# E-5730 Optics
## Exercise IV 8.2.2021

**Question Q1.** Show that for two linearly polarised co-propagating plane waves

$$\vec{E}^{(1)}(\vec{r},t) = E_1 e^{i(\vec{k}_1\cdot\vec{r}-\omega_1 t+\phi_1)}$$
$$\vec{E}^{(2)}(\vec{r},t) = E_1 e^{i(\vec{k}_2\cdot\vec{r}-\omega_2 t+\phi_2)}$$

the total intensity can be written as

$$I_{TOT} = (I_1 + I_2)\left[1 + \frac{2\sqrt{I_1 I_2}}{I_1 + I_2}\cos\left(\Delta\vec{k}\cdot\vec{r} - \Delta\omega t + \Delta\phi\right)\right]$$

where $\Delta\vec{k} = \vec{k}_1 - \vec{k}_2$, $\Delta\omega = \omega_1 - \omega_2$ and $\Delta\phi = \phi_1 - \phi_2$.

**Question Q2.** Two mutually coherent plane waves propagate in collinear way and interfere. If the plane waves are formed of two laser beams having vacuum wavelengths of 632.9913 nm and 632.9914 nm, what kind of time dependence the interference fringes have?

**Question Q3.** A narrow spectral line at 2000 $cm^{-1}$ is to be measured using a Michelson interferometer. The desired resolution of the measurement is 1 $cm^{-1}$. What is the travelling distance of the moving mirror? At what speed the scanning mechanism must move the mirror for the photo detector to capture 100 intensity fringes per second? [Hint: one can assume a monochromatic light source].

**Question Q4.** A 60 Watt tungsten filament lamp operates at a temperature of 1800 K. How many photons does it emit per second in the narrow wavelength interval from 500 nm to 500.1 nm in the visible green? Assume that the filament emits as a blackbody and make use of the fact that

$$\int_0^\infty \frac{x^3}{e^x - 1}dx = \frac{\pi^4}{15}$$

[Ans: $3.4 \times 10^{13}$ photons/s].

**Homework Question HQ 1.** (return by February 8) A blackbody radiator is at 1200 deg C temperature. The hole in the radiator's cavity is circular and has 4 mm diameter. A photodetector (the radius of the detector's active area is 3 mm) is placed 150 mm away from the blackbody. The radiator and photodetector share the same optical axis and the incident angle of radiation on the detector is zero. A spectral band-pass filter is placed between the blackbody radiator and the detector. The centre wavelength of the filter is 1 μm and the width of the band-pass $\Delta\lambda$ = 30 nm.

a) What is the optical power reaching the detector's active area?
b) The detector will be rotated to a 45-degree angle with respect to the optical axis going through the cavity. What is the optical power reaching the detector in this case? (You can ignore changes in the reflection coefficient due to rotation.)

**Homework Question HQ 2.** (return by February 8) Derive the Wien's displacement law. According to the Wien's displacement law the wavelength $\lambda_{max}$ where the spectral distribution of blackbody radiation reaches its maximum value at a temperature T can be obtained from $\lambda_{max}T$ = constant. The sun can be considered as a blackbody radiator having a temperature of about 5800 K. What is the wavelength corresponding to the sun's peak spectral distribution? Do you think there is a connection to photometry?

**Homework Question HQ 3.** (return by February 8) Calculate the spectral irradiance $E_e$ at O due to a Lambertian disk source located at O'. The disk source has radius *R* and spectral radiance $L_e$. Study also the two limiting cases, *h* >> *R* and *h* << *R* where *h* is the distance between O and O'.