UNIVERSITÄT LEIPZIG

Experimental Physics IV IPSP

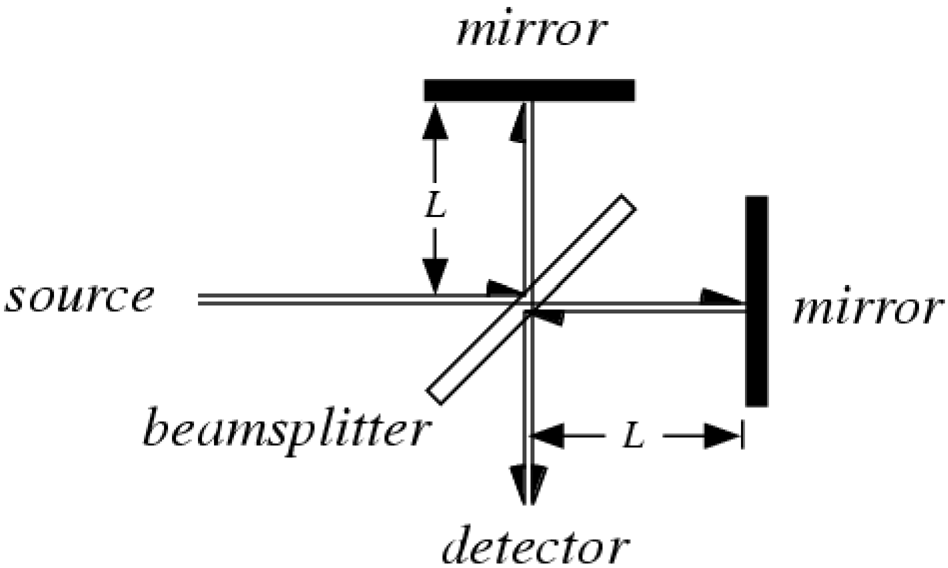
Problem Set 5

Deadline: Thursday, 16.05.2011, before the seminar

Problem 15: 3+1+2+1 points

Michelson and Morley developed an experiment to prove the existence of aether. Therefore they used a Michelson interferometer (see sketch) to measure the changes of interference patterns when the instrument is rotated. Michelson and Morley thought that one finds different beam travel times depending on how fast the system (here: earth with v= 30km/s) travels through the non-moving aether.
Assume that the light (λ=500nm) traveled L=11m from the beam splitter to the mirror.

a) Derive a formula for the different beam travel times for both branches of the interferometer using the assumption that aether exists.
b) Repeat the calculation of a) with an interferometer rotated by 90°.
c) Calculate the relative change of the interference patterns when you rotate the interferometer from position 1 (task a) to position 2 (task b).
d) Michelson and Morley found that the interference patterns do not change. What can you conclude from that?



Hints:
Assume that one of the branches is pointing in direction of the aether wind and one perpendicular to the aether wind. The aether wind blows homogenous. The beam travel speed using this assumptions can be larger or smaller than c.
Taylor-expand were v^2/c^2-terms occur.
c) The relative change of the interference pattern is defined as the quotient of optical path length difference and the wavelength.

General hint:
The concept of aether can be thought of like an object in a liquid where every flux of the liquid influences the movement of the object. In this sense photons "swim" in aether and vector addition of velocities are allowed.

Problem 16: 4 points

Let $\Phi_1(x)$ and $\Phi_2(x)$ be solutions of the time-independent Schrödinger equation (SE). Show that $\Phi_3(x) = c_1\Phi_1(x) + c_2\Phi_2(x)$ is also a solution of the time-independent SE.

Problem 17: 2+3+3 points

Solve the time-independent SE for a particle in a box! The potential V is given by

$$V(x) = \begin{cases} \infty & \text{for} \quad x < 0 \\ 0 & \text{for} \quad 0 < x < d \\ \infty & \text{for} \quad x > d \end{cases} .$$

a) Use the ansatz $\Phi(x) = e^{-ikx}$ and the superposition principle (Problem 16) to calculate the general solution.
b) Plug in the boundary conditions for $x = 0$ and $x = d$ and calculate c_2 and k.
c) Normalize the possible wavefunctions and calculate c_1:

$$\int \overline{\Phi}_n \Phi_n \, dx \overset{!}{=} 1$$