

Zero Point Energy Tapping (ZPET)

by

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Ever since a celebrated authority on Quantum Electrodynamics (QED), Nobel Laureate physicist Richard Feynman, pointed out that according to QED there is enough energy in a vacuum volume the size of your cupped hands, to boil all the oceans on earth, people have been wondering if it will ever be possible to tap this inexhaustible source of free energy in a practically useful way.

The standard story of the subject is that given in an anonymous internet posting of 01/04/05 shown in Appendix 1 below. A somewhat more detailed 1999 version is in Appendix 2 below. [For less popular but more complete information consult the papers of Haisch, Rueda, Marshall, Cole *et al* of the *California Institute for Physics & Astronomy* at <http://www.calphysics.org/zpe.html> and the papers of Puthoff, Ibrison *et al* of the *Institute for Advanced Studies at Austin* at <http://www.earthtech.org/> and the work of Valone *et al* of the *Integrity Research Institute* at <http://users.erols.com/iri/>; for possible deep flaws in classical physics (concerning speed of light, instantaneous action-at-a-distance, and other challenges to mainstream paradigms) see the papers of Van Flandern of *MetaResearch* at <http://www.metaresearch.org/home.asp> .]

While I agree with many of the statements in such standard accounts as in the Appendices below, particularly the mathematical equations from Quantum Mechanics (QM) and QED referred to in such accounts, I dissent strongly from the standard physical interpretation of such equations, often referred to as the Copenhagen Interpretation of QM/QED.

For a documented popular exposition of my dissents, see my paper about the Big Bang on my website, wherein I not only advocate replacement of QM/QED by SM/SED [see below] but also advocate replacement of the conventional interpretations of Special & General Relativity (SR/GR) by more recently published neo-classical versions [e.g. by Lorentz & Ives, and by Wilson] which would be perfectly understandable by Euclid & Newton and would not require the reader's "willing suspension of disbelief" in the sense of disregarding logical coherence and imagining that somehow reality is actually weird.

The Copenhagen interpretation, started by Bohr and furthered by Heisenberg, postulates that at rock-bottom, nature is intrinsically random, i.e. consists of effects without causes. So-called "virtual particles" are postulated to "pop into and out of existence" at unpredictable epochs of time, and as a fallout from the conventional interpretation of SR/GR one speaks of "distortions of the fabric of spacetime" as if space & time are some kind of a melded entity. [For the necessity of Newtonian absolute time as even prior to logic itself, see my cited paper on the Big Bang.]

Feynman himself said repeatedly that anyone who claims to understand QM/QED is deceiving himself, and famously cautioned against trying to figure out "how can it be like that ?" because, in his opinion, no one understands how reality can be so strangely different on the microscopic level from what is well-understood by common sense on the macroscopic level. Other writers have referred to the bizarre world of microphysics as "weird."

Actually, if one adopts the *neo-classical* interpretation of QM pioneered by Fenyés & Nelson, and the neo-classical interpretation of QED pioneered by Boyer, then the weirdness goes away and classical human "physical intuition" honed on macroscopically understandable & visualisable conceptions of reality becomes applicable again.

The "weird" and "inherently random" conception of microphysics came about because Bohr made several mistakes in his famous model of the hydrogen atom. He knew that somehow there must be some kind of validity to his argumentation because he had by elementary arguments teachable to children come up with a simple "derivation" of a formula that explained the Rydberg constant with astonishing accuracy and made sense of a vast data-bank of previously mysterious spectroscopic measurements. So he convinced himself by

incoherent rhetoric that previously well-established principles of physics could be ignored and became not only a great contributor to the progress of science but also the father of modern muddle-headed thinking, abandoning what had hitherto been the *bedrock* of all of mathematics, all of logic, and all of science as a rationally coherent discipline, namely Aristotle's *Law of the Excluded Middle*. Later his thinking became so mystical that he opined that a great truth is a proposition whose negation is also a great truth!

However, with the benefit of hindsight it is easy to correct Bohr's errors and see where he went wrong and see how to patch things up so that they would have been perfectly understandable to Euclid and Newton.

Bohr's first mistake was to ignore the electrostatic forces stemming from all other charged particles in the visible universe at the present epoch of cosmic time. While it is true that these forces have a zero AVERAGE which is normally used to justify their neglect, they do not have a zero VARIANCE which, as we shall see below, explains QM perfectly in terms of classical concepts when QM is replaced by Stochastic Mechanics (SM).

Bohr's second mistake was to ignore the well-established fact that an accelerating charged particle emits electromagnetic radiation (according to the Faraday/Maxwell/Lorentz theory of Electromagnetism [EM]). By illogical hand-waving Bohr convinced himself that this principle could be ignored when a particle is moving on a circular orbit consisting of an integral number of de Broglie wavelengths. The truth is that Bohr was ignoring the EM radiation emanating from the oscillations of all other charged particles in the universe for the same mistaken reason that he ignored the background electrostatic forces. Actually, charged particles which are in accelerated motion do in fact emit EM radiation, but they also *absorb* radiation from the cosmic background, and the amount emitted is exactly balanced by the amount absorbed, precisely if and only if the particle's path is in the lowest-energy Bohr orbit. [For recent rigorous elaboration upon this idea of Boyer, see Cole & Zhou's paper <http://www.calphysics.org/articles/ColeHydrogenPRE.pdf> .]

The first of Bohr's mistakes can be rectified if one understands an "Electrostatic Mach's Principle," first published by Bass & Zes in a 1995 paper on Zero Point Fluctuations (ZPF), and a more recent paper by myself pointing out that this work had actually predicted several startling astrophysical discoveries which appeared on the front pages of national newspapers during 1998-2001, both of which papers are available on my website.

The second of Bohr's mistakes can be rectified if one understands an "Electromagnetic Mach's Principle" first published by Luis de La Pena & Ana Maria Cetto in 1984.

My claim is that Newton could have derived Schroedinger's Equation of QM from Newtonian mechanics, and simultaneously derived the correct value of Planck's constant h to go into this equation, if he had known about Coulomb's Law of electrostatic attraction & repulsion and if he had known about the stochastic calculus as a probabilistic generalization of his own deterministic calculus, and if he had known the mean number-density n of charged particles in the universe. I have proved this by deriving Planck's h , the basis of all microphysics, from Hubble's constant H (the basis of all cosmological macrophysics).

An earlier effort along these lines had been published by de La Pena & Cetto, starting with EM and using Boyer's Stochastic Electrodynamics (SEM) as a replacement for QED. However, they were dealing with numbers of the order of 10^{80} and so were unable to get an estimate of h better than within a couple of orders of magnitude, whereas my formula for h as proportional to n yields a prediction of H within a few percent of its latest measurement.

To return to the subject of tapping the ZPE, the best illustration of ZPE is probably the Casimir Effect discussed in the Appendices below, where it can be predicted quantitatively with great precision strictly in terms of classical EM concepts augmented by probabilistic considerations as in the authoritative treatise on SED, *The Quantum Dice*, by de La Pena & Cetto.

Therefore the best way to understand the origin of ZPE in a rational, non-mystical, neo-classical manner is to study the abovementioned Electromagnetic Mach's Principle.

However, the best way to understand how the ZPE can be tapped is to understand the abovementioned Electrostatic Mach's Principle, which explains the ZPF of condensed matter.

Indeed, the best hope of ZPET consists of using some type of nonlinear condensed-matter circuit as a sort of "antenna" to convert ZPE into observable ZPFs which can be used to drive an electrical current by some kind of resonant interaction.

Just as the ZPE is what makes the lowest Bohr orbit stable, the same phenomenon is what makes a crystal stable: in a particular orderly & periodic arrangement, the EM oscillators in a crystal pick up just as much energy from the ZPE background as they lose by radiation.

But the ZPET idea is the hope that some particular arrangement of condensed matter can be found in which the amount of energy picked up from the ZPE is actually greater than that lost by radiation to the ZPE. In ordinary condensed matter the balance is perfect, but there is no logical reason why a particular configuration might not be discovered in which the energy absorption/emission balance is not symmetrical, and in which more energy (originating from all of the EM oscillators in the entire universe) is absorbed than is re-transmitted.

Appendix 1

From <http://zpenenergy.com/modules.php?name=News&file=article&sid=1100>

ZPE

Posted on Tuesday, January 04, 2005 @ 23:10:07 PST by vlad

In the free-energy yahoo group, Paul (metalspiderkiller) writes: Physicists know that we are immersed in an energetic field. The existence of zero point electromagnetic energy was discovered in 1958 by the Dutch physicist M J Sparnaay. Mr Sparnaay continued the experiments carried out by Hendrik B G Casimir in 1948 which showed the existence of a force between two uncharged parallel plates which arose from electromagnetic radiation surrounding the plates in a vacuum. Mr Sparnaay discovered that the forces acting on the plates arose from not only thermal energy, but also from another type of radiation now known as classical electromagnetic zero point energy.

Mr Sparnaay determined that not only did the zero point electromagnetic energy exist in a vacuum, but also that it persisted even at a temperature of absolute zero. This term Zero Point Energy has been based on the concept that even if matter were cooled down to absolute zero (minus 273 degC), in terms of its temperature, this energy still remains. Because it exists in a vacuum, ZPE is homogenous and isotropic as well as ubiquitous. In addition, since ZPE is also invariant with respect to Lorentz transformation, the ZPE spectrum has the characteristic that the intensity of the energy at any frequency is proportional to the cube of that frequency. Consequently, the intensity of the energy increases resulting in an infinite energy density for the radiation spectrum.

It appears that this energy is quite intense. Nobel Laureate Richard Feynman and one of Einstein's protégés, John Wheeler, calculated that there is more than enough energy in the volume of a coffee cup to evaporate all the worlds' oceans. We fail to easily recognize this immense energy source as it is analogous to trying to weigh a beaker of water underneath the ocean.

With the introduction of zero point energy into the classical electron theory, a vacuum at a temperature of absolute zero is no longer considered empty of all electromagnetic fields. Instead, the vacuum is now considered as filled with randomly fluctuating fields having the ZPE spectrum. It is thought that one of the most extraordinary manifestations of ZPE is the random intense fluctuations in energy levels of electrons. Electrons are continuously changing state: energy into matter and back into energy again, as Einstein revealed. Special characteristics of ZPE are that it has a virtually infinite energy density and that it is ubiquitous (even present in outer space), and these make it very desirable as an energy source.

Andre Sakharov, the Soviet Physicist, argued that we should regard all matter as floating in a sea of energy. Modern physics tells us that the space between the stars and the space between the particles that which make up matter are filled with vast amounts of fluctuating energy: fluctuations that are fundamental to our view of the fabric of nature.

However, because high energy densities exist at very high frequencies, and because conventional methods are able to convert or extract energy effectively or efficiently only at lower frequencies at which ZPE has relatively low energy densities, effectively tapping this energy source has been believed to be unavailable using conventional techniques for converting this electromagnetic energy to electrical or other forms of easily useable energy. Consequently, zero point electromagnetic energy which may potentially be used to power interplanetary craft as well as provide for society's other needs has remained unharnessed, until now.

Various researchers around the world have been discovering scientific anomalies which are being attributed to the conversion of ZPE. It is also thought that discovering the secret of ZPE could be the key to opening the door to a unified theory of the Universe. In other words, our current understanding of science is like a puzzle with a large missing piece. ZPE would be the missing piece which completes the picture, possibly ushering a "Second Coming" of science. In essence, the implication of this energy field, is that all physical matter can be considered to be floating in a sea of energy, which if collected and converted into electrical energy, could more than meet the world's insatiable energy demand.

In conclusion, the fabric of space is actually NOT an empty vacuum, despite what is still erroneously taught to many physics undergraduates, but is in fact a vast seething plenum of abundant and dense energy, in which particles continually form and decay. This is not new knowledge, rather a decades old and very well proven and replicated experimental fact.

Paul see thread at: <http://groups.yahoo.com/group/free-energy/message/16991>

Appendix 2

Zero-Point Energy Extraction Feasibility

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Presented to Conference on New Energy Alternatives, Extraordinary Technology & USPA Conferences

Introduction

In partial fulfillment of the doctoral requirements for the School of General Engineering at Kennedy-Western University, a 180-page *Feasibility Study of Zero-Point Energy Extraction from the Quantum Vacuum for the Performance of Useful Work* was completed in 2003. The entire study has been updated and expanded, including a one-page "Vacuum Engineer's Toolkit" in a book entitled, *Practical Conversion of Zero-Point Energy* available on Amazon and elsewhere.

This zero-point energy (ZPE) study marks a new dimension in research directions for our fuelless energy future, one which this author believes is essential for the survival and travel independence of the human race. A number of significant discoveries were made with the study, by interpreting little-known journal articles with an engineering focus toward energy and propulsion applications.

Zero-Point Energy Primer

Zero-point energy (ZPE) is a universal natural phenomenon of great significance which has evolved from the historical development of ideas about the vacuum. In the 17th century, it was thought that a totally empty volume of space could be created by simply removing all gases. This was the first generally accepted concept of the vacuum. Late in the 19th century, however, it became apparent that the evacuated region still contained thermal radiation. To the natural philosophers of the day, it seemed that all of the radiation might be eliminated by cooling. Thus evolved the second concept of achieving a real vacuum: cool it down to zero temperature after evacuation. Absolute zero temperature (-273C) was far removed from the technical possibilities of that century, so it seemed as if the problem was solved. In the 20th century, both theory and experiment have shown that there is a non-thermal radiation in the vacuum that persists even if

the temperature could be lowered to absolute zero. This classical concept alone explains the name of "zero-point" radiation.

In 1891, the world's greatest electrical futurist, Nikola Tesla, stated, "Throughout space there is energy. Is this energy static or kinetic? If static our hopes are in vain; if kinetic – and we know it is, for certain – then it is a mere question of time when men will succeed in attaching their machinery to the very wheelwork of Nature. Many generations may pass, but in time our machinery will be driven by a power obtainable at any point in the Universe."

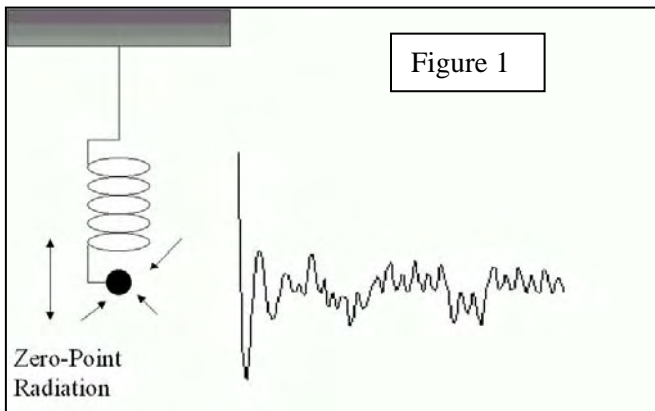
"From the papers studied the author has grown increasingly convinced as to the relevance of the ZPE in modern physics. The subject is presently being tackled with appreciable enthusiasm and it appears that there is little disagreement that the vacuum could ultimately be harnessed as an energy source. Indeed, the ability of science to provide ever more complex and subtle methods of harnessing unseen energies has a formidable reputation. Who would have ever predicted atomic energy a century ago?"

A good experiment proving the existence of ZPE is accomplished by cooling helium to within microdegrees of absolute zero temperature. It will still remain a liquid. Only ZPE can account for the source of energy that is preventing helium from freezing.

Besides the classical explanation of zero-point energy referred to above, there are rigorous derivations from quantum physics that prove its existence. "It is possible to get a fair estimate of the zero point energy using the uncertainty principle alone." As stated in Equation (1), Planck's constant h (6.63×10^{-34} joule-sec) offers physicists the fundamental size of the quantum. It is also the primary ingredient for the uncertainty principle. One form is found in the minimum uncertainty of position x and momentum p expressed as

$$\Delta x \Delta p \geq h/4\pi . \quad (1)$$

In quantum mechanics, Planck's constant also is present in the description of particle motion. "The harmonic oscillator reveals the effects of zero-point radiation on matter. The oscillator consists of an electron attached to an ideal, frictionless spring. When the electron is set in motion, it oscillates about its



point of equilibrium, emitting electromagnetic radiation at the frequency of oscillation. The radiation dissipates energy, and so in the absence of zero-point radiation and at a temperature of absolute zero the electron eventually comes to rest. Actually, zero-point radiation continually imparts random impulses to the electron, so that it never comes to a complete stop [as seen in Figure 1]. Zero-point radiation gives the oscillator an average energy equal to the frequency of oscillation multiplied by one-half of Planck's constant."

Executive Summary

Based on the quality of research uncovered and the level of agreement between theory and experiment demonstrated by the thermodynamic mode of ZPE conversion, it is concluded that further attention and funding be primarily dedicated to the exploitation of zero-point energy extraction, beginning with the microscopic realm. While the other three modalities (fluidic, mechanical, electromagnetic) offer interesting and promising developments, the feasibility rating and energy quality rating is the highest with the thermodynamic mode. In particular, it is recommended that:

- 1) metal-metal nanodiodes should be researched, with attention to the Johnson noise voltage and purported lack of diode barrier, along with the possible mass production of high density substrates;
- 2) more ratchet and ratchetlike asymmetries should be researched, by government, industry and academia, so that a TB lattice or diode assembly may one day offer a truly solid state transducer for ZPE;
- 3) research should continue into quantum coherence, refractive index change, and stochastic resonance with a goal of reducing the present relatively large energy investment, so that more robust avenues of product development in ZPE thermodynamics may be achieved. Brownian motors, thermal fluctuation rectifiers, and quantum Brownian nonthermal rectifiers utilizing AQSR have already achieved a level of theoretical and

experimental confidence where further physics research and engineering studies can offer fruitful rewards in the production of rectified DC electricity. This mode of ZPE conversion research and development needs to be continued with earnest in order to expand mankind's woefully limited portfolio of energy choices.

A broad outline of how to undertake the recommended development work necessarily has specific tasks and milestones associated with

- a) the confirmation of ZPE quantum effects described in this study on a larger scale;
- b) replication of results but also optimization of results; and
- c) engineering tasks of conductor and semiconductor design, nanowires and ohmic contacts.

All of these, along with other tasks not mentioned, need to be included. The project would also include estimates of output current and energy production with any given geometry. Parallel development paths in research and development will always accelerate the completion of the optimum design. A market study should also accompany the work, so a clear focus on the existing niche to be filled is maintained. A national or international project proposal that estimates the required project scope, resources, break-even point and identifies major milestones, has to be formulated, if major progress in ZPE usage is to be achieved. Simply commissioning another study to follow up this study will lead only to institutionalizing the effort without accomplishment of set goals.

This feasibility study of ZPE extraction for useful work has presented a balanced and detailed assessment with scientific integrity, engineering utility and the likelihood of success for further development. It is justifiably concluded that *zero-point energy is deserving of more attention by engineers and entrepreneurs as a serious and practical energy source for the near future*. The proposed project plan for ZPE development, yet to be written, has been reduced to a business endeavor and an exercise in return on investment. A few amazing examples of some recent ZPE discoveries follow below.

Focusing Vacuum Fluctuations

A method has now been found to concentrate and focus ZPE.

In a Casimir Workshop held in 2002 at Harvard University, L.H. Ford and N.F. Svaiter (Physics Department, Tufts University, Medford, MA 02155) found that the quantization of the electromagnetic field in the presence of a parabolic mirror is possible in the context of a geometric optics approximation. They calculate the mean squared electric field near the focal line of a parabolic cylindrical mirror. This quantity is found to grow as an inverse power of the distance from the focus. Ford and Svaiter give a combination of analytic and numerical results for the mean squared field. In particular, they find that the mean squared *electric field can be either negative or positive*, depending upon the choice of parameters. The case of a negative mean squared electric field corresponds to a repulsive Van der Waals force on an atom near the focus, and to a region of negative energy density. Similarly, a positive value corresponds to an attractive force and a *possibility of atom trapping in the vicinity of the focus*.

Movement from Nothing

Empty space can set objects in motion, a physicist claims.¹

Motion can be conjured out of thin air, according to a physicist in Israel. Alexander Feigel of the Weizmann Institute of Science in Rehovot says that objects can achieve speeds of several centimetres an hour by *getting a push from the empty space of a vacuum*².

¹ Philip Ball, *Nature*, Feb. 2004 <http://www.nature.com/Physics/Physics.taf?g=&file=/physics/highlights/6974-3.html&filetype=& UserReference=C0A804F54651F06AE1CBD407899240295C0F>

² Feigel, A. Quantum vacuum contribution to the momentum of dielectric media. *Physical Review Letters*, **92**, 020404, doi:10.1103/PhysRevLett.92.020404 (2004)

No one has yet measured anything being set in motion by emptiness. But Feigl thinks it should theoretically be possible to make use of the effect to shunt tiny amounts of liquids around on a lab chip, for example. Such small-scale experiments could be useful for chemists interested in testing thousands of different drugs at the same time, or for forensic scientists who need to do analyses on tiny amounts of material.

Empty space contains energy from virtual particles which can move objects.

The whole idea of getting movement from nothing sounds like a gift to advocates of perpetual-motion machines. But there's nothing in Feigl's theory that violates the fundamental laws of physics, so this doesn't provide a way to cheat the Universe and get free energy.

Instead, Feigl draws on the well-established notion that empty space does contain a little bit of energy. This 'vacuum energy' is a consequence of the uncertainty principle — one of the cornerstones of quantum mechanics.

Because of the uncertainty principle, subatomic particles or photons can appear spontaneously in empty space — provided that they promptly vanish again. This constant production and destruction of 'virtual particles' in a vacuum imbues the vacuum with a small amount of energy.

Moving in a vacuum

Feigl considered the effects of virtual photons on the momentum — a property defined as mass multiplied by velocity — of objects placed in a vacuum, and came to a surprising conclusion.

He started with the fact that electrical and magnetic forces between objects are mediated by photons that flit between them. So an object placed in strong electric and magnetic fields can be considered to be immersed in a sea of these transitory, virtual photons.

Feigl then showed that the momentum of the virtual photons that pop up inside a vacuum can depend upon the direction in which they are traveling. He concludes that if the electric field points up and the magnetic field points north, for example, then east-heading photons will have a different momentum from west-heading photons. So the vacuum acquires a net momentum in one direction — it's as though the empty space is 'moving' in that direction, even though it is empty.

It is a general principle of physics that momentum is 'conserved' — if something moves one way, another thing must move the other way, as a gun recoils when it shoots a bullet. So when the vacuum acquires some momentum from these virtual photons, the object placed within it itself starts to move in the opposite direction.

Feigl estimates that in an electric field of 100,000 volts per metre and a magnetic field of 17 Tesla — both big values, but attainable with current technology — an object as dense as water would move at around 18 centimetres per hour.

General Relativity and Vacuum Energy

Jordan Maclay, a NASA-funded quantum researcher, has some interesting observations about ZPE that show its power and complexity.³ In general relativity, he notes, any form of energy has an equivalent mass, given by $E = mc^2$, and is therefore coupled to gravity. This enormous zero-point energy density is equivalent to a mass density of about 10^{92} kg/cc, and would be expected to cause an enormous gravitational field. This large field leads to some major problems with general relativity, such as the collapse of the universe into a region of space that is about 1 Planck length across. Thus we have an inconsistency in two very important and well-verified theories, QED and General Relativity. A brief discussion of this problem is given in the excellent book *Lorentzian Wormholes* (Springer-Verlag, 1996, p. 82) by Matt Visser.

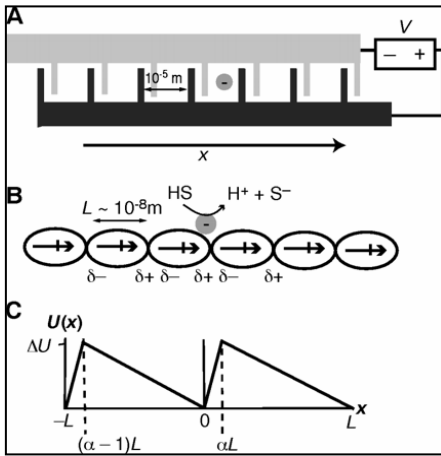
The ZPE in a region of space the size of a proton is equivalent to the mass of the universe.

As an instructional exercise, it is possible to compute the equivalent mass for a region of the vacuum about the size of a proton, which is approximately a sphere about 10^{-13} cm across, using the enormous energy density formally predicted above. This process yields an equivalent mass of about 10^{53} kg. This means the vacuum energy contained within a region of space the size of a proton is equivalent to a mass of about 10^{53} kg. A very rough estimate of the number of nucleons in the universe is 10^{80} . This number is based on the statistical distribution of stars in galaxies and the number of galaxies. Most of the mass of matter is in nucleons, so the mass of the universe is roughly the weight of a proton times 10^{80} or about 10^{53} kg, which is the same as

³ Jordan Maclay, Quantum Fields, LLC www.quantumfields.com

the mass equivalent of the vacuum energy in a region the size of a proton. Conclusion: A volume the size of a proton in empty space contains about the same amount of vacuum energy as all the matter in the entire universe! This sounds like the poet's words, which now ring true, "To see the world in a grain of sand."

Brownian Motor



R. Dean Astumian has proposed experiments for nonequilibrium fluctuations, whether generated externally or by a chemical reaction far from equilibrium, that can bias the Brownian motion of a particle in an anisotropic medium without thermal gradients, a net force such as gravity, or a macroscopic electric field.⁴ Fluctuation-driven transport is one mechanism by which chemical energy can directly drive the motion of particles and macromolecules and may find application in a wide variety of fields, including particle separation and the design of molecular motors and pumps. Recent work has focused, however, on the possibility of an energy source other than a thermal gradient to power a microscopic motor. If energy is supplied by external fluctuations or a nonequilibrium chemical reaction, Brownian motion can be biased if the medium is anisotropic, even in an isothermal system. Thus, directed motion is possible without gravitational force, macroscopic electric fields, or

With no net input force, a tiny Brownian motor can transport particles, thus performing work.

long-range spatial gradients of chemicals.

In devices based on biased Brownian motion, net transport occurs by a combination of diffusion and deterministic motion induced by externally applied time-dependent electric fields. Although the electric generator is certainly a macroscopic device, *the electric field in the x direction averaged over a spatial period is zero no matter what the voltage, and so there is no net macroscopic force.*⁵ A nonequilibrium fluctuation can be produced by using a switching device that imposes an externally defined but possibly random modulation of the voltage. Recent experiments have shown that unidirectional motion of microscopic particles can be induced by modulating the amplitude of such an *anisotropic sawtooth potential* [see Figure 2]. Theory shows that the direction of flow is governed by a combination of the local spatial anisotropy of the applied potential, the diffusion coefficient of the particle, and the specific details of how the external modulation is carried out.

The recent work on fluctuation-driven transport leads to optimism that similar principles can be used to design microscopic pumps and motors – machines that have typically relied on deterministic mechanisms involving springs, cogs, and levers – from stochastic elements modeled on the principles of chemical reactions and noise-assisted processes.

Energy from a Single Heat Bath

Nothing gets the classical physicist's goat more than asserting that energy can be drawn from a single heat source, in apparent violation of thermodynamics. However, that is precisely what now seems perfectly feasible: a quantum Carnot engine in which the atoms in the heat bath are given a small bit of *quantum coherence*. The induced quantum coherence becomes vanishingly small in the high-temperature limit at which they operate and the heat bath is essentially thermal. However, the phase, associated with the atomic coherence, provides a new control parameter that can be varied to increase the temperature of the radiation field and to extract work from a single heat bath. The deep physics behind the second law of thermodynamics is not violated; nevertheless, the quantum Carnot engine has certain features that are not possible in a classical engine.⁶ This invention is a stellar example of quantum physics paving new ground in the inevitable conversion of ZPE for macroscopic use.

⁴ Astumian, R.D., "Thermodynamics and Kinetics of a Brownian Motor," *Science*, 276, 1997, p. 5314

⁵ H. Linke, et al., "Experimental Tunneling Ratchets," *Science* – 286 (5448), 1999, p. 2314; also see L. P. Faucheux, et al., *Phys. Rev. Lett.* **74**, 1504 (1995)

⁶ Marlan O. Scully, "Extracting Work from a Single Heat Bath via Vanishing Quantum Coherence" *Science*, Vol. 299, Issue 5608, February 7, 2003, p. 862-864

In the presence of unbiased, asymmetric forcing, a noise-directed current always occurs in a dissipative tight-binding (TB) lattice, because of the ratchet-like effect of the asymmetric forcing, like the stochastic ratchets that rectify thermal noise. With stochastic resonance, nonthermal fluctuations are effectively rectified, creating a measurable current. Goychuk believes that the effect should be already observable in superlattices and/or optical lattices.⁷ Anomalous transport properties, using SR, which do not exploit the ratchet mechanism have been investigated in driven periodic tight-binding lattices near zero DC bias with the combined effects of DC and AC fields, or DC field and external noise. In particular, Goychuk et al. have found that periodic TB lattices can be driven by unbiased nonthermal noise generated from the vacuum ZPF, generating an electrical current as a result of a “ratchetlike mechanism,” as long as there is quantum dissipation in the system.

For reference, it is worth mentioning that with crystal lattices, thermal fluctuations appear at environmental temperatures, with $\frac{1}{2} m\omega_0^2 \langle u^2 \rangle = 3(\frac{1}{2} k_B T)$ energy level where m and ω_0 are the mass and frequency of the harmonic oscillations and u is the displacement from a fixed lattice site. The nonthermal oscillations associated with ZPE are $m\omega_0^2 \langle u^2 \rangle = 3(\frac{1}{2} \hbar\omega_0)$ in terms of energy, adding to the lattice thermal fluctuations.

With the introduction to aperiodic quantum stochastic resonance (AQSR) along with the rectification of nonthermal noise, it makes sense to investigate the amplification of quantum noise. Milonni points out that “the vacuum field may be amplified...if the spontaneously emitted radiation inside the cavity is amplified by the gain medium, then so to must the vacuum field entering the cavity. Another way to say this is that ‘quantum noise’ may be amplified.” Since the SR TB lattice current output depends on the noise level, as in the Goychuk simulation, the optimum level of energy extraction depends on parameter control, as in quantum optics, which utilizes quantum noise amplification. This is similar to amplified stimulated emission (ASE) which also uses a gain medium.

Conclusion

A few pioneers have proposed that a solid state diode or diode array can serve as the template for a ZPE converter. For example Joseph Yater, with his patents and Physical Review articles, was one of these notable visionaries. He theorized that a Schottky diode, formed between a semiconductor and a metal, with nonlinear rectifying characteristics and fast switching speeds, could be the diode of choice for rectifying thermal noise. Yater notes in his U.S. patent #4,004,210 that “for the long range design goals, sub-micron circuit sizes are required if all the high power goals of megawatts per square meter are to be achieved.”

In regards to **rectifying thermal electrical noise**, it is worth mentioning the U.S. Patent #3,890,161 by Charles M. Brown that utilizes an array of nanometer-sized metal-metal diodes, capable of rectifying frequencies up to a terahertz (10^{12} Hz). Brown notes that thermal agitation electrical noise (Johnson noise) behaves like an external signal and can be sorted or preferentially conducted in one direction by a diode. The Johnson noise in the diode is also generated at the junction itself and therefore, requires no minimum signal to initiate the conduction in one direction. The thermal noise voltage is normally given by $V^2 = 4k_B TRB$ where R is the device resistance and B is the bandwidth in Hertz. Brown’s diodes also require no external power to operate, in contrast to the Yater diode invention. Brown also indicates that heat is absorbed in the system, so that a cooling effect is noticed, because heat (thermal noise) energy energizes the carriers in the first place and some of it is converted into DC electricity. In contrast, the well-known Peltier effect is the closest electrothermal phenomenon similar to this but requires a significant current flow into a junction of dissimilar metals in order to create a cooling effect (or heating). Brown suggests that a million nickel-copper diodes formed in micropore membranes, with sufficient numbers in series and parallel, can generate 10 microwatts. The large scale yield is estimated to be several watts per square meter.

Taking these two inventions as a starting point for hardware, the transition to engineering quantum Brownian *nonthermal rectifiers* can be much smoother for the nanophysicist or nanotechnician. For example, the latest news in this ongoing development is that a molecular photodiode rectifier has been invented, which meets some of the characteristics required for ZPE conversion [see Figure 3].⁸ Another gratifying confirmation is that “experimentally measured spectral density of current noise in Josephson junctions provides direct evidence for the existence of zero-point fluctuations.”⁹

⁷ Goychuk, I. et al., “Nonadiabatic quantum Brownian rectifiers” *Physical Review Letters*, Vol. 81, No. 3, 1998, p. 649

⁸ S Yasutomi et al. 2004 *Science* 304, p. 1944 – Note for ZPE extraction, the fluctuation amplitude simply needs to exceed the forward junction barrier in the diode of choice.

⁹ C Beck et al. Astrophysics abstract, preprint, 23 June 2004, <http://xxx.arxiv.org/abs/astro-ph/0406504> and *Nature*, 430, 126, 8 July 2004

Resources

The most comprehensive textbook covering the Casimir effect and related vacuum phenomena is *The Quantum Vacuum*, by Peter Milonni, Academic Press(1994). The Casimir effect is covered in *Quantum Mechanics*, Leslie Ballentine, Prentice-Hall (1990). The most recent resource paper with many references on Casimir forces was published by S. Lamoreaux, *American Journal of Physics*, vol. 67, pp. 850-861, October, 1999. A good review describing the breadth of Casimir phenomena is "Casimir Forces" by Peter Milonni and Mei-Li Shis, in *Contemporary Physics*, vol. 33, 313-322 (1992). Another informative review is E.Elizalde and A.Romero, "Essentials of the Casimir Effect and its Computation," *Am. J. Phys.* **59**, 711-719 (1991). A long and detailed review is given by P. Plunian, B. Muller, W. Greiner, "The Casimir Effect," *Physics Reports (Review Section of Physics Letters)* **134**, 2&3, pp. 87-193 (1986). Much information is contained in the text *The Casimir Effect and its Applications* by V. Mostepanenko and N. Trunov, published by Oxford University Press, 1997.

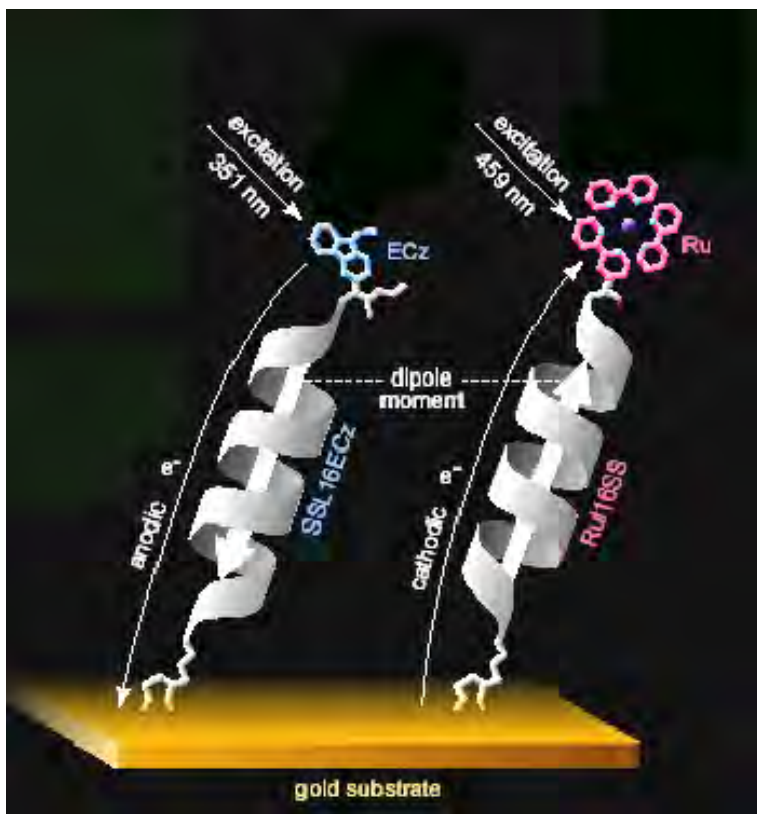


Figure 3

Nanosized peptide photodiodes conduct electrons in a direction that is dependent on which molecule is attached to the end. Diodes on this scale will also rectify ZPE nonthermal fluctuations if their forward drop is low enough.