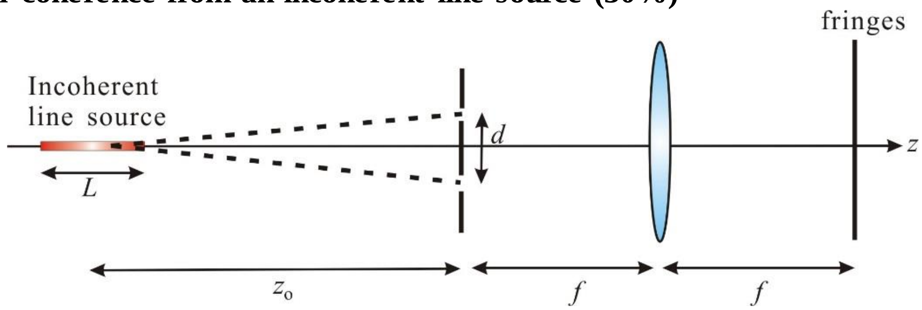
Statistical Optics and Image Formation

Homework Set 3 **Due: January 6, 2020**

1. Partial coherence from an incoherent line source (30%)



Consider an incoherent monochromatic line source with length L lying on the optical axis. A double-pinhole (separated by a distance d) screen locates at a distance z_0 from the center of the line source. A biconvex lens with focal length f is used to collimate the fields from the pinholes and overlap them on an observing screen at the back focal plane of the lens. Assuming d and L are much smaller than z_0 and f, so you can invoke the paraxial approximation.

(a) Deduce the visibility of the fringes as a function of d ,
(b) Estimate the coherence area generated on the plane at a distance z_0 from the center of the line source,
(c) Find the complex coherence factor $\mu(\vec{r}_1 = 0, \vec{r}_2 = \vec{r})$ on the plane at a distance z_0 from the center of the line source.

2. Spectrum of a Superposition of Two Waves. (20%)

An optical wave is formed by superposition of two waves $U_1(t)$ and $U_2(t)$, which both have an identical spectra $S_1(\nu) = S_2(\nu)$ with a Gaussian profile of spectral width $\Delta\nu$ and central frequency ν_0 and may be partially correlated. (a) Derive an expression for the power spectral density $S(\nu)$ of the superposed field $U(t) = U_1(t) + U_2(t)$. (b) Is it possible that the superposed field is also Gaussian, but with a shifted central frequency $\nu_1 \neq \nu_0$? Is this contradictory with Doppler effect (*i.e.*, frequency shift without object moving)?

3. Phase retrieval from diffraction pattern (50%)

A 600-nm wavelength optical wave is focused by a plano-convex microlens onto a camera positioned at the back focal plane of the lens. The lens is made by a 1.52-index of refraction glass with a radius of curvature of 10 cm and a diameter of clear aperture of 1.024 mm. A phase plate in direct contact with the back surface of the microlens causes a diffraction pattern dp.bin recorded on the camera (you can read in the binary file with the matlab command fread(fid, [N, N], 'real*4')).

(a) Develop a phase retrieval script based on the hybrid input-output (HIO) algorithm (ref. workshop 6) to retrieve the phase profile of the wave (directly behind the phase plate) from the diffraction pattern.

(b) Derive an expression of phase profile for the microlens based on the device parameters specified above. Remove the influence by the lens to reveal the phase profile of the phase plate. What is the resulting phase profile as a function of radial distance from the optical axis?