Leibniz-Institut für Astrophysik Potsdam

The Michelson experiment Potsdam 1881

Here, in the eastern basement of the former Astrophysical Observatory on the Telegrafenberg, you see a copy of the interferometer invented by A.A.Michelson at its original place. With the help of this instrument, Michelson tried to measure the influence of the motion of the earth on the propagation of light. In connection with the theory of relativity of A.Einstein, the experiment became so famous that it made its path even into the grammar school books, where it is one of the very few which find some place there to be explained in detail.

The interferometer

The interferometer is able to measure extremly small changes in lengths, and its basic concept is unchallenged in this task. It is an array of mirrors, which admits to see two reflections of one source at nearly identical positions. Thus the beams from the two reflections produce an interference pattern similar to Newton's rings. When one of the paths of the light is changed by only 30 nanometer, this can be observed by a change in the interference pattern.

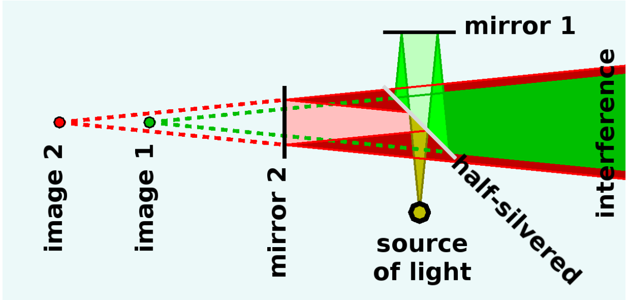


Image formation

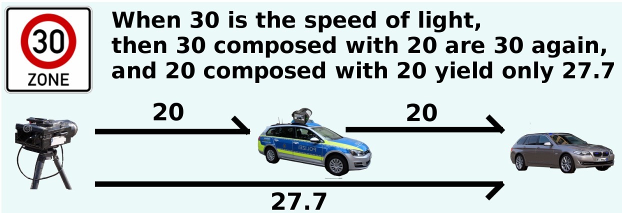
The famous experiment: Michelson intended to demonstrate that his interferometer was able to fulfil the intricate task to verify the effect of the motion of the earth on the propagation of light. It was expected, of course, that the velocity of light is composed with that of the earth like the velocity of a car relative to a patrol with the velocity of the patrol itself. The speed of the oncoming light should exceed the speed of the light which traverses the orbit by 30 km/s. In that case, the distance of the two images would depend on the orientation of the interferometer. Michelson was disappointed. The interferometer did not find any difference in the two velocities. Michelson had to conclude that the propagation of light was determined by the walls, just as the propagation of sound in the air of the basement room had to relate to the walls.

Interferenz

The problem: What is strange with this result? When we expect that the propagation of light is mediated by some ether just as sound by the air, the ether is enclosed in the room precisely like the air. The problem does not consist in the question how a viable mechanical model of the ether could be imagined, but in a tiny and barely spectacular observation. The problem is the aberration of starlight. This aberration is kind of an umbrella effect, which we all experience when we wait for the bus in the rain. It results in the stars closings ranks in the direction of the actual orbital motion of the earth. The effect can be observed only by use of telescopes, but it demonstrates that the earth is really moving in the environment of stars. However, the light is not a rain of drops, but a wave. For the time being, wave fronts do **not** show any aberration. It was A.Fresnel who observed this and found an excuse. He pointed out that a telescope does not measure wave fronts, but excised kind of crests out of the waves and showed that these crests pass the telescope again like droplets. This excuse, however, works only in case the telescope and the walls do **not** hamper the propagation of light, in contrast to the result of Michelson. Many dead ends were searched for a loophole in this dilemma.

Umbrella and aberration

The solution: The contradiction between Fresnel and Michelson can only be resolved if one abandons the common prejudice that the velocity of light is composed with that of the earth by addition or subtraction as we accept it in the case of the street, the car, and the patrol. When we accept that, in compositions with other velocities, the speed of light might change its direction but **never** change its magnitude, all problems with the propagation of light disappear.



Einstein's composition of velocities

It was Einstein who stated this, intrepidly. His arguments were first the relativity of any velocity, which was stated by Galileo more the 200 years before. (When the composition of velocities is a mere addition, one finds, as Michelson expected, a velocity without relation to some material object. When we do not invent the ether, this would destruct relativity.) His second argument was the method used to synchronize distant clocks by light or radio signals. Because one needs the value of the speed of light for doing this, one will later observe just this velocity. The speed of light belongs to the axioms, not subject to scrutinity of measurements.

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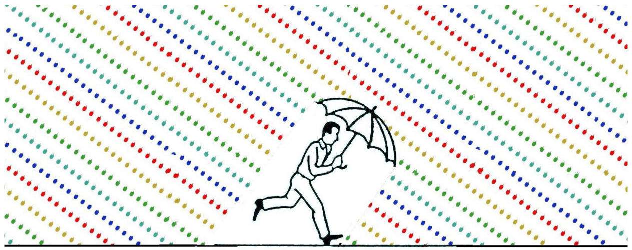
The amazement: Einstein's axiom, which is called a bit ambiguously *constancy of the speed of light*, concerns **exclusively** the invarability of the speed of light in composition with other velocities. This axiom explains many oddities found by intricate constructions in the former dead ends now as simple logical consequences. The most frequently cited of these is the connection between energy and mass. However, the most important is the relativity of simultaneity.

The relativity of simultaneity: We return to the aberration of starlight. When we demand that wave fronts must show aberration, they have to be found inclined into the direction of motion when we start to move. In this case, the wave fronts reach the floor in front of us earlier than expected, and behind us later than expected.



Inclined wave fronts

Events which had been observed as simultaneous, now, after starting, are simultaneous no more. When two observers move with respect to each other, they obtain different results in deciding on the simultaneity of distant events. This conclusion, the relativity of simultaneity as implication of an aberration of wave fronts, was found by H.A.Lorentz already in 1900, but considered as an excuse only. Obviously, it is never observed in everyday life. The analysis of the pending question, how to synchronize real clocks, motivated Einstein to try to develop physics from his axiom. It yielded the theory of relativity. Today, we call it *special*, because another step was necessary to viably include gravitation. Einstein's axiom leads by elemantary geometry to the relativity of simultaneity, and no ether is necessary any more to solve Fresnel's dilemma, or to understand Michelson's result. There are many often cited curiosities connected with the relativity of simultaneity, sometimes called even paradoxes. All are solved by correct observance of this relativity.

Acceptance: When Michelson won the Nobel prize in 1907 for the technics of his interferometer, the importance of the logical presumptions and intermediate steps to the theory of relativity paled beside the experiment. It was seen not only as a backing of the theory, but as its foundation. It was even hailed as proof of the theory. Michelson always rejected this view because he could only prove the failure of Fresnel's excuse, and he constantly tried to find his ether. Einstein won the Nobel prize of 1921 not for the theory of relativity, but for the explanation of the photo effect. Some authors believe that a member of the Nobel committee had tried to develop his own alternative to Einstein's theory (as it is tried in vain by some people even today), and impeded the honouring of the theory of relativity.

The (special) theory of relativity is an exceptionally well backed theory: Not only the various effects are observed. Merely by its structure, the theory led to the explanation of the spin of elementary particles and and to the prediction of the existence of antiparticles.