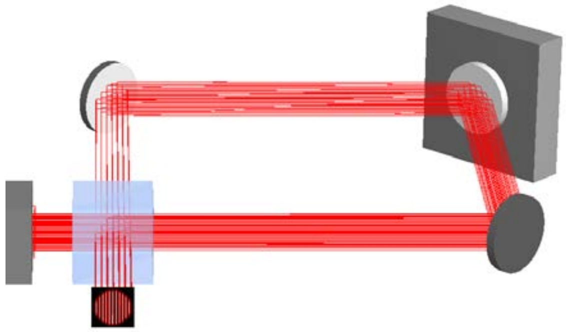
FRED Interferometry Application Note



Introduction

The coherent irradiance feature in FRED allows for simulation of physical optics phenomena such as diffraction and interference. With this capability, components such as Gaussian laser beams and interferometers can be accurately modeled and incorporated into optical systems.

Example 1: Poisson's Spot

FRED performs diffraction and interference calculations using a technique called coherent beam superposition. The coherent beam superposition technique works by modeling arbitrary optical fields with the coherent summation of smaller fundamental beams. In FRED, these smaller fundamental beams are Gaussian beamlets. It has been demonstrated that Gaussian beams can be represented and propagated with real rays[1]. Those rays can be traced through an optical system while maintaining the Gaussian beam representation. Near and far field diffraction can be calculated coherently summing the Gaussian beams, which are represented by real rays traced through the system.

As an example, the Poisson's Spot experiment is modeled in FRED. A simple coherent plane wave optical source is created, followed by a small circular obstruction. Coherent irradiance behind the obstruction is evaluated at two different distances to show development of the diffraction pattern.

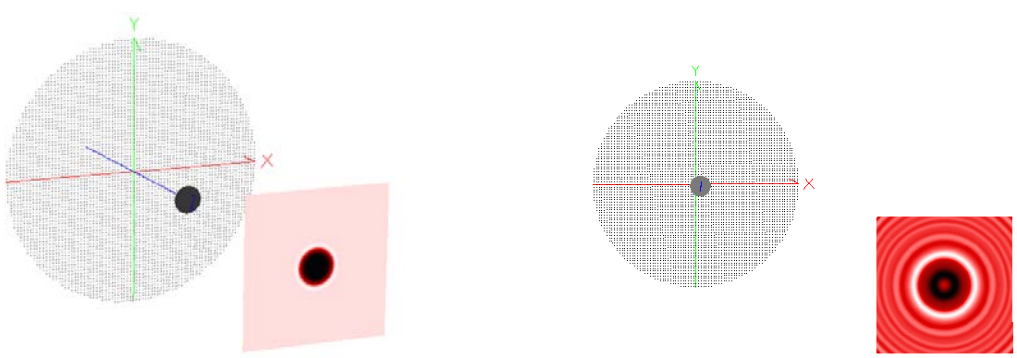


Figure 1. Poisson's spot irradiance pattern. A 588 nm coherent plane wave source shines behind a circular obstruction with 0.1 mm radius. Coherent irradiance is evaluated at two different distances: On the left side, light 2 mm beyond the obstruction does not undergo significant diffraction. On the right side, light 40 mm beyond the obstruction undergoes Fresnel diffraction and exhibits a characteristic Poisson Spot on axis.

Example 2: Michelson Interferometer

Interferometer systems can be modeled in FRED using coherent lights sources. A Michelson interferometer can be found in the *Coherence* folder of the FRED sample files. It consists of a coherent plane wave source, beam splitter to divide the input beam, flat reference mirror, and test mirror. The test mirror contains a defect which is modeled as a Zernike function. To add a defect, create a dummy surface which is not traceable. Open the dialog for the test mirror's reflective surface and click on the *Modifiers* tab. Check *Apply another surface's sag as a deformation to this surface*, and select the dummy surface. Lastly, check *Deforming surface is applied in coordinate surface of the base surface.* The coherent light source can be monochromatic or polychromatic; however, the maximum detectable defect is inversely proportional to the bandwidth of the source.

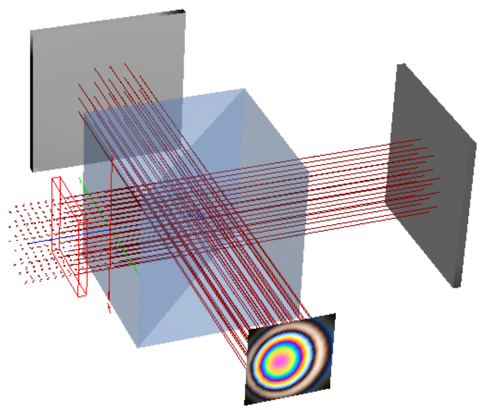


Figure 2. White light Michelson interferometer. A "white light" (405-669 nm) coherent light source is split by a cube beamsplitter. A color image is generated to show white light fringes. The test mirror is modified by a Zernike polynomial function with [$6R^4$-$6R^2$+1] coefficient = 1 and [($10R^4$-$12R^2$+3)Rsin(A)] coefficient = 0.5. This sample file is found in C:\Program Files\Photon Engineering\FRED 14.40.1\Resources\Samples\Coherence\ interferometerWhiteLightMichelson

Example 3: Newton's Rings

Newton's Rings form when reflections from a planer surface interfere with reflections from a spherical surface in contact. The interference pattern is based on increasing optical path difference from the point of contact outward. As spherical surface curvature increases, the amount of rings increases. A FRED model of Newton's Rings is shown below:

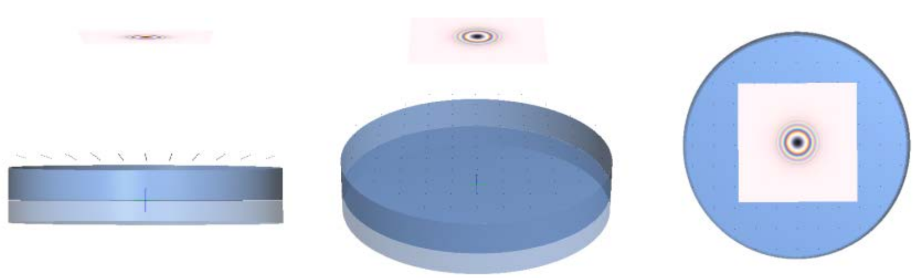


Figure 3. Newton's Rings. A slow (R=150 cm, D=1.25 cm) lens is placed in contact with a flat glass surface. Coherent, collimated "white" light (400-700 nm) shines from above. The uncoated glass surfaces partially reflect the light and interfere. White light fringes are visible near the point of contact. The fringes wash out as soon as optical path difference exceeds the coherence length of the light source.

Example 4: Fizeau Measurement of Lens Surface

Interferometers can be used in metrology to measure surface quality of manufactured lenses and mirrors. A Fizeau interferometer is commonly used for such a measurement (Figure 4).

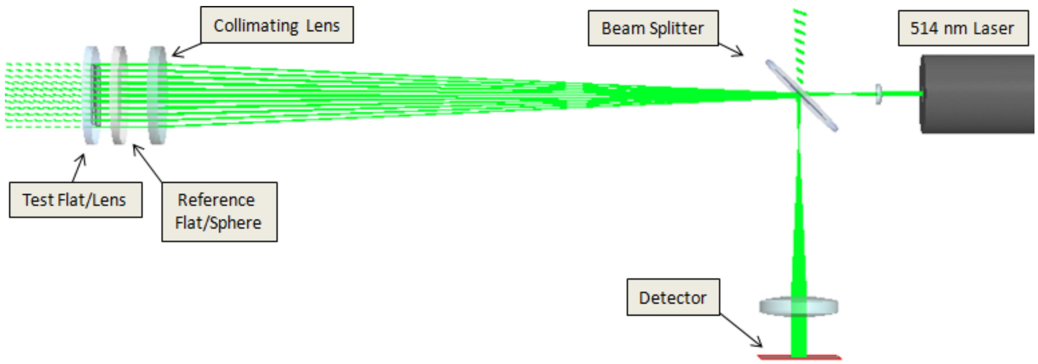


Figure 4. Fizeau interferometer for surface measuremetns. Laser light is expanded and collimated. Interference occurs between reflections from a reference optic and test optic. If the test opic is a lens or curved mirror, a reference sphere is used to produce a converging wavefront. The test surface is placed in its matching wavefront, and defects are measured relative to this wavefront. This sample can be found in C:\ Program Files\Photon Engineering\FRED 14.40.1\Resources\Samples\Coherence\interferometerFizeau

To modify the FRED file in Figure 4 for lens metrology, the reference flat becomes a reference sphere and the test flat becomes a plano-convex lens. The reference flat has a back radius of -70. Its curved surface is transmissive and its flat surface is uncoated. The test flat a front radius of 80. It is relocated to a Z shift of 54.25. The imaging lens has a Z-shift of 150 and the detector has a Z-shift of 10. The test lens is located in its nominal wavefront, and a slight axial displacement of this lens leads to interference fringes (Figure 5).

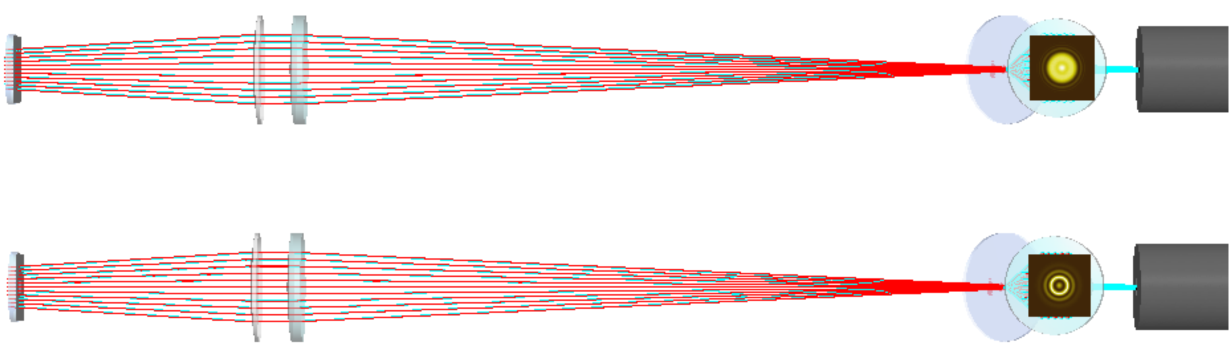


Figure 5. Fizeau measurement of lens surface. When the lens is in its nominal wavefront, a null interferogrm is formed. If the lens is axially displaced (in this case, brought closer with a Z shift of 53), power fringes appear in the interferogram.

References:

1. Arnaud, Jacques, “Representation of Gaussian Beams by Complex Rays”, Applied Optics, Vol. 24, No. 4, p. 538-543, Feb 1985.

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