1 (f = 100 mm)
- L2 (f= 150 m)
- OAP (EFL = 101.6 mm, θ = 60◦)
- CMOS camera + aspheric objective

Alignment procedure (1)

- Define the optical axis for the Keplerian telescope using M1 and M2
- Measure the beam size using the camera before the entrance of the telescope or at the exit of the source. The later case is treated here: FWHM ~ 0.66 mm. HeNe div ~ 1 mrad => Beam diam at telescope entrance ~ 2.66 mm
- Build the telescope and place the second lens on a translation stage. Check the collimation. After the telescope, the FWHM = 26.6 mm.
- F# = 3.82 => theoretical FWHM min = 1.81 um.

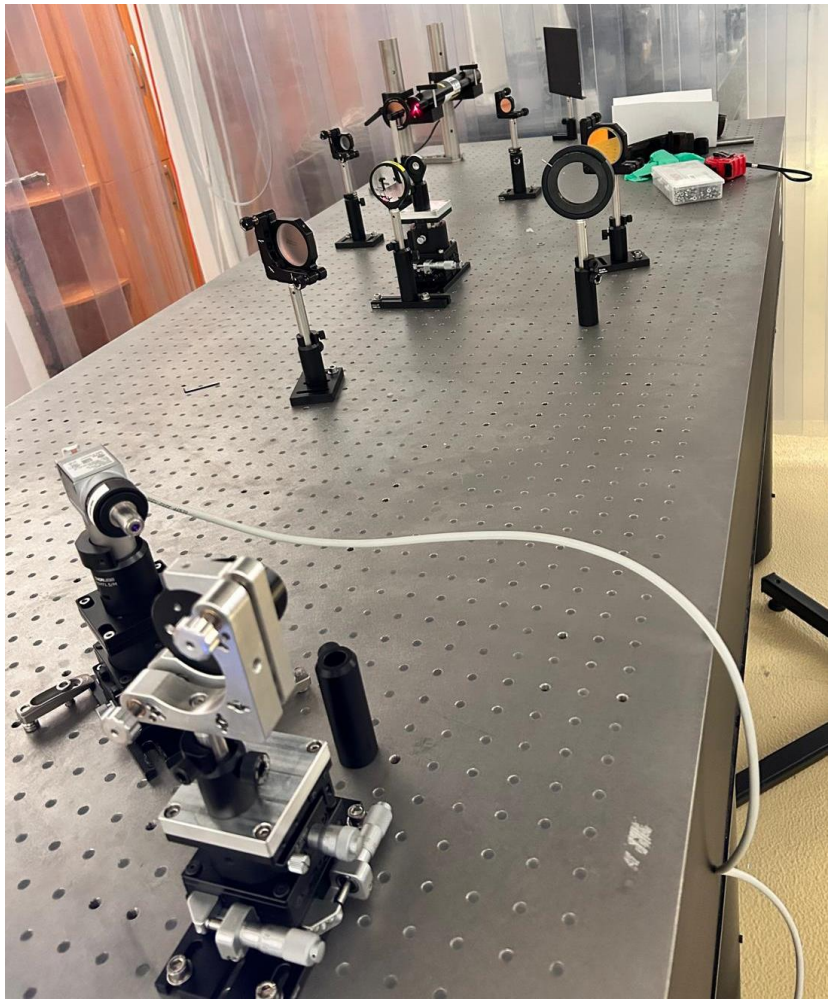


Fig. 4. Photo of the set-up.

Alignment procedure (2)

- Place the OAP such that the beam is centered on it
- Place the camera without an objective such that its chip is in the focal plane
- The beam will be astigmatic, as shown in Fig 5.
- Check the rotation of the OAP around the z axis and correct for it, if needed.
- Perform a rough optimization of the spot by translating the OAP such that the beam is centered and adjust the tip and tilt to decrease the astigmatism.

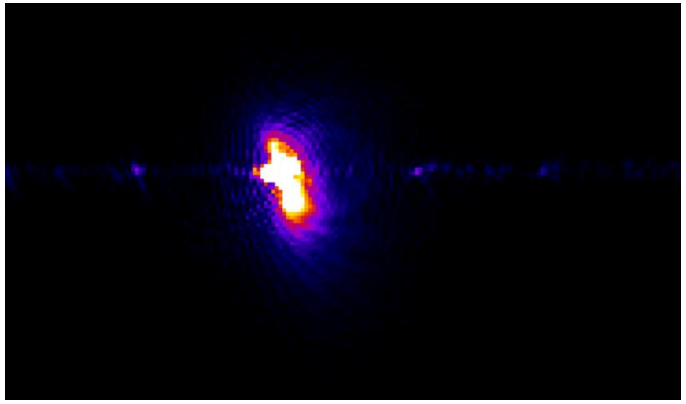


Fig 5. Focal spot right after placing the camera in front of the OAP. The beam is astigmatic and out of focus.

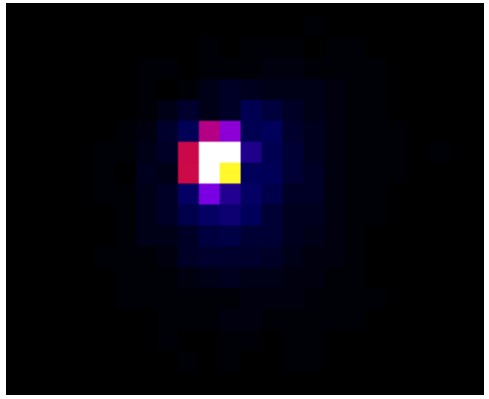


Fig 6. Focal spot after rough optimization. Astigmatism is still visible. To further improve it, magnify the beam by introducing the aspheric lens.

Alignment procedure (3)

- Introduce the aspheric lens and translate the camera towards the OAP while maintaining its orientation.
- Further optimize the tip and tilt of the OAP to obtain a round spot as shown in figure 7. The main aberration that needs to be reduced is astigmatism.
- After obtaining a satisfactory beam, the camera was calibrated by translating the OAP on the x axis by a fixed amount (in this case, 50 um). 5 datapoints were acquired, as shown in fig 8 and the slope was extracted to calculate the size of the pixels.
- 1 px ~ 0.16 um
- FWHM = 16.7 px => 2.7 um

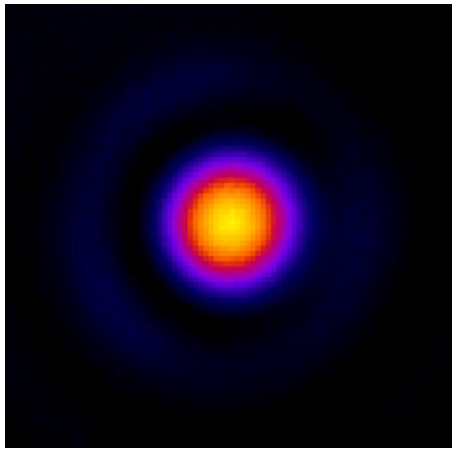
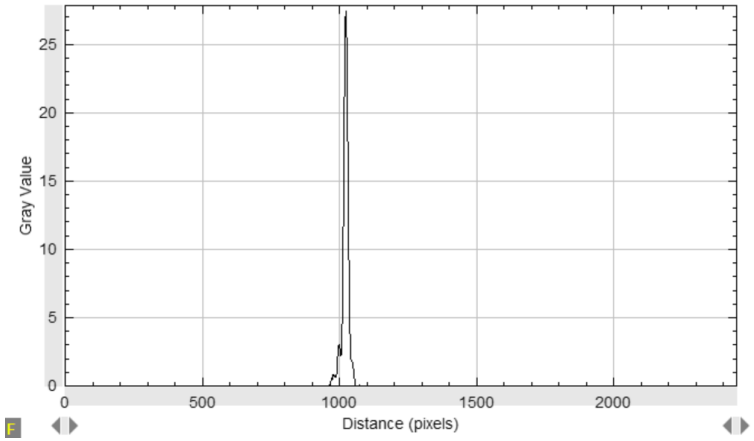


Fig. 7 Final focal spot after optimization.



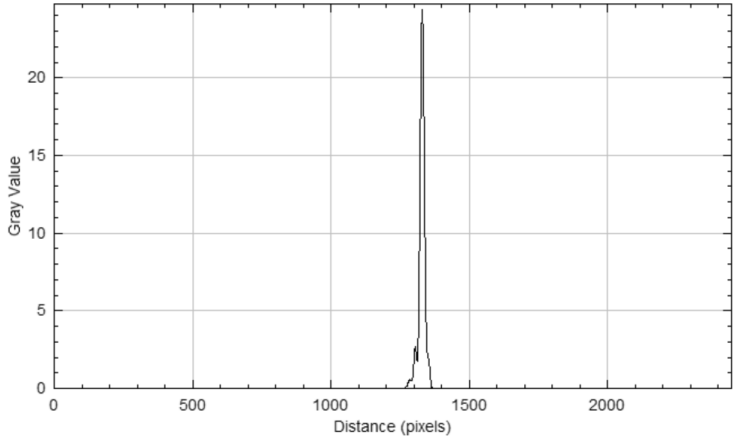
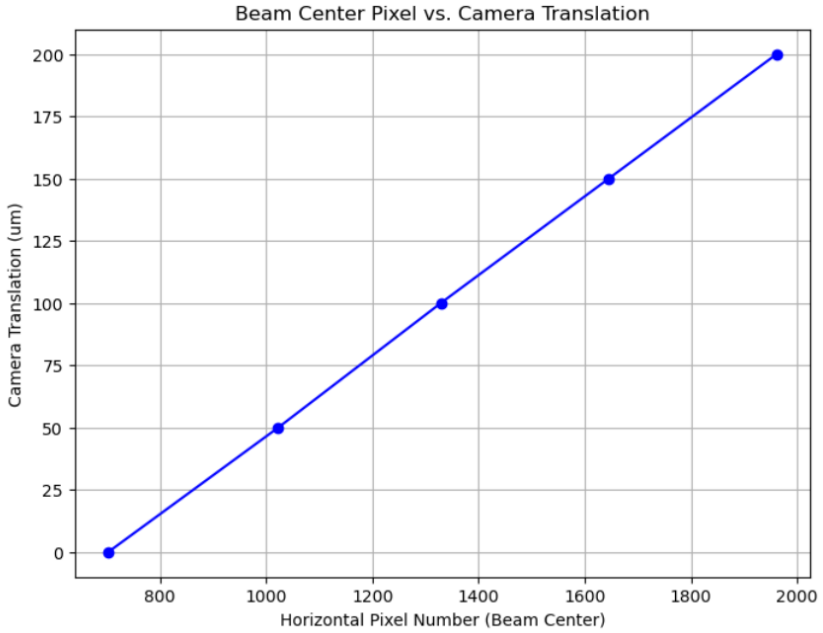


Fig. 8 Calibration plot.



Conclusion

- An experimental set-up consisting of a HeNe laser, Keplerian telescope, OAP and CMOS camera was built to optimize the focus
- The optimization was done initially without further magnification of the beam, but astigmatism was still evident
- An aspheric lens was placed in front of the camera, and the camera was moved towards the OAP to find the new effective focal length of the system.
- The tip and tilt were further improved to remove the astigmatism until a super-gaussian focus was obtained.
- After calibrating the system by translating the camera on the x axis, a FWHM ~ 2.6 um was calculated.