

OPTICS, 114210 - Homework Exercises

J. Imaging: 2. Spatial filtering.

2.1. A weak phase object has the form $f(x) = \exp[i\phi(x)]$ where $|\phi(x)| \ll 1$. It is imaged by means of parallel coherent illumination and an imaging lens.

(a) Show that in the Fourier plane u , the light has amplitude $\delta(u) + i\Phi(u)$, where $\Phi(u)$ is the Fourier transform of $\phi(x)$.

The following filters are inserted in the Fourier plane. What are the forms of the image (in terms of $\phi(x)$)?

(b) a dark ground filter (blocks the point $u=0$)

(c) Zernike phase-contrast filter (changes the phase at $u=0$ by $\frac{1}{2}\pi$)

(d) a filter whose amplitude transmission is $t = Au^2$

(e) a Schlieren filter, $t=1$ for $u>0$, $t=0$ for $u \leq 0$ (qualitatively).

2.2. A photographic transparency shows a picture of a monkey behind a fence which consists of equally-spaced narrow vertical bars. Devise a coherent optical filtering system which will destroy the fence, hurting the monkey as little as possible.

2.3. A telescope lens is apodized by a Gaussian mask, with parameter σ in order to reduce the prominence of the diffraction rings around a point image. If the telescope aperture radius is R , what ratio σ/R is necessary to reduce the intensity of the first diffraction ring to 10% of its original value? How does this affect the resolution, according to the Rayleigh criterion?

2.4. A laser beam is filtered and expanded by first focusing it to a point with a microscope objective (focal length $F=5\text{mm}$) and putting a pinhole at this focus, and then recollimating the emerging beam with a converging lens at a larger distance. Assuming the laser beam has a Gaussian profile with $\sigma=1\text{mm}$ with the addition of noise at higher spatial frequencies, what size of pinhole will allow about 95% of the laser light to be transmitted, but will reject the noise?

2.5. A phase object consists of several transparent discs which change the phase of the incident light by β and together cover half of the field of view. Design a spatial filter to give maximum contrast in the image.