Natuurkundig Onderzoeks- en Ontwikkelingsbureau
BonPhysics
Research and Investigations B.V.
Laan van Heemstede 38, 3297 AJ Puttershoek

Proposal for the repetition of the Michelson-Morley experiment ala Demjanov

Dr. ir. ing. V.O. de Haan

Preface

This proposal gives an overview of the investment needed for the realization of a repetition of the famous Michelson-Morley experiment.

The experiment and the interpretation of its measurements have been a source of controversy ever since the first version was performed in 1881 by Michelson in Berlin. This controversy is alive as ever and deals with the existence or non-existence of the light carrying medium or ether.

The experiment has been repeated many times with different instruments under different conditions always giving results that seem to be in favor of the non-existence of the ether. However, when Prof. Demjanov repeated the experiment systematically in the 1960's, he showed that the effect was at least a factor of 40 smaller than previously expected. Because of this, the so-called null-results can also be interpreted as due to the limited accuracy of the measurements. Especially as it has been shown that the data reduction of many of these measurements contained systematic errors, reducing the measured effect even more.

Using modern day technology and computer aided data acquisition it is possible to rebuild the interferometer of Michelson-Morley in a more stable way and perform measurements that are much more accurate. These modern day interferometers have been constructed and experiments performed. However, in the design of these interferometers the important findings of prof. Demjanov have not been included. He discovered that the effect is proportional to the difference of the refractive index with respect to 1. Unfortunately, all modern day interferometers are operated in vacuum, giving a null-result within experimental accuracy.

According to prof. Demjanov, if these interferometers would be operated with air or other gases with refractive index differing from 1, the measurements would clearly indicate the existence of the ether.

The contents of this proposal was generated by BonPhysics by means of

resources of BonPhysics,
information obtained from prof. Demjanov,
references as quoted in the reference list.

Contents

1. Introduction

Since at the end of the 19th century methods became accurate enough to measure the speed of light, experiments were devised to measure the anisotropy of the speed of light at the Earth surface. This was sought to be done by so-called first order experiments, where the effect depends in first order on the ratio v/c, where v is the velocity of the observer with respect to a preferred rest frame and c is the speed of light in this frame. When Fresnel [1] introduced his famous Fresnel drag coefficient it was believed that all possible first order effects were compensated by an ether drag. Then Maxwell [2] came along with the notion of second order experiments, where the effect depends in second order on the same ratio. Although Maxwell thought at that time it would be beyond any means of experimental method to measure a second order effect, one year later in 1881 Michelson [3] devised an apparatus that should be able to measure the change of the velocity very accurately. The apparatus is now known as a Michelson-Morley interferometer. After some comments on the experiment by Lorentz in 1886 [4] Michelson and Morley [5] increased the sensitivity of the apparatus with almost a factor of ten overcoming the accuracy objections of Lorentz. The accuracy of the apparatus was further increased with a factor of 6 by Morley and Miller [6] and by Miller in a series of experiments between 1905 and 1930 [7,8,9,10]. In all these experiments the *expected* magnitude of the effect was never observed. This is satisfactorily explained by the Lorentz-Fitzgerald contraction [11] or by Einstein's theory of relativity [12].

However, Miller in his elaborate series of experiments, always claimed that he measured a small second order effect and also a first order effect. The second order effects were quite small with respect to the *expected* magnitude for the effect, but larger than the experimental error. He analyzed these second order effects by combining measurements at different epochs. Assuming the Sun moves relative to the preferred rest frame he was able to find a preferred direction in space and a velocity. The first order effect depended very much on the detailed experimental settings and were not analyzed to find an anisotropy.

In February 1927 a conference on the experiment and theoretical background was held at the Mount Wilson Observatory [13]. This conference did not succeed in finding a flaw in either experiment or theory, leaving the discrepancy intact. In view of this discrepancy some researchers tried to find experimental evidence of first or second order effects in Michelson-Morley interferometer type instruments. This has been done by, for instance, Piccard [14,15], Illingworth [16] and Joos [17]. All these authors report the absence of the expected magnitude of the effect.

In 1955 Shankland, a former pupil of Miller, re-analyzed Miller's data [18] and concluded that the second order effects do exist and remarks that *they remain essential constant in phase and amplitude through periods of several hours and are then associated with a constant temperature pattern in the observation hut*. Assuming that during several hours the second order effect should change considerably, he then concludes that there is no second order effect and contributes any other changes to temperature effects. However, it was already shown by Miller [10] that during several hours changes could be very small depending on the sidereal time and the epoch. Hence, the conclusion of Shankland is unsupported and the discrepancy between Miller's results and theoretical expectations remains.

In 1968 Demjanov [19] repeated the Michelson-Morley experiment and discovered that the effect was dependent on the material used as optical path. In vacuum the effect is absent and in air it is reduced by a factor of about 40. He also derived the same conclusion from the Fresnel ether drag formula and taking into account Lorentz contraction. Unfortunately, by that time, special relativity theory had reached dogma status and his findings are being ignored by mainstream physics until this day [20]. By now, the claim of a reduced sensitivity is followed by Spaverie [21], Consoli [22] and Cahill [23].

New interests in the theory and experiment of the interferometric method to determine the anisotropy (or its absence) of the speed of light at the Earth surface emerged at the end of the last century. Múnera [24] discovered systematic errors in the data reduction of the measurements. He showed that the interpretation of the amplitude and phase of the second order effect should be done for each rotation of the interferometer separately, not by averaging on forehand. Further, following Hicks [25] and Righi [26] De Miranda Filho describes possible first order effects in a Michelson-Morley interferometer [27]. Recently Múnera [28] reported an experiment claiming to see second order effects. He used a Michelson-Morley interferometer being stationary in the laboratory frame. The rotation of the Earth was used to change the direction of the velocity of the apparatus with respect to the preferred frame. This idea was followed by Cahill [29] using a fiber optical version of the interferometer. In these experiments the influence of the temperature on the signal was acknowledged. Múnera corrects his data for it and Cahill claims that the temperature can not influence the signal significantly. De Haan [30] copied the set-up of Cahill, with a stabilized temperature. He found a second order signal, but no sidereal dependence.

In view of the history of the experiment described above and the new insight of its reduced sensitivity it is of paramount importance that the Michelson-Morley experiment is repeated. This modern day repetition should copy as close as possible its original form under temperature controlled conditions with a fully-automated data acquisition. The knowledge of systematic errors in the data reduction of previous experiments must be used for the data reduction procedure.

2. Principle

2.1. Physics

In the plane-wave approximation a light beam with angular frequency ω travelling in direction of the wave vector $\vec{k}$ can be described by an optical phase

$$\phi = \phi_0 + \vec{k} \cdot \vec{r} - \omega t \qquad (1)$$

where $\vec{r}$ is the location in space, $k = 2\pi / \lambda$ where λ is the wavelength and ϕ_0 the optical phase at the origin for *t =0*. When the optical phase at some location and time in space is know, it can also be calculated at any other location in time and space. For light waves in the stationary ether the relation between the length of the wave vector and angular frequency is given by the dispersion relation

$$kc = n\omega \qquad (2)$$

where n is the refractive index of the material of the optical path and c the velocity of light in vacuum. As can be inferred from (1) two light beams with the same frequency travelling into the same direction have a constant optical phase difference. This optical phase difference can only change if the direction of the beam changes.

2.2. Geometry

A sketch of the Michelson-Morley interferometer is shown in figure 1. A light source is used to create a pencil beam of light. By means of a beam splitter the beam is split into two parts that travel in mutual orthogonal directions in space. At the end of each path a mirror is placed where the light beams are reflected by 180^o. When the light beams reaches the beam splitter again the light is combined and partly transmitted or reflected depending on the optical phase difference between the two light beams.

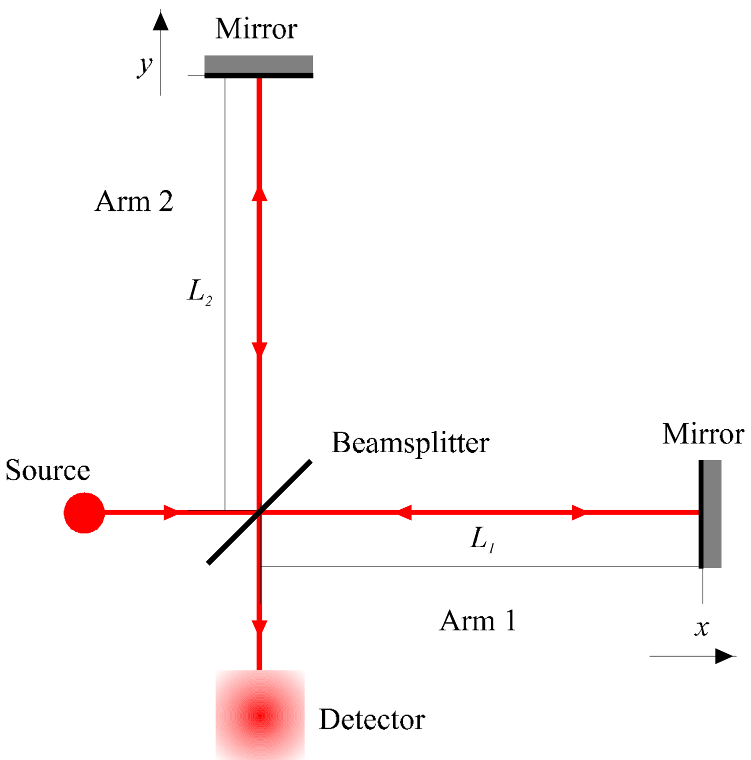

Figure 1: *Sketch to elucidate principle of Michelson-Morley interferometer.*

The intensity of light transmitted or reflected towards the detector is recorded and depends on the phase difference of the two light beams, according to

$$I = i_0 + \hat{i}\cos(\Delta\phi + \alpha)$$

where $i_0, \hat{i}, \alpha$ are instrument dependent parameters and the phase difference of the two light beams is determined by the optical phase difference $\Delta\phi$.

2.3. Optical phase difference stationary setup

The difference in optical phase between light beams that travelled along the different path can be determined by applying the boundary conditions for the light beams. The optical phase of the light beam in arm 1 between beam splitter ($x = 0$) and mirror ($x = L_1$) can be defined as

$$\phi^{1+}(x, y, t) = \phi_0^{1+} + kx - \omega t$$

and the optical phase of the reflected light beam in arm 1 is defined as

$$\phi^{1-}(x, y, t) = \phi_0^{1-} - kx - \omega t$$

At the mirror surface the difference between the optical phase of the incident and reflected beam is a constant $\Delta\phi_m$, defined by the type of mirror. Hence,

$$\phi^{1-}(L_1, 0, t) = \phi^{1+}(L_1, 0, t) + \Delta\phi_m$$

so that

$$\phi_0^{1-} = \phi_0^{1+} + 2kL_1 + \Delta\phi_m$$

From this follows that the optical phase of the light beam reaching the beam splitter is

$$\phi^{1-}(0,0,t) = \phi_0^{1+} + 2kL_1 - \omega t$$

An identical derivation can be applied to the light beams in arm 2 so that

$$\phi^{2-}(0,0,t) = \phi_0^{2+} - 2kL_2 - \omega t$$

Hence, the optical phase difference between the light beams hitting the beam splitter for the second time is

$$\Delta\phi = \phi_0^{1+} - \phi_0^{1-} + 2k(L_1 - L_2) \qquad (3)$$

and the intensity at the detector depends on the difference in length of the two arms of the interferometer. In a material light travels with the phase velocity so that the phase difference can also be expressed as the travel time difference for the two beams

$$\Delta\phi = \phi_0^{1+} - \phi_0^{1-} + \omega(t_1 - t_2) \qquad (4)$$

where it was used that wavelength and frequency of light are coupled by the dispersion relation (2). Equation (4) is often used to calculate the fringe shift. However, one should keep in mind that the interference is not determined by the travel time difference but by the optical phase difference. As long as the light beams have the same frequency and dispersion relation (3) holds, both equation (3) and (4) can be used to determine the optical phase difference.

2.4. *Moving setup*

In the above derivation it was assumed that set-up was stationary with respect to the light carrying medium or ether. If, however the set-up would be moving with respect to it, then the calculations become more complicated. If the set-up is moving with a velocity v parallel to the first arm then the trajectory of the light beams have to change to be able to interfere at the detector. This is shown in figure 2A. The sketches are made for the case that $L_1 \approx L_2$. Normally, when the optical path consists of vacuum, to calculate the phase difference between the two optical beams it is silently assumed that equation (4) can be used. In such a case, the time difference is determined by the difference in distance of the paths, as light in the stationary ether moves with the same velocity in all directions. Then, the optical phase difference becomes

$$\Delta\phi_A = \omega\left[\frac{\gamma L_1}{c+v} + \frac{\gamma L_1}{c-v} - 2\frac{L_2\sqrt{1+(v/c)^2}}{c}\right]$$

for motion parallel to arm 1 and

$$\Delta\phi_B = \omega\left[2\frac{L_1\sqrt{1+(v/c)^2}}{c} - \frac{\gamma L_2}{c-v} - \frac{\gamma L_2}{c+v}\right]$$

for motion parallel to arm 2. $\gamma = 1$ if no Lorentz-Fitzgerald contraction is taken into account and $\gamma = \sqrt{1-(v/c)^2}$ if it is. The difference upon rotation of the set-up becomes

$$\Delta\phi_{AB} = \Delta\phi_A - \Delta\phi_B = 2k(L_1 + L_2)\left[\frac{\gamma}{1-(v/c)^2} - \sqrt{1+(v/c)^2}\right] \qquad (5)$$

which becomes *0* if Lorentz contraction is taken into account.

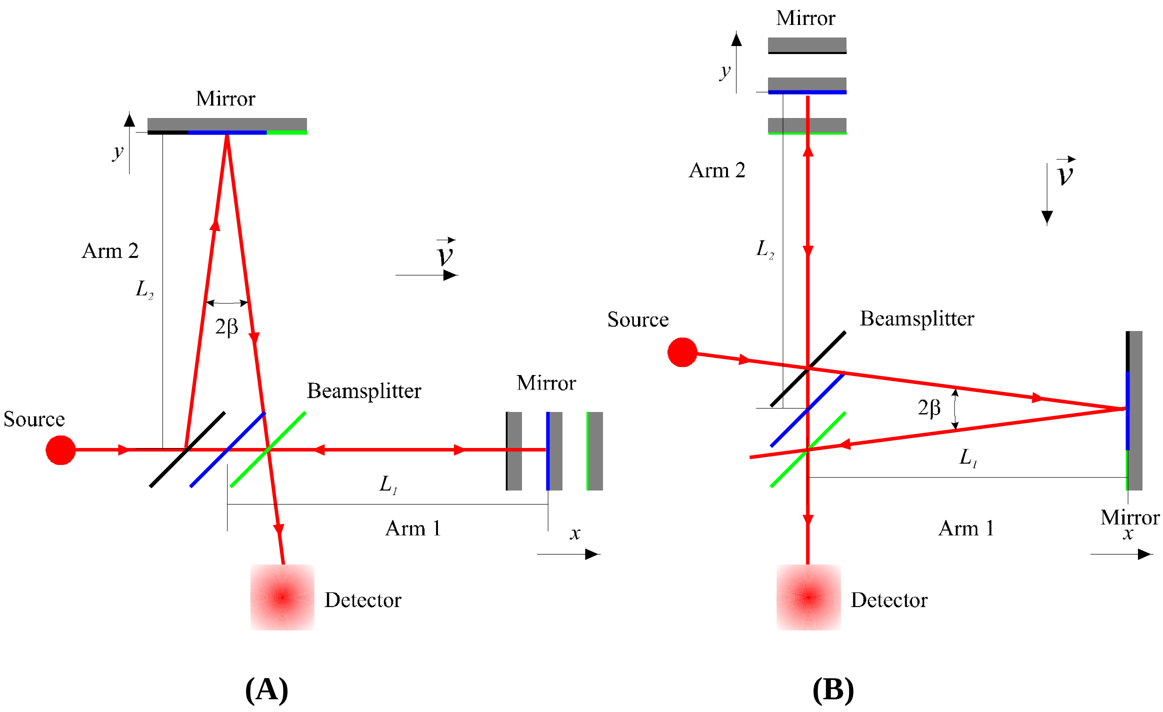

Figure 2: *Trajectories of light beams when set-up moves through the ether. (A) motion parallel to arm 1. (B) motion parallel to arm 2. The black lines correspond to the moment the light beam is split into the two arms. The blue lines correspond to the moment the light is reflected on the mirrors and the green lines correspond to the moment the light merges at the beam splitter.*

The validity of equation (4) is not at all obvious. The dispersion relation (2) is not changed, because we are still referring to the stationary ether. However, due to the Doppler effect (Appendix A), the frequency of the waves after emission by the source or reflection at the beam splitter and mirror is different from the initial frequency as these objects are moving through the ether. It can be shown that the wavelength of the wave is only determined by the direction it is travelling in, not by the way this direction is reached. However, the frequency of the wave as measured by the *moving* detector depends on both the wavelength and the light beam velocity effectively canceling the Doppler effect. Hence, when the travel time difference in the moving frame is determined, also the optical phase difference can be calculated, because measured in the *moving* frame the frequency of the light beam remains constant. In most ether theories the travel time difference in the ether frame and moving frame is the same or coupled via time dilation, hence it is possible to use equation (4).

2.5. Light dragging in materials

In the previous derivation of the optical phase difference it was assumed that the light beam travel in vacuum, where the refractive index equals 1. As soon as a material is inserted (for instance air or glass) the derivation becomes much more complicated as the light dragging effect must be included. Fizeau [31] was the first to study the dragging effect experimentally and found that the velocity of a light wave in a moving medium (represented by refractive index *n’*, when the refractive index in material stationary with respect to the ether equals *n*) could be expressed as

$$\frac{1}{n'} = \frac{1}{n} + \beta\left(1 - \frac{1}{n^2}\right)$$

with respect to the ether frame $\beta = v / c$, where the material is moving with velocity *v* with respect to the ether parallel to the light beam. For a homogeneous medium this can be generalized into

$$\frac{1}{n'} = \frac{1}{n} + \beta\cos\alpha\left(1 - \frac{1}{n^2}\right)$$

where α is the angle between the velocity of the moving medium and the light beam direction as determined in *the ether frame*. The light beam direction as determined in *reference frame of the moving medium i*s given by α'. The relation between the two is given by

$$\cos\alpha = \frac{\cos\alpha' - n\beta}{\sqrt{(\cos\alpha' - n\beta)^2 + (1-\beta^2)\sin^2\alpha'}} \approx \cos\alpha' - n\beta\sin^2\alpha'$$

hence

$$\frac{1}{n'} \approx \frac{1}{n} + \left(\beta\cos\alpha' - n\beta^2\sin^2\alpha'\right)\left(1 - \frac{1}{n^2}\right)$$

up to second order in β. Lorentz [11] further generalized this equation by introducing the dispersion of the medium $D_\lambda = \frac{\lambda}{n}\frac{dn}{d\lambda}$

$$\frac{1}{n'} = \frac{1}{n} + \beta\cos\alpha\left(1 - \frac{1}{n^2} - D_\lambda\right)$$

The dispersion comes into play as due to the Doppler effect the frequency of the light changes in the ether frame. In the derivation of this formula Lorentz neglected all terms that contained orders of β larger than 1.

It is also possible to derive this velocity up to first order in β from the velocity addition theorem of special relativity [32]

$$\frac{1}{n'} = \frac{\sqrt{1+\beta^2 n^2 + 2n\beta\cos\alpha' - \beta^2\sin^2\alpha'}}{n + \beta\cos\alpha'} \approx \frac{1}{n} + \left(1 - \frac{1}{n^2}\right)\left\{\beta\cos\alpha' + n\beta^2\left(\frac{\sin^2\alpha'}{2} - \frac{\cos^2\alpha'}{n^2}\right)\right\}$$

where Laue used the angle α'. With respect to α this becomes

$$\frac{1}{n'}=\frac{1-n^2\beta^2}{n\sqrt{1-\beta^2}\sqrt{1-n^2\beta^2+\left(n^2-1\right)\beta^2\cos^2\alpha}-\beta\cos\alpha\left(n^2-1\right)}$$

To second order in β this is

$$\frac{1}{n'}=\frac{1}{n}+\left(1-\frac{1}{n^2}\right)\left\{\beta\cos\alpha-\beta^2 n\left(\frac{\sin^2\alpha}{2}+\frac{\cos^2\alpha}{n^2}\right)\right\}$$

Deviations from the previous formula of the effective refractive index with respect to the ether occur only due to dispersion and second order effects. The dispersion term is absent as the velocity addition theorem ignores the frequency aspects of light. Here, the second order effects include time dilatation and Lorentz contraction. One should remember that the refractive index *n'* is with respect to the ether due to a moving medium, it is not with respect to the moving medium itself. Hence, this refractive index can only be used in the ether frame.

The dragging effect is generalized according to

$$\frac{1}{n'}=\frac{1}{n}+\left(1-\frac{1}{n^2}-D_\lambda\right)\beta\cos\alpha+\beta^2\left(\tau_2\cos 2\alpha+\tau_0\right)$$

where the parameters D_λ,τ_0 and τ_2 determine which model for the dragging effect is taken (see table 1). All models yield the same result for the first order dragging effect, but differ for the second order effect. The values for τ_0 and τ_2 in case of special relativity were derived by making sure that the experimental effect (derived in the next section), including the dispersion, is exactly 0.

Model	D_λ	τ_0	τ_2
Demjanov	D_λ	*0*	*0*
Velocity addition rule	0	$-\frac{\left(n^2-1\right)\left(n^2+2\right)}{4n^2}$	$\frac{\left(n^2-1\right)\left(n^2-2\right)}{4n^2}$
Velocity addition rule and dispersion	D_λ	$-\frac{\left(n^2-1\right)\left(n^2+2\right)}{4n^2}$	$\frac{\left(n^2-1\right)\left(n^2-2\right)}{4n^2}$
Special relativity	D_λ	$D_\lambda\left(\frac{n^2\left(D_\lambda+1\right)}{2}+1\right)-\frac{\left(n^2-1\right)\left(n^2+2\right)}{4n^2}$	$D_\lambda\left(\frac{n^2\left(D_\lambda-1\right)}{2}+1\right)+\frac{\left(n^2-1\right)\left(n^2-2\right)}{4n^2}$

Table 1: *Values for parameters* D_λ,τ_0 and τ_2 *depending on the model used.*

The light dragging effect as predicted by Fresnel [1] was based on theoretical considerations and in that context without approximation and valid for all values of the velocity of the medium with respect to the ether. The experiments by Fizeau and most of all other measurements to date are accurate only up to first order, so that *experimentally no distinction can be made* between the two equations given earlier.

2.6. Optical phase difference moving setup with material in the arms

The travel time of the light beams must be calculated in the ether frame, because the light dragging effects are only derived for the ether frame. It is assumed that the light travels exactly between the centers of the beam splitter and mirrors with a velocity given by the refractive index *n'* (see figure 4).

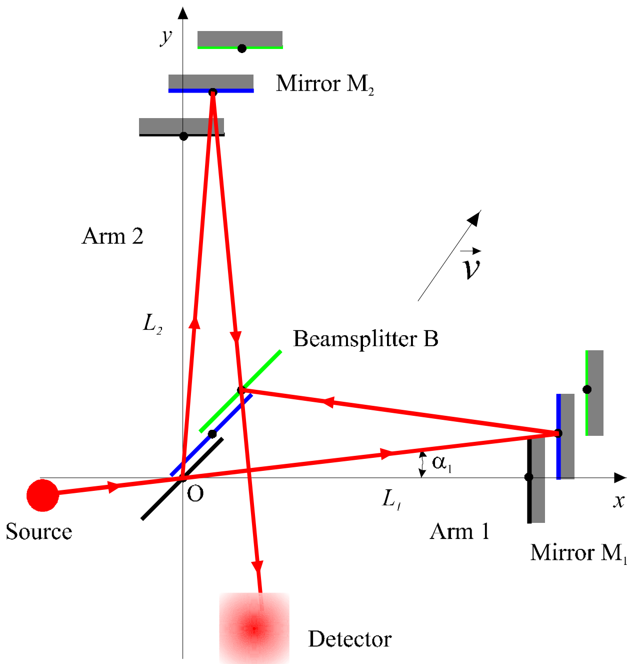

Figure 4: *Effect of motion of the set-up through the ether on the trajectories of the light beams in a Michelson-Morley interferometer for arbitrary angle of ether velocity. The black lines correspond to the moment the light beam is split into the two arms. The blue lines correspond to the moment the light is reflected on the mirrors and the green lines correspond to the moment the light merges again at the beam splitter.*

In that case the distance travelled between beam splitter and mirror is directly given by the start and end point of the light beam. This distance is only a function of travel time, their position at the start and the ether velocity. For arm 1 and the light beam going from beam splitter to mirror M_1, this distance is

$$\sqrt{L_1^2\left(1+g(g+2)\cos^2\alpha\right)+2L_1\Delta t_1\beta c\cos\alpha(g+1)+(\Delta t_1\beta c)^2}$$

where $g=\sqrt{1-\beta^2}-1$ is a small number and 0 when Lorentz contraction is ignored. The direction of the light beam with respect to the ether velocity is given by

$$\cos(\alpha-\alpha_1)=\frac{L_1(g+1)\cos\alpha+\Delta t_1\beta c}{\sqrt{L_1^2\left(1+g(g+2)\cos^2\alpha\right)+2L_1\Delta t_1\beta c\cos\alpha(g+1)+(\Delta t_1\beta c)^2}}$$

The light has travelled this distance in a straight line with a velocity depending on the direction of the light beam and is given by

$$\frac{c}{n'}\Delta t_1=\left\{\frac{c}{n}+\beta c\left(1-\frac{1}{n^2}-D_\lambda\right)\cos(\alpha-\alpha_1)+c\beta^2\left(\tau_2\cos 2(\alpha-\alpha_1)+\tau_0\right)\right\}\Delta t_1$$

When these distances are compared to each other the travel time can be calculated. The result is

$$\Delta t(\alpha, L, n) = \frac{nL}{c}\left(1 + \frac{D_\lambda n^2 + 1}{n}\beta\cos\alpha + \frac{\beta^2}{2}\left(a\cos^2\alpha + b\right)\right)$$

where

$$a = 1 - f + 2D_\lambda\left(n^2(D_\lambda - 1) + 2\right) + \frac{(n^2-1)(n^2-2)}{n^2} - 4\tau_2$$

and

$$b = 1 - p + 2n^2 D_\lambda + 1 - n^2 + 2(\tau_2 - \tau_0)$$

For Lorentz contraction on instrument: *f = 1* else *f = 0* . For time dilatation taken into account *p = 1* else *p = 0*. In case the ether wind is not in the plane of rotation it can be shown that the above formula holds if $\cos\alpha$ is replaced by $\cos\alpha\cos\phi$ where ϕ is the angle between ether velocity and plane of rotation. For travel back and forth the travel time will be

$$\Delta t_{bf}(\alpha, L, n) = \frac{nL}{c}\left(2 + \beta^2\left(a\cos^2\alpha + b\right)\right)$$

For the time difference of two perpendicular arms

$$\Delta T = \Delta t_{bf}(\alpha, L_1, n) - \Delta t_{bf}\left(\alpha + \frac{\pi}{2}, L_2, n\right) = \frac{n(L_1 - L_2)}{c}\left(2 + \beta^2\left(b + \frac{a}{2}\right)\right) + \frac{n(L_1 + L_2)}{2c}\beta^2 a\cos 2\alpha$$

Under the condition that no material is not present ($n = 1; D_\lambda = 0$) the time difference should not depend on the ether velocity. This yields, with $a = b = 0$,

$$\tau_2 = \frac{1-f}{4} \quad \text{and} \quad \tau_0 = \frac{1-p}{2} + \frac{1-f}{4}$$

Hence, a null result can be obtained under vacuum if both these conditions are fulfilled. Note that neither time dilatation nor Lorentz contraction is needed to obtain a null result, if the dragging effect in vacuum compensates for it. As the dragging effect has only been measured up to first order, it is impossible to conclude from the experiment that any of these effects take place. Of coarse the most simple case is to take these effects into account, resulting in $\tau_0 = \tau_2 = 0$ for vacuum. The values of *a* and *b* are shown in table 2 for the four models of table 1 including Lorentz contraction and time dilatation. It is clear that in the magnitude of the effect depends critically on the second order term of the dragging effect.

Model	*a*	*b*
Demjanov	$2D_\lambda\left(n^2(D_\lambda - 1) + 2\right) + \frac{(n^2-1)(n^2-2)}{n^2}$	$2n^2 D_\lambda + 1 - n^2$
Velocity addition rule without dispersion	*0*	*0*
Velocity addition rule and dispersion	$2D_\lambda\left(n^2(D_\lambda - 1) + 2\right)$	$2n^2 D_\lambda$
Special relativity	*0*	*0*

Table 2: *Values for amplitudes a and b depending on the model used.*

The second order dragging effect is not determined experimentally and it is argued first by Demjanov [19] and later by others [20,21,22] that it is possible that for interferometers with gasses in the arms instead of vacuum the second order dragging effects might be absent or at least different from the ones required by special relativity yielding a measureable signal.

3. Examples of different magnitudes effect

The proposal aims at repeating the Michelson-Morley experiment as closely as possible. The magnitude of the set up can be determined for three different materials used in the arms of the interferometer.

3.1. Air

The refractive index of air as function of absolute temperature and wavelength is given by Edlén [33] and revised by Bönsch [34]

$$n(p,T,\lambda)=1+10^{-8}\times\frac{p}{p_0}\frac{T_0}{T_0+T-273{,}15}\left[8670+\frac{2{,}50068}{0{,}130\times10^{-3}-\left(\frac{\lambda_0}{\lambda}\right)^2}+\frac{0{,}0166263}{0{,}389\times10^{-4}-\left(\frac{\lambda_0}{\lambda}\right)^2}\right]$$

where $p_0 = 1$ bar; $T_0 = 280{,}03$ K and $\lambda_0 = 1\,\text{nm}$, from which also the dispersion can be calculated. From this the relative amplitude for the different models can be calculated. They are shown in figure 5. The relative amplitude is 3 to 4 orders of magnitude smaller than expected from the simple no-dragging ether calculations. If the arms of the interferometer are made 10 m long, and the fringe detection accuracy is 1 promille, the minimum ether velocity that can be detected will be of the order of 80 – 300 km/s.

3.2. Standard glass BK7

The refractive index of BK7 is given by

$$n_{BK7}(\lambda)=\sqrt{1+\frac{1{,}03961212\times10^{-6}}{6{,}0007\times10^{-9}-\left(\frac{\lambda_0}{\lambda}\right)^2}+\frac{0{,}231792344\times10^{-6}}{2{,}0018\times10^{-8}-10^{6}\times\left(\frac{\lambda_0}{\lambda}\right)^2}+\frac{1{,}01046945\times10^{-6}}{1{,}0356\times10^{-4}-\left(\frac{\lambda_0}{\lambda}\right)^2}}$$

where $\lambda_0 = 1\,\text{nm}$, from which again the dispersion can be calculated. From this the relative amplitude for the different models can be calculated. They are shown in figure 6. The relative amplitude is 1 to 2 orders of magnitude smaller than expected from the simple no-dragging ether calculations. If the arms of the interferometer are made 10 m long, and the fringe detection accuracy is 1 promille, the minimum ether velocity that can be detected will be of the order of 8 – 30 km/s.

3.3. High refractive index glass SLAH-7

The refractive index of SLAH-7 is given by

$$n_{SLAH7}(\lambda)=\sqrt{1+\frac{1{,}9828\times10^{-6}}{1{,}190\times10^{-8}-\left(\frac{\lambda_0}{\lambda}\right)^2}+\frac{0{,}3167584\times10^{-6}}{5{,}2716\times10^{-8}-10^{6}\times\left(\frac{\lambda_0}{\lambda}\right)^2}+\frac{2{,}444726\times10^{-6}}{2{,}1322\times10^{-4}-\left(\frac{\lambda_0}{\lambda}\right)^2}}$$

where $\lambda_0 = 1\,\text{nm}$, from which agian the dispersion can be calculated. From this the relative amplitude for the different models can be calculated. They are shown in figure 7. The relative amplitude is 0 to 1 orders of magnitude smaller than expected from the simple no-dragging ether calculations. If the arms of the interferometer are made 10 m long, and the fringe detection accuracy is 1 promille, the minimum ether velocity that can be detected will be of the order of 2 – 8 km/s.

Hence the effect can be greatly enhanced under the conditions that the different models hold. The use of high refractive index glass increases the effect enormous for all models except for the special relativity model.

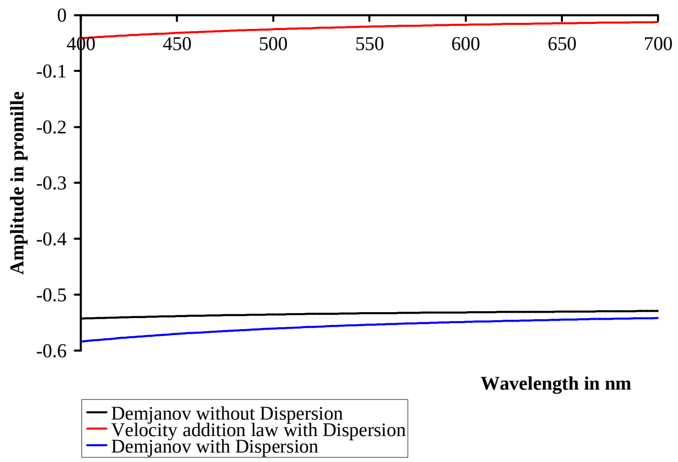

Figure 5: *Relative amplitudes of effect in promille for different models as function of wavelength in air.*

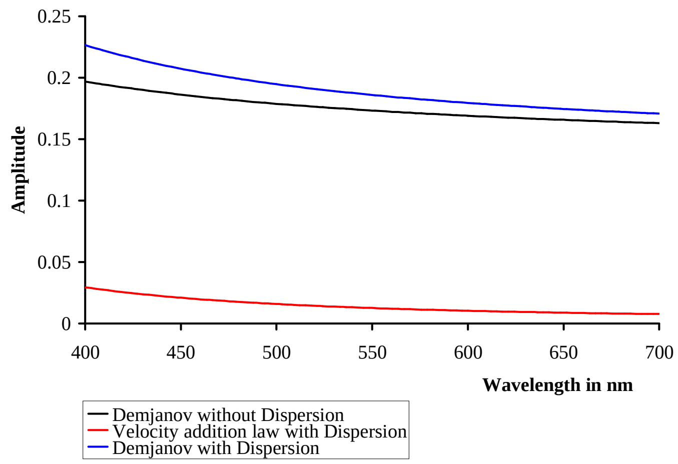

Figure 6: *Relative amplitudes of effect for different models as function of wavelength in standard glass BK7.*

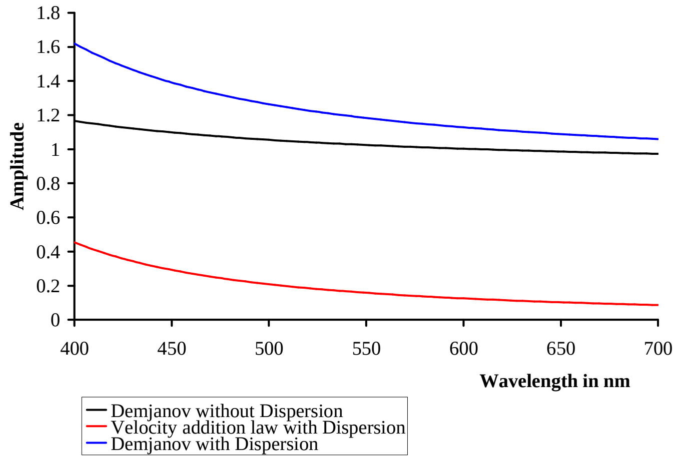

Figure 7: *Relative amplitudes of effect for different models as function of wavelength in glass SLAH7 with high refractive index.*

4. Experimental set up

The apparatus that needs to be build consists of two optical path perpendicular to each other with a total distance of 10 m mounted on a stable optical platform. The complete optical path will be realized by multiple reflections, much according to the apparatus as used by Miller [10]. The complete platform must be able to rotate automatically around a vertical axis over 360 degrees and be maintained on a stable temperature of the order of 0,01 K to prevent disturbing temperature fluctuations. The materials used in the optical path must be interchangeable between air and glass. As the effect depends on the wavelength used, several monochromatic coherent light sources will be used, to be able to check this dependence and still observe the fringes with a reasonable contrast. The fringe shift will be recorded by a detector. To be able to find a sidereal dependence the complete set up must be controlled automatically and operated during one year.

4.1. Environment

The environment the apparatus is operated in must be air-conditioned and have a solid foundation to prevent vibrations, temperature or humidity changes to have too much influence.

4.2. Rotation table

The rotation table must be able to support the optical table and its components. Rotation speed must be of the order of 360 degrees per minute to be able to get a sufficient data collection rate. The weight that must be rotated will be of the order of 2500 N.

4.3. Temperature and humidity control

The optical platform supporting the optical paths, optical equipment and materials the optical path consists of, need to be temperature controlled to keep the distance fixed within an appropriate accuracy. It is estimated that a temperature stability of 0,01 K is sufficient to eliminate the influence of temperature changes. Some optical components are sensitive to humidity changes. Especially the refractive index of air depends on the humidity. During the measurements the humidity must be measured and if needed controlled. During selection of the components the effects of temperature and humidity variations need to be considered and minimized.

4.4. Optical platform and equipment

The optical platform is used to support the optical paths and to isolate vibrations from the environment. The area of the platform will be of the order of 1 m^2 and will be equipped with easy adaptable connection possibilities. The optical paths will be constructed by a beam splitter and suitable mirrors. Between beam splitter and mirrors it must be possible to install different optical materials to be able to change the refractive index and the dispersion.

4.5. Light sources

The light source will be three different lasers (blue, red and green). It must be possible to also use infrared lasers, as that may have advantageous for the refractive index and dispersion. The lasers must have a sufficient coherence length. This eliminates the need for an exact optical path distance match. However, it must be kept in mind that the mode sweep of each laser is small enough not to disturb the measurements.

4.6. Detector

The detector must be able to measure the light intensity at all wavelength used and give a reading of the phase difference of the two interfering light beams. This can be done by locating the fringe pattern position by means of a linear detector array. For this it is needed that the beams behind the beam splitter are not perfectly parallel. If the beams are perfectly parallel the intensity recorded by the detector is proportion to the cosine of the optical phase difference of the two beams. The detector need to be able to record the optical phase difference with an accuracy of at least 1/1000th of a fringe.

4.7. Automation

For the experiment to be successful, not only the change of the optical phase for each rotation must be measured, but also the daily variation of this change during a complete year. This is needed to eliminate all possible traditional explanations for the possible experimental results, like stresses in the arms or daily temperature variations. This can only be accomplished if the complete set up, including the determination of the optical phase is automated.

5. Investment and time schedule

On overview of the complete investment and yearly operating costs in man-hours and expenses are shown in table 3. The realization is divided into five phases: detailed design, construction, commissioning, operation and closure. After the detailed design phase a go/no go mile stone is reached when it can be decided to continue the project or not. After one year of operation it can be decided to close the project or to continue depending on the obtained results.

5.1. Detailed design, construction and commissioning

During the detailed design phase the definitive set up is defined and needs and requirements for the equipment established. During the construction phase the equipment is purchased or manufactured if not available in the market, further the components are put together. The commissioning phase is needed to test the instrument and to fine tune all the parameters to obtain the optimal performance of the instrument. The hours indicate the man-hours needed for the specific tasks. The expenses are for tasks that need to be out-sourced or for actual equipment. The total investment for the detailed design, construction phase is estimated to be 740 man-hours and 161 kEuro ex. VAT.

5.2. Yearly operation

The yearly operating costs are 230 man-hours and 30 kEuro ex. VAT. The expenses are due to rental of space to set up the experiment and maintenance costs.

5.3. Closure

After the experiment had been finished the results must be made available to the stake holders and the instrument dismantled. The costs for dismantling are estimated to be 10% of the construction costs. The man-hours are needed for reporting.

5.4. Total investment

For the complete experiment at least 1066 man-hours and 201 kEuro ex. VAT are needed. BonPhysics costs of man-hours *for this project* would be 80 euro per hour ex. VAT, hence in total 85 kEuro ex. VAT. Hence, a third party investment would be 286 kEuro ex. VAT for the first two years

5.5. Time schedule

An overview of the time schedule is shown in figure 8. The time schedule is split into the four phases: detailed design, construction, commissioning and yearly operation. The time-schedule has been made keeping in mind the needed man-hours and turn around time of purchase and construction. The realization of the set-up will take one year and the minimal operation time is also one year.

Item	***Detailed Design***		***Construction***		***Commissioning***		***Yearly Operation***		***Closure***	
	hours	*Costs*	*hours*	*Costs*	*hours*	*Costs*	*hours*	*Costs*	*hours*	*Costs*
Environment	10	0	50	10	10	6	50	12	8	1
Rotation table	20	5	10	30	10	0	5	2	2	3
Temperature and	20	0	40	10	10	0	25	2	2	1
Optical platform	20	10	50	25	20	0	10	2	1	2.5
Light sources	10	0	10	10	10	0	10	10	1	1
Detector	10	0	20	5	10	0	10	1	1	0.5
Automation	40	0	80	10	40	40	40	1	1	1
Reporting	80	0	80	0	80	0	80	0	80	0
Total	**210**	**15**	**340**	**100**	**190**	**46**	**230**	**30**	**96**	**10**

Table 3: *Investment needs for realization of experiment, costs in kEuro ex. VAT.*

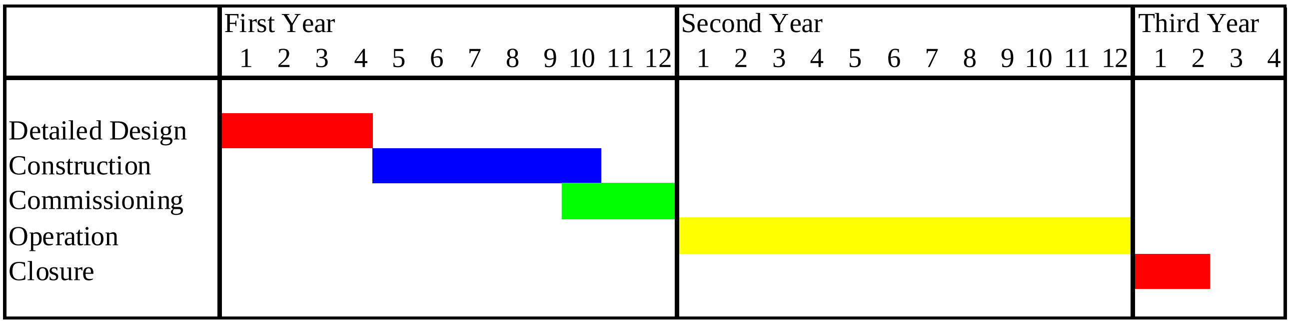

Figure 8: *Time schedule for realization of experiment.*

6. Conclusions

All though the Michelson-Morley experiment has been repeated many times, still questions concerning the interpretation of the experimental results can be raised. It is possible to answer these questions by repeating the experiment in the same way as has been done by Demjanov. The main difference is that instead of using vacuum in the arms of the interferometer one should use a material with a high refractive index and dispersion. This will make the experiment sensitive to the precise dragging effect of light by moving materials enabling the discrimination of several models for the dragging effect, differing only in second order of the ratio between ether and light velocity.

The total investments costs of 286 kEuro are considerable, but negligible compared to other investments in fundamental physics.

References

[1] Fresnel A., Ann. de Chim et de Phys **9** (1818) p57-66
[2] Maxwell J C, Proceedings of the Royal Society of London, **30** (1879-1880) p108-110
[3] Michelson A A, American Journal of Science Series 3 **22** (1881) p120-129
[4] Lorentz H A, Archives Neerlandaises des Science exactes et naturelles **21** (1886) p103-176
[5] Michelson A A and Morley E W, American Journal of Science Series 3 **34** (1887) p333-345; Michelson A A and Morley E W, Philosophical Magazine, fifth series, **24** (1887) p449-463
[6] Morley E W and Miller D C, Philosophical Magazine Series 6 **9** (1905) p669-680
[7] Miller D C, Phys. Rev. **19** (4) (1922) p407 - 408
[8] Miller D C, Science **63** (1635) (1926)
[9] Miller D C, Astrophysical Journal **24** (1930) p82-84
[10] Miller D C, Reviews of Modern Physics **5** (1933) p203-242
[11] Lorentz H A, Versuch einer theorie der electrischen und optischen erscheinungen bewegten körpern, Leiden, 1895
[12] Einstein A, Annalen der Physik **17** (1905) p891
[13] Conference on the Michelson-Morley Experiment held at the Mount Wilson Observatory Pasadena, California, February 4 and 5, 1927, Astrophysical Journal **68** 5 (1928) p341-402
[14] Piccard A and Stahel E, Comptes Rendus **183** (1926) p420-421
[15] Piccard A and Stahel E, Comptes Rendus **184** (1928) p152
[16] Illingworth K K, Physical Review **30** (1927) p692-696
[17] Joos G, Annalen der Physik S 5 **7** 4 (1930) p385-407
[18] Shankland R S, McCuskey S W, Leone F C and Kuerti G, Reviews of Modern Physics **27** (2) (1955) p167-178
[19] Demjanov V V. *Undisclosed mystery of the great theory*. Novorossiysk: 1st ed 2005 p174; 2nd ed 2009 p330
[20] Demjanov V V, Phys. Lett. A **374** (2010) p1110-1112 (retracted by editor)
[21] Spavieri G, Guerra V, De Abreu R, and Gillies G T, Eur. Phys. J. D. **47** (3) (2008) p457
[22] Consoli M and Constanzo E, Phys. Lett. A. **333** (2004) p355
[23] Cahill R T and Kitto K, Apeiron **10** (2) (2003) p104
[24] Múnera H A, Apeiron **5** No 1-2 (1998) p37-53
[25] Hicks W M, Philosophical Magazine Series 6 **3** (1902) p9-42, p256
Hicks W M, Nature no. 1685 **65** (1902) p343
[26] Righi A, Comptes Rendus **168** (1919) p837-842
Righi A, Comptes Rendus **170** (1920) p497-501, p1550-1554
[27] De Miranda Filho R C, Andion N P and Da Costa N C A, Physic Essays **15** (4) (2002) p422-437
[28] Múnera H A, Hernàndez-Deckers D, Arenas G and Alfonso E, Electromagnetic Phenomena **6** 1 (16) (2006) p70-92
[29] Cahill R T and Stokes F, Progress in Physics **2** (2008) p103-110
[30] De Haan V O, Can. J. Phys. **87** (2009) p999-1008
[31] Fizeau M, Ann. de Chim et de Phys 3e serie **58** (1860) p129-136
[32] Laue M, Annalen der Physik **328** (10) (1907) p989–990.
[33] Edlén B, Metrologia **2** (2) (1966) p71-80
[34] Bönsch G and Potulski E, Metrologia **35** (1998) p133-139
[35] Lodge O J, Philosophical Transactions Royal Society, **184** (1893) p727-804
[36] Voigt W, Nachrichten von der Königl. Gesellschaft der Wissenschaften und der Georg-Augusts-Universität zu Göttingen **2** (1887) p41-51

Summary

In 1968 Demjanov repeated the Michelson-Morley experiment and discovered that the effect was dependent on the material used as optical path. In vacuum the effect is absent and in air it is reduced by a factor of about 40. In view of the history of the experiment and the new insight of its reduced sensitivity it is of paramount importance that the Michelson-Morley experiment is repeated. This modern day repetition should copy as close as possible its original form under temperature controlled conditions with a fully-automated data acquisition. The knowledge of systematic errors in the data reduction of previous experiments must be used for the data reduction procedure.

Within two year of the start of the realization of this proposal and at a costs of 286 kEuro ex. VAT it is possible to have a modern day repetition of the Michelson-Morley experiment giving an answer to a most important question:

Can ether be detected by interferometers using Demjanov’s adaption?

Appendix A: Doppler effects

The Doppler effect by reflection to a moving mirror has been calculated by Lodge [35], Hicks [25], Righi [26], Hedrick [13] and many others. The result is shown in figure A1.

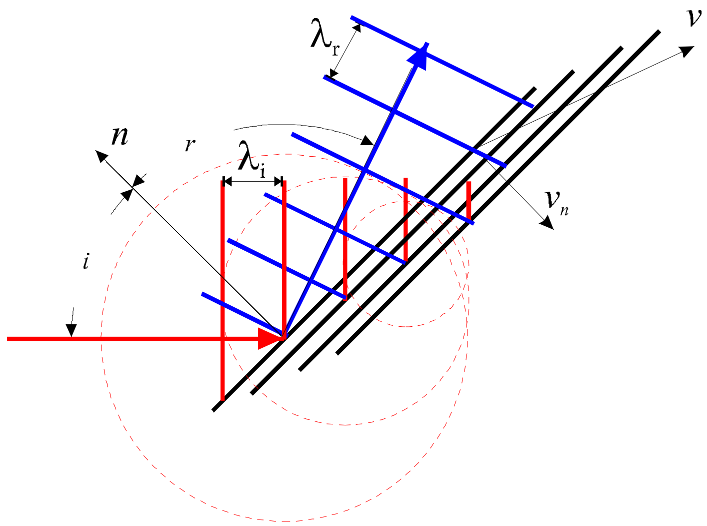

Figure A1: *Reflection of a light wave from a moving mirror exhibiting the Doppler effect.*

In formula this yields

$$\tan\frac{r}{2} = \frac{c - v_n}{c + v_n}\tan\frac{i}{2} \quad \text{or} \quad \tan\frac{i+r}{2} = \frac{\sin i}{\cos i - \frac{v_n}{c}} \tag{6}$$

where i is the incident angle, r the reflected angle and v_n the magnitude of the component normal to the mirrors surface. v_n is positive when the mirror is moving away from the incident light. All angles taken in the ether rest frame. The ratio of the wavelengths after and before reflection is simply given by

$$\frac{\lambda_r}{\lambda_i} = \frac{\sin r}{\sin i} \quad \text{or} \quad \frac{\lambda_r}{\lambda_i} = \frac{c^2 - v_n^2}{c^2 + v_n^2 - 2cv_n \cos i} \tag{7}$$

Further, by the Doppler effect the frequency emitted by the source is different when the source is moving compared to when it is stationary. This was first elucidated by Voigt [36]. The wavelength of a light beam emitted by a source of constant frequency in a direction making an angle α with the direction to which the source is moving (with respect to the ether) is given by

$$\frac{\lambda_e}{\lambda} = 1 - \frac{v}{c}\cos\alpha \tag{8}$$

and differs from the wavelength emitted by the stationary source.

As the source, beam splitter, mirrors and detector are fixed with respect to each other the wavelength after reflection to a mirror or beam splitter can be calculated by inserting the direction of the reflected wave directly in equation (8). The wavelength of the wave is only determined by the direction it is travelling in, not how this direction is reached. However, the frequency of the wave as measured by the moving detector depends on both the wavelength and the light beam velocity effectively canceling the Doppler effect.