Engineer The EM Quantum-Vacuum Now

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According to Quantum Electrodynamics, QED, we are surrounded by a hidden source of great momentum and energy, called the EM Quantum Vacuum. A new prime-mover, a Quantum light-sail, will use refraction to induce asymmetric boundary conditions in the EM radiation pressure of the Quantum Vacuum, on its two sides. In terms of Newton's First Law, this asymmetric radiation-pressure acts as an outside-force that pushes harder on one side of the light-sail than on its opposite side. Multiple layers of sails will be separated by a material which allows the EM Quantum-Flux to manifest within it. In this way, dramatic combined-forces might be obtained, even if individual layers contribute extremely small forces. It is likely that such a meta-material can be inexpensively built, tested and produced, using existing knowledge, materials, techniques and equipment.

1. Introduction: A new prime-mover

According to Quantum Electrodynamics, QED, we are surrounded at all times by a hidden source of great momentum and energy. It is called the EM Quantum Vacuum.[1] If it could be seen, it would look like the tiny flashes of static-snow that are seen on televisions, in-between channels. It is believed to consist of photons that momentarily manifest, then promptly disappear. Section 3 derives the formula to calculate the magnitude of its radiation-pressure.

NASA's Breakthrough Physics Propulsion Program report says that it might be possible to induce Casimir-like propulsive forces by developing new means of imposing asymmetric boundary conditions on the EM Quantum Vacuum.* A practical approach to accomplishing this is explored.

Just as sails on ships and the blades on windmills capture the cost-free energy and momentum of the wind, so also Quantum Sails can be driven by asymmetries in the energy and momentum of the normally-isotropic radiation pressure of the EM Quantum Vacuum. This radiation-pressure will provide the motive force for a new class of macroscopic prime-movers, a kind of mass-less propulsion, a new energy-conversion device.

2. Objectives

The purposes of this paper is not to to prove that any of this is true, rather, the point is to establish that the proposed experiment is worthwhile. It is also important to find individuals who will help recruit, fund and equip a research team to design and produce the Quantum-Sail that is described in this paper. To do so, it is necessary to overcome a large number of theoretical objections to this sort of proposal.

Rather than being some sort of new discovery, this paper is a fresh perspective on commonly accepted science. Although the proposed device is simple, it is not intelligible if the science that it is based upon is not re-articulated from this new perspective, first.

3. Understanding the Radiation-Pressure of the EM Quantum Vacuum

According to Quantum Electrodynamics, the Quantum-Vacuum surrounds everything at all times. It is present everywhere. This energy field is what is left in space after all matter and heat are removed. It is believed to consist of particle-pairs that pop into existence then vanish a short time later. They vanish because each particle of matter forms in conjunction with a particle of anti-matter. They quickly annihilate each other. Some of these particles are photons. Photons appear in every possible wavelength. Then they vanish after traveling about half of a wave-length.

One explanation of why these particles appear in the first place is based on the Heisenberg Uncertainty Principle. It implies that the energy level of a particular location of space cannot be zero. This is because a place in space that has zero energy would be simultaneously knowable in terms of its energy magnitude and its exact location. Instead, it must fluctuate according to a random distribution of wavelengths and locations. This is where the term Quantum-Flux comes from.

On the other hand, Dirac held that there is great sea of particles that fluctuate between a positive state in which they are manifestly present and a negative state in which they are not manifestly present. This point of view was historically rejected because it of its superficial resemblance to a material ether that would not be Lorentz Invariant, in accordance with General Relativity. However, Timothy Boyer demonstrated that the $1 / \lambda^3$ distribution of the Quantum-Flux would be Lorentz-Invariant.+

In any case, 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. Each energy value is represented by u. Planck's Constant is ħ.

$u = \hbar\omega\,(n + 1/2);\ \{ n = 0, 1, 2, 3 \ldots n,\ n+1\}$ (Eq. 1)

The existence of the Zero Point Energy Field is most clearly seen in the instance where n = 0; this leaves Eq. 2.

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

The point is this: The radiation that is attributable to emissions from atoms is given by n, which is always a whole number. However, actual readings of Black Body Radiation reveals the extra term: 1 / 2. So in addition to the part of the Black Body Radiation field which originates in orbital transitions inside of atoms, another field is present. It is called the Zero-Point Energy Field, perhaps because it would be detected by itself when n equals Zero. Zero-Point Energy, u_{zpe} , is the energy from the EM Quantum Vacuum.

Despite what skeptics often insist, this is positively not a figment of 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.

Planck's Constant is the energy per cycle, the energy per single photon. Planck's Constant is represented by the letter h. The constant h-bar, $\hbar = h / 2\pi$, is used with ω which is frequency in radians per second. $\omega = 2\pi f$. (Eq. 3) merely converts (Eq. 2) from radian measure to frequency in cycles per second, hertz.

(Eq. 2) $= \hbar\,\omega = [(h / 2\pi)\,(2\pi f) / 2] = u_{zpe} = h f /2$ (Eq. 3)

A single photon is one wavelength long. $1 / \lambda^3$ gives the total number of photons that can fit into one cubic meter. (Eq. 4) gives the total energy of quanta of that one wavelength that is in a cubic meter.

$(h / 2) * (1 / \lambda^3) = u_{zpe}(\lambda^3) = h / 2\ \lambda^3$ (Eq. 4)

$c = f\ \lambda$ (Eq. 5)

$h / 2\ \lambda^3 = u_{zpe}\,(f^3)\,df = (h f^3 / 2 c^3)\,df$ (Eq. 6)

Integrating $u_{zpe}(f)\,df$ sums the energies of all photons of *every* wavelength that can simultaneously occupy one cubic meter. (In practice, longer, partial-wavelengths are negligible.)

$U(f) = \int (f^3 / 2 c^3)\,df = U(f) = h f^4 / 8 c^3$ (Eq. 7)

$(h f^4 / 8 c^3) * c / c = (h c f^4 / 8 c^4) = U(f) = h c / 8\ \lambda^4$ (Eq. 8)

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.

$Pr = U(f) / 3 = h c / 24\ \lambda^4$ (Eq. 9)

In practice, one can justify not counting wavelengths that are larger than λ specified since one only needs to specify wavelengths that significantly impact the material that has been chosen. The energy density of progressively longer wavelengths quickly becomes insignificant. This is because every two-fold increase in wavelength is accompanied by a sixteen-fold decrease in energy-density. This is due to the λ^{-4} term. For practical purposes, λ_2 can be any number that is a few times greater than $\lambda_{specified}$ 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 $\lambda_{1\ specified}$ to $\lambda_{2\ specified}$ is physically valid, within a corresponding margin of error.

4. Using the EM Quantum-Vacuum to Push

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.

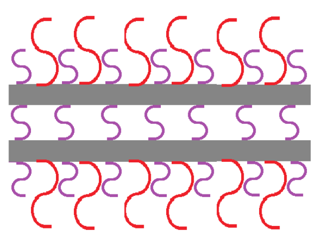


Fig. 1

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 inevitably 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 Fig. 1, the smaller purple waves represent all of the wavelengths that can form both inside-of and outside-of the space between the plates. Since the smaller waves are equal and opposite to each other, they exert no net forces on the plates; however, the longer red wavelengths can only form outside of the space 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. 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.

Casimir's original interpretation of the Casimir Effect was that the plates would be moved by the radiation-pressure of the EM Quantum-Flux. He insisted that this explanation was just as good as the competing, more popular, interpretation, that the electrically-neutral plates induce localized charges in each other.

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. Casimir's Wavelength Exclusion Model is based on well-understood, perfectly ordinary electrodynamics. Its derivation is a simple variation of the derivation in Section 3.

The only really new thought here is this. Suppose the EM Quantum Flux really exists. Suppose it really appears and disappears as advertised. If one assumes 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.

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. If a net force can be produced on an isolated single-sail, then the EM Quantum-Flux must exist, independent of whether or not any matter is present, since a self-contained object cannot exert a net force back onto itself and cause itself to move.

5. The Quantum-Flux Has Already Done Work

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. If the EM Quantum Flux has an independent existence, this 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 the larger wavelengths of the EM Quantum Flux do not fit inside of conductor-lined spaces that are smaller than those wavelengths. In this case, the Casimir Force Experiments would be found to be doing nothing that has not been continuously happening in the spaces inside of matter, everywhere, since the formation of the first condensed matter.

In other words, no human is providing this energy. 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 collide. In other words, Zero-Point energy has, quite likely, already been used to propel Casimir's Plates.

6. Casimir Plate Movement & the Four Laws

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; therefore, it would have to move in order to not violate the Zeroeth Law.

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 do.

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; nonetheless, its spectrum is, 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. This adaptation of the Third Law is no more extraordinary than when the Third Law is adapted to cover systems that require non-thermaldifferences in electrical potential or hydraulic pressure.

Many object that using some of this energy before it winked-out would change the amount of energy remaining 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. Instead, 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.

On the other hand, if one posits 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.

These musings are no more- or less- fanciful then insisting that we even can know if the energy balance of the universe has to match our small-minded, pathetically uninformed expectations.

7. A Patented, Potentially-Practical Casimir Device

The Casimir Effect currently presents severe problems in Microscopic Machines. It causes sticktion which means that the small clearances between small parts form unintended Casimir Cavities. In other words, Casimir Forces tend to jam very-small parts together so that they cannot function properly. So already, the Casimir Effect is a force to be reckoned-with. However, one man has found a potentially-practical method of capitalizing on the effect.

Fabrizio Pinto has secured a patent[2] for reciprocating Casimir Plates. Unfortunately, such an approach may only produce small forces, and motions that are less than a micrometer in length. It may very well prove to be useful for microscopic machines; but it may be impossible to use it to create useful macroscopic forces. This is due to the difficulty of maintaining large parallel surfaces at nano-scale separations.

8. Asymmetric Boundary Conditions on Two Sides of a Single Conducting Plate

Perhaps, instead of using a pair of plates, a single isolated plate can be used to impose different boundary conditions with the EM Quantum Vacuum on its two sides. This effect could be easily distributed over large areas. Also, many layers of sails could be stacked; they would be separated by a material that allows the EM Quantum-Flux to manifest within it. In this way, macroscopic combined-forces might be obtained, even if individual layers contribute extremely small forces. Can a single plate theoretically, by itself, interact asymmetrically with the radiation pressure of the EM Quantum Vacuum?

9. Conclusions of NASA's Breakthrough Physics Propulsion Program (BPPP)

Propellant-less Propulsion is the sort of concept that will cause many readers to quickly put this paper down. That is because, on its face, it *seems* like a hopelessly absurd thing to attempt. NASA's Breakthrough Physics Propulsion Program (BPPP) evaluated possible avenues of novel research. It hoped to identify new insights and methods that might enable science to eventually surpass current expectations of what is considered possible. The BPPP authors examined many proposals; electric rockets, nuclear rockets, laser powered sails; interstellar ramjets. No mass-based propulsion methods appear adequate to take anyone, even just to the second-nearest Star, in a single lifetime.

Therefore, the BPPP was particularly interested in identifying avenues of research that might lead to Propellant-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 slow. DARPA's Hundred Year Starship Program has such a depressing name because none of the approaches that are currently being actively pursued is likely to ever take someone to a nearby star and back in a single human lifetime.

NASA's Breakthrough Physics Propulsion Program final report[App. B] mentioned the possibility of developing a Quantum light-diode sail.[3] It would let more EM Quantum Vacuum radiation pass through the diode from one side than from the opposite side. This would cause the isotropic EM Quantum-Vacuum radiation-pressure to exert a net force toward the less-transparent, more-reflective side of the Quantum-Diode.

It sounds theoretically impossible to derive a net force from equal and opposite influxes. It is tempting to dismiss this entire notion by simply invoking Conservation of momentum; however, this general objection is easily refuted by a simple example, a mechanical diode for rubber balls:

Two teams of astronauts throw equal and opposite influxes of rubber balls at a wall that is floating in Space, between them. At this point, most people will insist that one should already know that the wall will not be moved in either direction. They will argue that all of the forces that are applied to the balls are equal and opposite; therefore, whatever one side of the system accomplishes, the opposite side of the system must undo it. In other words, they are saying, since the applied momentum sums to zero, then so must the final momentum sum to zero. This is true but it does not mean that the wall does not move.

What if the wall itself *responds* differently to the two influxes of balls? What if the wall itself introduces asymmetric reaction-forces? If the wall is made of little doors that only open in one direction, then half of the balls will impart a full-measure of momentum to the wall as they bounce off of the one side where the doors stay closed; but the remaining balls will only impart a small amount of their momentum to the wall, in the opposite direction, as they push the doors open and continue onward.

In other words, a door experiences a stronger collision-force from a rubber ball if that door remains closed than from a rubber ball that pushes on through the door from its opposite side. This happens because the collision-force that a given rubber ball exerts on a door must equal the reaction force that door applies to the rubber ball. On one side, that reaction-force is limited to whatever small amount of force it takes to push a door open.

It is quite remarkable that two equal and opposite influxes can indeed impact the same wall asymmetrically. This does not prove that one could in-practice make a light-diode; but it does prove that this sort of thing is not impossible from the standpoint of Momentum Conservation.

In this last example, the doors experienced different collision forces on their two sides. Similarly, in the next example, a two-sided mirror is approached by equal and opposite influxes of EM Quantum-Vacuum radiation-pressure. Again, the reaction-forces are different on each of the two sides. In this case, a difference in pressure forces arises on opposite sides of the two-sided mirror because one side is covered with a refractive-material and the opposite side is bare.

10. The Defining Problem

This paper proposes a realistic, simple solution to a profoundly difficult problem: The EM Quantum Flux Radiation-Pressure is equally energetic in every direction. Put another way, this radiation-pressure normally pushes equally hard on opposite sides of most objects. All of these forces would normally be totally used-up, just counteracting each-other. Since these forces are normally equal and opposite among themselves, a single, isolated two-sided mirror floating in Space would normally remain stationary. See Fig. 2

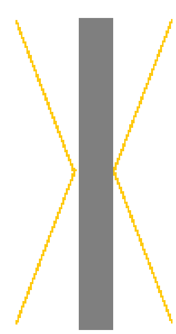


Fig. 2

The two yellow rays represent the light of the EM Quantum-Vacuum. In particular, they represent the fact that its light rays strike any given point on the mirror at mostly non-perpendicular angles. They also represent the fact that, usually, the light rays of the EM Quantum-Vacuum would strike a two sided mirror equally on each side. Therefore, this floating, two-sided mirror would not be pushed in either direction by the light of the EM Quantum-Vacuum.

11. An Elegant Solution

The problem in Fig. 2 is not merely that the rays of light are equally-intense. Rather, the difficulty lies in the fact that they are equally-intense *and* opposite. Fig. 3 illustrates one way to obtain a net force from two beams that are equally-intense.

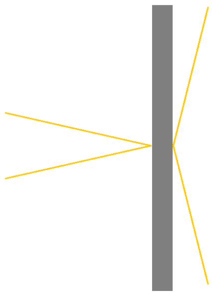


Fig. 3

Two equally-intense beams of light are striking a two-sided mirror that is floating freely in Space. The beam on the left strikes the mirror at an angle that is more-perpendicular to the plate than the beam on the right; therefore, the beam on the left hits the plate harder than the beam on the right. Consequently, the plate will be pushed to the right, even though the beams are equally-intense.

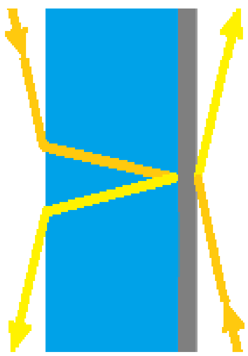


Fig. 4

The blue area in Fig. 4 is a refractive material. The incoming light is shown by the gold lines. The outgoing light is shown by the yellow lines. Outside of the refractive material, the two light rays are parallel, equal and opposite as in Fig. 2; but then the ray on the left enters the refractive-material. That ray strikes its side of the double-mirror at a much steeper angle than the light that is striking the opposite, bare side of the mirror. So the mirror is experiencing a net EM radiation-pressure force from two beams of light that had been equal and opposite. Therefore a net force acts on the mirror, to the right, just as in Fig. 3.

In Fig. 4, two equal and opposite beams of light remain equally-intense but *become* non-opposite. One light-beam approaches the blue refractive-material at an angle that is equal and opposite to the light-beam that is approaching the bare side of the mirror on the right; but then the beam on the left is refracted. As in Fig. 2, the light on the left strikes the mirror at a steeper angle than the light that strikes the right side of the mirror. Therefore, a net force to the right acts on the two-sided mirror, just as in Fig. 3.

Many experiments, for many years, prove that, under certain circumstances, light does in-fact exert a stronger force on a mirror that is in a refractive material, than the same light exerts on the same mirror when there is no refractive material present[4, 5]

Again, this proposed arrangement *sounds* like it violates Conservation of Momentum: As with the ball diode, the applied momenta are equal and opposite to themselves, yet the mirror is moved. In the case of the ball-diode, the two equal and opposite influxes of balls applied asymmetric collision forces to the doors because the doors applied asymmetric reaction-forces to the balls. With the refractive mirror system, the refractive material and the light exert refraction forces on each-other; thus, the path of the light is altered on the refractive side of the mirror and not altered on the bare side of the mirror, as in Fig. 4.

12. Reduced Radiation-Pressure in a Refractive-Medium

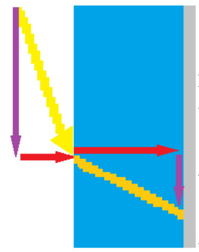


Fig. 5

So far, the refractive mirror setup has had light entering a refractive surface that is *parallel* to the mirror. This arrangement, shown again in Fig. 5, yields a result where the force on the mirror increases when the refractive material is present. The red perpendicular momentum vectors verify this change in momentum; the red momentum vector is larger, after the light enters the refractive material. It is important to note that changes in these vector lengths are a consequence of the fact that the angle of the ray of light changes, relative to the mirror.

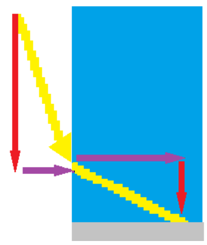


Fig. 6

Sometimes the force on the mirror will decrease inside a refractive medium. Fig. 6 demonstrates how one can obtain this result with an experimental setup that is similar to the one in Fig. 5.

This time, the light enters the refractive material through a surface that is *perpendicular* to the mirror. Therefore, in this case, the refraction is causing the light to strike the mirror inside the refractive material at a shallower angle than if the refractive material were not present.

Therefore, this time, the force on the mirror is less when the refractive material is present. This can be verified by comparing the momentum component vectors: In Fig. 5 the red perpendicular vector became longer as the light entered the refractive material. In Fig. 6 the red perpendicular momentum vector becomes shorter as the light enters the refractive material. In this case, the system in Fig. 6 is nothing more than a trivial variation of the system in Fig. 5.

13. Momentum in a Refractive Medium

The *mirror* in these arrangements will definitely experience a net force;[4] but, does the refractive-force that acts on the refractive-material exert a force that is equal and opposite to the net force that acts on the mirror, so as to render the entire system motionless? The answer to this question has long-been obscured by the century-old Minkowski-Abraham discussion concerning the momentum of light inside a refractive-medium.

According to Minkowski, light acquires extra *total* momentum as it enters a more refractive medium. It is said to increase by a factor that is equal to the refractive index of the medium. According to Abraham the momentum will *decrease* by a factor that is equal to the *inverse* of the refractive index of the medium. Each of these hypotheses are seemingly-supported by an abundance of experimental observations. These two viewpoints and their accompanying experiments are reconciled in the following discussion.

In Figs. 7 & 8 we are viewing the edges of two mirrors, which are represented by silver lines. The mirror in Fig. 7 is bare. A refractive material covers the back side of the mirror in Fig. 8; it is represented by the blue area.

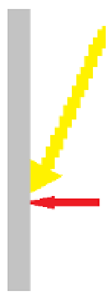


Fig. 7

The yellow rays represent the average of all of the rays that are approa-ching each mirror. In Fig. 8, these two rays are shown *as though* they had the same red perpendicular vector-momentum both before- and after the ray in Fig. 8 enters the refractive material. The ray in Fig. 7 strikes its mirror at the same angle at which the ray in Fig. 8 approaches the refractive material; however, because of refraction, the ray in Fig. 8 strikes its *mirror*, which is inside the refractive medium, at more-perpendicular angle than the ray that is striking the bare mirror in Fig. 7.

This leads to a very unsettling fact: In many different experiments, performed by different researchers, the ray in Fig. 8 strikes its mirror with more force than the ray in Fig. 7.

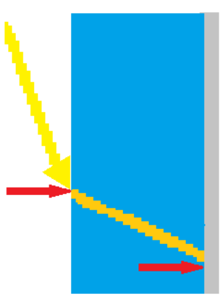


Fig. 8

The red arrows in Fig. 8 show what *would* happen if momentum were con-served in the expected way. The red arrows represent the component of the light's momentum that is perpendicular to the mirror. The perpendicular momentum outside of the refractive material is *represented* as being equal to the perpendicular momentum that is inside the refractive material. Therefore, (if this were really true!), the light in Fig. 8 would hit its mirror with the same perpendicular force as the light in Fig. 6 when it hits *its* bare mirror; but this is *not* what occurs.

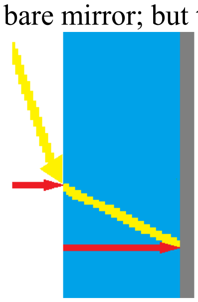


Fig. 9 shows us what really happens. The magnitude of the perpendicular vector is actually greater, inside the refractive material, even though it is still the same ray of light as it was outside of the more-refractive medium.

Fig. 9

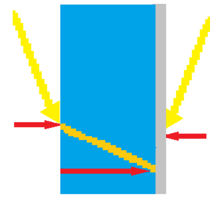


Fig. 10

Fig. 10 combines the features of Figs. 7 & 9. It consists of a two sided mirror. The back side of the mirror is covered with the refractive material, as in Fig. 7. The front side is bare, as in Fig. 6.

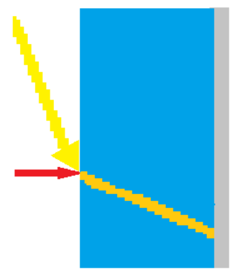


Fig. 11

Equal and opposite light influxes approach both sides of the entire system. Since so many experiments prove that the *perpendicular* momentum is greater in Fig. 9 than in Fig. 6, why doesn't Fig. 10 outright-prove that we can get a net force from equal and opposite influxes of light?

Minkowski took this dilemma at face value and concluded that the beam of light *somehow* actually acquires extra *total* momentum as it enters the refractive medium. (Except for the explanation that is offered in this paper, this is just as inexplicable today as when Minkowski first made this famous conjecture.) This so-called extra total momentum is called Canonical Momentum.

He took the position that this situation would still be consistent with conservation of momentum, as long as the light loses the same amount of extra momentum as it exits the refractive medium. In other words, he was adding extra momentum into his math, for when the light enters the more-refractive medium. Therefore, to salvage his approach to the problem while still Conserving Momentum, he *had* to subtract this *extra* momentum out of his figures for when the light exits the refractive medium. Again, no causative mechanism is proposed. This would also mean that any extra-momentum forces that are acting on the mirror because of this Canonical momentum would have to be counteracted by refractive forces that operate in the opposite direction, as the light exits the refractive medium.

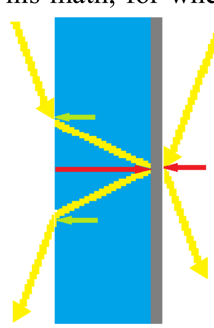


Fig. 12

In Fig. 12, the green arrows indicate the direction that the refraction forces would have to act if Minkowski was correct. On the one hand, if Minkowski is correct, then there would be no net force acting on the entire sail system as it is represented in Fig. 12. On the other hand, if there is no equal and opposite refraction force to counteract the net reflection force that acts on the mirror then Minkowski is mistaken and there will be a net force acting on the entire sail system as is shown in Fig. 14.

14. Refractive Counter-Forces?

As light enters the more-refractive material, it slows down. It is as though it is exerting deceleration reaction forces on the refractive medium. These forces may be thought of as being analogous to a car that imparts a forward-directed force to the roadway as it decelerates upon entering a school zone. This forward-directed force is directed *into* the slow-speed zone.

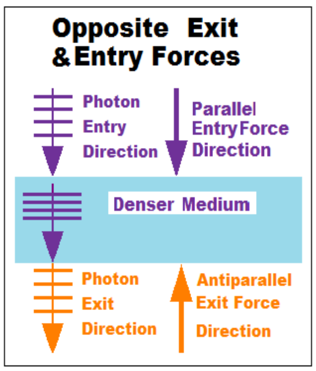


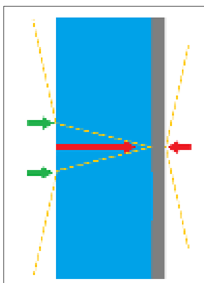
Fig. 13

Surprisingly, it turns out that a force also acts back toward the refractive medium as the light exits the refractive medium.[6] This exit force has been experimentally demonstrated. A laser was shined through a glass fiber and a recoil force was noted; it bent the fiber as the light exited out the end of the fiber.[7] Loudon and Baxter also claimed this result in their paper on Poynting's work.[8]

Analogously, this time, the car in the example is exerting backwards-directed forces on the roadway, as it pushes against the road to **ac**celerate while leaving the school-zone.

In summary, the refraction-forces, that act on the refrac-tive material, are always pointing toward the refractive-material, both when the light is entering the refractive-material and when it is exiting the refractive-material.

In Fig. 13, these entry and exit forces are equal and opposite-to each-other; however, they are equal and opposite only because, in this instance, the light enters into one side of the more refractive material and exits from the opposite side of the more refractive medium; but this is not always the case.



The green arrows show that both the entry- and exit-forces act in the same direction as the net reflection-force.

Fig. 14

In Fig. 14, the actual refraction forces are shown with the green arrows. Both refractive forces are still directed toward the refractive medium; but in this case, "exerting a force toward the refractive-material" means the entry-forces and exit-forces are both exerted in the same direction since the light both enters and exits from the same side of the refractive material.

This time, the refraction forces do not counteract each-other. Neither do they counteract the net reflection force, that is acting on the mirror, that is implied by the longer red arrow. All three forces are directed toward the back of the plate. Therefore, there will indeed be a net force acting on the entire sail system, including the refractive material.

15. Redistribution of Energy and Momentum

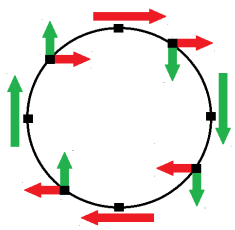


Fig. 15

Extra energy and extra momentum are positively not magically appearing inside of the refractive material, not temporarily, not at all. The same amount of total-energy and momentum-amplitude are present on the bare side of the double-mirror as on its refractive side, inside the refractive-material; but that energy is organized differently by the refractive-forces.

Suppose a car is coasting in a circle, its speed is a steady ten miles per hour, but its velocity constantly changes. Its velocity changes only because its motion changes direction. Even so, its speed and its momentum-amplitude remain the same and are continually expressed in new directions. Its kinetic energy also changes direction, but it also retains the same kinetic-energy amplitude in each new direction. In Fig. 15, energy and momentum are constantly transferring between the horizontal vectors and the vertical vectors. So also can the parallel vectors and the perpendicular vectors of the light exchange momentum and energy when refraction turns the light.

The momentum of the car was altered by the forces that acted between the tires and the road Likewise, in the case of the turning light, its momentum was altered by the refraction forces; therefore, its momentum and energy change direction but they do not change amplitude. The light is just as energetic now as it was before it changed direction.

Each photon takes its energy and translates that energy to a different orientation as it decelerates into the refractive material. The photons and the refractive material exert forces on each other, forces that are perpendicular to the mirror. As the refractive material exerts forces on the refracting light, first, it slows one side of a light particle, then, an instant later, it slows the opposite side of the same light particle as it finishes turning the particle.

In other words, the fast side of a photon pivots around its slow side as it is crossing over into the more refractive material. The exact same thing happens in reverse as a photon leaves the refractive material and pivots in the opposite direction. [App. F]

Each photon takes the energy of its momentum and translates that momentum to a different orientation as it passes into a refractive material. The exact same thing happens in reverse as a photon leaves a refractive material; a force is exerted toward the refractive material.

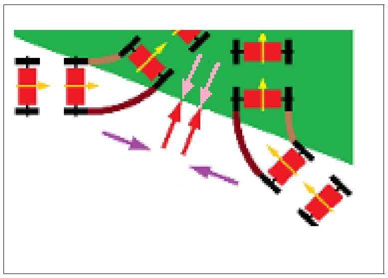
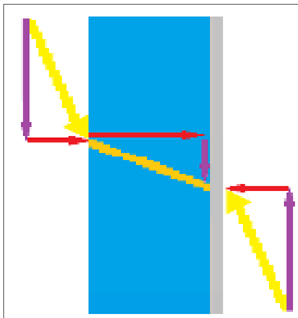


Fig. 16

There are two ways to turn a vehicle: Turn some or all of the wheels in the manner that we turn automobile front wheels; alternatively, make some wheels travel faster or slower than the other wheels like the way a Segway turns.

Each wheel of these Segways follows a rule; each is programmed to individually travel slower when it crosses over onto the grass. The outside wheels had to slow down first since they were first to enter the grass. These outside wheels make the light-brown tracks in the grass. They start going slow, sooner than the right wheel. Meanwhile, the still-faster right wheel travels a longer distance in the same amount of time. The light brown line tracks show the comparatively small distance that is traveled by the wheels that enter the slow-zone first, during this time period. The dark brown tracks show the longer distance that is traveled by the opposite wheel on each Segway, in the same amount of time. This has the effect of turning the vehicle since the faster wheel is pivoting around the slower wheel.



As the light enters the refractive medium, the short red perpendicular momentum vector outside of the more-refractive material becomes longer, inside the refractive medium; but the parallel momentum vector (purple) is longer outside of the refractive-material and shorter, inside the refractive-material.

Fig. 15

The same thing happens to each photon. In the case of light, the fast side of the photon pivots around its slow side. The photon exerts a force toward the refractive material. It slows down because the refractive-material exerts an outward-directed reaction force on it. Really, each photon is pivoting around this reaction force.

In Fig. 15, the average-ray (yellow) that is approaching the refractive material on the back of the sail, is equal and opposite to the corresponding average ray that is approaching the bare mirror that is on the front of the sail; this can be verified by observing their short red perpendicular component vectors; they are equal and opposite.

As the light enters into the refractive material the parallel momentum of the light decreases by the same amount that the perpendicular momentum increases. This can be verified by comparing the momentum-component vectors of the light before and after it enters the refractive-material: The purple parallel component vector is longer outside the refractive-material but shorter inside the refractive material. However, the red perpendicular component vector was lengthened as it entered the refractive material. This implies that momentum is being caused to flow less in the parallel direction and more in the perpendicular direction as the light is bent by refraction.

As the light passes into the more-refractive material, the entire beam turns. The direction of its total momentum magnitude has also turned as the light resumes traveling in a straight line, but in a new direction. It is now acting more-perpendicularly to the mirror inside the refractive-material than is the light that is acting in the opposite direction on the bare side of the mirror; therefore, the reflection force that is acting on the refractive side of the mirror is stronger than the reflection-force that acts on the bare side of the double-mirror. This can be verified by comparing the momentum-component vectors that act on both sides of the double-mirror, in Fig. 8. The red perpendicular component, inside the refractive medium, is longer than the red perpendicular component that is acting in the opposite direction, on the bare side of the mirror. Again, it is critical to recognize that the vector lengths are a function of the changes in the angle of the yellow light-beams, relative to the double-mirrors.

Some object that all of this violates entropy. That objection is answered in Appendix E, along with many other objections.

Normally, the pressure above a surface is one third of the energy-density above that surface. This is because normally the energy is distributed equally in every direction. Refraction changes this energy distribution. So by using refraction, it is indeed possible to increase the amount of pressure that acts on the mirror surface that is inside the refractive-material.

16. Moving Forward

The project might be broken-down into three phases. Phase One might consist of testing the Refractive Mirror Concept using lasers to make certain that equal and opposite light beams really can simultaneously produce a net force in a refractive-mirror system. Confirming that premise would provide a reason to persist in solving any problems that arise uniquely at smaller wavelengths or from using the distinctively ephemeral photons of the EM Quantum Vacuum.

The second phase of research will involve trying to measure Quantum Vacuum EM radiation forces that are acting on a single-sail system. It appears likely that net pressures of two- or three-hundred Pascal are within reach of a reasonably modest research effort. This does not sound like much pressure or energy; but such a sail would easily lift thousands of times its own weight, since it could be made to be merely a few-hundred nanometers in thickness.

The sail cannot be exposed to the air when it is supposed to be exploiting VUV wavelengths since these wavelengths do not form in ionizable mediums such as air.

A third phase of research will involve stacking many layers of sails to form a meta-material, thousands of sails thick. There is no particular constraint on how broad an area might be covered by each sail.

In Fig. 16, the material with the lowest refractive index is light blue. It is the material that separates the various sails.

The material that has the highest refractive index is dark blue. The gold color is gold or some other highly reflective metal. Individual gold/dark-blue pairs comprise individual sails.

Generally speaking, the metal-layers must be at least three times the thickness of the skin-effect for the wavelengths of interest; it can be much thicker if this is more convenient. The light blue, low-refraction material must have a thickness that is at least two times the wavelengths of interest; but again, it can be as much thicker as is convenient.

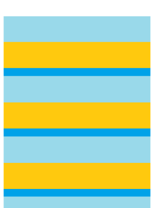


Fig. 17

The dark blue, highly refractive material must be *less* than a quarter of the smallest wavelength of interest. This is because the photons of the Quantum-Vacuum only travel about half of a wavelength before vanishing.

Smaller wave-lengths are much more powerful but the metal is more transparent to smaller wave-lengths so it may require trial and error to determine what wavelengths will prove to be optimum with which materials.

A prototype might resemble many layers of Mylar. It might consist of a thin aluminum sheet that is coated with plastic on one side and a highly refractive substance on the opposite side. Many yards of this could be wound up and cut off a large flat roll, already stacked. It may be useful to use a vitreous metal sheet to eliminate the crystal structure of the metal to enhance its smoothness.

It is necessary to recruit experts in optical films, to design and perform these experiments. Phase one will require an optical lab with lasers and equipment for measuring very small forces or displacements. Please contact the author for more information.

Eq. 10 gives the net pressure that acts upon a tow-sided refractive-mirror. The net pressure is obtained by subtracting the unaltered pressure that acts on the mirror's bare side from the increased pressure of the refractive side of the mirror. (n_1 is the refractive index of the material that coats one side of the light-sail. *n_1 is the most refractive material. n_2 is the refractive index of the material that separates the different sails.)*

Eq. 9 = $h\,c / 24\;\lambda^4$

Net Pressure = Pr = $(n_1 - n_2)\,h\,c / 24\;\lambda^4$ (Eq. 10)

n = 2	
nm	Pa
50	1325
60	639
70	345
80	202
90	126
100	83
110	57
120	40
140	22
160	13

This table shows the pressures that can be expected by exploiting a given wavelength and all wave-lengths that are greater than that wavelength.

It gives the ideal net pressure assuming that the refractive index n_1 is two. It uses the following equation.

(n_1 is the most refractive material. n_2 is the refractive index of the material that separates the different sails.)

Pressure = Pr = $(n_1 - n_2)\,h\,c / 24\;\lambda^4$

This equation is derived in Appendix A.

Table 1

17. Summary

The ball-diode proves that equal and opposite influxes can, in principle, be tapped to produce a net force, and to extract energy from equal and opposite influxes. Casimir's original interpretation of the Casimir phenomenon was that it was driven by asymmetries in the radiation-pressure of the EM Quantum-Vacuum. Therefore it is reasonable to try to develop other methods of inducing useful asymmetries in the EM Quantum-Flux.

For many years, various experiments have revealed that light can exert more pressure on a mirror if it is covered with a refractive material, than if it is not covered with a refractive-material. However, this idea has acquired extra-baggage in the form of incorrect assumptions concerning the direction of the refractive forces that act on the refractive material. According to these incorrect assumptions, there could be no net force acting on the entire system. According to the experimentally-confirmed assumptions about refractive forces, a net force should act on the proposed system as a whole.

Seemingly, no one has simultaneously measured the refraction forces and the reflection-forces to determine if a net force can be generated by the refractive mirror system that has just been discussed.

The simplest explanation is that the momentum-magnitude and energy intensity of a beam of light changes direction as the beam is refracted. Therefore, it may be possible to use refraction to cause the isotropic radiation-pressure of the EM Quantum Vacuum to exert a net force on a passive Light Sail.

The ability to lay down many layers of mirrors and various refractive-materials means that even very modest forces may potentially be combined to produce practical net forces. This may have potential for energy production and vehicular propulsion of all kinds, using currently available technology.

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Engineer The EM Quantum-Vacuum Now

According to Quantum Electrodynamics, QED, we are surrounded by a hidden source of **great momentum and energy**, called the EM Quantum Vacuum.

A new prime-mover, a Quantum light-sail, will use refraction to induce asymmetric boundary conditions in the EM radiation pressure of the Quantum Vacuum.

In terms of Newton's First Law, this **asymmetric radiation-pressure acts as an outside-force** that pushes harder on one side of the light-sail than on its opposite side.

Multiple layers of sails will be separated by a material which allows the EM Quantum-Flux to manifest within it. In this way, **dramatic combined-forces** might be obtained, even if individual layers contribute extremely small forces.

It is likely that such a meta-material can be **inexpensively built, tested and produced, using existing knowledge, materials, techniques and equipment.**