The mechanism of Faraday magneto-optical effect and its physical significance are explained in detail

详解法拉第磁光效应的机理及其物理意义

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[Abstract] : The mechanism of Faradic magneto-optical effect is that the external magnetic field changes the motion state of electrons and nuclei in the medium, which leads to the polarization direction of the secondary refracted light which is slightly different from the incident light and is transmitted in the medium and accumulates continuously. It directly proves that refracted light is not incident light, but a new secondary light produced by the medium and related to incident light. Its physical significance will overturn people's understanding of the law of interaction between light and medium, and will have a profound and huge influence on the whole physics field.

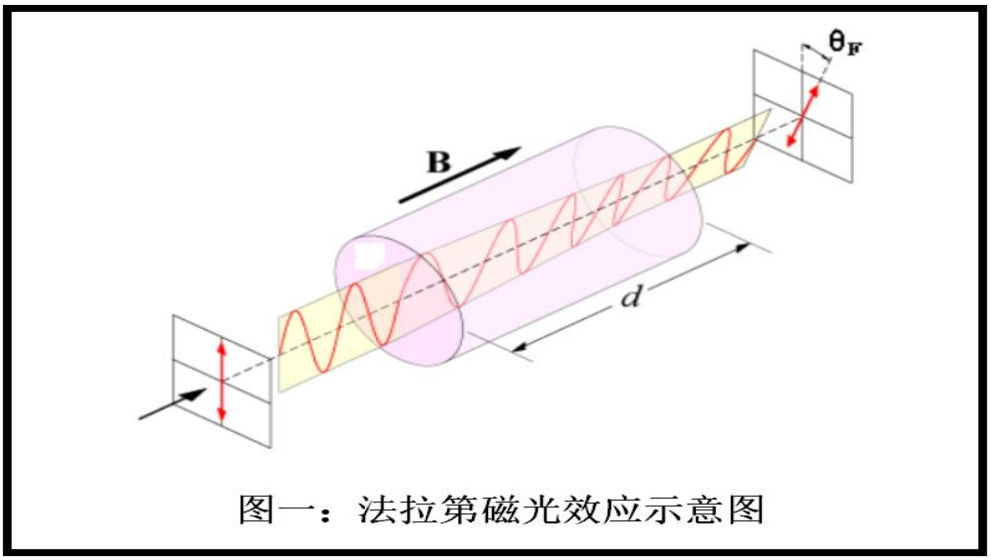
【文章摘要】：法拉第磁光效应的机理是外加磁场使介质中的电子与原子核改变运动状态，从而导致其产生的次生折射光的偏振方向与入射光存在些许差异并在介质中传递而不断积累所导致的。它直接证明了折射光并非入射光，而是由介质产生的、全新的、与入射光存在一定联系的次生光。其物理意义将颠覆目前人们对光与介质相互作用规律的认识，将对整个物理学界产生深远而巨大的影响。

First,Introduction to Faraday magneto-optical effect

一、法拉第磁光效应简介

Faraday magneto-optical effect. When the linearly polarized light propagates in the medium, if a strong magnetic field is added parallel to the propagation direction of the light, the vibration direction of the light will be deflected. The deflection Angle is proportional to the product of the magnetic induction B and the length of the light traveling through the medium d, i.e., $\psi = VBd$. The proportionality coefficient V is called Feld constant, which is related to the properties of the medium and the frequency of the light wave. The direction of deflection depends on the properties of the medium and the direction of the magnetic field. This phenomenon is called the Faraday effect or the magneto-optical rotation effect. [from 360 Encyclopedia]

法拉第磁光效应。当线偏振光在介质中传播时，若在平行于光的传播方向上加一强磁场，则光振动方向将发生偏转，偏转角度 ψ 与磁感应强度 B 和光穿越介质的长度 d 的乘积成正比，即 $\psi = VBd$，比例系数 V 称为费尔德常数，与介质性质及光波频率有关。偏转方向取决于介质性质和磁场方向。上述现象称为法拉第效应或磁致旋光效应。[摘自 360 百科]



图一：法拉第磁光效应示意图

Figure 1: Faraday magneto-optical effect diagram

Second,Analysis of Faraday's magneto-optical effect mechanism

二、法拉第磁光效应机理分析

1. Analysis of possible factors

1、可能因素分析

According to ψ=VBd, it can be seen that the Faradic magneto-optical effect of refracted light can occur only when both the applied magnetic field B and the medium length d are not 0, and neither of them is necessary. It can be seen that there are three possible factors leading to this effect: A, the external constant magnetic field B directly changes the polarization direction of the polarized light; B. The external constant magnetic field changes the motion state of the electrons and nuclei in the atoms in the medium, resulting in the polarization direction changing through the electromagnetic wave or photon in the medium; C. The external constant magnetic field changes the motion state of electrons and nuclei in atoms in the medium and causes the polarization direction of the secondary light produced by them to be different from that of the incident light.

根据 ψ=VBd 可知：只有当外加磁场 B 和介质长度 d 均不为 0 时才有可能出现折射光的法拉第磁光效应，二者缺一不可。由此可见肯定：导致本效应的因素共有三种可能性：A、外加恒定磁场 B 直接使偏振光改变偏振方向；B、外加恒定磁场使介质中的原子中的电子与原子核改变运动状态导致通过介质中的电磁波或光子改变偏振方向；C、外加恒定磁场使介质中的原子中的电子与原子核改变运动状态并导致其产生的次生光的偏振方向与入射光出现差异。

2. Analysis of the possibility of the polarized light directly changing the direction of polarization caused by the external constant magnetic field B

2、外加恒定磁场 B 直接使偏振光改变偏振方向的可能性分析

Because when d=0, the deflection Angle ψ=0. Therefore, we can rule out the possibility that the external magnetic field directly causes the polarization direction of polarized light to change.

Otherwise, a constant magnetic field in a vacuum would also change the direction of polarization of the polarized light. This also proves from one side that a constant magnetic field does not change the direction of light's polarization. This also conforms to the law that electromagnetic fields only follow the principle of vector superposition, and cannot interact to change each other.

由于当 d=0 时，偏转角 ψ=0。因此，可以排除外加磁场直接导致偏振光的偏振方向发生改变的可能性。否则，在真空中的恒定磁场也会使偏振光的偏振方向改变偏振方向。这也从一个侧面证明了恒定磁场并不能使光发生偏振方向的变化。这也符合电磁场仅遵循矢量叠加原理，并不能相互作用而改变彼此的规律。

3. Analysis of the possibility that electrons and nuclei in atoms in the medium will change their motion state due to the external constant magnetic field, leading to the change of polarization direction through electromagnetic wave or photon in the medium

3、外加恒定磁场使介质中的原子中的电子与原子核改变运动状态导致通过介质中的电磁波或光子改变偏振方向的可能性分析

3.1. The external constant magnetic field changes the motion state of electrons and nuclei in atoms. When the electromagnetic wave passes through the medium, it will of course cause the trajectory of the electromagnetic wave to change, but it should not cause the polarization direction to change. That is to say: if the applied constant magnetic field changes the motion state of the atom, it will only change the trajectory or direction of the electromagnetic wave, but will not change the direction of its polarization. In this case, therefore, the refracted light will only take a different path than it would have without an applied constant magnetic field. But this is not the case. Therefore, this possibility can be ruled out.

3.1、外加恒定磁场使原子中的电子与原子核改变运动状态，当电磁波通过介质时，当然会致使电磁波的运动轨迹发生变化，但不应该会导致其偏振方向的变化。也就是说：如果外加恒定磁场使原子的运动状态发生变化，只会改变电磁波的运动轨迹或方向，不会改变其偏振方向。因此，此种情况下，只会使折射光的路径与无外加恒定磁场时有异。但实际情况并非如此。因此，可以排除此种可能性。

3.2. The external constant magnetic field changes the motion state of electrons and nuclei in atoms. When the photon passes through the medium, it will certainly change the trajectory of the photon, but it should not lead to the change of its polarization direction. Because photons don't have their own direction of polarization, and even if they did, they wouldn't change depending on the state of the atom. Therefore, this possibility can also be ruled out.

3.2、外加恒定磁场使原子中的电子与原子核改变运动状态，当光子通过介质时，当然会使光子的运动轨迹发生变化，但不应导致其偏振方向的变化。因为光子本身并不存在偏振方向，即使是存在，也不会因为原子运动状态的变化而改变。因此，此种可能性也可以被排除。

3.3. Even if light has wave-particle duality and constant magnetic field changes the motion state of electrons and nuclei in atoms, when light passes through the medium, it will only change the

trajectory of light, but cannot change its direction of polarization. This can also be ruled out.

3.3、就算光具有波粒二象性，外加恒定磁场使原子中的电子与原子核改变运动状态，当光通过介质时，也只会改变光的运动轨迹，而不可能改变其偏振方向。此种情况也可以被排除。

4. Analysis of the possibility that the external constant magnetic field changes the motion state of electrons and nuclei in atoms in the medium and causes the polarization direction of the generated secondary light to be different from that of the incident light

4、外加恒定磁场使介质中的原子中的电子与原子核改变运动状态并导致其产生的次生光的偏振方向与入射光出现差异的可能性分析

If refracted light is regarded as incident light or secondary incident light produced by nearby atoms, molecules and molecular groups, which polarizes atoms (electric field generated by light causes electrons and nuclei to move in the exact opposite direction, resulting in electric dipolarization) and generates secondary light, the mechanism of this effect is relatively easy to understand: Incident light or secondary incident light polarizes atoms (in fact, it is mainly electrons that change their motion states. Although nuclei also change their motion states, the actual amount of change is two orders of magnitude smaller than that of electrons, and its effect can be ignored at visible wavelengths) and generates secondary light. The electron will change its motion path under the action of external constant magnetic field (compared with that without external constant magnetic field), and this change of trajectory will directly change the polarization direction of the secondary electric field generated by it. This is why the Faraday magneto-optical effect is proportional to the length d of the medium. Because the larger the length of the medium, the more times the medium will produce secondary light, when each polarization direction change the same amount, the more times, the greater the total change of nature. This is the fundamental reason why this effect is proportional to the length of the medium.

如果把折射光视为入射光或邻近其他原子、分子和分子团产生的次生入射光使原子产生极化（光产生的电场使电子与原子核朝正好相反的方向运动导致电偶极子化）并产生次生光，则本效应的机理就比较好理解了：入射光或次生入射光使原子极化（实际上主要是电子改变运动状态，原子核虽然也会改变运动状态，但实际改变量要比电子小二个数量级或以上，在可见光波段时可忽略其影响）并产生次生光的过程中，电子会受到外加恒定磁场的作用而改变运动轨迹（与无外加恒定磁场时相比），这种轨迹的改变将直接导致其产生的次生电场的偏振方向的改变。这也是为什么法拉第磁光效应与介质的长度 d 成正比的原因。因为介质长度越大，介质产生次生光的次数就会越多，当每次偏振方向改变量相同时，则次数越多，总的改变量自然也就越大。这才是本效应与介质长度成正比的根本原因所在。

In conclusion, it is only when the refracted light through the medium is regenerated by the medium that the applied constant magnetic field has a chance to change the direction of the polarization of the light by changing the motion state of the atoms in the medium. This is the real mechanism of Faraday's magneto-optical effect.

综上所述，只有当通过介质的折射光是由介质重新产生的全新的光时，外加恒定磁场才有机会利用改变介质中原子的电子运动状态的机会让光的偏振方向发生改变。这才是法拉第磁光效应的真实机理。

Three, the refraction of light through the medium for the medium to produce secondary light evidence brief introduction

三、通过介质的折射光为介质产生的次生光的佐证简介

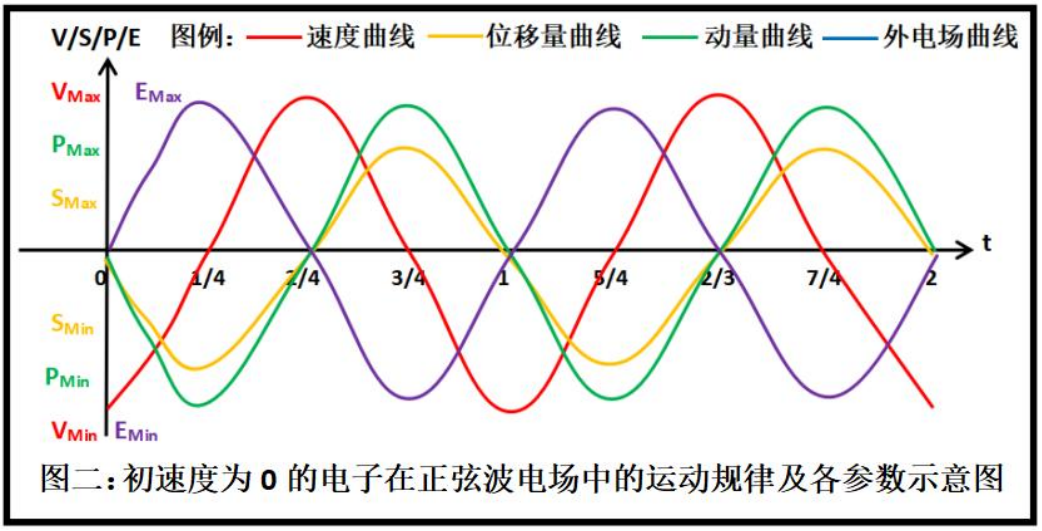
1. The half-wave loss phenomenon of reflected light proves that reflected light is not incident light

1、反射光存在的半波损失现象证明反射光并不是入射光

As shown in Figure 2 below: When the incident light irradiates on the interface of the medium, the electrons in the medium move forward towards the electric field generated by the incident light. When the amplitude of the incident photoelectric field is sinusoidal wave, the acceleration of the electrons synchronizes with the amplitude of the electric field. However, the phase change of the electron velocity will lag behind the amplitude of the electric field by 90 degrees, and the phase change of the electron displacement will lag behind the amplitude of the electric field by 180 degrees. When the distance between the electrons in an atom and the nucleus changes, the atom becomes an electric dipole and generates an electric dipole secondary electric field, which changes in amplitude proportional to or in phase with the amount of electron displacement. Therefore, there is a half cycle or 180 degree difference in phase between the amplitude of the secondary electric field generated by the medium and the amplitude of the incident light. That's why reflected light has a half-wave loss. In fact, the phase of the scattered light, refracted light, transmitted light, diffracted light and diffracted light produced by the medium is half a period out of phase with the incident light.

如下图二所示：入射光照射到介质界面上时会使介质中的电子朝入射光产生的电场正向运动，当入射光电场的振幅为正弦波时，其使电子的加速度与电场的振幅同步，但电子的速度变化相位会滞后于电场振幅 90 度，电子的位移量相位变化会滞后于电场振幅 180 度。当原子中的电子与原子核的距离发生改变时，原子就会成为电偶极子并产生电偶极子次生电场，其振幅变化与电子的位移量成正比或相位相同。因此，由介质产生的次生电场的振幅与入射光的振幅间的相位存在半个周期或 180 度的差异。这才是反射光存在半波损失的原因。实际上，由介质

产生的散射光、折射光、透射光、衍射光和绕射光的相位都与入射光存在半个周期的相位差。

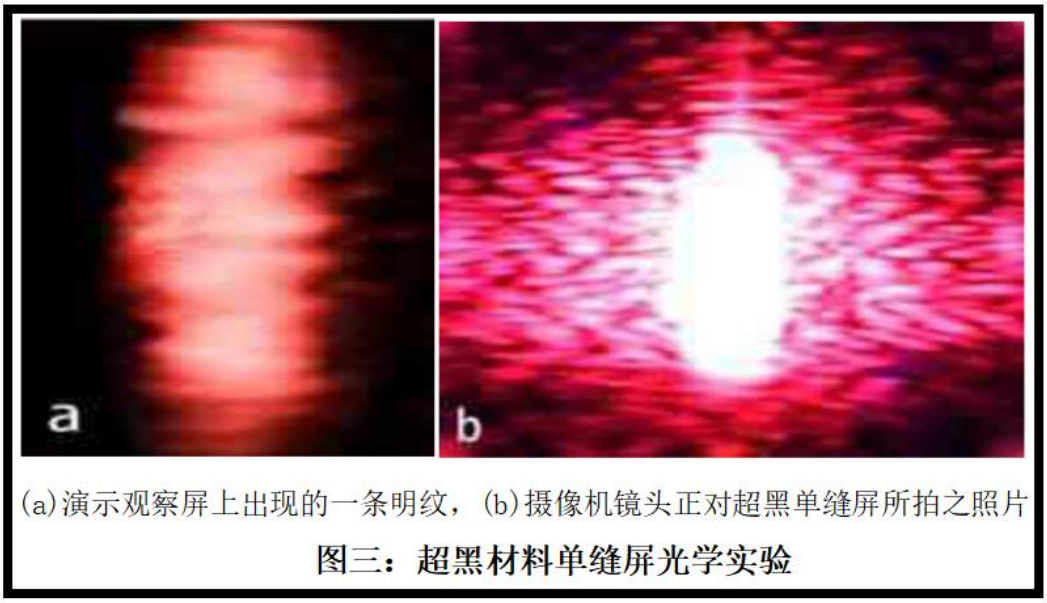


图二：初速度为 0 的电子在正弦波电场中的运动规律及各参数示意图

Figure 2: Motion law and parameters of electron with initial velocity of 0 in sine wave electric field

2. The phenomenon of no diffracted light in the single slit experiment of superblack material proves that diffracted light is not the result of direct light diffraction

2、超黑材料单缝实验无衍射光现象证明衍射光不是直射光绕射的结果



(a)演示观察屏上出现的一条明纹，(b)摄像机镜头正对超黑单缝屏所拍之照片

图三：超黑材料单缝屏光学实验

Figure 3: Experimental photo of non-diffracted light covering single slit edge with superblack material

As shown in Figure 3, when a single slit edge is covered with ultra-black material, there is no so-called diffracted light on the screen. This directly proves that diffracted light is not the result of diffraction or diffraction of direct light, but secondary light produced by the slit edge.

从上图三所示：当用超黑材料覆盖单缝边缘时，则屏幕上就不会出现所谓的衍射光。这就直接证明了衍射光并不是直射光衍射或绕射的结果，而是缝边缘产生的次生光。

To sum up, both reflected, refracted and diffracted light are not the result of incident light

changing the direction or speed of motion, but secondary light produced by the medium irradiated by incident light. Just like the case of public security investigation, the three cases of light reflection, refraction and diffraction prove that the reflected, refracted and diffused light are all secondary light generated by the medium, which forms a complete and mutually corroborating evidence chain, which is much more reliable than the double-slit experiment indicating that the light is electromagnetic wave and the photoelectric effect indicates that the photon exists.

综上所述，无论是反射、折射和衍射光都不是入射光改变运动方向或速度的结果，而是由入射光照射的介质产生的次生光。就如公安侦办案件一样，由光的反射、折射和衍射三种情况综合证明了反射、折射和衍射光均是由介质产生的次生光，这就形成了一个完整的、相互印证的证据链，其可信度要比双缝实验预示着光为电磁波、光电效应预示着光子存在要高得多。

Fourth, the physical significance of Faraday magneto-optical effect

四、法拉第磁光效应的物理意义简述

1. Prove that the transmitted light after passing through the medium is not incident light

1、证明穿越介质后的透射光并非入射光

Faraday magneto-optical effect proves that the interaction between light and medium is not that light (quantity) is reflected/scattered, refracted/transmitted by molecules or atoms in the medium and changes the direction and speed of motion or phase and frequency, but that the time-varying electric and magnetic fields of light make the atoms in the medium polarized into electric dipoles and generate secondary electromagnetic fields.

法拉第磁光效应证明：光与介质的相互作用并不是光（量）子被介质中的分子或原子反射/散射、折射/透射作用而改变运动方向与速度或相位与频率，而是光具有的时变电场与磁场使介质中的原子极化成为电偶极子并产生次生电磁场。

2. Prove that starlight is not raw light

2、证明星光不是原生光

According to the so-called cosmic background radiation phenomenon: interstellar space there is a lot of cold matter and isotropic. These cold materials produce little possible light, but can transmit visible light. The starlight observed on Earth is the secondary light caused by this cold interstellar material, not the primary light. Interstellar material causes the frequency of starlight to decrease as the distance the starlight travels through space. This may be the fundamental reason why starlight redshift is proportional to distance. Hubble's law, then, may be completely out of line

with reality.

依所谓的宇宙背景辐射现象可知：星际空间存在大量低温物质且各向基本同性。这些低温物质几乎不能产生可能光，但可以透射可见光。地球上观测到的星光是被这些低温星际物质作用后的次生光，而非原生光。星际物质会使星光的频率随星光在宇宙空间中的运动距离增加而不断降低。这可能才是星光红移量与距离成正比的根本原因。如此一来，哈勃定律可能就是完全不符合客观实际的了。

3. The photoelectric effect does not prove the existence of photons

3、光电效应不能证明光（量）子的存在

When light encounters a metal surface, it changes the speed and direction of electrons and nuclei in atoms near the metal surface. When the frequency of the external electromagnetic field is close to the frequency of the electron moving around the nucleus, some electrons with appropriate phase in the electron will be accelerated synchronously by the external electric field, and the external magnetic field will make the electron change the direction of motion. When an electron is accelerated synchronously to escape velocity, it escapes from the atom with the help of a magnetic field and becomes a photoelectron. This is the essence of the photoelectric effect. That's why light at too high a frequency doesn't produce the photoelectric effect.

光遇到金属表面后，会使金属表面附近的原子中的电子与原子核发生运动速度与运动方向的改变。当外来电磁场的频率接近电子绕原子核运动频率时，则电子中部分相位合适的电子就会被外来电场同步加速，同时外来磁场会使电子改变运动方向。当电子被同步加速到逃逸速度时，在磁场的作用下就会从原子中逃逸出来成为光电子。这才是光电效应的本质因素。也是为什么频率过高的光反而不能产生光电效应的原因所在。

4. The Compton effect does not prove the existence of photons

4、康普顿效应不能证明光（量）子的存在

X-rays are also light, but at frequencies above the upper limit of the visible spectrum. When X-rays irradiate light metals, the varying electromagnetic fields produced by them also change the speed and direction of the electrons and nuclei of the atoms in the metals, especially the outermost electrons. But because the frequency is much higher than the frequency of the outer electrons orbiting the nucleus, there are multiple cycles of varying electromagnetic fields caused by X-rays on the electrons as they orbit the nucleus. In this way, the electrons' motion, although affected by X-rays, can only change their trajectory rather than causing synchrotron acceleration, which fundamentally changes their motion around the nucleus. There is no chance of a photoelectric effect. At the same time, as the X-ray changes the motion of the electron, the electron produces a secondary ray with a frequency close to that of the X-ray. The frequency and phase of these secondary rays will vary depending on the direction of the emission. This is the root cause of the Compton effect. It is not the result of the collision between the X-ray particles and the outer electrons. Otherwise, the X-ray quanta should also collide with the inner electrons and nuclei, or even with two or more electrons or nuclei simultaneously or successively, so that the outgoing X-rays in different directions would have many frequencies instead of just one.

X 射线也是光，只是其频率高于可见光频率段上限而已。当 X 射线照射轻金属时，其产生

的变化电磁场也会使金属中原子的电子与原子核发生运动速度与方向的变化，特别是最外层电子。但因其频率远高于外层电子绕原子核运动的频率，电子绕核运动一周期间会有多个周期的X射线产生的变化电磁场作用于电子。这样一来，电子的运动状态虽然会受到X射线的影响，但只能改变电子运动轨迹而不能形成同步加速而从根本上改变电子围绕原子核运动的状态。也就不可能形成光电效应。同时，X射线改变电子运动状态过程中，电子就会产生与X射线频率接近的次生射线。这些次生射线的频率和相位会因出射方位不同而不同。这才是康普顿效应的根本原因。并不是X射线（量）子与外层电子相互碰撞作用的结果。否则，X射线量子也应该与内层电子和原子核发生相互碰撞，甚至同时或先后与两个与两个以上的电子或原子核发生相互碰撞，从而不同方向的出射X射线的频率会有很多种而非一种频率。

5. The Michelson-Morley results do not prove that the speed of light is constant

5、迈克尔逊－莫雷实验结果不能证明光速恒定

When light moves in the atmosphere, its velocity is determined by the atmosphere and has nothing to do with the speed of incident light. Because light moving through the atmosphere is actually refracted light, the speed of secondary light from the polarization of atoms in the atmosphere. Therefore, when the atmosphere is not moving fast relative to the ground during the experiment (the wind speed is not big enough to make the experiment impossible), the speed of light during the experiment will of course be basically constant and isotropic relative to the speed of the measuring device. Therefore, the experimental result must be that there is no interference fringe change. In fact, the experiment would have produced the same results even if it had been conducted in a vacuum. Because the reflected and transmitted light produced by the semi-lens and mirror in the experimental device is the secondary light produced by the mirror body, and its speed is of course only constant relative to the speed of the mirror body group. That's a constant velocity relative to the device.

光在大气层内运动时，其运动速度由大气层决定，与入射光速无关。因为在大气层内运动的光实际就是折射光，是大气层中原子极化产生的次生光的传递速度。因此，当实验过程中，大气层相对地面运动速度不大时（风速不大，大了也做不了实验了），实验过程中的光的速度相对测量装置速度当然也会基本恒定且各向同性。因此，实验结果肯定是不可能有干涉条纹的变化。实际上，该实验即使是在真空中进行，也会得出同样的结果。因为，实验装置中的半透镜、反射镜所产生的反射、透射光是镜体产生的次生光，其速度当然仅相对镜体组速度恒定。也就是相对实验装置速度恒定。

In short, almost all the current physical phenomena and experimental results can be explained by using the law of interaction between light and medium described in this paper.

总之，利用本文所阐述的光与介质相互作用规律几乎可解释目前所有与其有关的物理现象和实验结果。