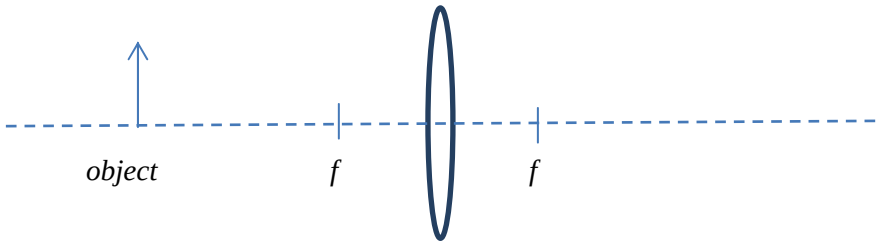
Optics/Photonics Ph.D. candidacy exam (August 2014)

This exam consists of 7 problems (10 points each). Time allowed: 150 min.

1.

(a) Sketch the necessary rays to trace the image formation process of the shown object by the given positive lens of focal length f.



(b) Explain how and why the above lens focuses light. Discuss in terms of light propagation velocity, refractive index, and elaborate on the issue of possible chromatic aberration.

2. A 1-mW laser produces a Gaussian beam of wavelength 610 nm and spot size $2W_0$ = 0.2 mm.

   (a) Determine the angular divergence of the beam, its depth of focus, and its diameter at an axial distance $z = 5 \times 10^3$ km.

   (b) What is the radius of curvature of the wavefront at $z = 0$, $z = z_0$, and $z = 2z_0$, where z_0 is the *Rayleigh range*.

   (c) What is the beam's *q parameter* at $z = z_0$

   (d) What is the optical intensity (in mW / cm^2) at the center of the beam at z = 0?

3. The visibility of an interference pattern described by $I = I_1 + I_2 + 2\sqrt{I_1 I_2}\cos\varphi$ is defined as the ratio $\vartheta = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$, where I_{min} and I_{max} are the minimum and maximum values of I. Derive an expression for ϑ as a function of the ratio $\frac{I_1}{I_2}$ of the two interfering waves and determine the ratio $\frac{I_1}{I_2}$ for which the visibility is maximum.

4. The intensity distribution of an object is given by $|O(x)|^2 = \delta(x - x_1) + \delta(x - x_2)$, where $\delta(x)$ is the Dirac-delta function. An imaging system, using incoherent illumination, has an *intensity* point spread function (PSF) given by:

$$|h\,(x)|^2 = 1 \qquad 0 \le x \le x_{\max}$$

$$0 \qquad \text{otherwise.}$$

(a) Sketch the intensity distribution of the image.
(b) What is the minimum distance between the two point sources in the object, $\Delta x = |x_2 - x_1|$, so they could be resolved in the image?

5. Explain what is meant by:

a) Cathodoluminescence
b) Electroluminescence
c) Photoluminescence
d) Why does a metal reflect visible light, and glass transmit it??

6.

a) Describe the two conditions that should be satisfied in order to achieve laser oscillation.

b) Describe the operating principles of two pulsed laser operating regimes: *Q-switching* and *mode-locking*.

7. An atom at room temperature with two energy levels corresponding to the transition with $\lambda_0 = 0.7$ μm, $t_{sp} = 3$ ms, $\Delta\nu = 50$ GHz is placed in a resonator of volume V = 100 cm^3 and refractive index n = 1. A radiation mode at the central frequency ν_0 is excited with 1000 photons.

a) Determine the probability density for stimulated emission (or absorption).

b) If N_2 such atoms are excited to the energy level 2, determine an effective time constant for the decay of N_2 due to stimulated and spontaneous emission. How many photons (rather than 1000) should be present so that the decay rate due to stimulated emission equals that due to spontaneous emission?