

Alvarez Lenses

Background: Read Zernike Notes sections 1, 2 and 5 on course website.

Introduction: The laboratory explores Alvarez lenses. An Alvarez lens is composed of two complementary phase plates defined by a third order polynomial. The plates are sandwiched together. Since they are complementary, when the plates are aligned with one another, their phase variations cancel and a beam passing through the elements only sees a constant phase. However, displacing the phase plates by equal and opposite amounts in x-direction induces defocus to be created in the beam passing through the plates. As a consequence, the Alvarez lens is a variable power element, meaning that its power changes in response to the translation of the phase plate.

Note: This write-up assumes a right-handed coordinated system with +z being the direction of propagation of the laser beam, +x being in the horizontal direction and +y being in the vertical direction

1. **Alignment** – Set up a laser, microscope objective, pinhole and collimating lens to create a collimated beam. Place a single Alvarez plate in the collimated beam with the flush side facing away from the laser. Observe the emerging beam. A strong comatic pattern will be seen. Rotate the phase plate so that the point of the coma pattern points in the +x direction. Remove this phase plate and set aside for the time being. Place the second phase plate in the collimated beam with the flush side facing towards the laser. Observe the emerging beam. Rotate the phase plate so that the coma pattern points in the -x direction. Finally, place both phase plates in the collimated beam with their flush faces nearly in contact. Align the lateral positions of the plates so the beam passing through the plates remains collimated.
2. **Testing** – Displace one of the plates by an amount Δx in the +x direction. Displace the second plate by an amount $-\Delta x$ (i.e. in the -x direction). What happens to the emerging beam? Repeat this process for various positive and negative values of Δx . Note: the step size should be about 100 microns. For converging beams, measure the focal length of the Alvarez lens. For diverging beams, place a positive thin lens in contact with the Alvarez lens and measure the focal length of the combination. Deduce the negative focal length of the Alvarez lens from your results.
3. **Analysis** – plot the power of the Alvarez lens as a function of displacement Δx . Based on the background reading, estimate the coefficients a_{31} and a_{33} of the coma and trefoil terms that make up the phase plates.