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Full Length Research Paper

A supplement to the Michelson-Morley experiment

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Based on the great Michelson-Morley experiment and predecessors' analyses, this famous experiment was reviewed under the principle that velocity of light is independent of the motion of the light source emitting or reflecting it, mainly on time difference or optical path difference (OPD). We will discover in this work that predecessors' analysis on the famous experiment may be improper, and that there is no difference or OPD in some directions, while there is difference or OPD in other directions after a lot of calculation is done. The light beam is divided into many light rays in the analysis, leading to the research on its effect on the light rays.

Key words: Aether, optical path difference (OPD), Michelson, interferometer, inertia, light, velocity.

INTRODUCTION

With the Michelson interferometer invented by Michelson, one of the most important inventions in the physical history, Michelson and Morley did the famous Michelson-Morley experiment jointly in 1887.

Predecessors' analyses

Let us look at predecessors' analyses on this famous experiment, as shown in Figure 1, where L represents light beam emitting from light source (S) (Mechanics, Tsinghua University Press, Apr 01, 1999; http://galileo.phys.virginia.edu/classes/252/michelson.html).

According to predecessors' analyses about the famous experiment, the light beam L travels along the paths in (a) actually and (b) seemingly (Figure 1), where the path in (a) is the expected path of light relative to the aether with an aether wind blowing. In the author's opinion, however, the analyses about the experiment are not quite satisfactory in some aspects. For instance, why does light travel along the path as shown in Figure 1a? This idea may come from the phenomenon – when we throw an apple vertically upwards on running train, the apple will fall back to the exact point before it was thrown off. The people on the train may say the apple moved vertically. However, the people on ground may say the apple actually travelled a slant way, as shown in Figure 1a. The essential difference between apple motion and light travel is that apple is featured by inertia.

In fact, the imagined material which is called aether is expected to be still in space. The aether wind is actually the effect caused by relative motion of the Earth, and in aether, light will travel along the direction when it is emitted or reflected. Therefore, when the reflected light beam (by G_1) enters aether, the beam will travel along the direction when it is reflected by G_1 – vertically upwards, not slant ways, plus the proven principle that velocity of light is independent of the motion of the light source emitting or reflecting it - light is not featured by inertia.

Why it is considered that light travels along the path (Figure 1a) may be that it seems that the reflected light beam (by G_1) will come back to the exact point on G_1' after the beam is reflected by M_2 during the experiment. Actually, to the author, the reflected light beam (by G_1) is not bound to come back to the exact point on G_1' after the beam is reflected by M_2. This is because the reflected light beam (by G_1) will travel vertically upwards and then vertically downwards with G_1 moving all the time. When the light beam reflected by M_2 reaches G_1', there may exist a little departure [that is, $\sqrt{(2(ut)^2)}$] from the point on G_1' when the beam was reflected. This departure between the reflection point on G_1' and the point when the light beam reflected by M_2 reaches G_1' may be very tiny because of the exceptionally high velocity of light. Therefore, it may be very difficult to observe this departure, leading to the consideration that there is no departure between the two points, as show in Figure 1b. In this way, it seems reasonable to consider that reflected light beam (by G_1) will come back to the exact point on G_1' after the beam is reflected by M_2, where the distance

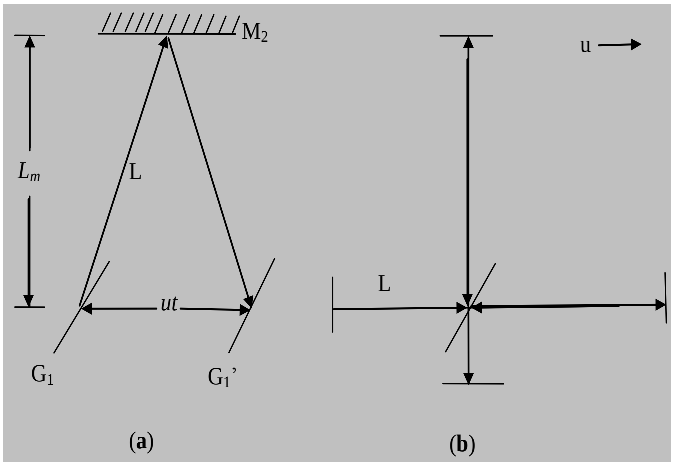

Figure 1. Predecessors' analytical illustrations.

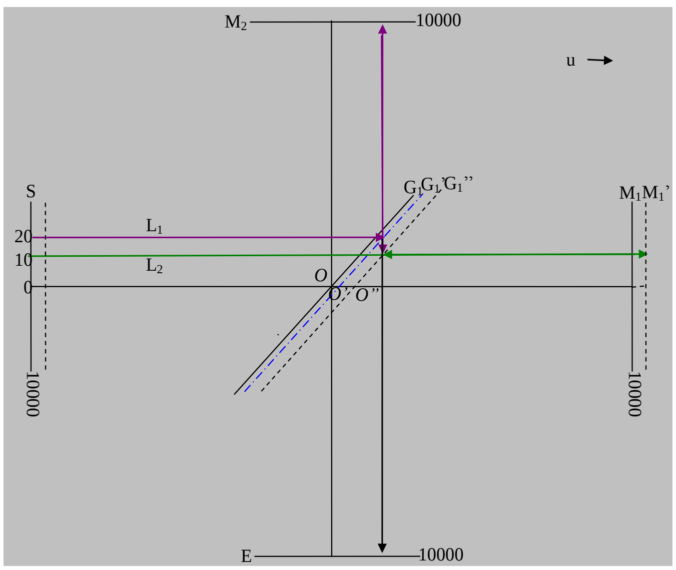

Figure 2. Top light rays which can superpose with each other.

between G_1 and G_1' is *ut,* as shown in Figure 1a. This leads to the wrong conclusion that with G_1 moving to G_1', the light beam reflected by G_1 must travel along the path as shown in Figure 1a to come back to the reflection point on G_1', which lets light to be featured by inertia.

Analysis

Under the principle, we all know that velocity of light is independent of the motion of the light source emitting or reflecting it:

Using the following data (where the unit of time is *s*, and the unit of length is mm) which may not be quite accurate:

U = 30000000 (http://en.wikipedia.org/wiki/Michelson%E2%80%93Morley_experiment)
C = 299792458000 (Waves and Optics, Tsinghua University Press, Jan 01, 2000; http://en.wikipedia.org/wiki/Speed_of_light)
c-u = 299762458000
c+u = 299822458000
c/u = 9993.0819333333333333333333333333
c/u-1 = 9992.0819333333333333333333333333
c/u+1 = 9994.0819333333333333333333333333
And:
SO = OM_1 = OM_2 = OE = 10000, and the diameter of light beam emitted from S is 40
From Figure 2, the following results can be obtained:
T_{11} = T_{SG} = (10000+20)/(c-u) = 3.3426467299650978976159849876865e-8

Δl_1= OO'= (T_{11}*c)/(c/u) = 1.0027940189895293692847954963 06
Or,
(10000+20)+Δl_1 = (c/u)Δl_1
Δl_1=1.0027940189895293692847954963 06

$T_{SM1'}$ = (10000*2)/(c-u) =6.6719495608085786379560578596537e-8
D = [($T_{SM1'}$ *c)/(c/u)]*2+10000*3-20-Δl_1
D = Δl(c/u)
29983.000375717495617813488839219 = Δl(c/u)
Δl = 3.0003757174956178134888392194864 = OO''

T_{12} = $T_{G'M2}$ = (10000-20)/c=3.3289696700775574547642556104597e-8
T_{13} = $T_{M2G''}$ = [(10000-20)+ (Δl -Δl_1)]/c= 3.3296359916094040259158901334747e-8
T_1 = SUM (T_{11}, T_{12}, T_{13})= 1.0001252391652059378296130731619e-7

T_{21} = $T_{SM1'}$= (10000*2)/(c-u) = 6.6719495608085786379560578596537e-8

T_{22} = $T_{M1'G''}$ = [(T_{21}*c)/(c/u) + (10000-20-Δl_1)]/c=3.3293028308434807403400728719672e-8
T_2 = SUM (T_{21}, T_{22}) = 1.0001252391652059378296130731 62e-7
OR,
T_2 = D/c = 1.0001252391652059378296130731618e-7

T_{E1} (which is the time L_1 takes to travel from S to E via M_2) = T_{11}+ T_{12}+ (10000*2)/c= 1.3342898304005696343891774887643e-7

From the results above, we can find that there is almost no time difference between the 2 superposed light rays, that is, there is almost no OPD between them.

If SO = 3000:

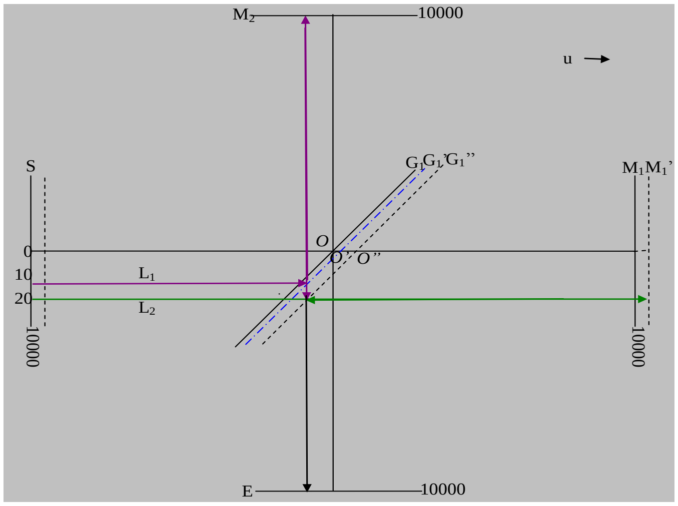

Figure 3. Bottom light rays which can superpose with each other.

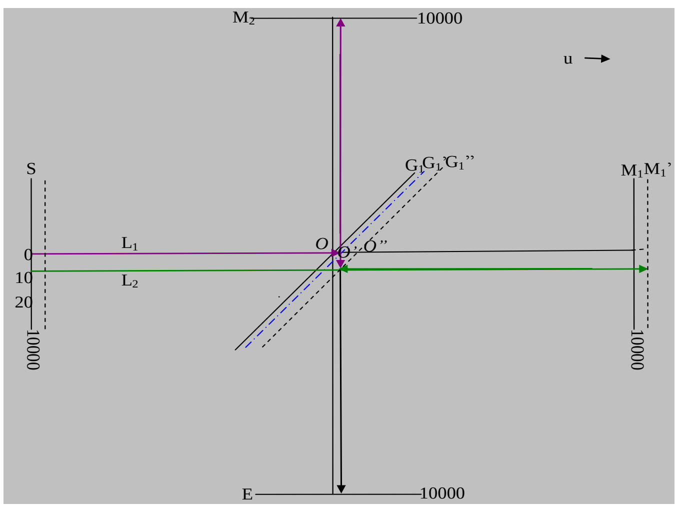

Figure 4. Mid light rays which can superpose with each other.

$T_{11} = (3000+20)/(c-u) = 1.0074643836820953743313647368077e\text{-}8$

$\Delta l_1 = OO' = (T_{11}*c)/(c/u) = 0.30223931510462861229940942104232$
OR,
$(3000+20)+\Delta l_1 = (c/u)\Delta l_1$
$\Delta l_1 = 0.30223931510462861229940942104232$

T_{SM1} ’= $(3000+10000)/(c-u) = 4.3367672145255761146714376087749e\text{-}8$
$D = [(T_{SM1'} *c)/(c/u)]*2+3000+10000*2-20-\Delta l_1$
$D = \Delta l(c/u)$
$22982.299821013610717056503453144 = \Delta l(c/u)$
$\Delta l = 2.2998210136107170565034531442227=OO''$

$T_{12} = (10000-20)/c=3.3289696700775574547642556104597e\text{-}8$
$T_{13} = [(10000-20) + (\Delta l - \Delta l_1)]/c = 3.3296359916094040259158901334747e\text{-}8$
$T_1 = SUM(T_{11}, T_{12}, T_{13})=7.6660700453690568550115104807407e\text{-}8$

$T_{21} = T_{SM1'} = (3000+10000)/(c-u) = 4.3367672145255761146714376087749e\text{-}8$
$T_{22} = [(T_{21}*c)/(c/u) + (10000-20-\Delta l_1)]/c = 3.3293028308434807403400728719672e\text{-}8$
$T_2 = SUM(T_{21}, T_{22}) = 7.666070045369056855011510480741e\text{-}8$
Or,
$T_2 = D/c = 7.6660700453690568550115104807406e\text{-}8$

The results we obtained above show that there is still almost no time difference when SO = 3000.

In Figure 3, the following results can be obtained:

$T_{SM1'} = (10000*2)/(c-u) = 6.6719495608085786379560578596537e\text{-}8$
$[(T_{SM1'} *c)/(c/u)]*2+10000*3+20-\Delta l = \Delta l(c/u)$
$30024.003169736485147182773634716 = \Delta l(c/u+1)$
$\Delta l = 3.0041782096659835749044629906993 = OO''$

$(10000-20+\Delta l) = \Delta l_1(c/u)$
$\Delta l_1=0.99899152681916360786917172509$3

$T_{11} = (10000-20+\Delta l)/c = 3.3299717560638786928972390836432e\text{-}8$
$T_{12} = [(10000+20)-(\Delta l-\Delta l_1)]/c = 3.3416433756039163533703588729822e\text{-}8$
$T_{13} = (10000+20)/c= 3.3423122338854835367472786790387e\text{-}8$
$T_1 = SUM(T_{11}, T_{12}, T_{13}) = 1.0013927365553278583014876635664e\text{-}7$

$T_{21} = T_{SM1'} = (10000*2)/(c-u) = 6.6719495608085786379560578596537e\text{-}8$

$T_{22} = [(T_{21}*c)/(c/u) +(10000+20-\Delta l)]/c = 3.3419778047446999450588187760104e\text{-}8$
$T_2 = SUM(T_{21}, T_{22}) = 1.0013927365553278583014876635663e\text{-}7$

$T_{E1} = T_{11}+T_{12} + (10000*2)/c = 1.3342897035630836037779132246123e\text{-}7$

In Figure 4, the following results can be obtained:
$10000+\Delta l_1 = \Delta l_1 (c/u)$
$\Delta l_1 = OO' = 1.0007924341212867956934086789481$

$T_{SM1'} = (10000*2)/(c-u) = 6.6719495608085786379560578596537e\text{-}8$
$D = [(T_{SM1'} *c)/(c/u)]*2+10000*3-\Delta l_1$
$D = \Delta l(c/u)$

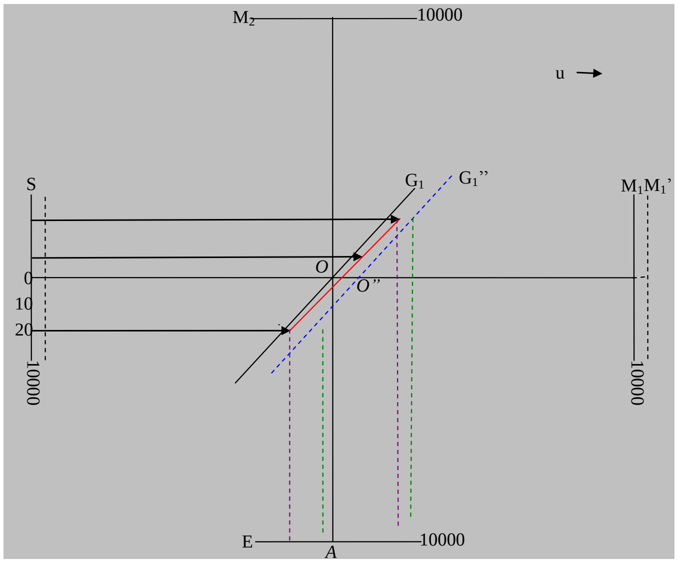

Figure 5. Front section.

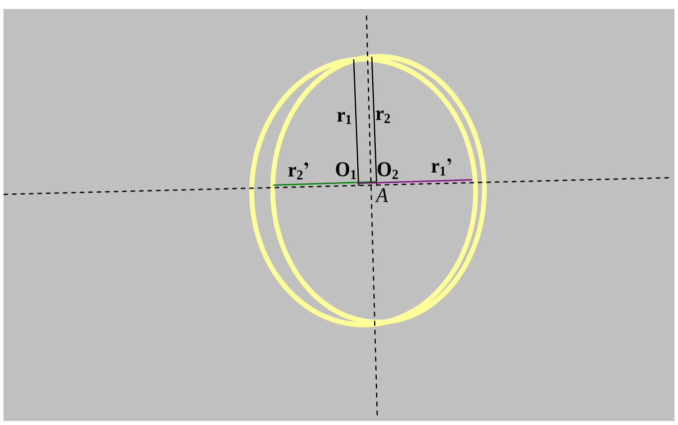

Figure 6. Facula.

30003.0023773023638603870802260 37 = $\Delta l(c/u)$
Δl=3.00237730236386038708022603684 42 = OO''

T_{11} = $T_{SOO'}$ = 10000/(c-u) = 3.335974780404289318978028929826 8e-8
Or,
T_{11} = (10000+Δl_1)/c = 3.335974780404289318978028929826 8e-8
T_{12} = $T_{O'M2}$=10000/c = 3.335640951981520495755767144749 2e-8
T_{13} = [10000+ (Δl -Δl_1)]/c = 3.336308608827058142200290714904 5e-8
T_1 = SUM (T_{11}, T_{12}, T_{13})= 1.000792434121286795693408678947 9e-7

T_{21} = $T_{SM1'}$= (10000*2)/(c-u) = 6.671949560808578637956057859653 7e-8

T_{22} = (T_{21}* u +10000-Δl_1) /c = 3.335974780404289318978028929826 8e-8
T_2 = SUM (T_{21}, T_{22}) = 1.000792434121286795693408678948e-7
Or,
T_2 = D/c = 1.000792434121286795693408678948e-7

T_{E1} = T_{11}+T_{12} + (10000*2)/c = 1.334289763634885080624533036407 3e-7

Let us compare the 3 Δl_1s of the 3 pairs of light rays above (SO = 10000):

Δl_1 (L_{top}) = 1.0027940189895293692847954963 06
Δl_1 (L_{mid}) = 1.0007924341212867956934086789481
Δl_1 (L_{bot}) = 0.9989915268191636078691717250 93

By comparing them, we can know that the Δl_1s decreases from top to bottom gradually. The rough front section of all light rays when they respectively arrive at G_1 is like the red line in Figure 5.

The final result we will see on view-screen is that the light intensity to the right is higher than that to the left. In Figure 6, r_1 is the radius (in vertical direction) of the facula (on view-screen) of the light beam reflected by M_2, and r_2 is the radius (in vertical direction) of the facula (on view-screen) of the light beam reflected by M_1. We can demonstrate that:

r_2>r_2'
r_1<r_1'

Let us compare the 3 T_{E1}s of the 3 light rays (reflected by M_2) above (SO=10000):

T_{E1} (L_{top}) = 1.334289830400569634389177488764 3e-7
T_{E1} (L_{mid}) = 1.334289763634885080624533036407 3e-7
T_{E1} (L_{bot}) = 1.334289703563083603777913224612 3e-7

We can find that the light rays (reflected by M_2) to the left arrive at E first. In fact, in Figure 5, we will find that the light rays (reflected by M_2) to the right travel a longer distance than that to the left. Similarly, the light rays (reflected by M_1) to the left arrive at E first.

If u is in the opposite direction (Figure 7), the following results can be obtained:

10000-Δl_1=Δl_1 (c/u)
Δl_1 = OO' = 1.0005921571091916003170116095 84

T_{11} = $T_{SOO'}$=10000/(c+u) = 3.335307190363972001056705365279 9e-8
Or,
T_{11} = (10000-Δl_1)/c = 3.335307190363972001056705365279 9e-8

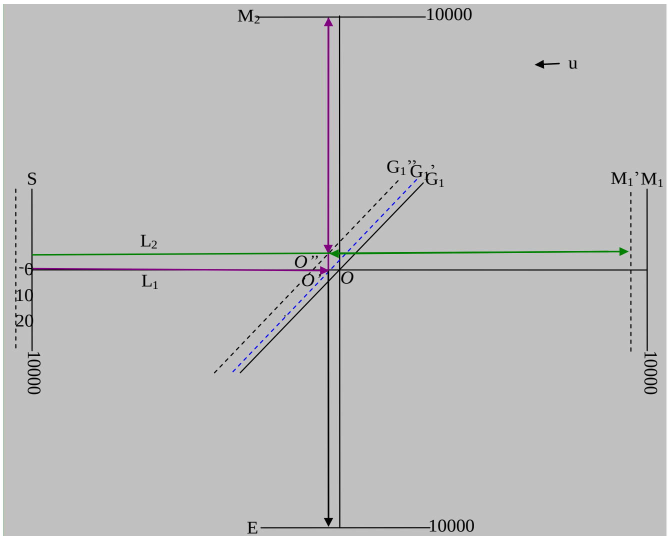

Figure 7. When u is in opposite direction.

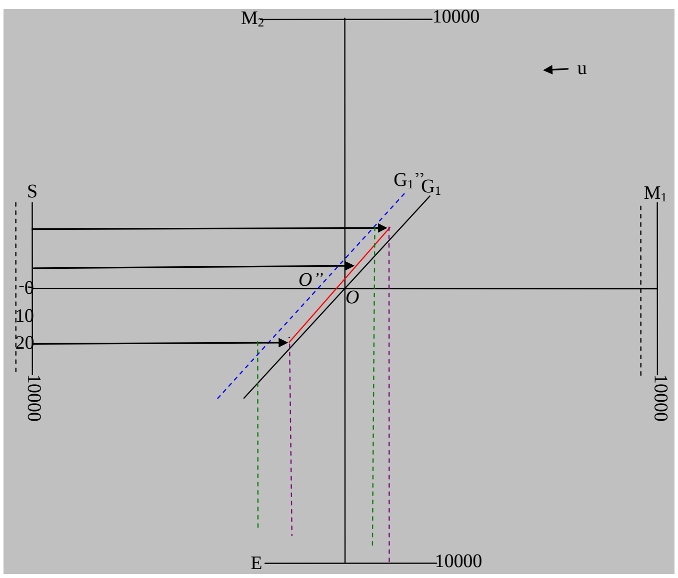

Figure 8. Front section.

$T_{12} = T_{O'M2} = 10000/c = 3.3356409519815204957557671447492e-8$

$T_{13} = [10000- (10000 /(c/u))]/ (c+u) = 3.3349734287464235063576435858106e-8$

$T_1 = SUM (T_{11}, T_{12}, T_{13}) = 1.0005921571091916003170116095839e-7$

$T_{21} = T_{SM1'} = (10000*2)/(c+u) = 6.6706143807279440021134107305598e-8$

$T_{22} = (10000+\Delta l_1-T_{21}*u)/c = 3.3353071903639720010567053652799e-8$

$T_2 = SUM (T_{21}, T_{22}) = 1.0005921571091916003170116095839e-7$

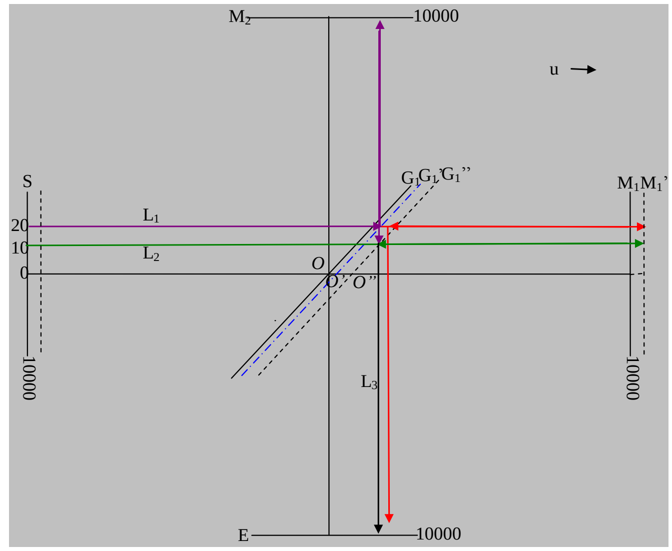

Figure 9. Reflected and transmitted lights.

It is very obvious that there is almost no time difference between the superposed light rays. The final result shows on view-screen light intensity to the right is higher than that to the left, except that the light rays to the right arrive at E first, as shown in Figure 8.

Figure 9 shows that the reflected light ray and transmitted light ray of L_1 will not arrive at E at the same time, because L_4 is reflected at one position between G_1' and G_1'', rather than at G_1'' position. Therefore, L_4 lags behind L_3.

When u is in the direction in Figure 10, it can be demonstrated that there is no OPD between any light rays, and they arrive at E at the same time. The facula is as shown in Figure 11. When u is in the direction as in Figure 12, use the following data:

cos45° = 0.70710678118654752440084436210485
$\sqrt{(2)}$ = 1.4142135623730950488016887242097
c-u cos45° = 299771244796.56440357426797466914
c+u cos45° = 299813671203.43559642573202533086
c+$\sqrt{(2)}$u = 299834884406.87119285146405066173
c-$\sqrt{(2)}$u = 299750031593.12880714853594933827
$\sqrt{(2)}*\Delta l_1$ = 1.4149923533787645867970063199242

$10000-\sqrt{(2)}\Delta l_1 = \Delta l_1 (c/u)$
Δl_1 = 1.0005506884012360212957595144385

$T_{11} = 10000/(c+\sqrt{(2)}u) = 3.3351689613374534043191983814616e-8$

$T_{12} = (10000+\Delta l_1 \cos45°)/(c-u \cos45°) = 3.3361130094260811374539223490032e-8$

$T_{13} = (T_{12}*c-T_{12}*\sqrt{(2)}u)/(c+\sqrt{(2)}u) = 3.3351688945464120728151667032255e-8$

$T_1 = SUM (T_{11}, T_{12}, T_{13}) = 1.0006450865309946614588287433689e-7$

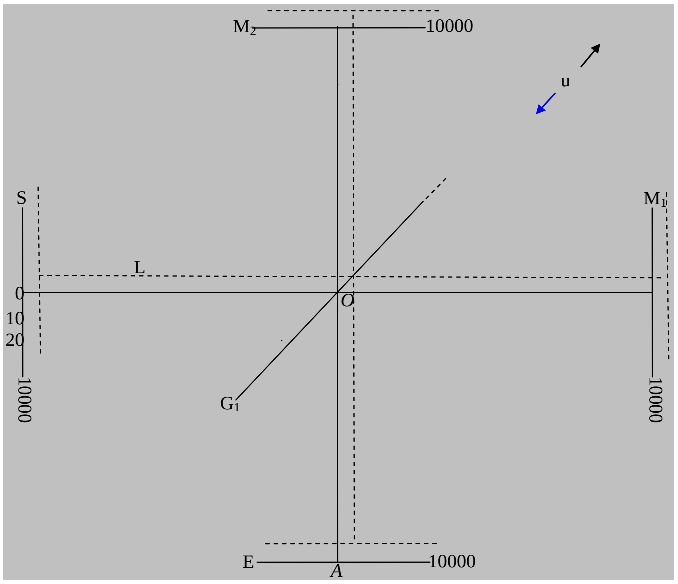

Figure 10. There is no OPD.

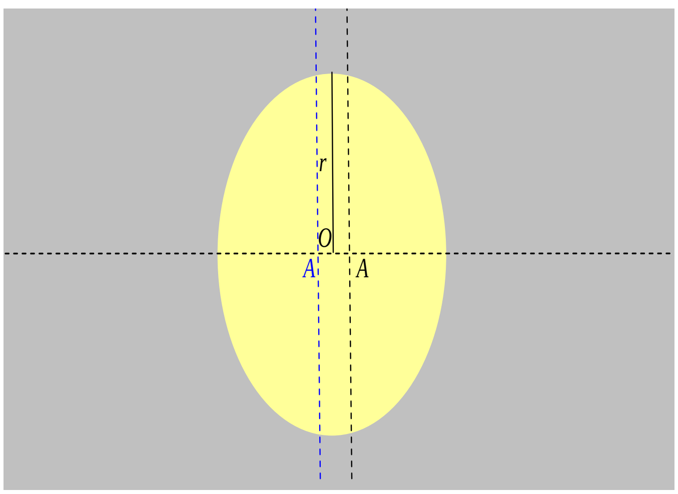

Figure 11. Facula.

$T_{21} = (10000*2)/(c+u\ \cos45°) = 6.6708098799234535687170395511858e\text{-}8$

$T_{22} = (10000+\sqrt{(2)}\ \Delta l_1 - T_{21}*\ u\ \cos45°)/\ c = 3.3356409185860001643978411697227e\text{-}8$

$T_2 = SUM\ (T_{21},\ T_{22}) = 1.0006450798509453733114880720908e\text{-}7$

$T_1 - T_2 = 6.6800492881473406712772273422988e\text{-}16$

We can find in this circumstance there is a time difference or OPD between the superposed light rays. When u is in the direction as in Figure 13:

$10000+\sqrt{(2)}\Delta l_1 = \Delta l_1\ (c/u)$

$\Delta l_1 = 1.000833922870808874658122387935 5$

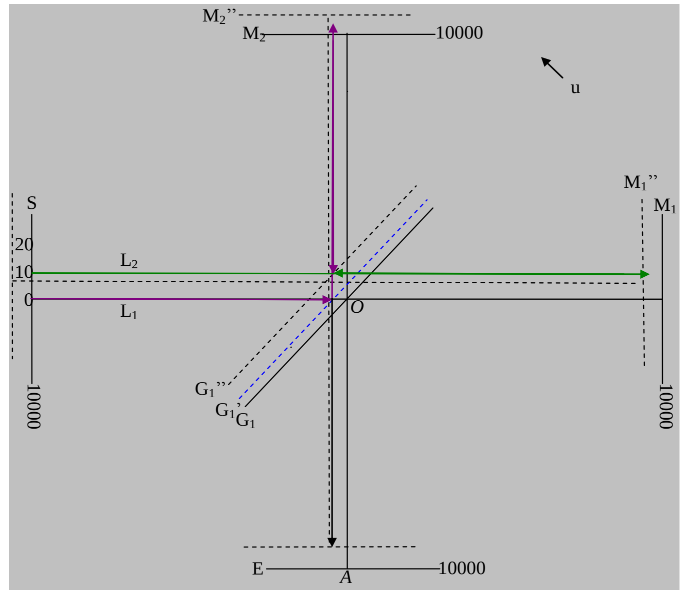

Figure 12. There exists OPD.

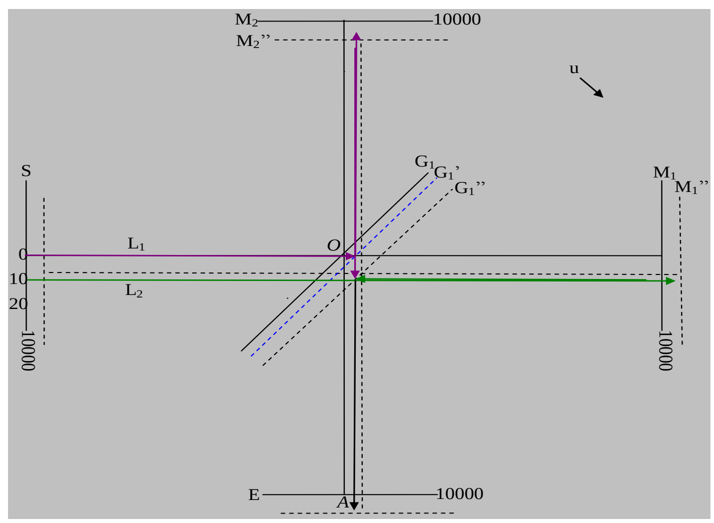

Figure 13. There exists OPD.

$T_{11} = 10000/(c-\sqrt{(2)}u) = 3.3361130762360295821937412931191e\text{-}8$

$T_{12} = (10000-\Delta l_1\ \cos45°)/(c+u\ \cos45°) = 3.3351688945369591850801126030842e\text{-}8$

$T_{13} = (T_{12}*c+T_{12}*\sqrt{(2)}u)/(c-\sqrt{(2)}u) = 3.3361130094166255738088173068873e\text{-}8$

$T_1 = SUM\ (T_{11},\ T_{12},\ T_{13}) = 1.0007394980189614341082671203 09e\text{-}7$

$T_{21} = (10000*2)/(c-u\ \cos45°) = 6.6717539948078484083404827142359e\text{-}8$

$T_{22} = (10000-\sqrt{(2)}\Delta l_1 +\ T_{21}*\ u\ \cos45°)/\ c = 3.3356410521822608211481468061983e\text{-}8$

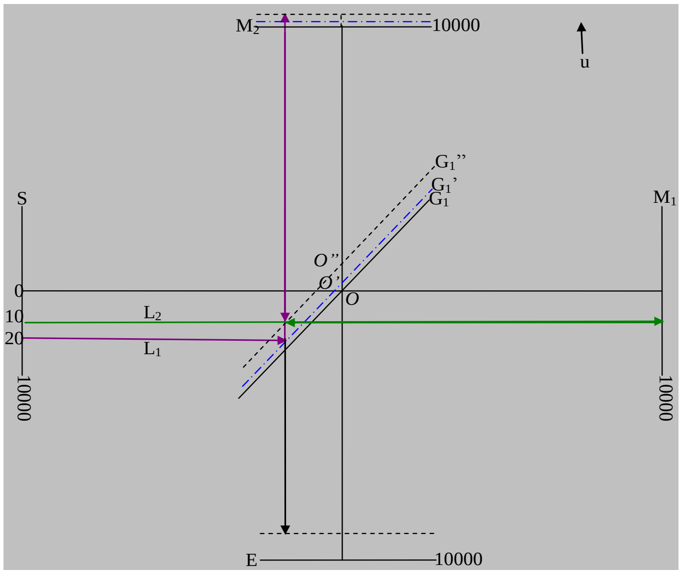

Figure 14. Bottom light rays which can superpose with each other.

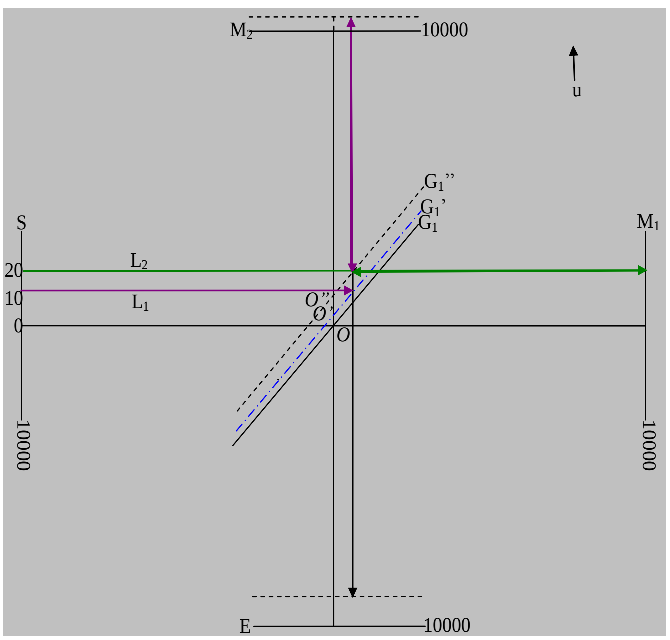

Figure 15. Top light rays which can superpose with each other.

T_2 = SUM (T_{21}, T_{22}) = 1.0007395046990109229488629520433e-7

$T_2 - T_1$ = 6.6800494888405958317343320940694e-16

We can find, in this circumstance, there is a time difference or OPD between the superposed light rays too.

When the direction of u is as shown in Figure 14, the following results can be obtained:

$(10000-20)-\Delta l_1 = \Delta l_1(c/u)$
$9980 = \Delta l_1(c/u+1)$
Δl_1 = 0.99859097279497321711637758636483

T_{11} = (10000-20)/(c+u) = 3.3286365759832440570545919545493e-8
T_{12} = $(10000+20+\Delta l_1)/(c-u)$ = 3.3429798573952162392587254463954e-8
T_{13} = $(T_{12}*c-T_{12}*u)/(c+u)$ = 3.3423108655098795078309698793761e-8
Or
T_{13} = $(10000+20+\Delta l_1)/(c+u)$ = 3.3423108655098795078309698793765e-8
T_1 = SUM (T_{11}, T_{12}, T_{13}) = 1.0013927298888339804144287280 32e-7

T_2 = $(10000*3+20+\Delta l_1)/c$ = 1.0013927231942837925968476624447e-7

(10000*2)/(c+u)=6.67061438072794400211341073055 98e-8
T_{E1} = $T_{11}+T_{12}$+(10000*2)/(c+u) = 1.3342230814106404298426728131503e-7

If SO = 3000:

$(3000-20)-\Delta l_1 = \Delta l_1(c/u)$
$2980 = \Delta l_1(c/u+1)$
Δl_1 = 0.29817646281853909689446945965603

T_{11} = (3000-20)/(c+u) = 9.9392154272846365631489819885 34e-9
T_{12} = $(10000+20+\Delta l_1)/(c-u)$ = 3.3427462008811051779862621988 04e-8
T_{13} = $(T_{12}*c-T_{12}*u)/(c+u)$ = 3.3420772557547435419587196064745e-8
T_1 = SUM (T_{11}, T_{12}, T_{13}) = 7.6787449993643123762598800041288e-8

T_2 = $(3000+10000*2+20+\Delta l_1)/c$ = 7.6787449324234896326500963774945e-8

In Figure 15, the following results can be obtained:

$10000*3-20+\Delta l = \Delta l(c/u)$
$29980 = \Delta l(c/u-1)$
Δl = 3.0003757174956178134888392194864
Or,
$\Delta l = (10000*2)/(c/u) + [10000-20+(10000*2)/(c/u)]/(c-u)*u$
Δl = 2.0013845711889122974534602868496 + 0.99899114630670551603537893263674
Δl = 3.0003757174956178134888392194857

$(10000+20-\Delta l) = \Delta l_1(c/u)$
Δl_1 = 1.0023934248822067814180813542128

T_{11} = $(10000+20-\Delta l)/c$ = 3.3413114162740226047269378473759e-8
T_{12} = $[(\Delta l-\Delta l_1) + (10000-20)+\Delta l_1]/(c-u)$ = 3.3303037486160110209042550749365e-8

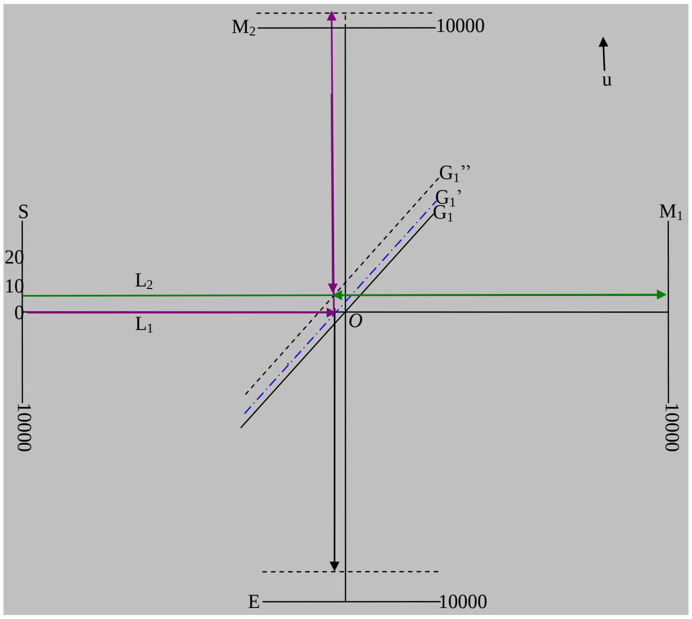

Figure 16. Mid light rays which can superpose with each other.

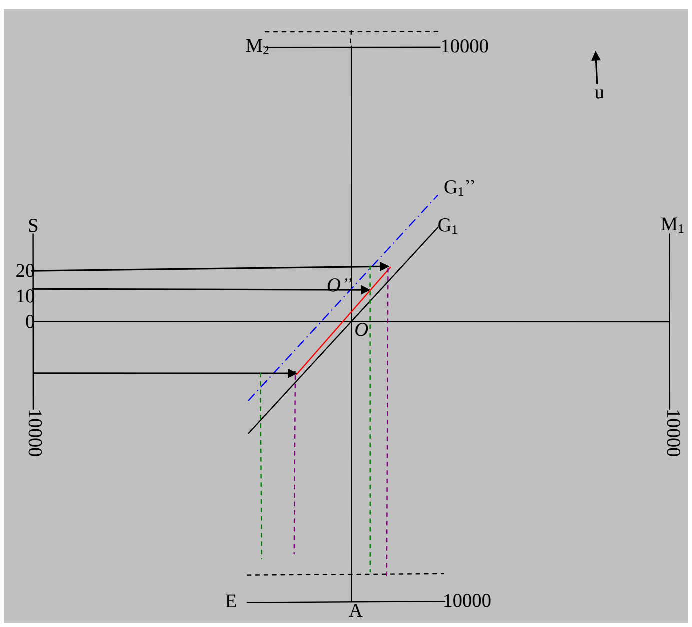

Figure 17. Front section.

$T_{13} = [(T_{11}+T_{12})^* \; u + (10000-20)] \;/c =$ 3.3296372934603534989821823195688e-8

$T_1 = \text{SUM}(T_{11}, T_{12}, T_{13}) =$ 1.0001252458350387124613375241 88e-7

$T_2 = (10000*3-20+\Delta l)/c =$ 1.0001252391652059378296130731621e-7

$T_{E1} = T_{11}+T_{12}+(10000*2)/(c+u) =$ 1.3342229545617977627744603652 87e-7

In Figure 16, the following results can be obtained:

$10000-\Delta l_1 = \Delta l_1$ (c/u)

Δl_1 = 1.0005921571091916003170116095 84

$T_{11} = 10000/(c+u) =$ 3.3353071903639720010567053652799e-8

$T_{12} = (10000+\Delta l_1)/(c-u) =$ 3.3363085754244479779386907121003e-8

$T_{13} = (T_{12}*c-T_{12}*u)/(c+u) =$ 3.3356409185855948094456343265682e-8

Or,

$T_{13} = (10000+\Delta l_1)/(c+u) =$ 3.3356409185855948094456343265682e-8

$T_1 = \text{SUM}(T_{11},T_{12},T_{13}) =$ 1.0007256684374014788441030403947e-7

$T_2 = (10000*3+\Delta l_1)/c =$ 1.0007256617562109981966363213717e-7

T_{E1} = 1.3342230146516363981108806807938e-7

By looking at the results above, we can find that when u is in the direction as in Figures 14-16, there exists time difference or OPD between the superposed light rays:

ΔT (L_{top}) = 6.6698327746317244510 26e-16
ΔT (L_{mid}) = 6.6811904806474667190 23e-16
ΔT (L_{bot}) = 6.6945501878175810655 88e-16

Let us compare the 3 Δl_1s of the 3 pairs of light rays above (SO = 10000):

Δl_1 (L_{top}) = 1.0023934248822067814180813542128
Δl_1 (L_{mid}) = 1.0005921571091916003170116095 84
Δl_1 (L_{bot}) = 0.99859097279497321711637758636483

By comparing them, we know that the Δl_1s decreases from top to bottom gradually. The rough front section of all light rays when they respectively arrive at G_1 is as the red line in Figure 17.

Let us compare the 3 T_{E1}s of the 3 light rays (reflected by M_2) above (SO = 10000):

T_{E1} (L_{top}) = 1.3342229545617977627744603652 87e-7
T_{E1} (L_{mid}) = 1.3342230146516363981108806807938e-7
T_{E1} (L_{bot}) = 1.3342230814106404298426728131503e-7

We can find that the light rays (reflected by M_2) to the right arrive at E first. In fact, in Figure 17, we find that the light rays (reflected by M_2) to the right travel a shorter distance than that to the left. Similarly, the light rays (reflected by M_1) to the right arrive at E first.

If u is in the opposite direction, (Figure 18), the following results can be obtained:

$10000+\Delta l_1 = \Delta l_1$ (c/u)

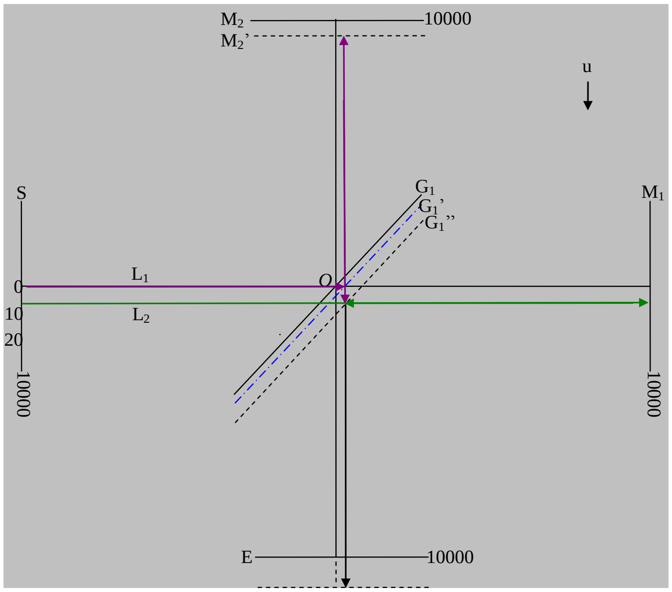

Figure 18. When u is in opposite direction.

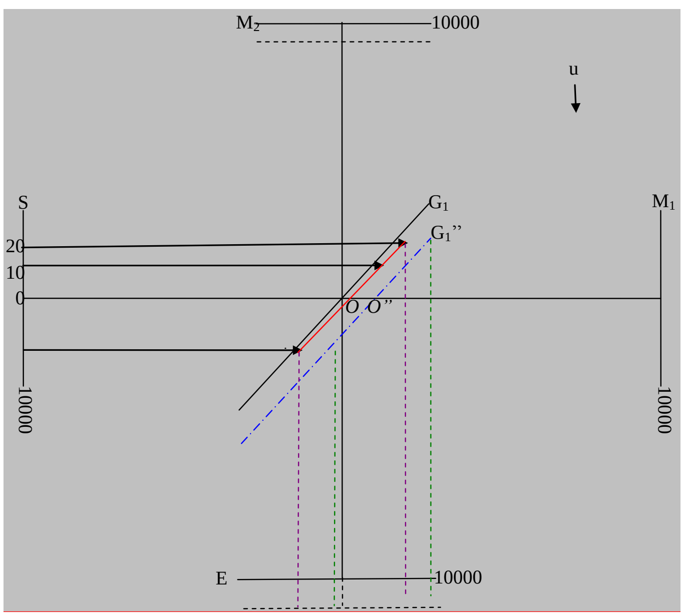

Figure 19. Front section.

Δl_1 = 1.00079243412128679569340867894 81

T_{11} = 10000/(c-u) = 3.33597478040428931897802892982 68e-8
T_{12} = (10000-Δl_1)/(c+u) = 3.33497339534381334209604358300 64e-8
T_{13} = (T_{12}*c+T_{12}*u)/(c-u) = 3.33564091857222451558770798153 82e-8
T_1 = SUM (T_{11}, T_{12}, T_{13}) = 1.00065890943203271766617804943 7e-7

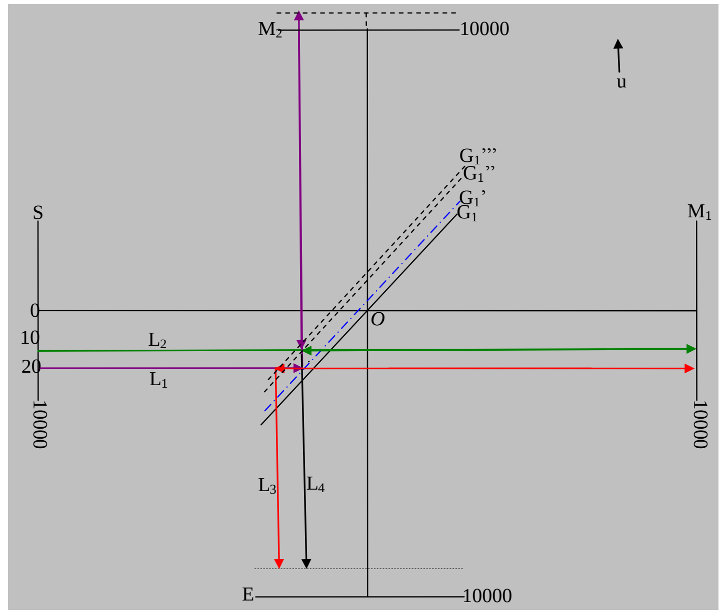

Figure 20. Reflected and transmitted lights.

T_2 = (10000*3-Δl_1)/c = 1.00065890275217926640450396491 7e-7
T_2 - T_1 = 6.6798534512616740845 2e-16

The results show that there exists time difference or OPD between the superposed light rays.

The final result show that on view-screen light intensity to the right is higher than that to the left, except that the light rays to the left arrive at E first, as shown in Figure 19.

Looking at the following and as for transmitted light ray of L_1:

T_{21} = 20000/c = 6.67128190396304099151153428949 84e-8
T_{22} = (T21*u+10000+20)/(c-u) = 3.34331438681063554406050855784 18e-8
T_{23} = [10000-20-(T21+ T22)*u] /(c+u) = 3.32763452333272776285468528416 43e-8
T_{E2} (which is the time L_1 takes travelling from S to E via M_1) (L_{bot}) = T_{21} +T_{22} +T_{23} = 1.33422308141064042984267281315 03e-7
T_{E1} (L_{bot}) = T_{E2} (L_{bot})

The result shows that the reflected light ray and transmitted light ray of L_1 will arrive at E at the same time, as shown in Figure 20, where L_3 is reflected at G_1''' position, rather than at G_1'' position.

In addition, if SO is shorter, Δl_1 is shorter accordingly (Figure 21). There is almost no OPD between the superposed light rays when u is in the directions marked in green as seen in Figure 21; and there exists OPD

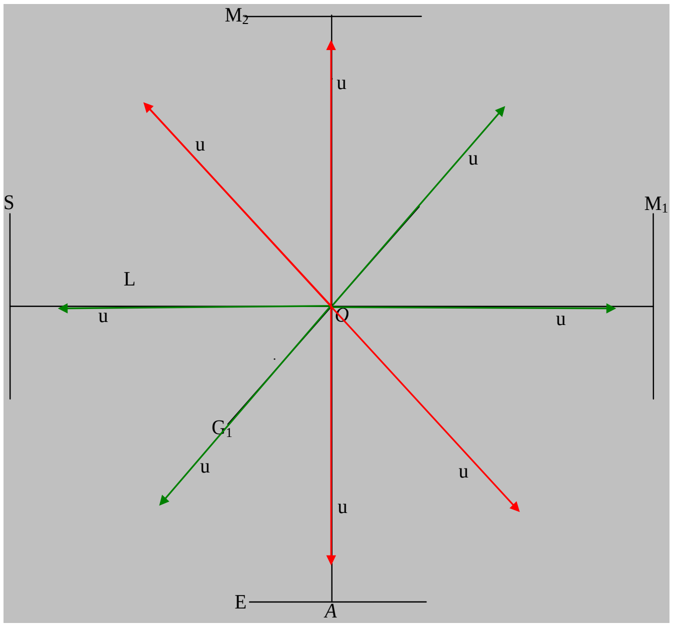

Figure 21. Overview.

between the superposed light rays when u is in the directions marked in red.

Conclusion

Through the simple, rough and surface calculations, analyses and discussion, we can generally understand that predecessors' analyses and inferences may not be satisfying in some aspects. However, the analyses above cannot perfectly explain the phenomenon: a shift of about 0.01 fringes was observed as the experimental apparatus is rotated through 90°.

To demonstrate why only a shift of about 0.01 fringes was observed, it is very possible that more complex mathematical and optical calculations and analyses need to be performed further.

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