Increased Quantum Vacuum Radiation- Pressure in a Refractive Nano-Scale Film

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Using the Radiation Pressure of the energy of the Quantum Vacuum is rigorously justified in terms of the Laws of Motion and of Thermodynamics. Eliminating certain conflated assumptions about light-momentum leads directly to a theoretical basis for designing a Quantum Sail, for Vehicular Propulsion and Energy Production. The sail will be made of meta-materials that react asymmetrically to the energy and momentum of the symmetric radiation influx of the EM Quantum-Vacuum. It is very likely that these meta-materials can be inexpensively built and tested, using existing materials and equipment.

It has been aptly and oft-repeated that progress is hindered less by the true things that are not yet known, than by the things we *know* to be true, that really aren't! This paper demonstrates that the completely-true, undeniable Laws of Thermodynamics and of Motion have become conflated with collateral presumptions, oversimplifications and over-generalizations. Once these errors are discarded, new unexpected possibilities emerge. These new possibilities are completely consistent with the essential truths of these Laws, just not with the onerous extra-baggage. This paper is merely demonstrating the possibility of new applications of the same old laws. Even the null hypotheses would hold considerable value since many presently accepted ideas would then be seriously in-doubt. This author does not insist that any of the presented-ideas, new or old, are actually true. Rather it is argued that the proposed experiments are justified by the merest possibility that such revolutionary things even *could* be true and by the broad base of experimental data that fits tightly-together to provide credible tokens of hope. Therefore, the reader is implored to suspend final judgment until conclusive experiments have verified or falsified these thoughtfully-constructed hypotheses.

It is impossible to reach the nearest star-system in a single human lifetime, if humans are limited to conventional rockets. NASA's Breakthrough Physics Propulsion Project (BPPP) explored possible avenues of novel research. It hoped to find new insights and methods that might enable science to surpass current expectations of what is considered possible. The BPPP authors examined many proposals; electric rockets, nuclear rockets, laser powered sails; interstellar ramjets that collect the interstellar matter for energy and reaction-mass. No mass-based propulsion methods appear feasibible to take anyone, even just to the nearest Star, in a single lifetime.

Therefore, the BPPP was particularly interested in finding avenues of research that might lead to propellent-less propulsion. Propellant-less Propulsion would not need on-board reaction mass. This is important because the reaction mass requirements of rockets is the largest part of what makes them so fuel-hungry, large, expensive and too slow. Accordingly, the BPPP found that Alcubierre Space-Warping Drive is worth further investigation. It would move space around the ship since, (supposedly) space can move faster than light. This was thought to hold great promise except that it would, from the standpoint of what is currently known, take unimaginable quantities of energy. So Warp Drive is out of reach, at least for now. This sort of outlook is the reason for DARPA's depressingly-named *Hundred Year Starship Program.*

Propellant-less Propulsion is the sort of concept that will cause many readers to put this paper down. That is because, on its face, this seems to be a hopelessly absurd thing to attempt, and a complete waste of time to consider. NASA doesn't seem to think so. On the one hand, NASA downplays the possibility of Gravity Shields and Force Fields that are based on EM Stimulation of Spinning Superconductors as first proposed by Eugenyev Podkletnov; on the other hand, NASA is mandated to review all superconductor-patent applications for possible classification or suppression.

Nonetheless, most aerospace researchers have publicly implied that rockets are the only means to boost a vehicle, up from the Earth into Space. Rockets use Newton's Third Law. In contrast, the present proposal is based on Newton's First Law: So where can we find a useful external source of energy and momentum to continuously apply an external force to accelerate a Space-craft without on-board fuel or reaction mass? Arguably, the most feasible approach was the one that received the least investigation. Harnessing the isotropic Radiation-pressure and momentum of the EM Quantum Vacuum was among the few ideas that were thought to merit further investigation by the authors of the final BPPP report. Specifically, the author of that section of the Report mentioned the possibility of creating a light diode that would allow the incoming radiation pressure of the EM Quantum Vacuum to reflect from one side and to pass-through from the opposite side, which would be expected to yield a net force toward the more-reflective side.

The possibility of using a material with negative refraction on only one side of a sail was also discussed. A material with a negative refractive index might be pulled on by light collisions, rather than pushed. Standard Optical Theory and actual experiments seem to indicate that some existing materials are indeed attracted to light. This is not at all surprising if the transverse EM fields of light are what cause radiation-pressure. If the transverse fields exert Lorentz Magneto-motive Forces, these forces could be parallel or anti-parallel to the light propagation-direction. In other words, the light “pressure” would be positive or the light-“pullure” would be a negative force. This insight forms the basis for the proposed experiment. Negative EM Radiation-Pressure, if confirmed, would prove that light does not conserve the directionality of its momentum.This insight gets at the root cause of the Abrahm-Minkowski Controversy and unifies these seemingly contradictory theories and unifies their two contradictory bodies of experimental evidence. This will be discussed in further detail later in the paper.

A fair number of scientists insist that the EM Quantum-Flux might be nothing more than matter reacting to a field that was emitted by other nearby matter. Nonetheless, many-, probably most- scientists believe that the Quantum Vacuum is self-existent. This would mean that it is there even when there is no matter present to cause its existence. The EM Energy of the Quantum Vacuum is widely-believed to fill the Universe. It is also called Zero-Point Energy, ZPE. Again, this author is not insisting that the Quantum-Flux is self-existent; rather, the proposed experiments have the potential to conclusively settle the question.

Most commonly, it is thought to consist of subatomic particles, including photons, that continuously pop-into existence and promptly vanish. The supposedly-vanishing particles are immediately replaced by the appearance of new particles in the same general distribution. Just as we are shouting “Foul! We can't have matter or energy being created or destroyed!” we are promptly hushed-up and hurried along (Nothing to see here!) We are then told that we have a positive event that is canceled by a negative event and this is supposed to constitute a net non-event in the sense that nothing invalid happened since nothing was changed, in the end. On the other hand, some argue that this notion of physically real matter appearing and disappearing is an absurd rationalization. It strikes some people as being akin to trying to convince a police officer that it is okay to drive up a one-way street in the wrong direction as long as you promise to “undo” it by driving back down the street in the right direction; after all, you end up right back where you started; thus, in the

end, who could prove that you ever drove on the street in the first place! Arguably, it is even worse than that; since the creation and the destruction of matter and energy are both forbidden, period neither direction is the right direction on this No-Way Street! Publicly, this is the most-prevalent interpretation of the Quantum-Flux; nonetheless, many people, (privately at least) still think that the King really might be as naked as he looks. Again, the point is not to argue for one viewpoint or another; rather, it is important to offer plausible answers to people who would otherwise find the whole proposition to be unintelligible.

Besides, we are not necessarily left, having to make lame excuses about matter and energy being made from nothing, and then being destroyed, leaving nothing. Alternatively, Dirac proposed the appearing-disappearing particles exist continuously, but they fluctuate between a manifest-state and a hidden state. Originally, his idea was presumed to not be Lorentz-Invariant and so it was discarded. (Lorentz-Invariance would mean that the spectrum of the EM Quantum Flux looks the same inside every inertial-frame.) However, Boyer demonstrated that the distribution of the Quantum-Flux is indeed Lorentz-Invariant. Puthoff, et al have continued to develop this notion.

This author proposes that a self-existent, Lorentz-Invariant, EM Quantum-Flux might be viewed as providing a Lorentz-Invariant carrier medium for light- and matter- waves. This would be similar to the manner in which sound is a coherent modulation that is superimposed on the incoherent, completely-random molecular motions of the air. The propagation of EM- and matter- waves could add to- or subtract from- the fields of the underlying Quantum-Flux photons. The extra-energy would prevent a given Quantum Photon from disappearing before it passed the extra signal energy along to a newly-appearing Quantum-Photon. The photon wavelength might be related harmonically related to the wavelength of its carrier photon-flux. Perhaps the strings of String Theory and of matter are standing waves. Perhaps this is similar to how an electron can be viewed as a standing wave around an atom's nucleus. This might be the consummate model for generating stable standing waves. Perhaps all particles are like atoms in the sense that opposite properties, colors, charges, etc. could cause one wave to encircle, perhaps even confine a second attractively-opposite wave. If this is true, then maybe string theory could be tested by creating large, observable, low-energy, stable particles based on this model. This notion is similar to the practice of using superconductors to simulate the photon emissions and absorptions of atoms, but on a macroscopic scale. Quasi-stable Ball Lightning is another candidate for a macroscopic electric-wave forming a relatively stable standing-wave. Again, the only value of these ideas is that they can actually be verified or falsified by the proposed predictions and experiments.

Another common objection is that, supposedly, the Quantum Flux cannot really fill the Universe and also have its requisite distribution because the gravitational attraction amongst all of its particles and photons would make them gravitationally collapse. This is not a problem because, on an average, these particles and photons are reappearing in the same distribution as the distribution of the previous generations of particles when they first appeared. Therefore, even if they are attracted to each-other, they cannot accumulate mutual accelerations, one toward another. In other words, the average distribution is reset by each new generation of particles. This is especially true of the photons which always travel at the velocity c, in empty Space, in every inertial-frame, in every direction, anyway. Even so, at any given time, this ephemeral matter would provide the necessary missing mass to restrain the Galaxies from spinning apart.

Arguably, the Big Bang is ongoing, and Space is still expanding. In other words, to make a Big Bang work we must admit that, at least at sometime in the past, more matter popped into existence than popped out of existence. Why do we insist that this ever stopped. Indeed, why extrapolate back to a single Big Bang. Perhaps all we ever needed was a sufficient number of Little Pops! This provides a mechanism for the Expansion of the Galactic Clusters away from each other. In other words, at those distances, the tendency of Gravity to pull the Clusters back toward each other is finally weaker than the expansion of the fabric of Space itself.

John Wheeler proved that *individual* photons could not be gravitationally energetic enough to collapse Space unless they were smaller than about a Planck-length. Therefore these yet-smaller particles would self-destruct even as they would first start forming. Again, there is no insistence that these things are actually true; the point is this, these possible-explanations are no more- or less- probable than the original objection against which they are directed.

John Wheeler's viewpoint leads one to ask what happens to wavelengths that are already at the Planck-length limit, when a vehicle accelerates. What happens when they Blue-shift? It seems likely that the blue-shifting Plank-sized wavelengths do not form in that inertial-frame. This may have implications for Superluminal Travel, since hyperaccelerated matter might not exist as far as the surrounding space, as observed from slower inertial frames. In other words, an outside observer might also pereceive a hyperluminal vehicle as traversing a shorter distance

Maybe both Space-twin and Earth Twin really age at the same rate. Space-twin really is traveling a shorter distance.

This might also explain mass in terms of its resistance to changing inertial-frames. Every time mass accelerates, its matter waves must become shorter in wavelength and therefore more energetic.

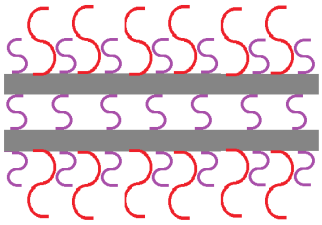
A rocket train uses the same amount of energy to accelerate one meter per second per second regardless of how fast it is already going. In contrast, an electrically accelerated train, is harder to accelerate one meter per second per second, the faster it is already going, relative to the stationary, electro-magnetomotive elements of the track.

For the sake of argument, the next part of the discussion assumes that there really is a self-existent EM Quantum Flux that exerts exerts radiation-pressure on matter. Even if so, how could one possibly obtain a net force from an isotropic EM flux? In other words, every object is approached by equal and opposite influxes of EM radiation? Wouldn't the resulting forces also have to be equal and opposite?

First, a mechanical analog will be considered. Suppose we have a wall that is made of doors. The wall is orbiting the Earth. Two teams, one of cosmonauts and one of astronauts throw equal but opposite influxes of balls at the two sides of the wall. One of the teams has rigged the the doors so that they swing open in only one direction. The balls that are thrown at the one side bounce off of the doors and move the wall away from those incoming balls. However, the balls on the opposite side usually push the doors open and pass through the wall. They impart much less of their momentum than the balls that are all bouncing off of the other side. In other words, the wall responds asymmetrically to equal and opposite, symmetric influxes of balls. The influx is symmetric, but the wall responds asymmetrically. It moves in one direction, even though all of the energies of the balls are equal and opposite, amongst themselves.

If the wall did not move, this would violate Newton's Second Law. So one must admit that equal and opposite influxes of photons could, in principle, be treated asymmetrically by opposite sides of an optical system.

Henrik Casimir is credited with being the first person to propose using the Radiation Pressure of the EM Quantum Flux to move a physical object. He described the unavoidable, observable consequences that would have to occur if EM Zero-Point Energy really exists. In 1948, he proposed a thought experiment. He described two electrically-neutral, electrically-conducting, parallel plates. At least one plate could move freely. They would be separated from each other by a very small distance. He pointed out that these plates would have to prevent the EM Quantum Flux from forming photons with wavelengths that were too long to form between the plates. (Recall that the particles and photons of the Quantum Flux are said to continually appear, then disappear after traveling about half of a wavelength.)



In In **Fig. 1**, the smaller purple waves represent all of the wavelengths that can form both inside- oand outside- of the cavity. Since the smaller waves are equal and opposite to each other, they exert no net forces on the plates; the longer red wavelengths can only form outside of the cavity between the two plates since they are too long to fit between the plates. The inward-directed Radiation Pressure, outside of the plates, consists of all-possible wavelengths. This is because all-possible wavelengths can form, outside of the confines of the space between the Plates. The longer (red) wavelengths push the plates inward since there are no long, red wavelengths inside the cavity to counteract them by pushing outwardly.

In 1996, Steve Lamoreaux, then at the University of Washington in Seattle, experimentally confirmed a version of this gedanken. Many additional independent experiments have consistently verified this phenomenon within 96% of the theoretical values, which is within the margins of error. The force that moves the "plates" together is called the Casimir Force. If Casimir's original idea is really correct, it should be called Casimir's EM Quantum-Flux Radiation Pressure Force.

The biggest problem with the Casimir Experiment is this. As long as there are two "Plates" most scientists will always insist that the two uncharged plates might somehow induce opposite sets of localized electrical charge distributions in each other. Indeed, the Casimir Effect is often described as an attractive EM force that the two uncharged plates exert on each other.

This description is in diametric opposition to Casimir's original idea. Again, the original idea was that the plates were altering the wavelength demographics of the birth and death of the photons of the Quantum Flux. It did this by limiting the wavelengths that could form between the Plates. Then the imbalance of EM Quantum Vacuum Radiation-pressure that is in-between the plates and the endless expanse, outside of the plates was what would push them together.

Casimir's Wavelength Exclusion Model is based on well-understood, perfectly ordinary electrodynamics. The only really new thought here is this. Suppose the EM Quantum Flux really exists. Suppose it really appears and disappears as advertised. Assume that ordinary electrodynamics is a correct description of EM behavior. Then the two plates would have to behave as described. Therefore, the other theories could only be true if there is no EM Quantum-Flux-caused Radiation Pressure. This is because the Quantum Radiation Pressure Theory both predicts and requires all of the forces that have been experimentally measured. There is little or no force left over for the other theories to play a very large role in this phenomenon.

Oddly, Casimir himself publicly said that the Electrical Attraction theory was as good of an explanation as his Radiation Pressure Theory. He may have been uncertain of the independent existence of the EM Quantum Vacuum. Indeed, part of the value of the present proposal is to once and for all-time establish whether the Quantum-Vacuum is merely a local manifestation of matter or whether it has an independent existence, whether or not any matter is present. Casimir's Quantum Radiation Pressure Theory has profound implications, if it can be conclusively verified. For one thing, the Casimir Effect would then be accepted as conclusive proof of the independent existence of the EM Quantum-Flux.

Suppose Casimir's Radiation Pressure Theory correctly models a real physical process. This means that the plates are not exerting any significant forces on each other. Instead, the plates are effortlessly altering the EM Quantum Vacuum Density by simply being there. They are then moved because of the pressure differences on opposite sides of each plate. They are moved by the energy and momentum of the Radiation Pressure of the EM Quantum Flux. This is is as unavoidable as the notion that electromagnetic photons cannot form inside of metals. It is simply part of the general nature of things that larger wavelengths of the EM Quantum Flux do not fit inside of conductor-lined spaces that are smaller than those wavelengths. In this sense, the Casimir Force Experiments would be found to be doing nothing that has not been continuously happening everywhere, since the formation of the first matter.

In other words, no human is providing this energy. This is energy that was already present. This is energy that would have been there, in the environment, whether or not anyone chose to use it. Furthermore, this energy is left behind as heat, when the plates stop moving. If this is really true, then we have already harvested zero-point energy and used it to propel an object through space. (Lab space.) Every form of environmental energy is cost-free until someone takes control of it and starts charging money. For example, Solar Energy is already-present, whether or not people choose to use it. Solar energy, (the energy itself,) is Cost-Free Energy, (except where they tax it!) We only have to buy and maintain the equipment. Likewise, if the energy of the Radiation Pressure of the Quantum Vacuum already exists, then it also is environmental Cost-Free energy if we can build suitable equipment to harness it. Unlike cost-free energy sources such as the tides, wind and Sun, it is always present, everywhere in the Universe, and in great abundance. This is why NASA's Breakthrough Physics Propulsion Program, BPPP, considered the EM Quantum Flux as a potential source of useful energy and momentum, and as an outside force for Propellant-less Propulsion. Its photon-collisions provide the "Outside Force" that is mentioned in Newton's First Law. In principle, if the EM Quantum Vacuum is self-existent, it could move or levitate all of our vehicles and turn all of our machinery.

At first glance, all of this appears moot. Seemingly, once the Plates come together, it will take at least as much energy to separate them again, as was generated as they came together in the first place. The two Plates do not seem to provide a basis for a practical device unless the Casimir Effect can be switched off and on, or even reversed. That thought forms the basis for some already-issued patents. In these patents, inventor Fabrizio Pinto proposes making moving plates out of a semiconductor material that can be switched between a conducting state and a non-conducting state. Incredible forces exist when the plates have extremely small separations. Therefore, in principle, the energy that could be obtained, by switching the conductivity back and forth, could very well be much greater than the required semiconductor bias-energy to switch semi-conductor states. However, it would probably take Quadrillions of nano-scale teeter-dodders to generate macroscopic amounts of energy, though they might be perfect for some nanotech applications.

If Casimir Plates did not move, that would violate the Zeroeth Law. This is because the freely-moveable Plate is located directly between a high energy-density radiation-pressure region and a low-energy radiation-pressure region.

The First Law is not violated. This is because the energy that is entering the system as a high-energy flux of photons, is equal to the work and low-energy photon flux that is leaving system as work and heat.

The Second Law is not violated. This is because an already-existing high energy-density, low entropy photon flux is crossing the system boundary, performing work and shedding high-entropy, low energy-density heat which then exits across the System Boundary. Therefore Entropy is increasing and energy density is decreasing, just as they should.

The Third Law concerns the usual inability of energy to transfer in the absence of two differing Thermal Reservoirs. It is not the machine that is exceptional in this case. Rather, the Quantum Flux itself is defined as the energy that remains in otherwise empty space, when all heat energy has also been removed. This is one reason why it is called Zero-Point Energy (ZPE.) Of course it is also still present at all non-zero temperatures.

ZPE literally has no thermal potential. However, its spectrum is nonetheless, highly energetic, especially at wavelengths below 50 nm. In other words, being at Zero-Temperature does not mean that its energy potential is Zero. Again, we are using the low-entropy, high-energy density Radiation Pressure of very-intense, very-small wavelengths to do work. That work is dissipated as low-energy, high-entropy wavelengths of infrared radiation. Basically, the Third Law comes into play more abstractly: High and low frequencies always exist in the ZPE Spectrum at all temperatures. Even at Absolute Zero Degrees, the high energy, low-entropy wavelengths function as the high energy reservoir and the cool heat-sink of space still serves as the low energy heat-reservoir, as usual. So we still have a high energy reservoir and a low energy reservoir. So, in principle, the Third Law is still being observed. In principle, this adaptation of the Third Law is no than when the Third Law is adapted to cover systems that require differences in electrical potential or hydraulic pressure differences.

The reason that the Quantum Flux has no thermal potential is quite simple. Its constituent photons do not persist long-enough to travel more than about half a wavelength before disappearing. As one generation of photons is vanishing, it is already being replaced by new photons that always appear in the same general distribution in which the previous generations of photons appeared. This means that the energy in adjacent regions of space with differing energy-densities does not flow from the high density region to the low density region, as thermal energy must do. For example, the open edges of Casimir's "Plates" form an abrupt boundary between the low density non-thermodynamic energy that exists between the Plates and the High energy-density that exists outside the Plates.

So, if this is really true, then how is a Casimir Plate pushed toward the low-energy region? This occurs because the denser photon flux on its outside surfaces imparts more momentum into the plate than the less-dense flux on the inside surfaces, between the "plates." In other words, even though a photon vanishes after striking the plate, it first induces momentum in the plate. Consequently, the Plate stores some of the Energy of colliding with many generations of ephemeral photons winking in and winking out.

Many object that this would change the amount of energy in the Universe. This depends entirely on where one draws the system-boundaries of the Universe. In other words, it is a mere semantic issue. On the one hand, if we define the Quantum Flux mechanism as part of the Universe then, perhaps, energy is not really being created and destroyed. Rather, it might be alternating between a hidden state and a manifest state. This is the essence of Paul Dirac's Theory of a vast Sea of Particles that alternate between a positive energy level and a negative energy level.

This view was originally rejected because it was assumed that, like the aether of the 19th Century, it would not be Lorentz Invariant. (All inertial frames would not look the same to all of the inhabitants of all of those inertial-frames.) It turns out, however, that each possible wavelengths would have density of $\mathbf{1 / \lambda^3}$. This is the only known distribution that would be Lorentz Invariant. It is $\mathbf{1 / \lambda^3}$ to the observers inside of every inertial frame of reference. Furthermore, negative energy states have been observed in various experiments, in recent years. Perhaps this theory will yet gain more acceptance.

On the other hand, if we posit that the Quantum Flux is not part of the Universe, then we are admitting that energy can enter and leave the Universe. Therefore, we would have no basis for assuming that matter and energy could not temporarily accumulate in one Universe while another Universe is temporarily depleted. Perhaps this energy would be passed back and forth more or less equally over time. The point is this. These musings are no more- or less- fanciful then pedantically insisting that we even can know that the energy balance of the universe has to match our pathetically uninformed expectations.

The Casimir Force experiments, that have been done to-date have detected very small forces; however, these results extrapolate to very large forces if we can develop a way to harness smaller wavelengths than have been used in these previous experiments. The forces could be dramatically large even with fairly large wavelength-usage, if materials with large internal reflecting surfaces can be developed.

The EM Quantum Vacuum Radiation Pressure is derived from energy values that have been experimentally detected. These values and their relationships are described by Planck's Black Body Radiation Spectrum Formula. This will be used to calculate the Radiation-pressure of the EM Quantum-Flux.

$$\mathbf{u = h\,(n + 1/2);\ \{ n = 0, 1, 2, 3 \ldots n, n+1\}} \qquad \textbf{(Eq. 1)}$$

The existence of the Zero Point Energy Field is most clearly seen in the instance where $\mathbf{n = 0}$; this leaves us with **Eq. 2**.

$$\mathbf{u_{zpe} = \hbar\omega / 2} \qquad \textbf{(Eq. 2)}$$

Zero-Point Energy $\mathbf{u_{zpe}}$ is the energy from a single wavelength of the EM Quantum Vacuum. It is positively not a figment of our mathematics. Historically, Max Planck derived the formula that included this term before anyone had any thoughts about a Quantum Vacuum. This term is an unavoidable mathematical consequence of physically-real experimental data. In other words, even if the theory of an EM Quantum Vacuum is wrong, something that is physically real is causing this term. The Zero-Point Energy interpretation came later. Saying that it is just a convenience to make our calculations work is like insisting that there has been no unacknowledged-elephant in the room while we are engaged in the very act of holding our noses while cleaning up the mess he (or she) left on the floor.

In terms of frequency in cycles per second, or hertz Planck's Constant is **h**. The constant h-bar, $\mathbf{\hbar = h / 2\pi}$. It is used with $\boldsymbol{\omega}$ which is frequency in radians. $\boldsymbol{\omega = 2\pi f}$, **f** is frequency in Hertz. (One very notable exception was when Richard Feynman used **h**, he usually meant **h-bar**, $\hbar$.)

(Eq. 3) merely converts **(Eq. 2)** from radian measure to frequency in cycles per second, hertz.

$$\textbf{(Eq. 2)} = \mathbf{[(h / 2\pi)\,(2\pi f) / 2] = u = h f /2} \qquad \textbf{(Eq. 3)}$$

(Eq. 4) gives us the total energy of quanta of a single wavelength that can fit into one cubic meter.

$$\mathbf{u_{zpe}(\lambda) = h / 2\,\lambda^3} \qquad \textbf{(Eq. 4)}$$

$$\mathbf{c = f\ \lambda} \qquad \textbf{(Eq. 5)}$$

(Eq. 4) = u_{zpe} (f) = h f^3 / 2 c^3 df **(Eq. 6)**

Integrating **u_{zpe} (f) df** sums the energies of all photon wavelengths that can simultaneously occupy one cubic meter. In practice, longer wavelengths are negligible.

U (f) = ∫ u (f) df = ∫ f^3 / 2 c^3 df = h f^4 / 8 c^3 **(Eq. 7)**

Ludwig Boltzmann proved that the isotropic radiation-pressure that is acting uniformly on a flat surface is equal to the energy-density above the surface, divided by three. This is easy to understand since the total energy of the EM Quantum Flux is isotropic. This means that it is equally- intense in all directions. Therefore, the total momentum of em radiation, P_T, that is approaching the Surface, must be divided equally among the three momentum vectors, P_X, P_Y and P_Z.

(Eq. 8) defines the momentum of a photon.

P = E / c **(Eq. 8)**

(Eq. 9) says that the total momentum of the photon is evenly distributed among the three momentum vectors.

P_T / 3 = P_X = P_Y = P_Z **(Eq. 9)**

Horizontal vectors + **P_X** and **– P_X** as well as **+P_Y** and **-P_Y** cancel each other out and do not affect the top or bottom surfaces of a metal plate. **+P_Z** acts only on the bottom surface and **-P_Z** acts on the top surface of a horizontally-oriented plate.

(Important! The three vector momenta are being discussed, not the motions of the EM fields of a photon.)

(Eq. 10) Converts Energy into pressure, again using Boltzmann's law of pressure and energy.

Pr (f) = U (f) / 3 = h f^4/ 24 c^3 **(Eq. 10)**

(Eq. 11) converts frequency notation back into wavelength notation.

h c f^4 / 24 c^4 = Pr (λ) = h c / 24 $λ^4$ **(Eq. 11)**

(Eq. 12) defines the Quantum-Flux Radiation Pressure in any specified range of wavelengths.

Pr (λ) / = h c / [24 ($λ_1^4$ - $λ_2^4$)] **(Eq. 12)**

In practice, we can justify not counting wavelengths that are larger than **λ** specified since we only need to specify wavelengths that significantly impact the material we have chosen. Having to subtract infinities from each other is not physically relevant since the energy density of progressively longer wavelengths quickly converges on zero. This is because every tenfold increase in wavelength is accompanied by a ten-thousand fold decrease in energy-density. This is due to the $λ^{-4}$ term. For practical purposes, $λ = ∞$ can be any number that is one or more magnitudes of $λ_{specified}$ Likewise, consideration of ever-smaller wavelengths also converges rapidly on irrelevance for the present purposes. This is because matter rapidly becomes transparent as very small wavelengths are considered. In practice, integrating from $λ_{1\ specified}$ to $λ_{2\ specified}$ is physically valid, within a corresponding margin of error.

The proposed light sail is based on altering the EM Quantum Flux on one side of a plate by coating that side of the plate with a highly-refractive material. Both, of the current two accounts of the momentum of light in such a refractive medium agree that the forces on the two sides of the plate will be unequal, but that any net force acting on the plate would have to be negated by opposite forces that must actually exist and must act on the refractive material. This conclusion should not be taken too seriously. This is because the two theories each predict a net force acting on the mirror alone, that acts in a direction that is opposite from the direction that is predicted by the other theory.

As currently interpreted, the subject of Light-Momentum as light enters or exits a more-refractive material is very perplexing. On the one hand, Minkowski proposed that more vertical momentum was (somehow) added to the light as it entered the more-refractive medium. This is supposed to be the only possible conclusion that conserves the directionality of Light-Momentum, based on a large body of experiments. On the other hand, Abraham argued that the light lost some of its momentum when it entered the more-refractive material. This is also supposed to be the only possible conclusion that conserves the directionality of Light-Momentum, based on a second body of many experiments. (Welcome to the Abraham-Minkowski Rabbit Hole!)

Fig. 1

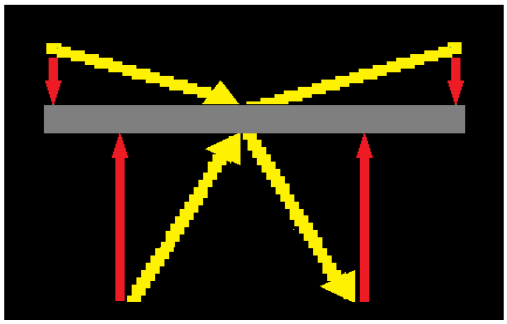


Fig. 2

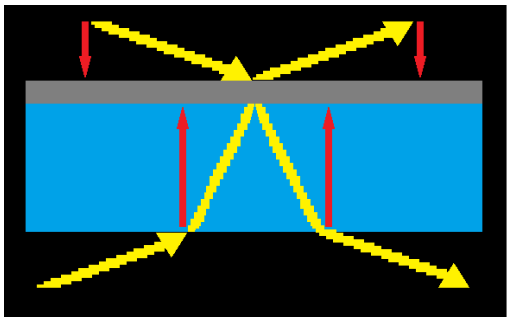


Fig. 3

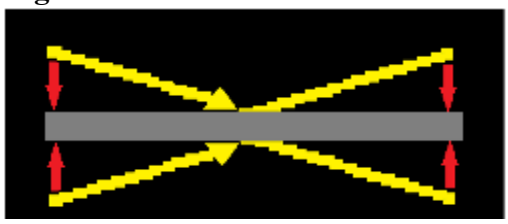
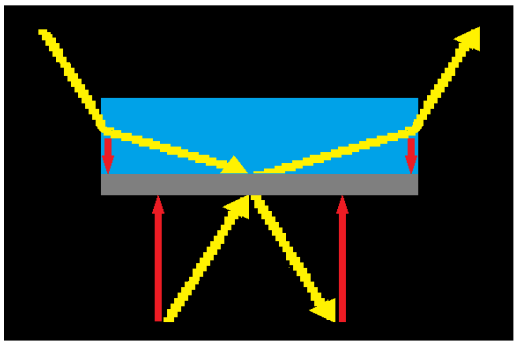


Fig. 4



In **Fig. 1**, the energy and momentum magnitude of the light ray on top is equal to the energy and magnitude of the momentum of the ray on the bottom; nonetheless, the ray that is reflecting off the bottom of the plate is going to impart a larger magnitude of momentum normal to the plate than the light ray that is acting on the top of the plate; we know this because, relative to the plate, the bottom ray has a larger normal-momentum component vector than the normal-momentum component vector of the ray that is on top; so the plate in **Fig. 1** experiences an upward-directed force. force.

In **Fig. 2**, none of the forces that are acting directly on the mirror have changed magnitude, direction or angle of attack, relative to the corresponding forces in **Fig. 1**. The net force acting on the mirror in **Fig. 2** is also the same magnitude as the net force acting on the bottom of the mirror in **Fig. 1**.

Here is the problem: The light ray that is reflecting at a steep angle off of the bottom of the plate in **Fig. 2,** started out at a much shallower angle, relative to the plate. Its angle of attack, relative to the plate, steepened when it was refracted.

Figs. 2 & 3 *show that the vertical momentum component, outside of the more-refractive material, So how did they acquire the extra momentum in the vertical component vector as it entered the more- refractive material?*

The forces acting directly on the plate in **Fig. 4**, are also equal to the corresponding forces in **Figs. 1 & 2**; but now, the more-refractive material is on top and the light rays enter and exit from the sides of the more-refractive material. The light ray on the top enters the more-refractive material at an angle that is steep, relative to the mirror. However this time, as it enters the more-refractive medium, it is bent to a shallower angle, relative to the mirror. This time, the light's normal momentum component vector is made smaller, relative to the plate, as it enters the more-refractive medium. Therefore, Abraham insists that the momentum of light must always decrease as it enters a more refractive material.

If one just dispenses with the unfounded insistence that light has momentum in which directionality is conserved, then this eliminates the contradictions between these two theories. This also reconciles both bodies of otherwise-contradictory experimental results.

Light refracts (turns) because one side of the wavefront slows down sooner than the opposite side. Both rays impart magnitudes of momentum to the plate, as though the magnitudes of momentum outside the more-refractive materials are conserved inside the more-refractive material, but the directionality of the momentum is not conserved.

One might imagine this to be a little bit like a car coasting around a corner. The magnitude of its momentum is conserved, but not its directionality. A car accomplishes this by means of exerting forces against the ground. Indeed, experimental-evidence seems to establish that light always exerts entry-forces and exit-forces toward the more refractive-medium. This is also just how a car exerts deceleration forces forward, toward a slow-speed zone as it enters that zone. It also exerts forces back

into the zone as it accelerates out of the zone.

Historically, Nichols (later, High-Vacuum) Radiometer proved that light causes matter to acquire momentum. Unfortunately, the whole notion immediately acquired extra-baggage. It was arbitrarily presumed that light-itself had every aspect of Newtonian Momentum. Both ordinary optical theory and at least one recent experiment seem to prove that light pulls on materials that have negative indexes of refraction, instead of pushing on them; if true, the momentum of light cannot possibly conserve its Directionality. Insisting that the momentum of light must always conserve Directionality is just as unfounded as insisting that light must have mass in order to have momentum. It may be better to think of Light-Pressure as nothing more than a Lorentz Force that arises between its EM transverse fields and the EM fields that are emitted by matter. So far, this interpretation provides the only physically-sensible explanation of how light can pull on an object that has negative-refraction. It also explains how it act as though it has momentum even though it possesses no mass.

Spurious presumption of light-momentum conserving Directionality, is at the very root of the Abraham-Minkowski dispute about the nature of light momentum as it enters and leaves a refractive material. (Both of their arguments destroy almost any remaining resemblance to Newtonian Momentum, anyway.) Neither Minkowski or Abraham offer any sort of mechanism for the unexpected changes in momentum as light enters or exits a more-refractive medium. Instead, they have confused the World with two mutually-incompatible mathematical models, each complete with its own multitude of supporting experimental-evidence. Their theories lead to large numbers of experiments that seem to validate one theory or the other theory, but never neither-or both.

On the one hand, people don't seem troubled at Abraham's contention that some light momentum disappears upon entering the more-refractive medium and reappears upon exiting the more-refractive medium. On the other hand, defenders of Minkowski go to great lengths to salvage the dubiously-presumed directional-conservation attribute of light-momentum. (As already noted, this is a problem that does not even need to be solved.)

The Minkowski approach cleverly invents Canonical Momentum that magically appears, only inside of the more-refractive medium, then conveniently disappears as the light exits the more-refractive medium. No actual mechanism is proposed as to what makes the magic work. The real magic is in the name; it turns out that a sophisticated name is almost as fashionable as an actual explanation.

In contrast, there is nothing unnatural, mysterious or paradoxical about the approach that is proposed in this paper. It is far simpler to say that the magnitude of its momentum stayed the same, but its total momentum changed direction. This is no stranger than saying that the momentum of light does not prove that light has mass. This approach merely proposes that the total momentum changes direction, but not magnitude, as it enters- or exits- a more refractive medium. It explains why the experimentally-observed forces occur, according to the incidence-angle of the reflection inside the more-refractive medium as though the mirror was being struck at that same angle outside of the more-refractive material. This force has nothing to do with conservation of momentum. Both Abraham and Minkowski violate conservation of momentum, strictly-speaking. Their excuses for letting momentum appear and disappear bring us once more to telling a police officer “It simply doesn't matter that I drove down the one-way street in the wrong direction, today. Just yesterday, I drove up the same street in the right direction; So how can you give me a ticket? Clearly the net result is as though I never drove down that street at all!”

Seemingly, since no mass is present, light cannot carry forward momentum in any ordinary sense. This should already have occurred to us since its energy is contained in its transverse motion. No one has proved that light is anything more than traveling transverse-wave, electromagnetic field oscillations. The phenomenon that makes light look like it has momentum is this; its transverse energy exerts a magnetomotive-forces as it reflects from mass-containing objects. This magnetomotive force is normal to both transverse fields. It is usually exerted parallel to its direction of propagation; however, in the case of negative-refraction materials, it is exerted in the anti-parallel direction.

Another problem is still hanging over the new theory of light momentum. The present discussion has gone from saying light has more momentum inside the more refractive material, to saying it has

less momentum inside the more-refractive material. Now it is being claimed that light has the same momentum magnitude whether or not it is inside the more refractive material; this is also problematic. This problem must also be solved before anyone can figure out exactly how the present proposal for a Quantum-Sail might work.

Since the frequency is the same inside- and outside- of the more-refractive medium, the energy is also the same, inside or outside of the medium. The experiments are telling us that the momentum magnitude is also the same, inside the more-refractive medium; but light speed seems to have a smaller value inside the medium. This is a serious problem because one would still define the momentum of light as $\mathbf{P} = \mathbf{E} / \mathbf{c}$; so if the speed of light is really smaller in magnitude, inside the more-refractive material, then this would yield a larger value for light-momentum magnitude inside the more-refractive material than when the same light is outside of that material. Yet again we seem to have a contradiction between the theory and the experimental facts.

Here is the resolution to this problem: Light still has the same momentum magnitude inside the more-refractive medium as outside of it. Light still takes more time to travel across the inside of the more-refractive material than across its outside; and yes, the light is traveling just as fast inside the medium as it is outside of the medium. Therefore, the distance must be greater, across the inside of the refractive material than across the outside of the material. Amazingly, this truly-bizarre possibility is supported by experimental evidence.

There are at least two peer-reviewed papers that describe experiments where light has traveled across an evacuated Casimir Cavity as though it had traveled faster than light can travel. This can also be interpreted by saying that the distance across the inside of the cavity was shorter than the distance across the outside of the cavity. How can this be?

Light, and perhaps the DeBroglie Wave-Nature of Matter, can be viewed as coherent signals that are superimposed on the random spread-spectrum "carrier waves" of the EM Quantum-Vacuum. This is similar to the manner in which coherent sound waves are transmitted across the completely incoherent, chaotic medium of air molecules. What is sound made of? Materially-speaking, sound is made of molecules that transmit a modulation in their average distance. In the same way, perhaps matter and EM waves actually are physically made of the background EM Fluctuations of the Quantum Vacuum. One would say that its average distribution and composition fluctuates in such a way as to transmit a coherent signals.

So what is meant by the term distance? One can imagine two parallel paths of stepping stones, side by side. One path has more stones than the other path. If two people are moving at the same number of stepping-stones per unit time, then the person on the path with fewer stepping stones would arrive sooner. In space-time, there is no distance between the stepping stones. The smallest particle can only exist on one stepping stone, not in between them. This is because a particular distance is being defined as a certain number of stepping stones. The maximum speed is the speed of light.

In these particular experiments, Casimir Cavities restricted the modes of EM Vacuum Energy that could arise inside of the confines of the Cavity. In other words, the EM Quantum-Flux Density was decreased inside these cavities; in other words, there were fewer "stepping stones." Therefore, the light in these Casimir Cavities arrives sooner since exists as a modulation of fewer EM Vacuum Modes.

Thus, we can define what we mean by the word distance in terms of the random EM Quantum-Flux Density. Of course the same distances are going to look different when viewed from other inertial-frames, while still retaining the same ratio of length-magnitudes.

There is a paper that describes condensed matter as constituting an aggregate of macroscopic Casimir Cavities. The aggregate Cavity has properties that are the average of the Casimir properties of all of the spaces inside the medium. This may be another way to describe the dispersion properties of refractive materials. Dispersion is modeled as a sort of interference with light inside of transparent materials that arises from electrical interference with the electromagnetic, fluctuating fields of the atoms and molecules. There are many papers that describe Casimir Cavities wherein the EM Flux Density is increased and the sign of the resulting Casimir Force reverses. So if decreasing the EM Flux

density shortens the distance, then increasing the flux density increases the distance across the inside of the media verses the distance across the outside of the media. This time, the light travels by modulating more vacuum modes, inside all of the Casimir Cavities. Since it moves across more modes of the Quantum-Flux inside a refractive material, it is thereby traversing a longer distance across the inside of a more-refractive material than across its outside.

Forces are exerted on the more-refractive medium because the light is, in effect, entering a different inertial-frame. In this view, the speed of light and distance are more fundamental than process-time. We can also view the altered distances inside of transparent material as a local change in the rate of process-time.

For example, a friend of this author, Fran Roarty predicted that radioactive gases would change their apparent spontaneous decay rate when confined in nano-powders or nano-porous materials such as Raney Nickel, materials that have many nanosized pores. This has been experimentally confirmed. According to Casimir's original Two-Plate Gedanken, the plates alter the energy of the space between them.

Roarty pointed out that one could expect very abrupt transitions between the interior of Casimir Cavities and the exterior a regions along the edges or openings of the cavities. Although these regions are mutually-stationary, they constitute differing inertial-frames. This apparent alteration of space-time may play a role in the Anomalous Heat Phenomenon, aka LENR, so-called Cold (Con)fusion. Regardless of the actual cause, or anyone's preferred semantics or theories, excess heat has been thoroughly documented hundreds of times, Worldwide by responsible scientists, including some at the Naval Research Laboratory and, more-recently at MIT, and NASA. Production of anomalous isotopes have also been found and repeated many times.

In short, this approach enables light to have the same energy and the same momentum inside a more-refractive material as outside of it. It also leads to a definition of what we mean by distance and location. It also provides a basis for viewing the DeBroglie matter waves as the basis for material existence. It could lead to direct correlations between string theory in terms of cohering the Quantum Vacuum. Boyer proved that the **1 / lambda cubed** distribution of any given EM Vacuum frequency is the only distribution that is Lorentz Invariant.

In terms of an Information Universe, this model provides a useful description of the pixels of the screen upon which all of the data in the Universe is displayed.

The Quantum Flux is a good candidate for so-called dark-matter, except that its density would supposedly cause a gravitational collapse of Space-time if it caused the extra gravitational attraction that seems to keep galaxies from spinning apart, due to their “excess” rates of rotation. Space-Time does not collapse due to the excess density of the EM Quantum-Flux because of the transience attribute of the EM Quantum-Flux. The modes travel only half of a wavelength, on an average, before vanishing. As one generation of photons is vanishing, it is being replaced by another generation of photons that appear in the same average distribution as the initial distributions of the previous generations. Therefore, Gravitational Collapse forces and changes in average distribution cannot accumulate.

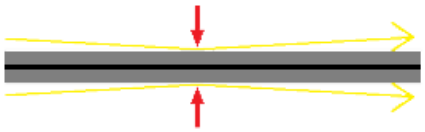
The intention of digressing in so many directions is simply to support the notion, that the approach in this paper is supported or at least plausible, according to a great deal of evidence, in many different fields of physics. Like so much that is believed today, it is little more than a fantasy until we do the necessary experiments. Indeed, the main value of speculation is if it leads to good experiements.

This approach also shows that entropy might be conserved at quantum scales. All photons or quanta have the same energy. High-frequency light has more energy because more quanta strike a target per unit time. Even though individual quanta have the same energy, a particular photon has different wavelengths in different inertial frames. So when a so-called Virtual-Photon does work on so-called Real Matter. The real matter is already thought to shed Virtual-Photons which then disappear-as only they can do! These photons that are produced by the matter are going to be lower in energy than the

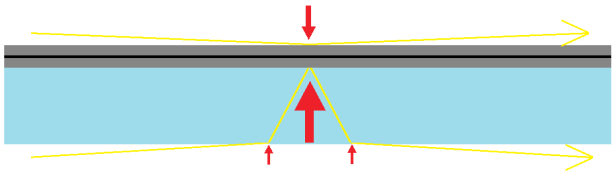
photons that accelerated the matter into a new inertial-frame. When one looks at this in terms of Larmor Radiation, all of the absorbed energy is released. Does this change the energy balance? Not really, because when one of the, disappears, it is replaced by another quantum-photon that could be of any possible energy in any possible direction. In other words, in any given inertial-frame the Quantum-Flux Energy stays the same.

This means that one can look in every direction and that every photon of a particular wavelength % What do we learn from the doppler-shift as a light beam approaches us and then recedes into the distance?%

A single isolated plate will normally have equal and opposite Radiation Pressure forces acting on its opposite sides. Below, jn **Fig.** two mutually equal and opposite rays strike the top and bottom mirrors. The upward-directed force is equal and opposite to the downward-directed force.

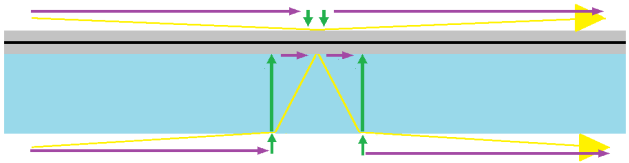


Below, in **Fig.** its bottom side mirror is covered by a (blue) highly refractive coating. Again, equal and opposite rays approach the refractive coating and the top of the mirror. However, the ray on the bottom is refracted. The refractive material bends the ray so that it strikes the bottom side of the mirror at a much steeper-angle than the ray that is striking the top side of the mirror.



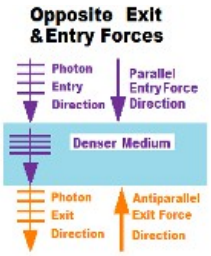
This can be seen by comparing the steepness of the two angles of the two rays. The smaller red arrow indicates the weaker normal force component that is acting downward on the top mirror with the stronger normal force component that is acting upward on the bottom mirror.

Below, in **Fig.** The vectors are portraying the directionalities and intensities of the total energy of the two rays. This leaves us with a net upward-directed force. The smallest green arrows at the



bottom show the forces that are exerted on the refractive material when the light enters the refractive material and when it leaves. Energy is being transferred from the horizontal vector that is outside of the refractive material; it is being transferred to the vertical vector inside the refractive material as the light enters the refractive material. Many published experiments have documented the apparent appearance of anomalous "extra" momentum within refractive materials. This will be discussed more, a little later. This expectation of non-conservation of momentum is consistent with Minkowski's- and also with Abraham's- accounts of photon momentum, as well as with both seemingly-contrary sets of positive experimental outcomes.

Can equal and opposite influxes of light really be made to exert asymmetric forces on the two-sided mirror? Before jumping to such an extraordinary conclusion, one should first examine other possible forces to see if they might counteract the asymmetric forces between the two sides of the system. For example, what sort of forces are exerted on the refractive medium as the directed-energy of a photon is refracted?



The normal forces are also illustrated in **Fig.** . In **Fig.,** the light pushes toward the refractive medium, both when it enters and when it leaves that refractive medium. Usually we are looking at the following situation when considering this phenomenon. Here the same thing is taking place, the entry-force and the exit-force are still directed toward the refractive material; however this time, the light is entering and exiting the refractive material on opposite sides. That is the only reason that, this time, the forces are equal and opposite. It is not because the forces "have to be" equal and opposite, no matter what. The salient point here is that the force of entry and of exit to and from a more refractive material are always exerted toward the material.

The major point is this. An entry-force is exerted toward the medium as the light slows. An exit force is exerted toward the medium as the light accelerates into the less refractive medium. In Fig. 2 these forces are equal and opposite. It was exactly the same way with the Segways: They exerted a force on the ground as they decelerated into the slower zone. This force was directed inward toward the center of the zone. Likewise, they exerted a force as they exited. This force was also directed toward the center of the slow-zone.

Because the mirror reflects the light, in Fig. 1, the light now exits on the same side of the refractive medium as the side that it enters. Both forces are still directed toward the material, for all of the same reasons. However now, they are now equal and parallel instead of being equal and opposite. They are both directed upward in the same direction as the forces on the mirror. Below, a barge with its deck is the same level as the two sides of the canal upon which it is floating. A car de-celerates as it drives onto the barge. This causes the barge to pick up some of the momentum of the decelerating car.

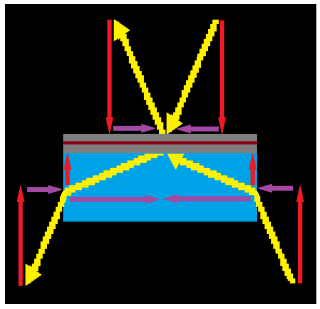
When light reflects, there are two forces, a collision force and rebound force. Both forces act toward the reflecting surface. It is considered settled science that reflecting light imparts twice as much energy as light that is merely absorbed. Reflection is considered an elastic collision and absorption is considered to be inelastic.

"Extra" energy is positively not magically appearing inside of the refractive material. The same amount of energy approaches the bottom refractive material as approaches the top side of the bare-mirror. The only difference is that, at the edge of the refractive material, the path of some of the parallel energy of the incoming-light is bent so that some of this horizontal energy is now subtracted from the horizontal vector and contributed to the vertical vector. So there total energy is conserved, but its directionality is not conserved. This is why more of the total available energy strikes the bottom mirror a steeper angle than the corresponding ray that barely glances off of the bare top mirror. In other words, some of the energy that had been parallel to the surfaces is now perpendicular.

What about conservation of momentum? Semantic issues can

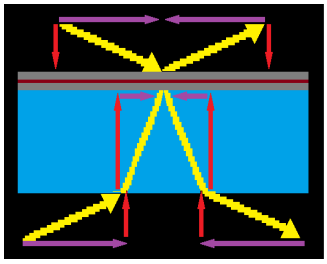
be important when we use the same term to describe things that may have significant differences. We must admit that light cannot have Newtonian Momentum because it does not have mass. Its momentum is defined as P = E / c. Since we are already allowing momentum without mass, we should at least be open to the possibility of other irregularities.

For example, the Minkowski-Abraham debate has been raging for many decades. This author is not claiming to have the final word on this vast topic. His point is merely that this debate reveals a whole new World of photon-momentum weirdness and humbling-uncertainty.



On the one hand, Abraham argued that the momentum of light is smaller by a factor of **1/n** after entering a more-refractive medium. The following illustration depicts at least one situation where this is occurring. It is not necessarily representative of all experiments which seem to confirm Abraham's hypothesis. The light is approaching the mirror at a steeper-angle before it enters the more-refractive medium. Then it refracts and strikes the mirror at a shallower angle, inside the more-refractive material. Ordinary conservation-of-momentum considerations lead us to expect that the perpendicular momentum that is imparted to the mirror is the same as the perpendicular momentum that the same light had before entering the material. In other words, it should still be equal and opposite to the light that strikes the bare surface, on the top-side mirror, despite the fact that it is striking the mirror that is inside the more-refractive material at a much steeper angle. Instead, it acts as though some of the perpendicular momentum has vanished. There is still a net force acting on the mirror, in accordance with the shallow angle at which the refracted light strikes the mirror, inside of the more refractive material. This net force is indicated by the small upward-directed red arrows. There is no equal and opposite force because the long forces, that are depicted by the long arrows, are equal and opposite to each-other. This happens because, this time, the mirror is normal to to the surface through which the light enters the more-refractive medium.

$$\mathbf{P_{Refracted} = P_{Not\ Refracted} / n} \qquad \textbf{(Eq. 14)}$$



Minkowski argued that the momentum of light is greater inside a more-refractive medium than it was before the same light entered into the more-refractive medium. **Fig. **** is not necessarily representative of all experiments that seem to support the hypothesis of Minkowski. Minkowski's formula is shown as **(Eq. 13).**

$$\mathbf{P_{Refracted} = n\ P_{Not\ Refracted}} \qquad \textbf{(Eq. 13)}$$

The point is this: If the momentum vector component, of the light that is normal to the mirror, had the same momentum inside a refractive medium, as it had outside of the refractive medium, then it would not matter that the light strikes the bottom mirror at a steeper-angle than the same light, before it entered the more-refractive medium. The normal vector would have to remain the same, inside the more refractive medium. The forces that are acting on the the top and bottom mirrors would still be equal and opposite since the light on the bottom started out with the same momentum, relative to the mirror, as the light on top. Amazingly, many experiments reveal that it strikes the mirror inside the medium with additional momentum, according to its steeper-angle inside the medium. In other words, it seems to pick up additional upward-directed momentum as it enters the more-refractive material. Minkowski called the additional momentum, that appears inside the material, Canonical Momentum. It is then argued that this Canonical Momentum has no net effect because of the entry-and exit- forces must be equal and opposite to the Canonical Momentum. No definitive explanation is given as to why extra, upward-directed momentum should magically appear. Furthermore, unrelated experiments reveal that the entry- and exit- forces are not always equal and opposite. These experiments indicate that the entry-force and the exit-force are both exerted toward the material.

The point here is not to attempt to resolve all of the details of all the many experiments that illustrate the problems that have been described, The point is that, from any standpoint, the momentum of light is not conserved in the same manner as in Newtonian Momentum.

Eqs. 15 and 16 use directed-energy vectors, to track the changes in the direction of travel of the light-energy. **Eq. 16** shows the distribution of these directed-energy vectors before they refract. In other words **Eq. 15** is Boltzmann's equation, using directed-energy vectors to track the direction in which the energy is traveling.

$$\mathbf{E_T X / 3 + E_T Y / 3 + E_T Z / 3 = E_T} \qquad \textbf{(Eq. 15)}$$

It is interesting that the formulations of Minkowski and Abraham both appear in both (**Eqs. 16a & b)**, below. This is the directed-energy vector distribution after the light is refracted. Combining these competing equations conserves energy without resorting to fictional forces such as those that arise from "Canonical." There simply is no experimental evidence of Canonical Momentum except they say they "have to" have something to keep all of the equations balance.

(Eq. 16) applies to **Fig. **.**

$$\mathbf{n{*}E_T X + n * E_T Y + E_T Z / (2n{*}3) = E_T} \qquad \textbf{(Eq. 16)}$$

(Eq. 17) applies to **Fig. **.**

$$\mathbf{E_T X / (2n{*}3) + E_T Y / (2n{*}3) + n * E_T Z / 3 = E_T} \qquad \textbf{(Eq. 17)}$$

Both of these preceding Equations imply that the directed-energy vectors exchange energy as the photon was turning while it was being refracted. As already-illustrated with the cars, this happens whenever any object changes its direction of travel but is still being tracked in the original inertial frame of reference. As with the refracting car, all entry and exit forces act perpendicular to the edge of the refractive material.

In other words, the total energy of the photon while it is inside the refractive medium is the same as the total energy of the photon when it was outside of this medium. However now, more of the energy resides in the directed-energy vector **Z**. Less energy now resides in the other vectors.

So we are left with **(Eq. 18)**. It calculates the net Pressure that pushes up toward the refractive side of the mirror in **Fig. ****.

$$\mathbf{(n * E_T Z / 3) - E_T Z / 3 = (n_1 - n_2)\ E_T Z / 3} \qquad \textbf{(Eq. 18)}$$

10% Efficiency
n1 – n2 = 0.5

nm	One Layer Pa	1000 layers Pa	One Layer lb thrust/f^2	1000 layers Lb thrust/f^2
30	1.02E+003	1.02E+006	10.3	10,316
40	3.23E+002	3.23E+005	3.3	3,264
50	1.32E+002	1.32E+005	1.3	1,337
60	6.39E+001	6.39E+004	0.6	645
70	3.45E+001	3.45E+004	0.35	348
80	2.02E+001	2.02E+004	0.20	204
90	1.26E+001	1.26E+004	0.13	127
100	8.28E+000	8.28E+003	0.084	84
200	5.18E-001	5.18E+002	0.005	5

Combining **Eq. (18 16)** with **(Eq. 14 12)** gives us **(Eq. 18)**

$$\mathbf{Pr(\lambda, n) = (n_1 - n_2) * h c / [24 (\lambda_1^4 - \lambda_2^4)]} \quad \textbf{(Eq. 18)}$$

Table one assumes 10 % efficiency, and $\mathbf{(n_1 - n_2) = 0.5}$. sums the effective radiation-pressure of all wavelengths equal-to or greater-than the specified. In other words, the entry-refraction force and exit refraction-force are both directed toward the more refractive medium. Both of these statements have been experimentally verified. **

Tsunami waves do not carry water across the ocean. Therefore, they do not carry momentum in the direction in which they are traveling. The water at each point merely absorbs and releases the passing energy as it rises and falls. Tsunami waves can refract as changes in depth slow them down or speed them up. (The same stream of water moves faster through a narrow channel or a shallow channel and slower through a wider or deeper channel.) This is part of why multiple waves seem to arise from one distant event. When we see a Tsumami traveling across the land, yes the water is moving, but this is only because the land is suddenly lower than Tsunami-Sea-level. The water is moving forward because of gravity, not because of the up and down motion of the original wave. (Tsunami waves can be miles across, from front to back. They are more like a high-tide.) The point is this. Waves carry transverse energy. They do not carry forward momentum because they are not moving mass forward. Light carries transverse electromagnetic energy. It only imparts energy to matter because its transverse energy exerts perpendicular Lorentz Forces on the charges in the matter. At least, there is no other mechanism to explain light's ability to move mass-containing matter/
Light cannot have *Newtonian* momentum since it has no mass to move. When its transverse electromagnetic forces act on a mass-containing object, the reaction is perpendicular to both transverse fields. This is why the object moves in a direction that is parallel or anti-parallel to the propagation-direction of the light.

An anti-parallel response to light-energy is seen quite clearly in the example of objects that have negative indexes of refraction. It has been experimentally-demonstrated that these objects are pulled toward the source of the light. In other words, the light pulls on them, instead of pushing on them. That would be impossible if radiation pressure was really caused by light having momentum, except in a very limited sense. At the end of the day, (people can dance around this for hours!--At the end of the day, one should either admit that light has no momentum in itself or we have to conclude that the directionality of its momentum is not conserved, which is pretty-much the same thing.

There is no basis for assuming that the electromagnetic energy of light has actual momentum, just because it can move objects that have mass. Strictly speaking, we cannot know that light has momentum, in any meaningful Newtonian sense of the word. At most, we can observe that its transverse energy motion exerts magneto-motive force on matter. In other words, its energy causes matter to acquire kinetic energy and to move which means that we can say that the moving matter has momentum.

Really, momentum is not some mysterious fluid that exists in matter that is different from kinetic energy. It is merely a convenient conceptual framework that facilitates analysis of how objects that may have different masses and velocities can alter each-others' velocities.

There is no reason to presume that light energy has any momentum which must conserve directionality.

The ideas in this paper are far more conservative than the widely accepted viewpoint of Minkowski. He thought that the momentum of light increased inside of refractive materials. It is probable that the Refractive Mirror analysis does a better job of explaining this than Minkowski's theory. His theory has experimental support, at least at very small wavelengths, infrared and smaller. Researchers actually invent a fictitious "Canonical Momentum" which is usually acknowledged as having no known physical mechanism; really, it is just a mathematical fiction that helps them rationalize the fact that the mirrors in these experiments really are experiencing larger forces than they "should" (according to yet-more conventional theories.) They say that the center of inertia is not altered a corresponding amount--but they seem to be forgetting that the mirror swings back and restores the center of inertia to its original position because of gravity pulling the mirror back down. It would be interesting to repeat their experiments with the laser emitting directly inside of the refractive fluid. If this makes Minkowski's effect vanish, then the refraction based explanation that is proposed in this paper is more-probable.

This is an interdisciplinary project. There are a lot of people that can tackle the details of actually performing this experiment. They can also detect issues that need to be resolved before finalizing a design. This process has to include the people who will ultimately fabricate these CasiMirrs.

It is probably a good idea to break the project down into two phases. Phase one will consist of trying to test the Refractive Mirror Concept using lasers. This will enable the team to test the basic premise at larger wavelengths where interactions between light and matter are best understood. Testing this premise would tell us whether there was any point in proceeding. Affirming that premise would give the team the confidence to persist in solving any problems that arise uniquely at smaller wavelengths or from using the distinctive photons of the EM Quantum Flux.

The preliminary design is just offered as a starting place for discussion among the various disciplines. It is overwhelmingly likely that the first CasiMir to be built will be similar but will use better materials and a different thickness for the refractive layer. The preliminary design involves:

- A flat silicon substate that is thick-enough to be rigid.
- An aluminum layer that is two hundred nm thick, on both sides.
- A 50 nm Silicon Nitride layer on one side, sputtered onto the aluminum on that side.
- Many layers of these tiles should be stacked, separated by a low-refractive-index material.

Individual layers should be tested in a Vacuum or should at least be coated with a material that has a very low refractive index. This is because the air itself can prevent the formation of VUV, which is why it is called Vacuum UV.

Rockets, because they are based on Newton's Third Law, must use on-board energy to expel on-board mass. They require an enormous vehicles, filled with astonishing quantities of fuel; after all of that, they only put a tiny payload into orbit. This is because they must expend on-board energy and expel on-board mass. In other words, they must carry all of the fuel and reaction mass

that they are going to need later in their ascent, from the beginning. Throughout most of a launch, most of the fuel is being expended just to lift the remaining fuel so it can lift the remaining fuel . . . This is why Space Travel with rockets is barely-possible, dangerous and expensive. We will never approach the Speed of Light with any conceivable kind of Rocket. It is overwhelmingly expensive and time-consuming to explore even-just our own Solar System with Rockets. Pioneer 10, our first Interstellar Space-craft has taken thirty years just to reach the edge of our Solar System.

Unlike, oil, gas, coal and centralized electrical distribution no one can control and manipulate the energy of the Quantum Vacuum. As with Solar-, Wind- and Hydroelectric- Energy, Nature pays the bill; to us, this is cost-free environmental energy; we only have to pay for the equipment and location. Anyone could inexpensively obtain energy for any purpose. Personal Energy-Freedom would break the Energy-Cabals' death-grip on the world. People would be free to start their own societies in Space.

Insisting that the momentum of light conserves its directionality is just as wrong as insisting that light must have mass just because it has momentum.