# Experiment Determining Light's Capacity to Directly Impart Mechanical Displacement to a Mirror

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## Abstract

It is commonly presumed that light, as a physical entity, is real. Light speed and light wavelength can be repeatedly measured to high accuracy but no experiment was carried out that would directly measure, and therefore verify, light's momentum. This situation exists even though the results of particular split-beam experiments, first proposed by Bell, established non-classical behavior for light.

It is therefore proposed to carry out the experiment where a laser beam imparts mechanical displacement to a mirror where such displacement is in line with classical expectation. It is proposed herein to quantify light's ability to exert pressure at mirror surface that is in accord with classical equations. Nevertheless it is expected that mirror will not receive light's momentum when subjected to light of any intensity.

Logical analysis shows that a perpetual machine would result if light's momentum were real.

Cases where light does produce mechanical motion are discussed as those where {a} light nondestructively heats material with resulting momentum transfer to contacting gas – i.e., light mill, or {b} light vaporizes material with subsequent mechanical particle jet stream ejection – i.e., laser weld or cut, or {c} light transfers its virtual momentum to particles such as electrons with ensuing momentum realization – i.e., photoelectric effect.

This experiment opens avenues to treating light in quantum mechanical context with consequent light and electron utilization in quantum computing, instantaneous communication, and more general understanding of quantum vacuum.

Edited for HyperFlight.com publication on May 11, 2001

# 1. Description

## 1.1. Introduction and Background

The present state of knowledge concerning light is mixed:

- On the one hand, we successfully use basic relationships between light's wavelength, light speed, and Planck constant to explain the photoelectric effect. On the other side, both the special and general relativity theories are finding many critics.
- Some are comfortable using words non-causal or virtual image when describing optical properties of light. Others may insist on classical or particle-like treatment of photons when it comes to interpreting the dual slit experiment and thus do not accept the possibility that a single photon may actually be at two places at the same time and at the same phase, no less.
- Results of Bell light experiments notwithstanding, some still profess that Michelson-Morley apparatus produces two independent photon streams in its beam-splitting mirror by random separating action where individual photons either pass through or are reflected.
- Using Feynman's diagrams, some are at ease using the entity of the virtual photon, yet we are not ready to say that all photons are virtual.
- Current pursuits in quantum photonics interpret the simultaneous absorption of a convolved photon pair as target-dependent rather than as inevitable.

We will stall in our understanding of light if we limit the explanations of light to wave-particle modalities, be it a part-time separate, measurement-dependent, or as co-joined wave-particle. For example, if a beam-splitting mirror or a crystal produces a convolved photon pair out of every photon, then the wave-particle representation of light does not apply because {1} the classical wave does not carry the property of instantaneous collapse and {2} the classical particle is always treated – in fact defined – as spatially bounded entity.

To prove that light cannot impart momentum to a mirror, then, is indeed a revolutionary concept. One may recall the light mill "toy" that has one side of its paddles opaque and light absorbing while the other sides are polished and light reflecting. Although the entire light mill is exposed to light, mill's paddles begin to rotate. Light mill is to this day subject of captivating debates – commencing with Maxwell who took the position that rotating light mill proves light pressure.

The subject experiment uses commercial laser beam and directs it at a mirror that is suspended off-center between two lightweight strands. Calculation will show that, should light's momentum be real, real force would be produced at the mirror and such force (or its multiple if we consider leveraged arrangement) would be greatly in excess of the resolution offered by commercial sensors that begin at 0.01 gram. Calibration of the apparatus will show that the mechanical force at the mirror – as expected by classical means – will be in range of producing accurate measurement with adequate resolution.

The subject experiment, straightforward as it may be to implement, is simple enough to make a strong physics milestone. The subject experiment brings focus to the often-contradictory explanations of light's nature. This experiment is also well suited for performance in many variations and in high school lab environment.

Another variation on this experiment can be as follows: If light's momentum is real then a space borne assembly consisting of a battery-powered laser with of a 45-degree mirror fixed at the end of a shaft extending from the laser should commence rotating in its entirety once the laser is turned on. It is a direct outcome of the subject laser beam experiment that no space borne laser produces recoil or acceleration when turned on.

**1.2. Evacuated Air Environment**
Returning to the light mill apparatus, we understand the rotation of the paddle assembly when the opaque (light absorbing) paddles recede from the light source as follows: Air molecules receive additional quantum of momentum when these come in proximity of the warmer opaque paddle sides. Real air molecules thus bounce and impart real momentum to the paddle. Others may argue this mechanism but the fact remains that the continuation of air evacuation from around the light mill's paddles diminishes paddle's rotation to the point where paddle movement ceases altogether. Classically, it is presumed that increase in light intensity is the only thing that stands in the way of reversing paddles' rotation and bright paddles would then commence receding from the light source. Classically, light's momentum is real and the bright side of the paddles receives twice the momentum of the dark side because light reflects or "bounces" from the bright side while the opaque side absorbs light and the opaque side receives just one times of the light's momentum.

The subject experiment establishes light to be completely virtual and light, in and of itself, will not and cannot move a mirror. The proposed mechanism is such that the only way for light to produce real energy is through light's interaction within matter. Light will reflect from a good grade mirror almost completely, 99.9% not uncommon, and consequently almost no real heat energy will be realized at the surface of the mirror. Evacuation of air from around the mirror establishes that even if the mirror absorbs 0.1% of light's energy, the resulting heat will not aid the mirror movement through the known light mill mechanism.

In summary, the execution of the subject experiment in vacuum is solely for the purpose of removing the question of mirror's reflectivity. It is, therefore, not necessary to perform the experiment in vacuum if high-grade mirror surface is deployed, and/or if the mirror is sufficiently thin such that both front and rear surfaces are at nearly equal temperatures while both front and rear surfaces share the same finish and thus share the same emissivity. Identical finishes and temperatures will in still air produce identical contact with air molecules and any movement mechanism will be equalized.

**1.3. The Advantage of Performing the Experiment in Still Air**
Free still air surrounding the mirror will have significant utility if we switch the laser beam between the (almost) totally reflective and the (almost) totally absorbing regions. In that case, laser beam will produce no movement if directed at the reflective spot, yet an identical laser beam will produce measurable force due to local heat that is transferred to the surrounding still air. Performing the experiment in free air, then, will have {1} no effect and will have {2} tangible effect; light reflection will be conclusively shown to produce no realization of light's momentum. Laser beam, being the sole source of energy in one case cannot – and in another case can – move the mirror.

If we were to repeat the experiment in vacuum, there will be no force exerted on the mirror assembly and this will be regardless of whether the light is absorbed or reflected. In vacuum, light's momentum is not realized by light's reflection and, in addition, light's momentum is not realized by light's absorption and/or by light's radiation. Repeating the experiment in vacuum is not considered necessary to prove the virtual nature of light but it will be performed if the sponsor so desires.

# 2. Work Plan

### 2.1. Setup

Mirror assembly's first moment of inertia passes through its axis of rotation. The mirror assembly, then, is symmetrical in weight and its structure rigid. The axis of rotation will be extended with fine strands; upper strand tied to a fixed ceiling while the lower strand tied to a manually rotating anchor for the purpose of removing any residual torque that may exist in the strands. The working angle of apparatus rotation will be small and limited by the displacement of the force gauge. Refer to Figure 2.1.

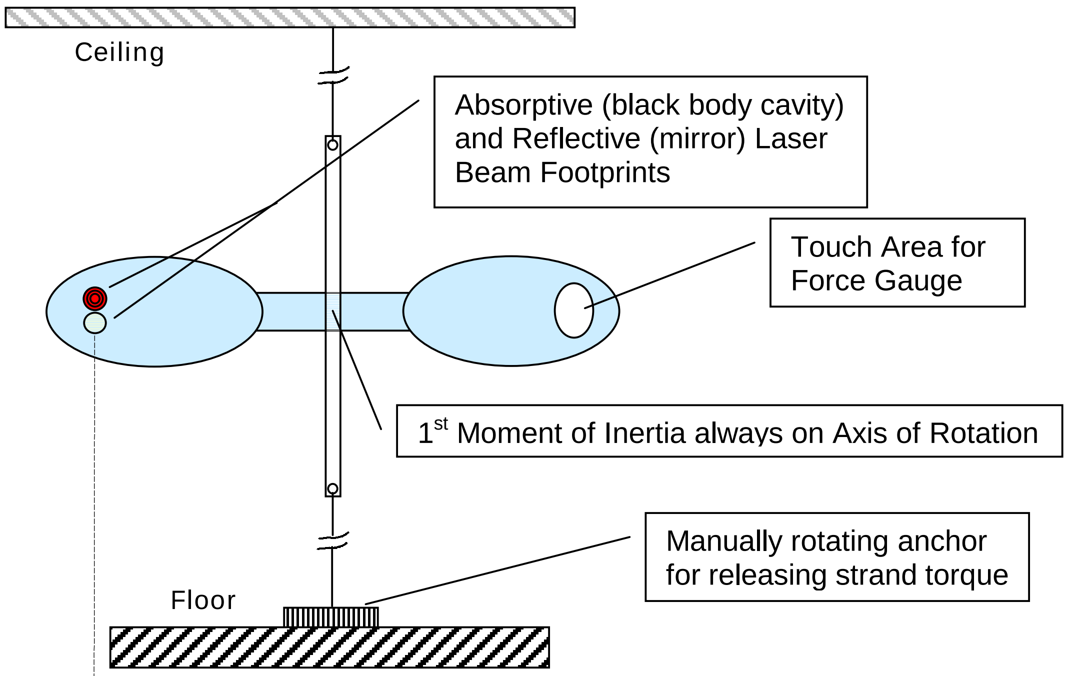


Figure 2.1: Setup, Vertical View

### 2.2. Calibration

Prior to laser beam turn-on, mechanical force at Laser Beam Footprint must produce identical reading at Touch Area by the Force Gauge if the distances from the axis of rotation (from strand) are the same. Force Reference Gauge is calibrated to a standard. Residual torque that may be present in the strand is removed by rotating bottom anchor. See Figure 2.2.

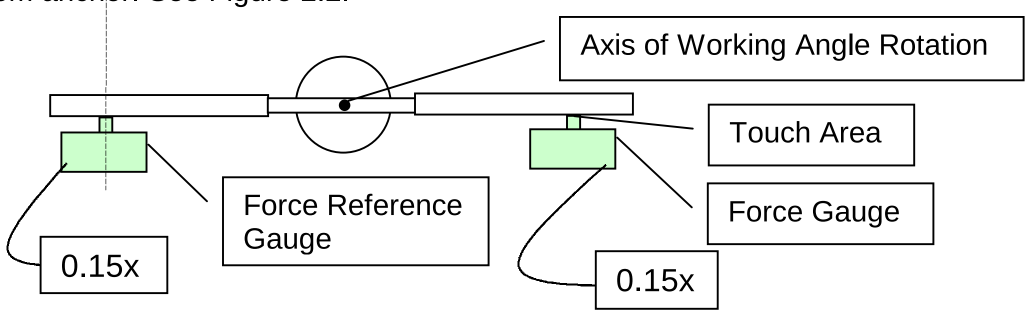


Figure 2.2: Calibration, Top View

### 2.3. Procedure

Laser beam will be first directed at the reflective spot for the duration of 20-30 seconds. Laser beam will then be redirected at the absorptive spot. Pressure gauge profile will be recorded during laser beam applications. In still air, we expect that the force at the gage will be proportional to the difference of front and rear temperatures rather than being coincident with the laser beam application at the absorptive spot. In vacuum, we expect the force at the gauge to be invariant at all times and without regard of the target presented to the laser beam.

Friction associated with mirror's movement over the range of the working angle must be at least an order of magnitude lower than the lowest force measurement figure. This can be qualified by turning the lower anchor well past the working angle while producing no measurement at the force gauge. Calibration process itself will show that force exerted at the laser side will translate completely to the force gauge.

Laser beam in the subject experiment will be of intensity that produces a sustainable output classically equivalent to at least one hundred times that of the smallest force successfully calibrated by mechanical means.

**2.4. Supporting Analysis**

Commercial laser will be analyzed to ascertain its light output. First, theoretical calculation will be performed with the goal of arriving at laser light's force output using classical computational methods. A review will be solicited to confirm the accuracy of calculations.[1] Second, direct method will be sought where a calibrated solar cell, for example, will be used to measure laser's light output directly.

The success of the proposed experiment – that is, that light cannot impart displacement to a mirror, is supported by the following analysis:

Assertion: Light approaches a mirror with certain energy, which is a function of its wavelength. Since light's (photon's) wavelength is the same before and after the contact with the mirror, the photon did not lose any energy as it reflected off the mirror and, therefore, net momentum and net energy left at the mirror is zero

Discussion: A real particle bouncing from a much larger stationary particle leaves the bounce with nearly the same amount of kinetic energy as before the bounce. Even the ideal frictionless bounce, however, will result in the smaller particle's momentum magnitude to decrease. The real particle's kinetic energy is a function of its mass and velocity and even the ideal bounce will result in lower departing velocity. Light's momentum (and light's energy as well) is a function of its wavelength only. Therefore, if we want to analyze light's bounce, we need to discuss light's wavelength.

Light's momentum is inversely proportional to its wavelength. Light's classical bounce is thought to produce twice the light's momentum at the mirror – yet we do not observe any loss of light's momentum since we do not observe any change in its departing wavelength. Small, 10% momentum loss would result in light shift from red to yellow, for example. Repeated mirror reflections would classically produce additive effect, but there is no color shift associated with repeated mirror reflections. Should we consider the scale at atomic granularity, photon's classical interaction with free and randomly moving electrons would produce reflected light containing many frequencies.

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[1] Intensity of radiation I at a distance d [cm] away from the laser is calculated as $I = 4P/(pi)(D+dØ)^2$, in Watts per $cm^2$ where P is the laser power [W]. Beam divergence, Ø, is in radians. D is beam diameter in cm.

We also cannot consider the mirror's mass to be an idealized spring or frictionless lattice because there is no time delay associated with light's reflection.

If we presume that some real momentum was imparted to a mirror, it must come at the expense of change in light's wavelength (frequency). Since we do not observe a change in light's wavelength, the photon can only be visualized as reflecting from the mirror without imparting any momentum to the mirror.

Further, since we know that light speed and light wavelength (energy) does not diminish after a mirror bounce, then by using the classical light approach one could obtain thousands of bounces between two parallel good quality mirrors from a single photon. If the photon's momentum were real, we could make a perpetual machine by allowing the mirrors to move back and forth or rotate, and extract work from the moving mirror(s). This is clearly not possible.

Presently, experiments applying lasers produce mechanical motion at the target by evaporating the material found at the target. The evaporated material expands rapidly and its jet stream ejection produces recoil that is likely consistent with classical calculations. However, this mechanism is not the focus of the subject experiment since the mirror surface will not be physically damaged. The subject experiment's focus is the intrinsic momentum that is carried by light.

Photoelectric effect is known for its release or ejection of electrons that acquire energy from light where such energy is consistent with classical light calculations. The subject experiment will show that light's energy and/or light's momentum does not become real (is not realized) when light changes direction by encountering mirror surface.

Another phenomenon that is attributed to light "pressure" is the comet's tail pointing away from sun as the comet orbits around the sun. Yet it is the solar radiation composed of energetic or ionized real particles that push comet's tail in the direction away from the sun. Further, several comet tails are observed, each owing its trajectory to a different mechanism.

By following straightforward procedures and precautions described in this proposal, the subject experiment will show that light of any intensity cannot move a mirror since light does not realize its momentum during light reflection. Therefore, the subject experiment will show that light and light's momentum is intrinsically virtual.