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Experimental physics 3 for physicists
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https://www.mpl.mpg.de/divisions/leuchs-division/teaching/

Problem sheet 9

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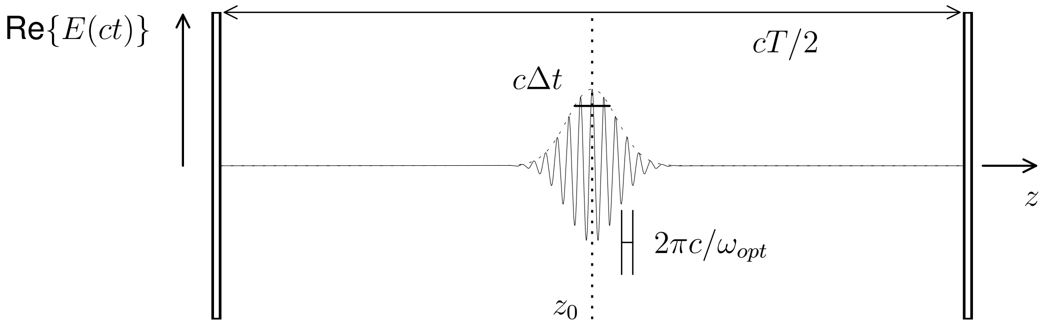
Problem 1: Optical mode structure of a HeNe-laser

Consider a HeNe-laser containing a helium-neon gas mixture at temperature $T = 500\,°\mathrm{C}$ as its active medium and two resonator mirrors separated by the distance $L = 50\,\mathrm{cm}$. The wavelength of emitted light is $\lambda = 633\,\mathrm{nm}$.

a. Calculate the spectral separation $\Delta\nu$ between two adjacent resonator modes (the so-called *free spectral range*). (Take the refractive index of the He-Ne mixture to be $n = 1$).
b. Determine the longitudinal Doppler broadening $\Delta\nu_D$ of the light emitted from Ne atoms at the indicated temperature and central frequency.
c. How many resonator modes are within the Doppler width? Compare the obtained values with those for a CO_2 laser: $\lambda = 10.6\,\mu\mathrm{m}$ and the same gas temperature. Take the free spectral range of the the CO_2 laser equal to be $\Delta\nu = 150\,\mathrm{MHz}$.

Problem 2: Pulsed laser

Consider a resonator with round trip time T generating a train of identical light pulses. A single pulse has a carrier optical frequency ω_{opt} and a Gaussian envelope of width $\sigma = \Delta t$.



Assume that the electric field of the light E in an arbitrary plane ($z = z_0$) of the resonator is given by the expression

$$E(t, z_0) \equiv E(t) = \sum_{n=0}^{N-1} E_0 \exp\left\{-\frac{1}{2}\left(\frac{t - nT}{\Delta t}\right)^2\right\} \exp\{-i\omega_{\text{opt}} t\}. \quad (1)$$

Here N is a number of coherent pulses in a train defined by losses and the noise. For simplicity we have assumed that the amplitude E_0 is equal for all pulses.

a. How is the round-trip time T of an optical pulse in the resonator related to the resonator length L?
b. By performing the Fourier transformation of the amplitude $E(t)$, determine the spectrum of the light field $\tilde{E}(\omega)$.
c. Comment on this spectrum.