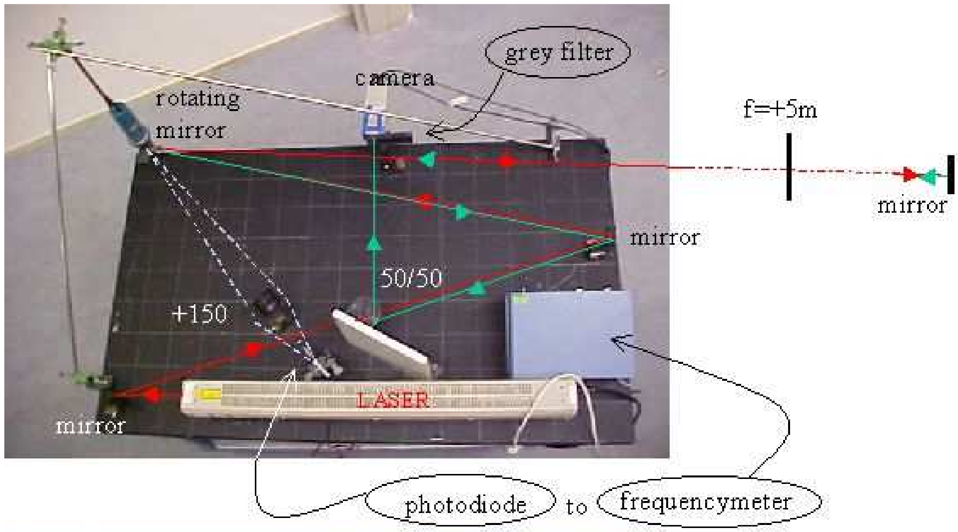
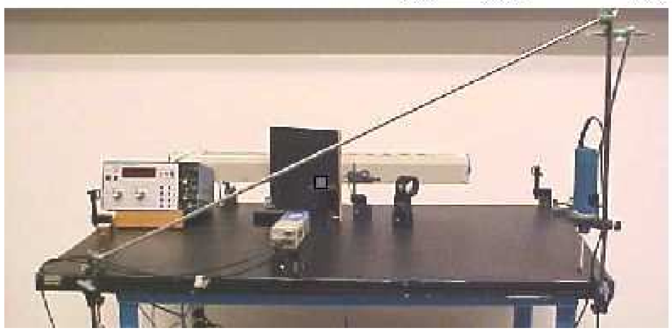
Speed of light;
Foucault-Michelson

Aim: To "measure" speed of light

Subjects: 6A01 (Speed of Light)

Diagram:





Equipment:

- Optical components (see Diagram).
- Camera without lens (see Diagram).
- Variable transformer to supply the motor of the rotating mirror.
- 5Vdc to supply the photodiode-circuit.
- Monitor, connected to camera.
- Double overheadsheet, explaining the assembly.

Speed of light; Foucault-Michelson

Presentation: Preparation:

Make the laserbeam go as horizontal as possible; careful alignment is essential in this demonstration. (Start at the laser and work step by step working yourself through the lightpath.)

The +5m-lens is positioned at about 5m distance from the rotating mirror.

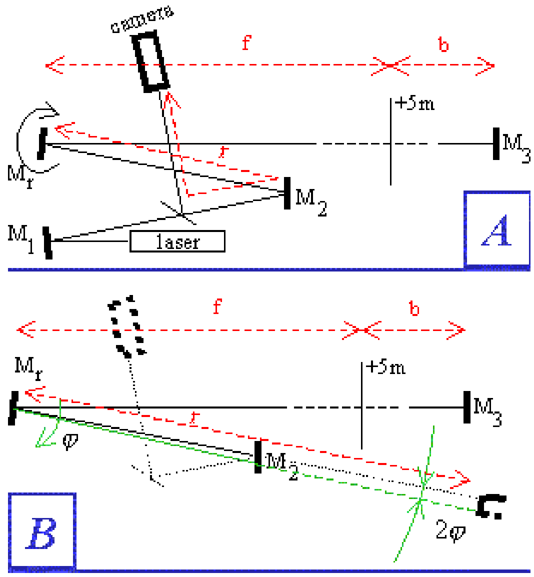


Figure 1

Image-distance *b* (see Figure1A) is chosen such that the image of the first mirror (M_1) is sharp at M_3 $\left(\frac{1}{f}=\frac{1}{r+f}+\frac{1}{b}\right)$.(In our assembly this means that *b* is around 25 meters.) Lens +5m and M_3 are carefully adjusted until, in the right postion of the rotating mirror (M_r) the laserbeam is reflected to the camera (the camera and M_1 have the same distance to M_3). Making the rotating mirror turn at its highest speed (about 500 rev. per second) the lightspot displaces, in our assembly, the whole width of the monitorscreen. This displacement is calibrated by placing a plastic ruler between the greyfilter and the camera (see Figure2A).

Speed of light; Foucault-Michelson

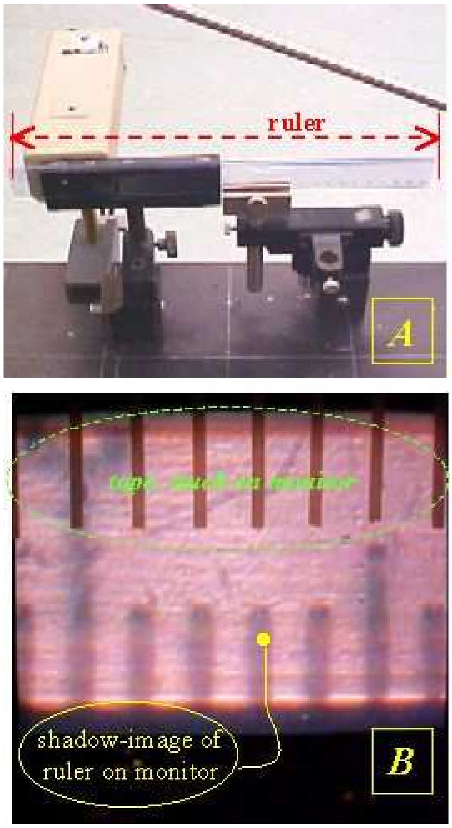


Figure 2

Shadow projection of the mm-lines on the sensitive layer of the camera show these lines on the monitor (we have 7mm across the full width of the monitorscreen; see Figure2B). The geometry of the assembly makes it possible to link the rotation of the mirror to the displacement on the monitorscreen (we have a displacement of around 2.5mm on the camera, corresponding to $\varphi = \frac{d}{2r} = \frac{2.5\times10^{-3}}{2\times2.6} = 0.48\times10^{-3}\,rad$ of M_r).

<u>Demonstration:</u>

The laser is switched on and the lightpath is shown to the students. By hand the rotating mirror is turned until a flash is seen on the monitorscreen. In this position the lightpath is as drawn in the Diagram. The principle of operation is explained to the students: In the time it takes the light beam to travel the distance M_r-M_3-M_r the rotating mirror has made a little angle (ϕ). This is observed on the monitorscreen (angle 2ϕ; see Figure1B).

Also the calibration is explained to the students.

While the speed of rotation of M_r increases the students see an increasing displacement of the lightspot on the monitorscreen. While running at a convenient speed (we use n=500s^{-1} to make calculations easy), this reading and that of the displacement on the monitorscreen are used to calculate the speed of light.

Explanation: During the time (Δt) it takes the light beam to travel the distance M_r-M_3-M_r the rotating mirror has made a little angle (ϕ) that is read from the monitorscreen. Observing the speed of rotation on the frequencymeter, the time it took to make this little angle can

Speed of light; Foucault-Michelson

be calculated. For instance we measure when M_r runs at 500 s^{-1}, a lightspot displacement of d=2.5mm on the monitorscreen. This means an angle of rotation of that mirror of $\varphi = \frac{d}{2r} = \frac{2.5\times10^{-3}}{2\times2.6} = 0.48\times10^{-3}\,rad$. With n=500s^{-1} (500x2πrad/sec) this means a time-span of $\Delta t = \frac{0.48\times10^{-3}}{500\times2\pi} = 0.15\mu\sec$. (So, the displacement measurement on the monitorscreen becomes in this way a Δt-measurement.) Our distance f+b=23meter. This gives us $c = \frac{2\times23}{0.15\times10^{-6}} = 3.1\times10^{8}\,m/s$. (The measurement of the lightspot displacement on the monitorscreen is done very roughly, so our result of c=3.1x10^8m/sec is satisfying.)

Remarks:

- Since 1984 the speed of light is a universal constant (having the exact value of 299792458 m/s; in vacuum). So principally it cannot be measured. Doing this experiment means measuring the distance f+b. But we just do the demonstration and "measure" the speed of light and in the end we mention this "complication" to the students.
- Measuring the speed of rotation with the photodiode is complicated since the lightspot sweeps very fast across the photodiode. We use a +150mm lens to make the lightspot stay longer on the photodiode during its sweep (see Diagram).
- The "grey filter" shown in the Diagram is a variable neutral density filter used to adjust the lightintensity to the camera.

Sources:

- Hecht, Eugene, Optics, pag. 5
- Leybold-Heraeus, Physikalische Handblätter, pag. DK535.222;b