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The *Doppler* Effect on Light Waves

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Abstract

After the *Doppler* effect on sound, where the sound of a passing vehicle is getting lower and lower, I calculate that in light the change in frequency due to the *Doppler* effect would only be about $5/3\ 10^{-6}$ of the frequency. Because of this, one has to go to the wavelength and look at a distance of about 10^6 wavelengths. Because of the high velocities, the rectilinearly moved receiver is replaced by one rotating on one wheel, in fact two, if you include the opposite one rotating with the opposite direction of speed. Specifically, light from a light source falls on two parallel mirrors mounted opposite each other on a wheel. At a certain angle of rotation, the reflected light comes together in a telescope lens fixed outside in the room and the interference of the two rays is considered enlarged. If the propagation of the light depends on the receiver, the mirrors, and if the distance from the light source to the mirrors is much greater than that from the telescope, the first is predominant and there is interference in contrast to static mirrors. If the propagation of the light depends on the transmitter, the interference occurs with a very large distance from the mirrors to the telescope. Possible dimensions are 500 *revolutions*/*min*, wheel radius = 0.5*m*, distance mirror-wheel = 2.5*m*. The experiment is only conceived, not executed. I expect the light to propagate depends on the receiver, the mirrors. Subsequently, several, even more difficult, tests are given of how to decide that the propagation is rotated with the receiver as it rotates around the transmitter or when one of them is rotated on its own.

Keywords. *Doppler* Effect, Light Propagation.

1. The *Doppler* Effect in General

The aim of this essay is to devise an experiment that proves that there is no *Doppler* effect on electromagnetic waves, especially light waves. If a source generates a signal

$F(t) = (f_1(t), f_2(t), f_3(t))$ at the point $x = (x_1, x_2, x_3)$ of the three-dimensional space, it is conventionally assumed that it radially propagates in the vacuum in the three directions at the velocity of light c. Here, it does not matter that the amplitude decreases, for example with $1/r^2$, where r is the distance from the source, $r = ||y - x||$. Because the amplitude depends only on the distance, it is a one-dimensional problem and I denote with y further any arbitrary but fixed spatial direction and with f the field F in that direction. The signal $f(t)$ is given at point x. At y I get a constant times $f(t)$ with infinitely fast light propagation. Since I do not care about the amplitude and the signal is proportional to that at x, at y I also say $f(t)$. Because of the finite propagation velocity c, I get the signal with the time difference T, which it takes to go through the distance $y - x$. $y - x = cT$, I get $f(t - T) = f(t - (y - x)/c)$. Now I always fix the place of the source and choose it as the origin of the coordinate system, $x = 0$. I only look at different receivers y. The signal simplifies to $f(t - y/c)$.

As mentioned at the beginning, I consider the signal only in one direction y. In the *Doppler* effect, the frequency is changed by a velocity v in that direction. This requires a periodic function f. Therefore, I now go to $f(t) = \sin \omega t$ as the simplest representative of such a function with the signal $\sin \omega(t - y/c)$. The *Doppler* effect is based on a signal dependent only on the source, which propagates in space. It does not matter if it happens in a vacuum or in a medium. Now, as a receiver moves away from the source at velocity v, he sees a slowed propagation velocity of $c - v$ as he moves away from the signal peaks and they follow him, moving towards the source he sees the velocity of $c + v$. With $T = 1/\mu$ I denote the oscillation period, $\omega = 2\pi/T$, and with $\mu = \omega/2\pi$ the frequency. The signal has traversed the path $d = cT$ after T. For the same distance d, if one moves with v from the source $d = (c - v)T_-$, corresponding to the angular frequency $\omega_- = 2\pi/T_- = 2\pi(c - v)/d = 2\pi(c - v)/(cT) = \omega(c - v)/c$ with the frequency $\mu_- = \omega_-/2\pi = (\omega/2\pi)(c - v)/c = \mu(c - v)/c = \mu - \mu v/c$. Similarly, if one moves to the source with $-v$ the increased propagation velocity $c + v$ yields, the same path $d = cT$ and $d = (c + v)T_+$ with the angular frequency $\omega_+ = 2\pi/T_+ = \omega(c + v)/c$ with frequency $\mu_+ = \omega_+/2\pi = (\omega/2\pi)(c + v)/c = \mu(c + v)/c = \mu + \mu v/c$. The frequency μ is essentially reduced by $-\mu v/c$ or set high by $\mu v/c$.

2. The *Doppler* Effect on Sound and Electromagnetic Waves

In the following, I give a numerical example of the *Doppler* effect. If you drive by bus at night on the highway, the traffic has calmed down and a lorry meets you only every 100 meters, you can hear the car sound from a distance with a high note, which is getting closer, louder and louder and gets lower, loudest, when the truck drives past one, then quietens again and gets still lower, until it disappears with a dark tone. This can be explained by the *Doppler* effect. At the beginning you move towards the source, the frequency is increased by $\mu v/c$, later decreased by $-\mu v/c$. The total difference is $2\mu v/c$. Only the velocity in the direction to the source, that is in the radial direction, enters in v. That the sound is getting lower, follows from the fact that this v at the beginning corresponds to the speed of the two vehicles on the highway, as they approach, the proportion in the direction of the distance gets always smaller until it is

after all almost 0 when they lie side by side, since the distance stands perpendicular to the velocity, and then it gets bigger again, but now you move away from the source. Overall, the speed v to be considered becomes smaller and smaller, so that the sound frequency decreases more and more.

In numbers: the trucks drive on the highway about 80*km*/*h*, so that it can be calculated easier afterwards, I say 90*km*/*h*, because they come from opposite directions the double speed counts, v = 180*km*/*h* = 180/3.6 *m*/*sec* = 50*m*/*sec*. The propagation speed of the sound is 330*m*/*sec*. v/c = 50/330 = $0.\overline{15}$…. The difference between the highest frequency μ_+ and the lowest frequency μ_- is $2\mu v/c = 2\mu\ 0.\overline{15}\ldots = 0.\overline{30}...\mu$. The value of v/c = 50/330 = 5/33 delivers μ_+ = 38/33 μ and μ- = 28/33 μ, the ratio of the two frequencies amounts to 38/28, ie about 4/3.

In the case of electromagnetic waves, for a ratio of v/c = 5/33 at v, it would be necessary to generate a speed of 300,000 5/33 *km*/*sec*, ie almost 50,000*km*/*sec*, which is in reality bad to manage. I now calculate which frequency shift you can really expect, if there is a *Doppler* effect. I'm assuming a wheel with a radius of 1 meter, which rotates with 5000 revolutions per minute. The circumference moves at a speed of 2π 1*m* 5000/*min*. π = 3.1415..., 2π = 6.283... ≈ 6. I'll cancel that for the 60 seconds and get the speed 500*m*/sec. It is equivalent to 3.6 times the kilometers per hour, ie 1800 kilometers per hour. For v/c I get 500/(3 10^8) = 5/3 10^{-6}. The *Doppler* effect assumes that the signal propagates in space at fixed velocity c. If I move to the transmitter with speed v, the wavelength λ remains unchanged. Only because of my velocity v do I see a propagation velocity of $c - v$ and thus a frequency $\mu_- = (c - v)/\lambda$. Regarding the frequency shift, I notice nothing at the small value 5/3 10^{-6}. You can also let the transmitter, as above the truck, move with v. Then the propagation velocity c remains, the frequency changes to μ_+ and thus due to $c = \lambda + \mu_+$ the wavelength. Now, one can prove a change in frequency over the change in wavelength by tracking the signal over so many wavelengths λ that the total change at the end of the path is approximately in the range of one wavelength. We have $c = \lambda_+\mu_+ = \lambda_+\mu(1 + v/c)$. It follows that $\lambda_+ = c / (\mu(1+v/c)) \approx (c/\mu)(1 - v/c) = \lambda(1 - v/c)$. The wavelength change $-\lambda v/c$ is therefore calculated roughly the same as the frequency change $\mu v/c$ only with the sign reversed. To determine the sum of all wavelength changes $n\lambda v/c$, it must be in the range λ, that is $n = c/v$ = 3/5 10^{-6} = 0.6 10^{-6}. I have to track the signal roughly over a distance of 10^6 wavelengths. Visible light has a wavelength of about 0.5 micrometers = 0.5 10^{-6}*m*. There would suffice a distance of 50*cm*, roughly 1 meter. The lengths of the ultra-short wave range from 1*m* to 10*m*. At 1*m* you would need a distance of 1000*km*. At only 1*cm* you have to take 10*km*. The last two wavelengths are not easy to use. That's why I find it easier to try with light, especially as you can see light. You could reduce the number of revolutions, which I have stated above with 5000 revolutions per minute, to 1/10. This then gives 500 revolutions, corresponding to 180*km*/*h*, and 1/10 v. The number of necessary wavelengths is then increased tenfold to $n = c/v$ 10, about 10^7, at λ = 0.5 10^{-6}*cm* you would need the realizable distance of 5*m*. One has to look at the superposition with a wave not changed by a speed v through a telescope. But that only applies if there is a *Doppler* effect. *Doppler* was a graduate of Technical University Vienna.

3. The Expected Wavelength Differences

Again, it's about showing that there is no *Doppler* effect with electromagnetic waves. The *Doppler* effect is based on the fact that a transmitter emits a signal, which can be received by each receiver only depending on the speed of the transmitter and the distance with respect to the receiver. Thus, the *Doppler* effect was caused by the sound in the medium air. Similarly, the explanation in a vacuum on electromagnetic waves takes place. If you want to show that there is a *Doppler* effect and you see a change in the frequency of the wave at differently fast transmitters, you have to prove the frequency change, because it is too small, about the resulting change in wavelength, which is over several meters added up to a half wavelength. But I say, one does not notice a *Doppler* effect and does not see a change in the frequency of the wavelength at differently fast transmitters, so a zero effect. This is due to the fact that light always propagates at the speed of light with respect to the receiver, independently of the transmitter. Differently moving receivers then see different signals. There is no *Doppler* effect, because the signal moves at the speed of light towards the receiver and exerts a force there. Without a receiver, nothing is broadcast in the space. There are no waves that fill the space. For details on the light emission, I think after the following description of the experiment.

Before that I calculate the wavelength change in different receivers, which is similar to the above and so far brings nothing new. The light always propagates at the speed of light c with respect to the receiver, ie with $c + v$ and $c - v$. We have $c = \lambda_+\mu_+ = \lambda_-\mu_-$. The wave runs after the receiver with v or $-v$. This means that the receivers see the same frequency $\mu_+ = \mu_- = \mu$ and the same wavelength. The differences in the wavelength can be seen when the two waves are superposed. $\lambda_+ = (c + v)/\mu = (c/\mu)/(1+ v/c)$, $\lambda_- = (c - v)/\mu = (c/\mu)/(1 - v/c)$. The wavelength difference amounts then to $2v/\mu$. The frequency for a mean wavelength of $0.5\ 10^{-6}m$ is calculated as $\mu = c/\lambda = 3\ 10^8 m/sec\ /\ (0.5\ 10^{-6}m) = 6\ 10^{14}/sec$. With the above-mentioned values for 5000 revolutions per minute, one then obtains $v/\mu = 500m/sec\ /\ (6\ 10^{14}/sec) = 8.\overline{3}...10^{-13}m$. In order to get into the range of a wavelength, one would have to set about 10^6 lengths in succession ($0.5 \approx 0.83$). At $\lambda = 0.5\ 10^{-6}m$ this corresponds to a distance of $0.5m$. At 500 revolutions per minute you get 1/10 of v/μ and you need 10^7 lengths corresponding to $5m$. But the wavelength difference is generated by $2v/\mu$ because of the opposite speeds and it is $2.5m$. The experiment cannot be carried out quite easily and demands high accuracy.

4. The Experiment

The difference in wavelength between a stationary observer moving in a straight line at a sufficiently high speed is difficult to produce. Therefore, I replace the comparison with the static observer by one with two observers moving on a circle in opposite directions. I compare two opposing observers at opposite speeds. The speed difference is then $v - (-v) = 2v$. To do this, I send light from a fixed source to two opposing mirrors rotating on a circle whose mirror plane is perpendicular to the tangent vectors. The mirrors are then in a plane with the surface on the same side. The

light always falls out in parallel again. Once during a turn, just at the right moment, it falls 45° in and out. Then it should shine in the same place in a telescope. Here I observe the interference of the light rays from the two mirrors. In order for them to hit the same spot in the telescope, I have to turn the mirrors slightly out of the common plane. First of all, I compare the interference at low v ($v \approx 0$) and high speeds.

The more detailed description looks like this. I use light of a monochromatic wavelength, which today is cheap from laser lamps. The source is located in the Cartesian coordinate system high on the z-axis. The light falls in the negative z-direction on the two mirrors on a circle with the radius r. These rotate in the x-z-plane around the zero point with the velocity $|v| = \omega r$. When the mirrors are just at $(r,0,r)$ and $(-r,0,-r)$, the light in the x-direction radiates to the same spot in a telescope, and I observe the interference of the two waves. Otherwise, the mirrored light beam rotates meaningless in a circle. At the first half turn, with the mirror surfaces facing up to the light source, the light is thrown against the wall, at the second half turn, the mirror surfaces face down, so you do not see any reflected light, unless you're using semi-transparent mirrors. Waves propagating in space, apart from the amplitude, can be described as $\sin(\omega t - kx)$. ω is the angular frequency, $\mu = \omega/2\pi$. The propagation velocity is $c = x/t = \omega/k$. The wavelength is $\lambda = 2\pi/k$. In addition, $c = \lambda\mu$, $\lambda = c/\mu$. For velocities $c + v$ and $c - v$ the wavelength is changed by v/μ and $-v/\mu$. With the values calculated above for a wheel with a radius of 1 meter and 5,000 revolutions per minute, I would then get $v/\mu = 500m/sec \,/\, (6\ 10^{14}/sec) = 8.\overline{3}...10^{-13}m$. In order to achieve a wavelength of $0.5\ 10^{-6}m$, you had to go through this length about 10^6 times, ie a distance of $0.5m$. At 500 revolutions per minute you would get 1/10 of v/μ and you would need 10^7 lengths corresponding to $5m$. If I take instead of the too big radius of the wheel only the half of $0.5m$, $2v$ comes in because of the opposite speeds, so that everything cancels each other out again. At the end of all, you need a distance of $5m$ from the lamp to the wheel for 500 revolutions per minute. All this applies to a full wavelength λ. For the waves to lift away, however, a path difference of half a wavelength $\lambda/2$ must be achieved. This requires a distance of $2.5m$. So that the waves do not accumulate due to a random distribution, one may need to take polarized light. You definitely need coherent light.

From the mirrors, the light is blasted again into a telescope. In this way, the propagation speed depends on the receiver, the telescope, and is the same for both beams. If it depended on the transmitter, then you would have to keep this distance correspondingly short so that it has little overall impact. The reflected light is due to the fact that the incident light acts on the mirror surface, electrical components such as electrons vibrate and new light is emitted. Thus, light emerges as from a light source that propagates at the speed of light with respect to the receiver, that is, the telescope. In the whole, it does not matter if you have hit the distances exactly like a distance of $2.5m$, you only have to notice a difference between a very slow speed v and a high one. The distance of the upper mirror on the circle with radius r at the point $(r, 0, r)$ to the z-axis is $r/\sqrt{2}$, so that its path to the horizontal telescope is longer by $2r/\sqrt{2} = \sqrt{2}r$ than that of the lower mirror. This must be considered in the coherence length of the light. You can also direct the telescope from the direction

(r,0,-r), ie at an angle of 45°, from the top left to the mirror. Then both mirrors have the same distance to the telescope in the moment to be measured.

You can also do the counter-sample whether the propagation velocity depends on the receiver by reversing the direction of radiation. It is necessary to replace the telescope with the light source and vice versa. If the light source, which is now actually in the mirrors, would determine the propagation, a phase difference would have to occur on the long path to the telescope, which is at rest. Of course, the assumption that the propagation velocity comes from the receiver means that there is already a phase difference from the light source to the mirrors. This happened for a wavelength λ in the factor v/μ of about 10^{-6}. You have to suppress this by choosing the path from the light source to the mirrors much shorter than that from the mirrors to the telescope. In the experiments on whether the propagation speed depends on the source or the receiver, so the distances of the mirror to the telescope and the light source are played out against each other.

5. The Meaning of the Experiment

That the electromagnetic waves propagate at the speed of light with respect to the receiver, means each receiver sees a different wave. There is no wave without a receiver and no wave in an empty space without objects. The Poynting vector $S = E \times H$ is then nonsense. The electric field E possesses the dimension *force by charge*, the dimension of H can be calculated from the equation: the path integral over H around a current-carrying conductor is equal to the current perpendicular through any surface that is bounded by the path. *Charge* is *current* times *time*. If you put this in, current cuts out, leaving *force*/(*way time*). Expanding this with the way you get *energy*/(*area time*), that is an *energy density per time* or *power per area*. The Poynting vector is intended to represent the energy per time flowing perpendicularly through the unit area piece spanned by E and H. As I said, it is not sensible to assign a wave energy to a spatial point in the receiver dependence of a wave. The electromagnetic waves propagate in the form of a sphere in space, as is conventional. You can say that if the propagation depends on the receiver and you have arranged around the transmitter on a ball many receivers that move with the direction and the amount of constant velocity v, but otherwise do not affect each other and also do not affect the transmitter, each one of them would follow the wave at the speed of light. That's why you can refer everything to them and look at the center of their sphere as the origin of the coordinates. They then rest and the light source moves backwards with (-vt,0,0). The light source no longer plays a role after the light generation, because the light propagation depends on the receiver. The light, which was emitted at $t = 0$, moves towards the now resting spherically arranged receiver, ie on a sphere. Returning to the old reference system, the light wave moves to spheres of radius ct and center velocity (vt,0,0). So it spreads spherical again, but on with (vt,0,0) moving balls. It would not change much if it were now propagated on a sphere stretched in x-direction, that is, an ellipsoid with the largest half-axis in the x-direction.

6. The Meaning of the *Michelson* Experiment

As may have been noticed, the experiment proposed by me is modeled after the experiment of *Adam Abraham Michelson*, which was first performed in 1881. Essentially, the difference is that at *Michelson*, the mirrors do not spin but rest. The experiment of *Michelson* is nonsense, because he starts from a kind of absolute space without reference to objects. In reality, however, objects act on other objects through forces, as above the transmitter to the receiver. This suggests to refer the radiation of the forces to the affected objects, the easiest way to take the transmitter or the receiver. I will briefly describe the *Michelson* experiment. In short, it lets light fall from a light source, such as on the z-axis in the negative z-direction, to a semitransparent, 45°-rotated mirror, may be at zero. A part goes through, is reflected by another mirror by 180°, falls back onto the rotated mirror and from there rotated by 90° in a telescope may be on the positive x-axis. The other part of the light goes from the rotated by 45° mirror perpendicular to the transmitted part to a third mirror, may be in the negative x-direction, from there back and through the rotated mirror also into the telescope. Essentially, the two rays returning to the rotated mirror are compared, magnified by the telescope. These are two transmitters and receivers with a fixed distance. The rays pass through mutually perpendicular paths. *Michelson* meant that the Earth should have different velocities in vertical directions. In fact, at an earth radius of approximately $r = 150\ 10^9 m$, a velocity is obtained of $v = 2\pi r/1 year \approx 6\ 150\ 10^9\ m/(365\ 86400\text{sec}) \approx 900\ 10^9\ m/(360\ 864\ 10^2 sec) = 10^8/(4\ 864)\ m/sec = 10^8/3456\ m/sec \approx 3\ 10^4 m/sec$. This exceeds my initially at 5000 revolutions per minute and a wheel radius of 1 meter introduced $v = 500 m/sec$ to the 60-fold. But regardless of whether the propagation velocity depends on the receiver or transmitter, the difference in velocity between the two is 0. A propagation with c in relation to one is also one with c in relation to the other. The distance between both remains constant r. Here one can take any time-dependent $v(t)$. Both when the propagation speed depends on the transmitter and when it depends on the receiver, the light passes through the path r at speed c and time r/c, is reflected and again traverses a distance of length r with c in time r/c independent of $v(t)$. With the experiment proposed by me with different moving transmitter and receiver, you can at least determine whether the propagation speed depends on the sender or receiver.

7. A Thought Experiment

So far, I have tacitly assumed that transmitters and receivers move on a straight line. But you can also change these two arbitrarily in space, in particular rotate. Also in this case, I claim that the propagation depends on the receiver. This can be distinguished by the following thought experiment from the other way. A *Hertzian* dipole shall be perpendicular to the x-y-plane and emit waves. If the amplitude $A(r)$ is received at a location in the x-y-plane with the distance r, the amplitude $A(r)\cos\theta$ is obtained in the z-direction further up on the same sphere of radius r, where θ is the angle of the new radius vector to the x-y-plane. If the propagation depends on the receiver, then, if it suddenly moves upwards from the x-y plane, it will also get there the amplitude $A(r)$

which it would have received with infinitely fast wave propagation in the plane. If the emission depends on the transmitter, it would only notice the amplitude A(r)cosθ above at greater z, where θ can be determined from sin$\theta = z/r$. Because the speeds required to measure the field would be too high, it remains a thought experiment.

Another experiment can be made to see that a beam of light is actually rotated in space, and it is indistinguishable whether it depends on the receiver or the transmitter. In the conventional sense, a ray of light propagates in a straight line in the space. I attach a transmitter and a receiver at a distance r on a rod. The transmitter emits a parallel wave bundle of thickness d exactly on the receiver. It is also sufficient if the waves are focused in the receiver to a point of thickness d, where d also represents the diameter of the receiver at the same time. Now, if the rod with the receiver and the transmitter is turned very fast, so that the transmitter remains in the center of the rotation, and the radiation occurs in a straight line in space, the receiver has moved a bit farther before the wave arrives at it, and the wave goes past it on the background. However, if the propagation is directed by the movement of the receiver or transmitter, the beam will turn with it and always hit it, leaving the background untouched. The whole thing is true even if the transmitter and receiver face each other on the edge of the circle, which is rotated around its center.

I now state the proportions for this experiment, where it can be seen that it is difficult to perform. The wave needs the time $t = r/c$ from the transmitter to the receiver. At U revolutions per second, the bar end returns the path $2\pi rUt$ in t seconds. The minimum distance for r/c seconds is d. So it holds

$$2\pi rU\, r/c = d \text{ and thus } U = dc/(2\pi r^2). \qquad (1)$$

At the beginning I talked about 5000 revolutions per minute. 5000/min = 500/6 1/sec. If I choose $d = 1mm = 10^{-3}m$, I get dc = 3 $10^5 m^2/sec$. 2π I estimate again with 6. It follows U = 3 $10^5 m^2/sec$ / 6r^2 = 500 $10^2 m^2/sec$ / r^2. Because U = 500/6 1/sec, I can cancel 500 and get 1/6 1/sec = $10^2 m^2/sec$ / r^2. The equation is satisfied by the distance $r = 10\sqrt{6}\ m$. This brings you to the limits of the possible. But you can rotate the arrangement around the center of the rod. Then the radius is halved, so also the speed $v = \omega r/2$. Instead, the bar ends turn in the opposite direction, which cancels everything out again by the factor 2. One only sees an effect when the beam spreads in relation to the transmitter, which I deny. This also applies to the following two refinements of this experiment. In the last improvement, however, one sees an effect when the propagation of the beam depends on the receiver.

You can increase the effect, if you send the ray between two mirrors back and forth several times. Because then the light source is in the way of the beam, you have to throw it from the back perpendicular to the first now semi-transparent mirror so that it goes back and forth between this and the second at rest. The distance r between the two mirrors is now the diameter of the circle, the radius $r/2$. For this purpose, one considers that the circle edge advances by $2\pi r/2\ Ut$ in the time t, correspondingly expressed in angle $\varphi r/2$, so $\varphi = 2\pi Ut$. The wave needs r/c to the end of the rod. The circle edge passes through the angle $\varphi = 2\pi Ur/c$. This corresponds to the angle of incidence at the other end and at the same time the angle of reflection. Until the beam

returns to the beginning, the rod again sets the angle φ back so that the beam enters at 2φ and exits at 2φ and so on. With every return to the beginning always 2φ comes to it. After n passes, the angle is $2n\varphi$ and at the opposite mirror $(2n+1)\varphi$. At high rotational speeds, the beam would then partially fall next to the mirror. Above I got the equation (1) $2\pi rU\ r/c$ = d. The distance traveled by the light retains its value r. The radius of the circle becomes $r/2$. It follows that

$$\pi rU\ r/c = d \text{ and } \pi Ur^2 = dc,\ U = dc/\pi r^2. \qquad (2)$$

This corresponds to $\varphi r/2$. If the beam goes back and forth twice or more, you get $rn\varphi$, corresponding to $2nd$. One only needs to achieve $d/2n$ for a single reflection and can work with $r/\sqrt{2}n$. At the top was $r = 10/\sqrt{6}\ m$ and, because d is included in the equation linearly and r squared, now suffices for $n = 3$ only $r/\sqrt{6} = 10m$, where r is the light path and the diameter, and the radius amounts to half of that, namely $r/(2\sqrt{6}) = 5m$. That's still pretty big.

A further refinement of the measurement accuracy is obtained by the following experiment. One sends the beam only once from the light source to a receiver. But before this you bring a slot or multiple slot. In a "*Physics lab for beginners*" of the University of Kaiserslautern in the experiment "*Diffraction at the slot*" I found out that slot widths of 65 and 55 micrometers are used. I take such a slot for my d, that is, $d = 5\ 10^{-5}m$ and measure the light falling behind at rest and very high rotations. Apart from that I take the values from the very first experiment, $U = 500$ *revolutions/sec*. As with the very first experiment applies

$$2\pi rU\ r/c = d \text{ and thus } 2\pi Ur^2 = dc. \qquad (3)$$

d is reduced from $1mm = 10^{-3}$m by a factor of $5\ 10^{-2}$ to $d = 5\ 10^{-5}m$. At $r = 10\sqrt{6}m$, this allows the value $r\sqrt{5}/10 \approx 0.22r$. This still gives too large a value of $\sqrt{30}m \approx 5.5m$ or $2.75m$ in half diameter. In these experiments, the light would have to fall next to the mirror or slot if the light propagates in a straight line in the space.

With the third and last improvement of the experiment you can check if the radiation depends on the receiver. It's all done the same way, but I'm measuring the light behind the spinning slot, with a device moving with it. The slot acts as a receiver and would, if my assertion is correct, move the light beam in the direction of rotation. I measure that through a telescope with photosensitive material behind it, which, as I said, are both turned. The light source, however, is fixed in space and hits the slot only once in one revolution. That does not bother, because the slot enters its shine a hundred times a second. To improve the sharpness you can still attach a fixed in space aperture in the beam direction. The proportions are similar to those just, but a telescope with hundredfold magnification increases the shift hundredfold. If I choose just as 500/6 *revolutions/sec* and $d = 5\ 10^{-5}m$, I achieve the displacement d with $r = 10\sqrt{6}m$ according to the equation (3) $2\pi Ur^2 = dc$. With $r/7 = 10\sqrt{6}/7\ m \approx 25/7\ m \approx 3.57m$ I get $d/49 = 5/49\ 10^{-5}m \approx 5/50\ 10^{-5}m = 10^{-6}m$. With a hundredfold magnification, I only need to distinguish $0.1mm$, which seems the most feasible.

In these experiments, the receiver rotates around the transmitter or both rotate around a common center. Because you need too large distances r, the velocities $v = \omega r$

become too large. Therefore, it is best to try to replace it with one in which one lets the location of both the sender and the receiver in space and lets one of them rotate around itself. This also creates a rotational movement with respect to the other part. If the propagation is determined by the transmitter, at high rotational speeds the beam would have to arrive shifted at the receiver if the propagation is dependent on the receiver, not. When the broadcast is guided by the receiver, the reverse is true, that is, a very fast-rotated receiver rotates the beam as compared to a resting one. So you can see here as in chapter 4. "*The experiment*", whether the propagation depends on the receiver or transmitter. There, the location of receiver or transmitter was reversed, here, whether they turn or not. This last experiment is not just a mere experiment at thought, but you can actually perform it. However, it requires high accuracy, much the same as the very first experiment with the rotating mirrors.

When the receiver determines the light propagation, I measure the incoming light direction by the following device. The rotating wheel is a narrow tube about $0.1m$ in length, through which the light must pass. In this I let the light in addition through slots and apertures enter and exit. Inside the tube, you can also attach a lens system, which bundles the beam so that it becomes very sharp. But you have to put it in the dark of the tube, which may then be thickened in the lenses. All of the slots, apertures and lenses are fixed together with the rotating tube and all rotate at the high rotational speeds. If these determine the light propagation as a receiver, the light beam is bent. For the distance r between the light source and the tube, the light needs the time $t = r/c$. During this time, the receiver has moved according to the previous equation (3) by $\varphi = 2\pi U\, r/c$. This represents the change in the direction of radiation. I choose high values as at the beginning of the chapter, $U = 5000\ revolutions/min$, the size $r = 10m$ is now not too much, 2π I estimate again with 6 and get $\varphi = 2\pi U\, r/c = 6\ 5000/60\ 1/sec\ 10/(3\ 10^8)\ sec = 5000/3\ 10^{-8} = 1.\overline{6}...10^{-5}$. That's radian. If I look at the deflection of the beam at a distance of $6m$, I have to take 6 times and get $5/3\ 10^{-5}\ 6m = 10^{-4}m$. Behind the receiver, I observe the displacement with a telescope with a hundredfold magnification. Then I have to distinguish only $10^{-2}\ m = 1cm$, which seems executable. For the last $6m$, the last receiver, for example the wall, rests and the beam is not turned further.

On the other hand, if the rotation of the beam depends on the transmitter, you would need to fix the light source on a rotating wheel and focus the beam at the stationary receiver as above, but now with a fixed tube, slots, apertures and lenses. The dimensions for the sizes used remain the same. I have to be able to detect a change in the beam direction of $10^{-2}m = 1cm$ with a telescope. For this I put the fixed tube on a device that can be adjusted with millimeter screws. The direction in which most of the light passes is the beam direction.

All this together means that accurate measurements can also be used to determine whether a beam of light is being rotated by rotating transmitters or receivers and whether the rotation is reigned by the transmitter or receiver, similar to the straight-line propagation.

8. Possible Forces

Now I think about which forces are compatible with usual ideas. I am not a follower of the law of conservation of energy, but one may require that the law of conservation of energy holds in the simple form: kinetic energy plus potential energy is constant. Another simple requirement is the third *Newtonian* law *actio = reactio*. I read this as the forces between objects in space are the opposite, in fact *actio = -reactio*. This means $m_i\ddot{x}_i = \Sigma_{j\neq i} K_{ji}$ with $K_{ji} = -K_{ij}$. First, the law of conservation of energy for forces possessing potential holds, $K_{ji} = -d/dx_i\ P_{ji}$. For if you multiply with $\dot{x}_i$ and integrate, so form the path integral, and sum, you get

$$\sum_i m_i/2\ v_i^2 - \sum_i m_i/2\ v_{0i}^2 = \sum_i \int m_i\ddot{x}_i\dot{x}_i dt = \Sigma_i \int \Sigma_{j\neq i} K_{ji}\dot{x}_i dt = \Sigma_i \int \Sigma_{j\neq i} (-d/dx_i\ P_{ji})\dot{x}_i dt =$$
$$\Sigma_i \Sigma_{j\neq i} P_{ji}(x_i(t_0)) - \Sigma_i \Sigma_{j\neq i} P_{ij}(x_i(t)).$$

The total energy of the system is conserved, the conserved quantity consists of the sum over $m_i/2\ v_{0i}^2$ and the double sum over $P_{ji}(x_i(t_0))$.

The following types of force are *not* suitable for energy conservation. The force depends on the location and rotates around a point, such as $K = (-2y,2x,0)$. It has no potential $P(x,y,z)$, because the second partial derivatives of P to x and y should be equal, but $P_{xy} = (-K_1)_y = 2 \neq -2 = (-K_2)_x = P_{yx}$. In the following, I always set the mass to 1. The equations of motion are then $\ddot{x} = 2y$, $\ddot{y} = -2x$. Solutions are $x = e^{-t}\cos t$, $y = e^{-t}\sin t$, because

$\dot{x} = -x - y$, $\dot{y} = -y + x$. $\ddot{x} = x + y + y - x = 2y$, $\ddot{y} = y - x - x - y = -2x$.

For e^{+t} instead of e^{-t} the equation of motion does *not* hold because of the wrong sign

$\dot{x} = x - y$, $\dot{y} = y + x$. $\ddot{x} = x - y - y - x = -2y$. $\ddot{y} = y + x + x - y = 2x$.

In both cases I obtain for the kinetic energy $1/2\ (\dot{x}^2 + \dot{y}^2) = 1/2\ ((x + y)^2 + (x - y)^2) = x^2 + y^2$. In the first case this results in e^{-2t} and goes for t against infinity towards 0, in the second e^{2t} and it goes towards ∞.

Impossible is also a force that goes in the direction of velocity and depends on the velocity, $K = (-v,0,0)$ or $K = (v,0,0)$. The solution would be $x = -e^{-t} + k$ or $x = e^t + k$ with a constant k. For $k = 0$, the kinetic energy would again go to 0 or ∞.

Bad is also a time dependent force like $K = (t,0,0)$. The solution $x(t) = t^3/6 + at + k$ again gives $v = t^2/2 + a$, which tends to ∞ including v^2.

Difficulties are caused by a force that is delayed in time by r/c like a light wave. I first consider the one-dimensional harmonic oscillator $\ddot{x} = -x$ with the center of force at zero. The force coming from there would have to arrive late with r/c. Because everything happens only on one straight line, $r = x$. So the equation is

$\ddot{x}(t) = -x(t - r/c) = -x(t - x/c)$). For x/c, the place where the mass was when the wave started, so it would have to be $-x(t - x(t - x/c)/c)$) and at the last x one would again insert $t - x/c$ and so on. Because I am not progressing, I take the two-dimensional oscillator $\ddot{x} = -x$, $\ddot{y} = -y$ and the initial conditions are chosen so that at infinitely fast propagation $x = \cos t$, $y = \sin t$ is a solution. The distance from the center of force is then constant $r = 1$. So the force should act $(-\cos(t - r/c), \sin(t - r/c))$. It is not perpendicular to the tangent to the circle with radius r, namely $(-y,x) = (-\sin t, \cos t)$, so has a share in the tangent direction and velocity direction. As a result, the body is driven faster and driven outward. Further out, the potential of the force $P = 1/2\ (x^2 + y^2)$ is increased, so that the speed and the potential energy, ie the total energy, increase. Therefore, with a $(t - r/c)$ dependence, the law of conservation of energy does not always hold and I therefore exclude such forces. I suggest that forces with a potential, which then depends on the location, spread infinitely fast. That is, the electrostatic forces emanating, for example, from a stationary electrically charged ball, possess an infinite propagation velocity. I cannot prove the infinitely fast radiation of static forces. My experiments are not meant for that. It should also be extremely difficult to prove. I separate these forces from those that come from a movement, such as a *Hertzian* dipole. For the last I prove in the following generally a conservation of energy.

Energy conservative is a force that is perpendicular to the speed. Apart from that, this force K can depend on everything, the place, the time, the speed and can have any time delay. It is perpendicular to the velocity v, that means the scalar product $(K,v) = 0$ for all times. We have $d/dt\ m/2\ (v,v) = (m\dot{v},v) = (m\ddot{x},v) = (K,v) = 0$. Hence, $m/2\ v^2 = m/2\ (v,v) =$ constant. This does not only apply to one body in the force field, but also to two bodies that interact with each other. A force perpendicular to v can be represented as a cross product $K \times v$ with another K. The proportion in the direction v is simply cut off. Here I must suppose the third *Newtonian* law in the way the interaction is the opposite. The bodies move at velocities v and w and experience the forces $K \times (w - v)$ and $K \times (v - w) = -K \times (w - v)$. v is always perpendicular to $K \times v$, $(K \times v, v) = 0$. It follows that $(K \times (w - v), v) = (K \times w, v) - (K \times v, v) = (K \times w, v)$, correspondingly $(K \times (w - v), -w) = (K \times (v - w), w) = (K \times v, w)$. The sum of the two forces is 0. They are the opposite, because $(K \times (w - v), v) + (K \times (v - w), w) = (K \times (w - v), v) + (K \times (w - v), -w) = (K \times (w - v), v - w) = 0$. Now I build the derivative of the kinetic energy.

$$d/dt\ (m_1/2\ (v,v) + m_2/2\ (w,w)) = (K \times (w - v), v) + (K \times (v - w), w) = 0.$$

From this follows the conservation of energy. If it applies to two each, it is also true for many. As forces $K_{ji} \times (v_j - v_i)$ and $K_{ij} \times (v_i - v_j)$ work with $K_{ji} = K_{ij}$. The opposite sign of the forces comes only from the interchange of velocities. I get that

$$d/dt\ \Sigma_i\ m_i/2\ (v_i,v_i) = \Sigma_i\ \Sigma_{j \neq i}\ (K_{ji} \times (v_j - v_i), v_i) =$$

$$\Sigma_{i<j}\ (K_{ji} \times (v_j - v_i), v_i) + (K_{ji} \times (v_i - v_j), v_j) = \Sigma_{i<j}\ 0 = 0.$$

9. Summary

The proposed experiment is to show that electromagnetic waves are formed as if they propagate infinitely fast, but then only with respect to the receiver, not to the transmitter, are radiated at the speed of light, following the receiver in the space with all its movements and rotations. If you ask for the law of conservation of energy, this propagation does not apply to the electrostatic field. It differs from the fact that it spreads infinitely fast, which the experiment does not explain and which is sure as good as not to show.