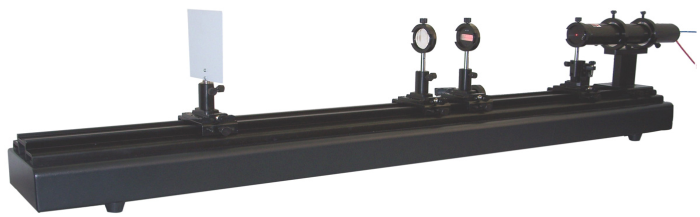
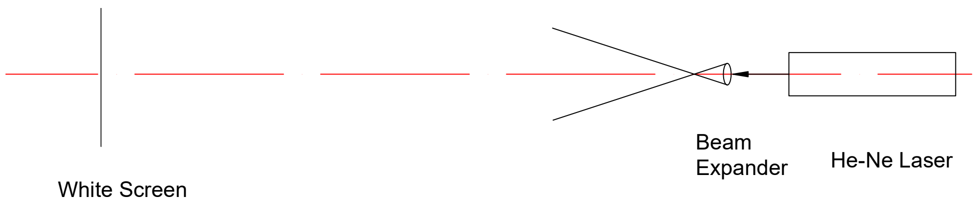
4 Experimental Procedure

4.1 Lens Aberration Experimental Examples

4.1.1 Spherical Aberration



Step 1: Insert the laser tube in laser tube holder and place it at one end of optical rail. Turn on the laser. Place the white screen at the other end of the rail. Put a lens (beam expander, *f*=4.5 mm) into a lens holder and place it onto a carrier in the optical path.

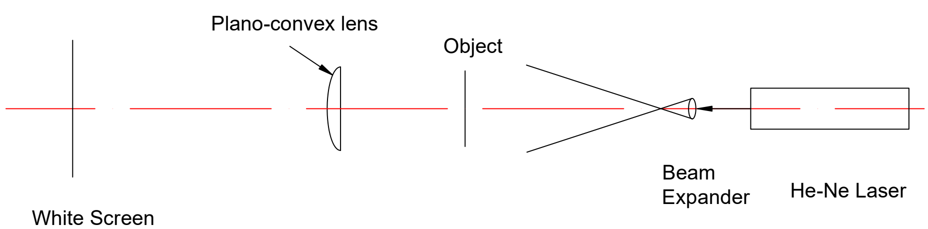


Step 2: Put the millimeter ruler in a lens holder and let it be illuminated by the expanded laser beam.

Step 3: Place the plano-convex lens (*f*=85 mm) in a lens holder and position it about 10 cm away from the millimeter ruler.

Warning: Avoid direct eye exposure to the laser beam!

Notice: Let the plane surface of the lens face the laser beam.



Step 4: Place the white screen around the end of the rail and adjust the position of the white screen or the lens until a clear enlarged image of the millimeter ruler is obtained. Then secure the carriers of the object and the lens.

Step 5: Mount the On/Off Axis aperture plate on the plate holder (SZ-12) and respectively place the On-axis aperture and the Off-axis aperture behind the plano-convex lens using the adapter piece (SZ-9) to make them as close as possible to the lens, while adjust the position of the white screen until a clear image is observed on the screen for the two cases. The difference of image distances between the two results demonstrates the existence and influence of the spherical aberration of the lens.

Step 6: Replace the On/Off axis aperture plate with the adjustable iris (SZ-15), change the aperture size. Repeat step 5 to observe the change of image quality and the change of image depth of different aperture sizes.

Step 7: Replace the PCX lens (*f*=85 mm) with a bi-convex lens (BCX) (*f*=85 mm) and repeat steps 3-6. Observe the imaging differences.

4.1.2 Curvature of field

Step 1: Mount laser tube at one end of the rail. Turn on the laser. Mount white screen at the other end of the rail. Place lens (f=4.5 mm) to expand the laser beam.

Step 2: Put the millimeter ruler in a lens holder and let it be illuminated by the expanded laser beam.

Step 3: Place the plano-convex lens (f=85 mm) in a lens holder and position it about 10 cm away from the millimeter ruler.

Step 4: Place the white screen around the end of the rail and adjust the position of the white screen or the lens until a clear enlarged image of the millimeter ruler is obtained.

Step 5: Move the screen slowly around the imaging plane while observing image quality changes respectively at the image center and the image outskirts.

4.1.3 Astigmatism

Step 1: Mount laser tube at one end of the rail. Turn on the laser. Place lens (f=4.5 mm) to expand the laser beam.

Step 2: Insert the adjustable iris in carrier and position it next to the beam expander. Reduce the iris aperture to about 3 mm in diameter as an object.

Step 3: Mount the plano-convex lens and the white screen on optical rail, and adjust them to the same height.

Step 4: Move the white screen until a clear image of the aperture is observed on the screen.

Step 5: Release the knob of carrier to change the aperture height of the iris while moving the screen along the rail. Observe change in image caused by astigmatism.

4.1.4 Coma

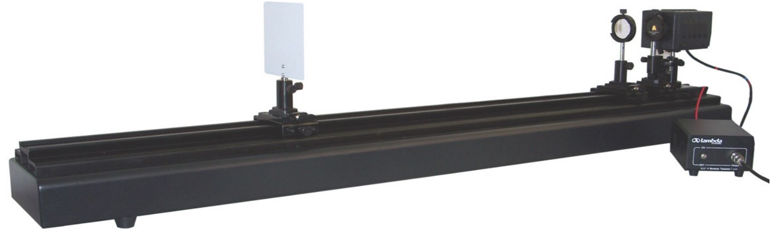
Step 1: Mount the laser tube at one end of the rail, turn on the laser. Mount the white screen at the other end of the rail.

Step 2: Mount lens (f=4.5 mm) in a carrier and put it in optical path, which is used as a beam expander and an object.

Step 3: Mount the plano-convex lens in carrier and put it on optical rail. Move the screen along the rail until a clear image is formed on the screen.

Step 4: Release the knob of the plano-convex lens and rotate the lens around vertical axis slowly while watching the screen. You will see "comet-like" blur.

4.1.5. Distortion



Step 1: Mount the bromine tungsten lamp at one end of the rail. Mount the white screen at the other end of the rail. This experiment does not need filter and ground glass in front of the lamp.

Step 2: Place the transmission letter used as an object and the plano-convex lens onto the rail, adjust them until a clear image is observed on the screen.

Step3: Watch the image as straight lines bent inward slightly, forming pincushion distortion on the screen.

Step 4: Put the iris close to the lens using the adapter piece (SZ-9) and adjust its position and aperture size to see how image changes.

4.1.6 Chromatic aberration

Step 1: Mount bromine tungsten lamp at one end of the optical rail and white screen at the other end.

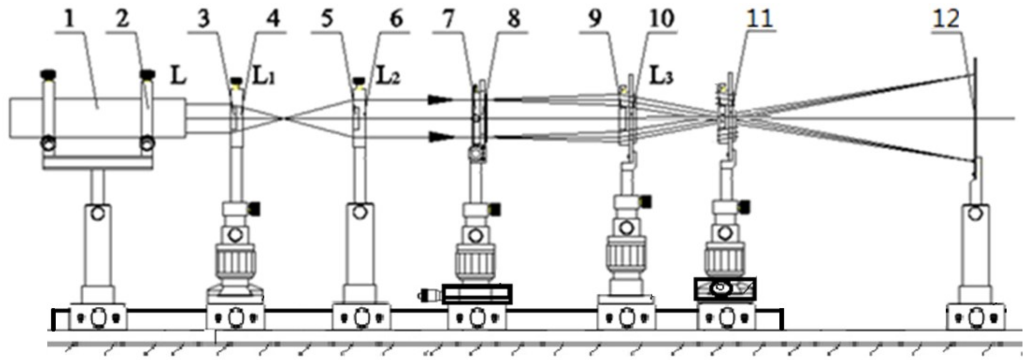
Notice: in this experiment, the ground glass in front of the lamp housing is not used.

Step 2: Place the DCX lens (*f*=85 mm) onto the rail and adjust the lamp and the lens to the same height.

Step 3: Move the screen and the lens until a clear image of the filament is observed on the screen. Record the position of the screen.

Step 4: Mount a color filter in a lens holder (SZ-08) or plate holder (SZ-12) on a carrier and put it in front of the lamp window in the optical path to allow white light from bromine tungsten lamp aperture to pass through the filter. Move the screen to get clear images. Change to another color filter while observing the change in image position.

4.2 Fourier Optics and Spatial Filter



Schematic of experiment setup

1: He-Ne Laser (LLL-2)

2: Laser Holder (SZ-42)

3: Beam Expander Lens L_1 (f'=4.5 mm)

4,6,8,10: Lens Holder (SZ-08)

5: Collimating Lens L_2 (f'=150 mm)

7. Transmission Character

9: Fourier Transform Lens L_3 (f'=225 mm)

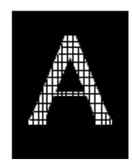
11: Adjustable Slit (SZ-40)

12: White Screen (SZ-13)

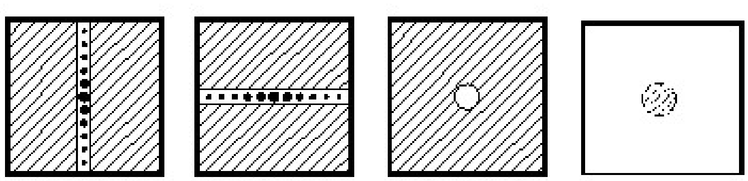
Others: Iris Aperture (SZ-15), Plate Holder (SZ-12) and Zero-Order Filter.

Experiment Procedure:

1) Refer to above schematic, arrange all components in same height along the rail;
2) Use L_1 and L_2 to construct a beam expanding system, to obtain a collimated beam with a larger aperture and illuminate on the transmission character;
3) Put the white screen (SZ-13) away from the transmission character at a remote location (>2 meters), move the transform lens L_3 back and forth to form an image of the transmission character with clear grids on the screen and observe the enlarged image (*a two-dimensional grid is embedded on the transmission letter/character*).



4) Insert the adjustable slit at the back focal plane of L_3; set slit direction in the vertical direction and adjust slit width to pass the central column of the spectral spots, observe the direction of the grid lines on the image screen; this is optical directional filtering.
5) Rotate slit direction by 90° to let the central row of spectral spots pass, observe the direction of the grid lines on the image screen;
6) Replace the slit with the iris, reduce the aperture size gradually, observe changes in image of the transmission letter, till only the zero order spectrum passes the aperture; this is optical low-pass filtering (the grid should disappear but the character should still be there);
7) Replace the iris with the zero-order filter to block the central portion of the spectrum on spectral plane, observe image changes on the image plane, this is optical high-pass filtering.



* User may make different filter transmission patterns to demonstrate optical filtering effects.