Critical Examination of Michelson – Morley Experiment
Shows it had no bearing on the existence of 'Aether'

Introduction

The historic significance of Michelson – Morley experiment has been due to the fact that it had proved the non-existence of aether medium. The existence of aether had been taken for granted throughout the 19th century. But as a consequence of the MM experiment, the non-existence of aether has been almost taken for granted ever since. Even though the Special Theory of Relativity had reconciled the results of MM experiment through special postulates, its success did not revive the old concept of aether medium. Therefore, in order to introduce even the revised concept of aether as an Elastic Continuum, we must re-examine the MM experiment in the light of our current knowledge of elementary particles and Quantum Mechanics.

The original MM experiment was conducted in the backdrop of 'aether current', or 'aether wind' which was expected to influence the propagation of light, viewed as a continuous wave motion. For the proposed critical examination of MM experiment, let us assume that there is no aether medium. Let us conduct the same old MM experiment in the backdrop of our familiar 'Vacuum' or 'Empty Space' to show that its negative result had nothing to do with the existence or otherwise of aether or vacuum

M M Experimental Setup

Let us consider the MM experimental setup as shown in fig. 1. Here A_0 is the starting point from where a monochromatic light beam is split into two mutually perpendicular beams. One of these is directed along A_0X_0 direction and the other along A_0Y_0 direction. X_0 and Y_0 are two reflecting mirrors, such that

$$|A_0X_0| = |A_0Y_0| = D \ .$$

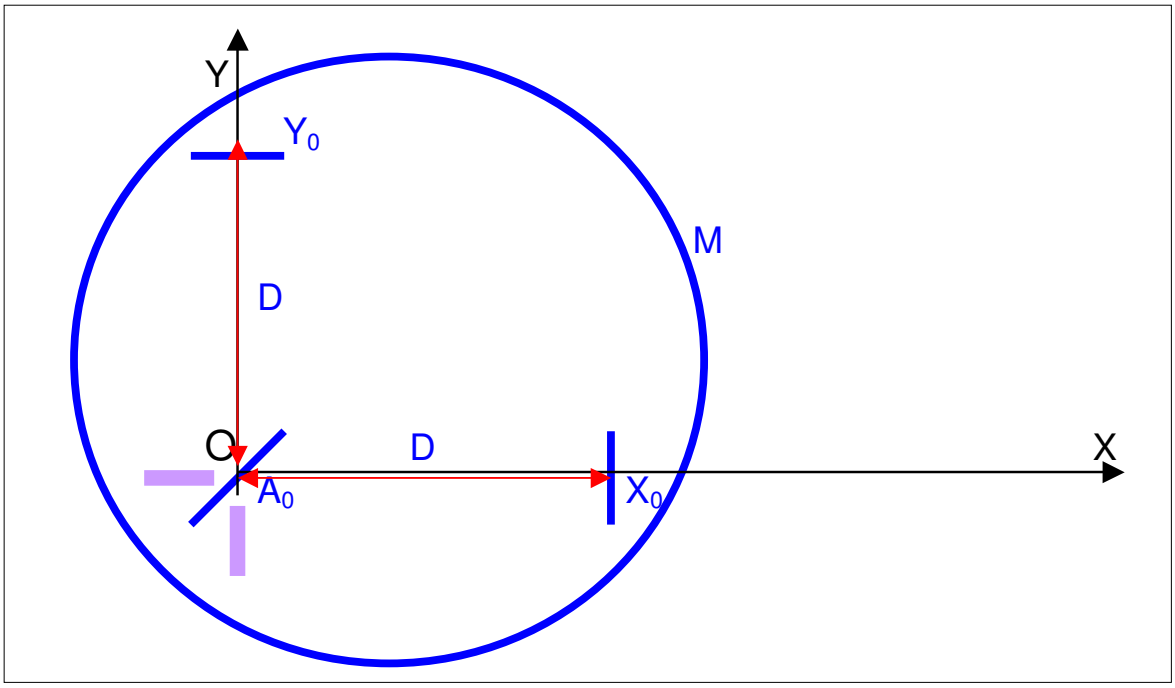
After reflection from mirrors X_0 & Y_0, the two beams are recombined at A_0 to study the interference fringes. The whole setup is mounted on a rotating platform M. Let us position this MM experimental setup (platform M) in a region of 'empty space' or 'matter free space' or 'Vacuum' with following essential properties.

a) The 'Vacuum' or 'empty space' offers no drag or resistance to the motion of particles or wave packets through it.

b) The 'Vacuum' is homogeneous and perfectly isotropic. That is, its properties are uniform all over and direction independent. That means the effect of 'Vacuum' on a moving particle too will be identical along all directions.

We shall attempt to prove the existence or otherwise, of this 'Vacuum' through the MM experiment, just as Michelson & Morley had attempted to prove the existence or otherwise of the 'aether'. Let us imagine a coordinate system fixed at the center of our galaxy. Let OXY be another coordinate system that is fixed relative to the above galaxy-centered coordinate system.

Fig. 1



Case Ⅰ : Experimental Platform M at Rest in OXY.

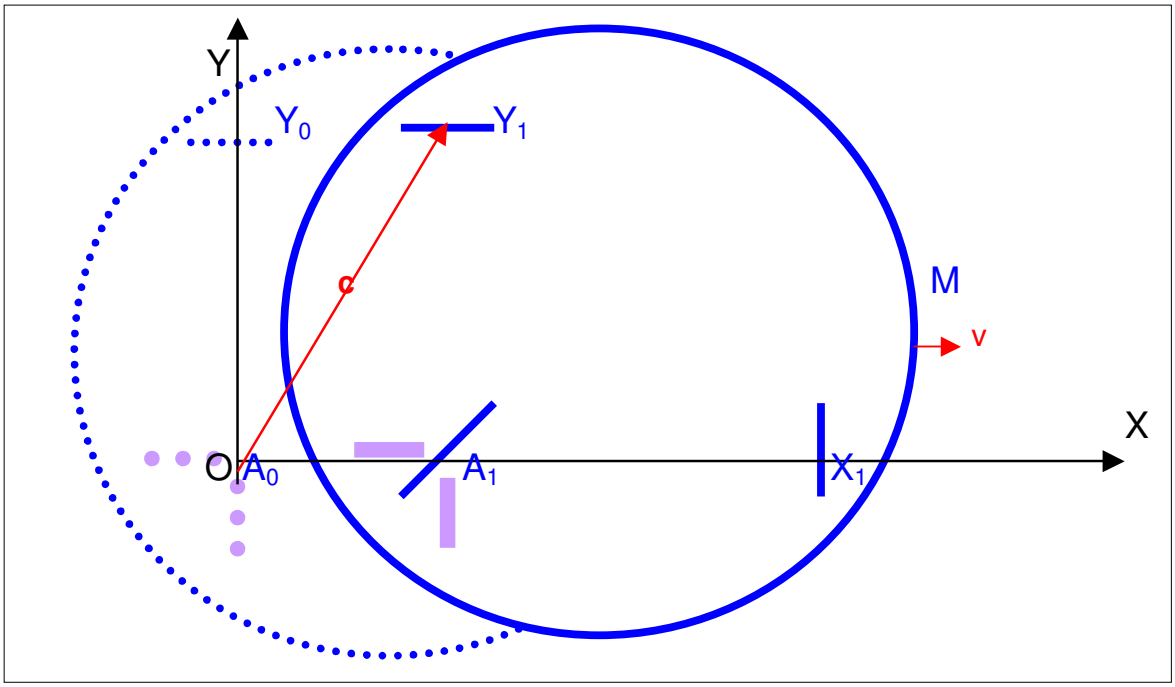
To begin with, at time t_0=0, let the point A_0 coincide with the origin O of the OXY coordinate system. Let the arm A_0X_0 align with OX axis and arm A_0Y_0 align with OY axis as shown in fig. 1. When the platform M is at rest in OXY during the MM experiment, two monochromatic light beams will set off from A_0 at velocity **c** towards X_0 and Y_0. After getting reflected from X_0 and Y_0 the two beams will arrive back at A_0 at the same instant of time (t=2D/**c**). Thus there will be no interference fringes and the rotation of the platform will not produce any fringe shift.

Case Ⅱ : Platform M moves along OX at uniform velocity 'v'.

In this case, at instant t_0=0, two light beams will set off from point A_0 at velocity **c** in the directions X_0 and Y_0 respectively. Let us call the beam set off towards Y_0 as the transverse beam and the other one moving towards X_0 as the axial beam. After an interval of time t_1, the platform M will move a distance $v.t_1$ along OX such that the point A_0 moves to a new position A_1 on OX as shown in fig. 2. Simultaneously the reflecting mirror locations X_0 and Y_0 would have moved to their new positions X_1 and Y_1 respectively such that,

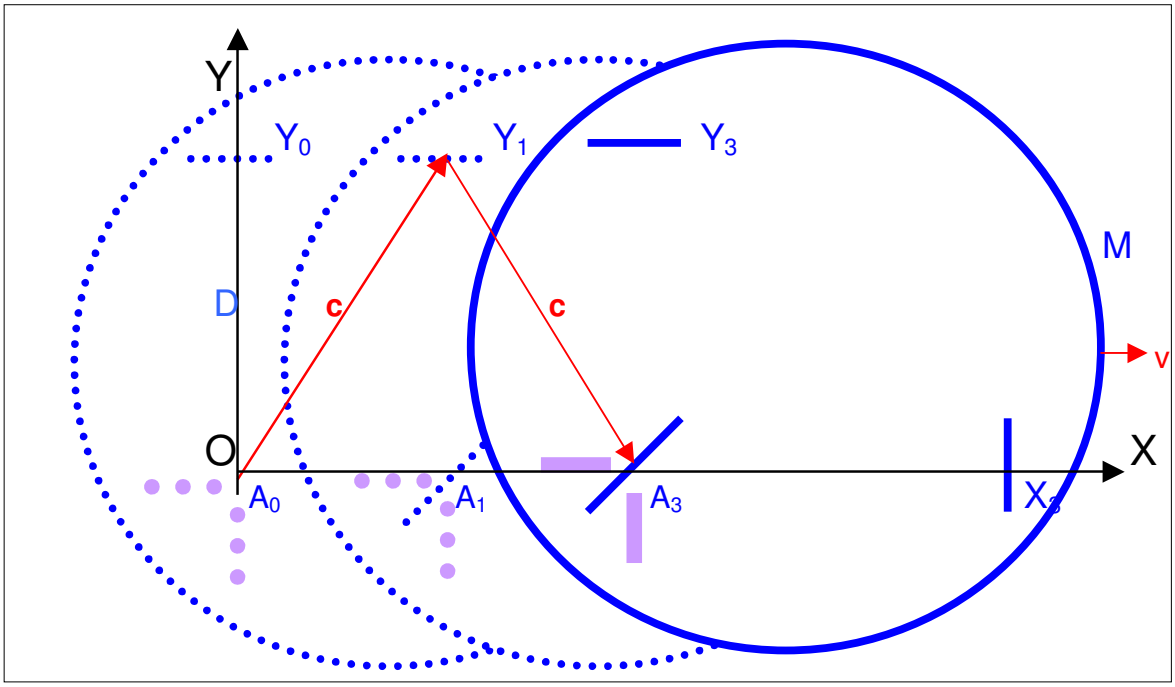
$$OA_1 = v.t_1$$
$$Ox_1 = D + v.t_1$$

Fig. 2



After an interval of time t_3 from the start, the platform M will move a distance $v.t_3$ along OX such that the point A_1 moves to a new position A_3 on OX as shown in fig. 3.

Fig. 3



Simultaneously the reflecting mirror locations X_1 and Y_1 would have moved to their new positions X_3 & Y_3 respectively such that,

$$OA_3 = v.t_3$$
$$Ox_3 = D + v.t_3$$

Let us take the time intervals t_1 and t_3 to be such that the transverse beam of light, starting from point A_0 at time $t_0=0$, travels through vacuum or empty space at a uniform velocity **c** (we may call it 'V'), gets reflected from the mirror at point Y_1 at time t_1. After reflection it arrives back to the receiver interferometer at point A_3 at time t_3 as shown. From the symmetry of the outward and inward light paths, we get $t_3=2\,t_1$. From triangle OA_1Y_1,

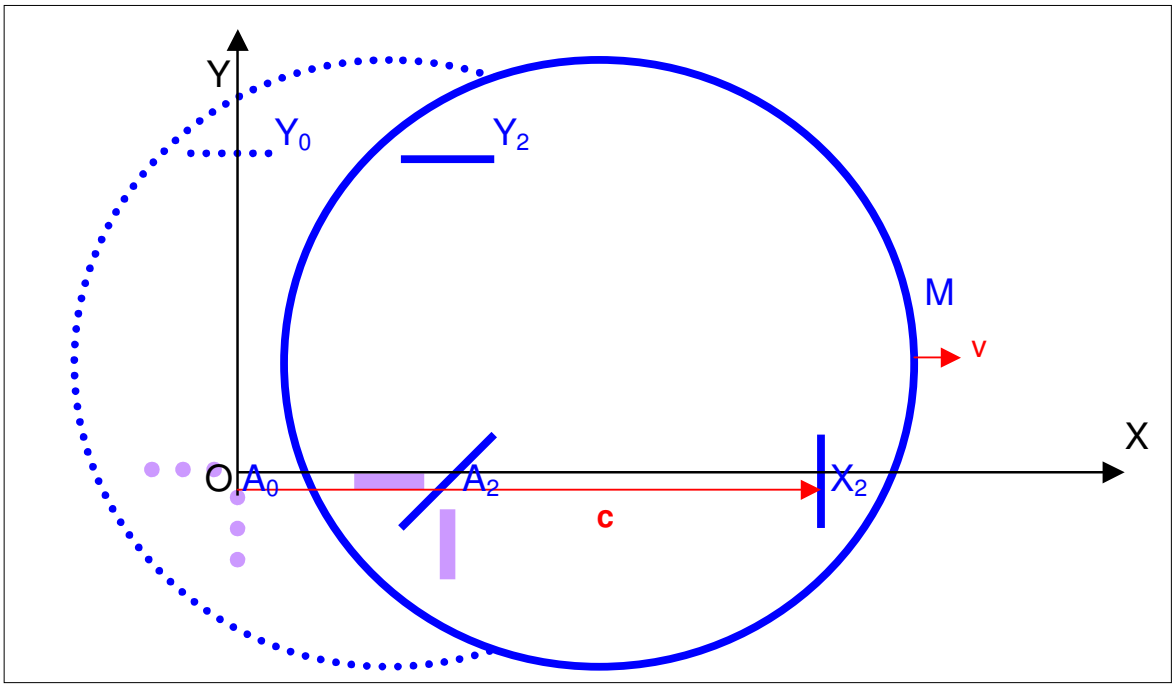
$$D^2 + (v.t_1)^2 = (\mathbf{c}.t_1)^2$$

Or

$$t_1 = \frac{D}{\sqrt{(c^2 - v^2)}} = \frac{D}{c}.\frac{1}{\sqrt{1 - v^2/c^2}} \qquad \text{and} \qquad t_3 = 2\,t_1 = \frac{2D}{c}.\frac{1}{\sqrt{1 - v^2/c^2}}$$

Now let us assume that the axial beam of light starting from point A_0 at time $t_0=0$, also travels through vacuum or empty space at a uniform velocity **c** and gets reflected from the axial mirror after a time interval t_2. At this instant t_2, whole platform M would have moved a distance $v.t_2$ along X axis and the points A_0, X_0 would have moved to positions A_2 and X_2 as shown in fig. 4.

Fig. 4



The time interval t_2 can be calculated the relation, $OX_2 = OA_2 + A_2X_2$

That is $\mathbf{c}.t_2 = v.t_2 + D$ or $t_2 = D/(\mathbf{c}-v)$

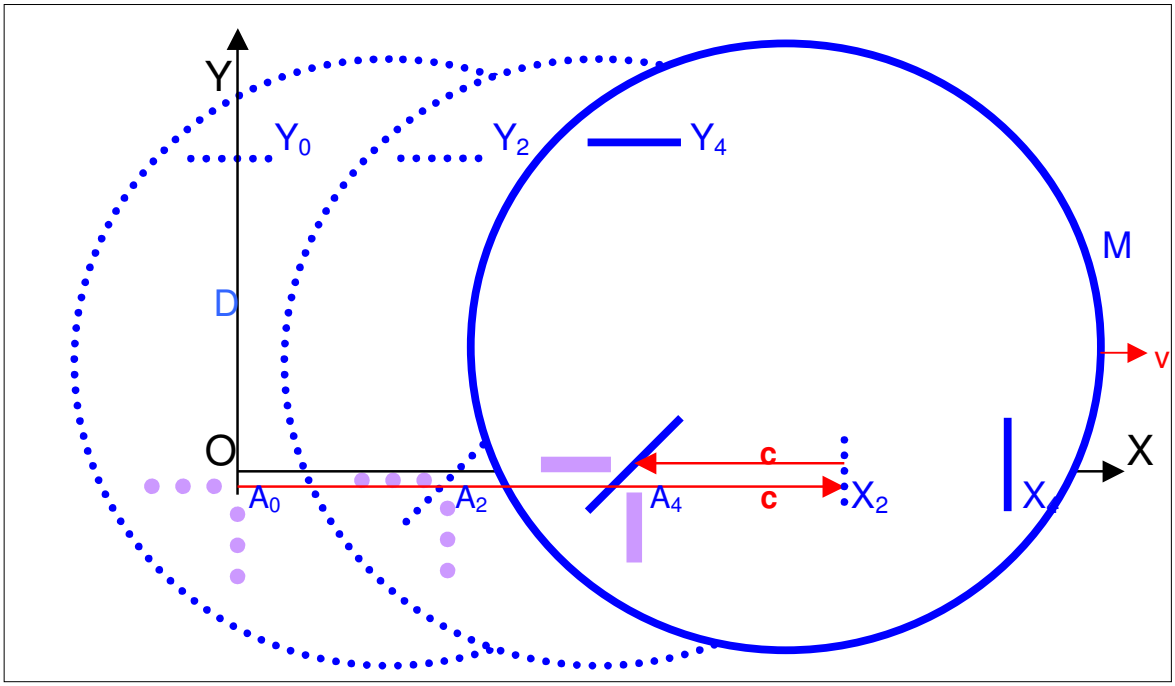
Let us further assume that the axial beam of light, after reflection from X_2 travels back at uniform velocity V and at instant t_4 reaches the interferometer which by now has shifted to A_4 as shown in fig. 5.

$$X_2A_4 = OX_2 - OA_4$$

Or $\mathbf{c}.(t_4 - t_2) = v.t_2 + D - v.t_4$ Or $(t_4 - t_2) = D/(\mathbf{c} + v)$

Hence $$t_4 = t_2 + \frac{D}{c+v} = \frac{D}{c-v} + \frac{D}{c+v} = \frac{2D}{c}.\frac{1}{(1-v^2/c^2)}$$

Fig. 5



Therefore, from the values of t_3 and t_4 we observe that the transverse and axial beams of light, after reflection do not arrive at the receiver interferometer at the same instant of time. The magnitude of difference between their arrival times is given by,

$$t_4 - t_3 = \frac{2D}{c}.\left(\frac{1}{(1-v^2/c^2)} - \frac{1}{\sqrt{(1-v^2/c^2)}}\right)$$

which yields, for $v^2/\mathbf{c}^2 \ll 1$, $t_4 - t_3 = (2\,D/\mathbf{c}).[(1+ v^2/\mathbf{c}^2 \ldots.) - (1+(1/2).(v^2/\mathbf{c}^2) \ldots.]$

$= (D/\mathbf{c}).(v^2/\mathbf{c}^2)$

Result of M M Experiment conducted in Vacuum

This is precisely the same result as obtained by Michelson and Morley in their calculations for the famous experiment conducted in aether current. This magnitude of time difference in the arrival of transverse and axial light beams, will yield observable fringe shift at the interferometer when the MM setup platform M is rotated by 90° or more. But when this MM experiment is actually conducted as originally done by Michelson & Morley, no fringe shift is observed. Even if we change the location of the platform M, or conduct the experiment at different times, still no fringe shift is actually observed. This result implies that regardless of the relative velocity of platform M with respect to coordinate system OXY, the axial and transverse beams actually always reach back at the same instant of time. Apparently that means our assumed 'vacuum' influences the axial and transverse beams of light differently and hence is not isotropic.

Well then, we may conclude that our MM experiment conducted in the thin 'vacuum' or isotropic 'empty space' has failed to show the predicted fringe shifts, just as the original MM experiment conducted in thin 'aether' had failed to show the predicted fringe shifts. Michelson & Morley had inferred from the negative result of their experiment that the 'non-existence of aether stands proved'. Therefore, following on their footsteps, we must also infer from the negative result of MM experiment conducted in the 'vacuum', that the non-existence of 'vacuum' stands proved!

Misleading Inferences from the M M Experiment

However, in reality, the MM experiment had neither proved the non-existence of 'aether' nor that of 'vacuum' or 'empty space'. The real culprit responsible for producing misleading results, inferences and proofs, were the set of explicit or implicit assumptions upon which the whole MM experiment was based, conducted and interpreted. Some of these assumptions are listed below.

a) The notion of aether current or aether wind in the MM experiment, analogous to the water current in a river, is quite misleading. When we consider a space ship in deep space, or a fish in an ocean, we never view their motion in terms of 'space current ' velocity or 'ocean current' velocity.
b) By assuming the aether as a thin, drag free elastic medium, which can support transverse waves of light and also permit drag free motion of solid bodies through it, we are implying self-contradictory notions to aether. It was logically improper to plan MM type experiment on aether without having any consistent and clear idea of its properties. Truly speaking aether is neither a thin medium as it was thought to be, nor it permits the motion of solid bodies through it the way it was visualized at that time. Clusters of solid particles actually propagate through highly elastic aether, somewhat like the propagation of strain wave packets through a steel block!
c) At the time of planning and conduct of MM experiment, light was assumed to be a continuous wave motion through the aether just like sound waves in the atmosphere. Actually as we know now, light consists of a stream of discrete

particles called 'quanta of light' or photons. These photons possess finite amount of electromagnetic field energy and momentum. Just as the motion (in vacuum) of other discrete particles like electron, neutron etc. is controlled by their energy and momentum characteristics, the motion of discrete photon particles too must be controlled by their energy and momentum. The interference characteristics of beams of photons will be governed by the mutual interaction characteristics of the photon particles. However, these interaction characteristics of photon particles have never been seriously examined so far. Neither have we explored the spatial extension nor the boundary characteristics of these particles. The assumption of light as a continuous wave motion, may be considered as a major factor responsible for producing misleading inferences from the MM experiment.

d) Even more than a century after the conduct of MM experiment, we are still not very clear about the exact mechanism of association of kinetic energy with a discrete particle in motion. Neither do we still consider it necessary to explore this mechanism. The implied assumption that the mode of association of K.E. with the particle in motion had nothing to do with the overall interpretation of the MM experiment, was also responsible for the misleading inferences.

Case III : M M Experiment with a Beam of Discrete Particles

Actually the motion of all discrete particles that contain finite energy content, finite momentum and display the property of Inertia, must be governed by the same set of physical laws. In this connection let us once again review and re-interpret the MM experiment conducted with a beam of electrons or neutrons. Let us assume that at point A_0 (Fig. 1.) we have a satisfactory arrangement for simultaneously emitting two pulses of electrons with uniform velocity V, one in the axial direction $A_0 X_0$ and another in transverse direction $A_0 Y_0$. When the platform M is at rest with respect to coordinate system OXY, the two pulses after reflection from the reflectors X_0 & Y_0 will obviously return back to the starting point at the same instant of time.

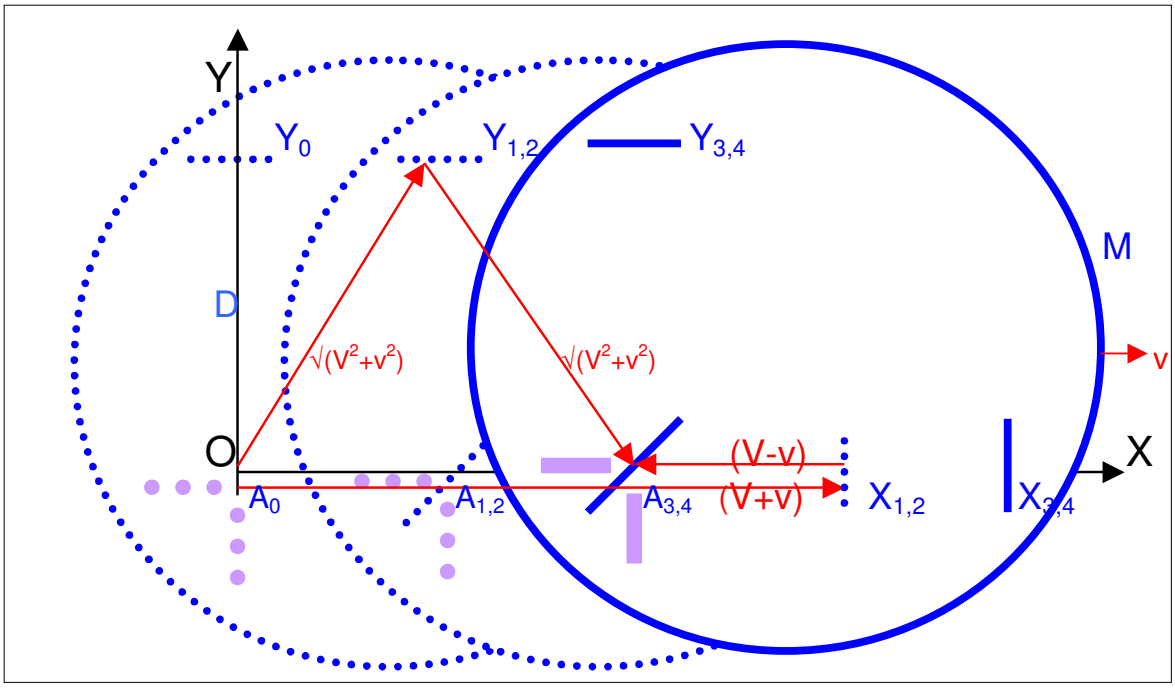
However, when the platform M moves, in vacuum, along OX at a uniform velocity v, the observers on the platform may not be aware of its motion along X axis. At time $t_0=0$, they emit an axial pulse of electrons from A_0 towards X_0 with a velocity V relative to the platform. Simultaneously at $t_0=0$, a transverse pulse of electrons is emitted towards Y_0 with a velocity V relative to the platform. During the interval of time $t_0=0$ to t_1, the velocity of electrons in the transverse pulse relative to the coordinate system OXY is $\sqrt{(V^2+v^2)}$. That is so because the platform velocity v gets vectorially added to the emission velocity V of the electrons. Therefore, the time t_1 taken by the transverse electron pulse to reach the reflector at A_1 will be given by

$$(V^2+v^2).t_1^2 = D^2 + (v.t_1)^2 \qquad \text{or} \qquad t_1 = D/V$$

Similarly the time interval t_3-t_1 taken by these electrons on their return path after reflection will be given by

$$t_3-t_1 = D/V \qquad \text{or} \qquad t_3 = 2\,D/V$$

Fig. 6



Now let us consider the axial electron pulse emitted from A_0 at time $t_0=0$, with emission velocity V relative to the platform. Obviously the pulse velocity in coordinate system OXY will be obtained by vectorially adding the platform velocity v to the electron emission velocity V, that is V+v. Therefore, from fig. 6, the time interval t_2 will be calculated as

$$OX_2 = OA_2 + A_2X_2$$

Or $(V+v).t_2 = v.t_2 + D$ Or $t_2 = D/V$

At time t_2, the axial pulse of electrons will get reflected from the reflector at X_2. Reflected velocity of these electrons with respect to the reflector will be the same as their initial velocity relative to the reflector (i.e. V) before reflection. That is the velocity of the reflected axial pulse relative to the reflector will be V towards A_2. Therefore the velocity of the reflected axial pulse relative to the coordinate system OXY, will be (V-v). At time t_4, when the reflected axial pulse of electrons arrives back to the receiver at A_4, we get from fig. 6,

$$X_2A_4 = OX_2 - OA_4$$

Or $(V-v).(t_4-t_2) = (V+v).t_2 - v.t_4$

$$= v.t_2 + D - v.t_4 = D - v.(t_4-t_2)$$

or $t_4 - t_2 = D/V$

or $t_4 = t_2 + D/V = 2\,D/V$

That means $t_4 - t_3 = 0$

Result of M M Experiment conducted with a Beam of Particles

This is indeed a remarkable result. It shows that the transverse and axial pulses of electrons, after reflection from their respective reflectors, will reach back at the receiver at the same instant of time, which is independent of the platform velocity v. This result should obviously hold good even when we conduct the MM experiment with the pulses or beams of any other discrete particles like neutrons, protons or photons. Michelson and Morley had conducted their original historic experiment with a beam of photons. No wonder that they did not observe any fringe shift even after repeating the experiment at different locations and at different times. Now we can easily appreciate that even though the observations of the original MM experiment were not wrong, their inferences were totally wrong and misleading, essentially due to their faulty expectations based on faulty assumptions. In historic perspective, perhaps it would have been more appropriate for Michelson and Morley to conduct their experiment for establishing the nature of light – that is, whether light consists of continuous waves like sound waves or whether light consists of discrete particles like electrons. It was wrong to attempt to prove or disprove the existence of aether by assuming continuous wave nature of light.

However, it was the greatness of Albert Einstein who beautifully accommodated the results of MM experiment by adopting his famous postulates of the Special Theory of Relativity.

Relativity of Reference Frames and Universal Frames

Finally, we would like to slightly elaborate our earlier remarks regarding the notions of aether current or aether wind and the logically inappropriate notions of ocean current velocities with reference to the movements of fish in the ocean. As per the highly successful Special theory of Relativity, all reference frames in uniform relative motion (Inertial Frames) are theoretically equivalent in the sense that all physical laws are valid and have the same form in all of them. This theoretical equivalence of all inertial frames is however, somewhat similar to the equality in law of all citizens of a state. [Say for example the United States President is equal in law to a street beggar!] But in actual practice and on very sound considerations, all citizens are grouped into different heirarchy levels, all of which are practically not equivalent.

On similar considerations of practical convenience and logical propriety, we may subdivide all theoretically equivalent reference frames into following heirarchy levels.

I. **Local or Proper Reference Frame** is the one in which the observer and his measuring tools are at rest. In our normal day-to-day life, we often observe the motion of objects around us in our local reference frames.
II. **Global Reference Frame** is the one, which is fixed or at rest relative to an Earth centered reference frame. A global reference frame will practically function as a Universal Frame of reference relative to all the local frames located on the surface or near vicinity of earth.

III. **Stellar Reference Frame** is the one, which is fixed or at rest relative to a Sun centered reference frame. A Stellar reference frame will practically function as a Universal Frame of reference relative to all the local and global frames located in the Solar system.

IV. **Galactic Reference Frame** is the one, which is fixed or at rest relative to a Galaxy centered reference frame. A Galactic reference frame will practically function as a Universal Frame of reference relative to all the local, global and Stellar reference frames located in that Galaxy.

V. **Universal Reference Frame** is the one, which is fixed or at rest relative to a reference frame fixed at the center of the Universe.

In the study and analysis of interaction problems involving two or more inertial frames, it is logically appropriate and practically convenient to associate their common relatively Universal reference frame as indicated above. However it is quite inappropriate to use a local reference frame to study a dynamic phenomenon occurring in a relative Universal frame. To illustrate this point, let us consider a specific example of a beam of high speed (say V=0.5c) protons passing through the solar system. Let us assume the total rest mass of the solar system (rest mass of all bodies and particles) to be M_s and the total kinetic energy of all bodies and particles of the solar system to be E_s. We can easily study the interactions of the proton beam with the solar system by using the Stellar reference frame S. However, the mutual interactions of the protons in the beam can be studied by using a Local reference frame P moving with the beam at uniform velocity V=0.5c. But we can not use this local reference frame P to study the interactions in S. For if we attempt to do so, frame S will appear to be in relative uniform motion at 0.5c with respect to the protons in P. That means in the reference frame P, the solar system with mass M_s and internal energy E_s will appear to be moving at velocity 0.5c and corresponding enormous amount of kinetic energy associated with it. From where did the solar system acquire this enormous amount of kinetic energy ? This fictitious amount of K.E. is attributed to our improper use of a Local reference frame to study the interactions in a relative Universal reference frame. Michelson & Morley had also attempted to study the interactions in the aether current by using a Local reference frame, which was logically inappropriate.

G. S. SANDHU

September 29, 2002