White Paper
Indirect Extraction of Energy from the Quantum Vacuum
(U.S. Patent 7,379,286)

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Introduction

As a game-changing innovative and unique technology with major implications for space missions as well as terrestrial applications, we propose to demonstrate that it is possible to indirectly tap a new source of energy, potentially greater than nuclear, well known in quantum physics but considered by physicists not to be useful since it cannot be directly accessed. We will investigate the feasibility of accessing this zero-point energy source *indirectly* by capturing electromagnetic energy emitted by transient changes in energy levels of electron orbitals, due to interactions of atoms (preferably monatomic noble gases) with the quantum vacuum field while cycling through Casimir cavities. We would induce shifts comparable in principle to, but larger than, the well-known Lamb shift, by suppressing quantum vacuum field modes within the Casimir cavities. The electromagnetic energy (photons) released by these shifts would be diverted to useful purposes and be replenished by the universal ambient quantum vacuum field outside the Casimir cavities, thereby not violating the second law of thermodynamics.

It has been shown that the ground-state of the hydrogen atom can be interpreted semi-classically as a state of equilibrium between Larmor emission by the electron and absorption of radiation from the quantum vacuum. This suggests that modification of the quantum vacuum – as occurs in Casimir cavities – can modify electron orbitals resulting in energy release. The effect is similar to the well-known Lamb shift whereby interactions between the electron and the vacuum cause orbital energy shifts. We therefore refer to this effect as a Casimir-Lamb shift

Zero-point energy is a well established concept originally proposed by Planck and Einstein in 1913. Later it was shown to arise in quantum physics from the Heisenberg uncertainty principle. It has a number of well-known effects. For example, zero-point energy prevents helium from solidifying under normal pressure even at absolute zero temperature. It can also be detected as quantum noise in circuits. Although very real on the quantum level, it is not directly evident in the large-scale world. What we are proposing is to use a quantum process to indirectly tap zero-point energy by using Casimir cavities to temporarily modify electron orbitals in atoms as they pass through the cavities. Continuous gas flow through properly sized Casimir cavities should result in energy extraction. In effect this process would siphon energy from the Universe at large. The inert gas serves solely as a catalyst and is not depleted. It is technologically straightforward to manufacture structures the size of a car battery that would contain millions of Casimir cavities. The process requires the continuous cyclic flow of inert, harmless gases such as neon, argon, krypton or xenon in a closed system. Energy capture and conversion devices are also required, whose exact characteristics depend upon precisely how the zero-point energy is released. Reasonable estimates of the strength and efficiency of this process suggest that a structure of car-battery size could generate on the order of one kilowatt. There would be no harmful, hazardous or polluting byproducts.

- Experiments from 100 years ago suggested that an atom consists of a nucleus around which electrons orbit... much like planets going round the Sun. This depiction is still widely used in textbooks and elsewhere.
- However, orbiting electrons would give off electromagnetic radiation which would lead to the electrons losing energy and quickly spiraling into the nucleus, destroying the atom.
- This led to the creation of quantum mechanics in which the electron is no longer thought of as an orbiting particle, but rather a fuzzy wave function spread out over "orbitals."
- Quantum mechanics also showed that there is a vast reservoir of energy at every point in the Universe in the form of fluctuating electromagnetic fields called zero-point energy.
- In the 1970s it was discovered that a classical orbiting electron in the ground state of hydrogen could be stable after all, because the energy lost by radiation can be balanced by absorption of zero-point energy.
- This discovery raises the possibility that quantum mechanical electron orbitals in general are stabilized by zero-point energy which, in turn, raises the possibility that changing the surrounding zero-point energy will change electron orbitals..
- Zero-point energy is changed in Casimir cavities.
- We have conceived of, and patented, a process for using Casimir cavities to change electron orbitals of certain gases in a way that would indirectly liberate zero-point energy, which could then be harvested and converted into useful heat or electricity.
- A somewhat similar process is well established. Electron orbital shifts due to zero-point energy effects occur in the well known Lamb shift (for which Willis Lamb won the Nobel prize in 1955).
- Our concept can be thought of as a more robust form of Lamb shift. For this reason, we refer to this process whereby usable energy can be liberated from zero-point energy as a Casimir-Lamb shift.
- Recent experimental work conducted at the University of Colorado at Boulder, has yielded promising but, as yet, inconclusive results.

We propose to model the quantum electrodynamics of the expected shifts and resulting photonic emissions; validate the shifts spectroscopically; and measure and characterize the photonic emissions with broadband pyroelectric signal detection apparatus. The technology is described further in U.S. Patent No. 7,379,286 (May 2008) assigned to the Univ. of Colorado, Boulder.

DARPA Contract and Present Signal Detection Status

We received a one-year $300k contract from DARPA for initial testing of the concept. We developed several approaches to fabricating the Casimir-cavity devices, including using a gap-cell geometry adapted from liquid-crystal fabrication technology, using nanoporous material, and using a filter having holes of the right dimensions. We developed several measurement stations and systems. The results were ambiguous. Flowing different gases through the nanopore filters, we saw clear emission from the devices, but the exact source of the emission remains uncertain.

Technical Summary

The “Lamb shift,” a well explored mainstay of quantum electrodynamics, consists of a shift in the energy levels of electron orbitals, resulting from an atom’s interaction with quantum vacuum fluctuations.[1] Recent experiments have shown that Lamb shifts can be controlled and enhanced.[2] It is likely that electron orbital shifts analogous to (but not identical with) Lamb shifts can be induced by moving atoms (such as inert gases) under modest pressure through Casimir cavities, due to suppression of some wavelengths of quantum vacuum fluctuations in Casimir cavities,[3] possibly resulting in emissions of electromagnetic energy. We refer to the shift so induced as the "Casimir-Lamb shift." As stated previously, the ground-state of the hydrogen atom can be interpreted semi-classically as a state of equilibrium between Larmor emission by the electron and absorption of radiation by the electron from the quantum vacuum.[4] A modification of the quantum vacuum in a Casimir cavity should modify electron orbitals resulting in energy release. As the gas atoms leave the Casimir cavity, the Casimir-Lamb shift would be reversed by quantum fluctuations, without violating the second law of thermodynamics.[5]

The argument that it is impossible to use quantum energy since it is already the lowest possible energy of a system is refuted by the Robert Forward battery thought experiment in which the Casimir force on parallel conducting plates is used to do work against an electric field. This process is useless in practice because, once pushed together, it would take more energy to separate the plates for a second cycle than is produced by the Casimir force. Nonetheless, there is genuine work done by the quantum field during the initial half-cycle.[6]

In the case of the Casimir-Lamb shift, recycling safe, inexpensive, monatomic, inert gases through microstructures of millions of Casimir cavities would yield substantial amounts of energy. Suitable emission might permit direct generation of electricity via photovoltaic cells. Alternatively, the emitted photons may release heat, which can be used directly for local heating purposes, or to drive turbines to generate power. The main energy "drain" on this process is the minute amount of pressure required to push the gas atoms through multiple Casimir caviteies. Once the photonic energy released in this process is characterized, it should be possible to design devices consisting of a closed gas system with a small pump, a stack of patterned disks (much

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[1] Lamb, W. & Retherford, R., *Fine Structure of the Hydrogen Atom by a Microwave Method*, Physical Review Vol. 72:241 (1947); Feynman, R., QED: The Strange Theory of Light and Matter (Princeton University Press 1985); Niering, M. et al., *Measurement of the Hydrogen 1s-2s Transition Frequency by Phase Coherent Comparison with a Microwave Cesium Fountain Clock*, Physical Review Letters Vol. 84, 5496 (2000); Walls, D. & Milburn, G., Quantum Optics (Springer-Verlag 1994). In the case of the Lamb shift, the nucleus of the atom (a single proton for hydrogen) slightly modifies the quantum vacuum in its vicinity. The result is that the $^2P_{1/2}$ and $^2S_{1/2}$ orbitals, which should have the same energy, are slightly shifted since they spread over slightly different distances from the nucleus, hence experiencing a slightly different electromagnetic quantum vacuum.

[2] Fragner, A. et al., *Resolving Vacuum Fluctuations in an Electrical Circuit by Measuring the Lamb Shift*, Science, Vol. 322, 1357 (28 November 2008). The authors note a variety of observable effects of the electromagnetic quantum vacuum, and measurement of a cavity-enhanced Lamb shift in an architecture known as circuit QED, involving the dispersive coupling of a superconducting electronic circuit acting as a quantum bit (qubit) to the vacuum field in a transmission-line resonator.

[3] Milonni, P., The Quantum Vacuum: An Introduction to Quantum Electrodynamics (Academic Press 1994); de la Pena, L. & Cetto, A., The Quantum Dice: An Introduction to Stochastic Electrodynamics (Kluwer Academic Publishers 1996).

[4] Puthoff, H., *Ground state of hydrogen as a zero-point-fluctuation-determined state*, Physical Review Vol. D 35, 10, 3266 (1987).

[5] Cole, D. & Puthoff, H., *Extracting energy and heat from the vacuum*, Physical Review E 48, 2, 1562 (1993).

[6] Forward, R., *Extracting electrical energy from the vacuum by cohesion of charged foliated conductors*, Physical Review B 30, 4, 1700 (1984).

like a stack of CDs) containing Casimir cavities, and a heat absorber (or photovoltaic cell). Such devices should be straightforward to manufacture, making it possible to harvest and deploy electromagnetic energy safely with no waste products or greenhouse gas emissions. The amount of energy tapped should be scalable in direct proportion to the volume of the device. Calculations suggest that a system would yield continuously one kilowatt or more per cubic foot in volume, scalable as needed for larger applications, whether stationary or transportable.

Key Technical Areas to Be Explored.

(1) Modeling of Electrodynamic Processes. In order to fabricate Casimir cavities to the proper dimensions and to calibrate signal detection instrumentation properly for the electromagnetic radiation that we anticipate, we must model the quantum electrodynamic processes for the Casimir-Lamb shifts mathematically. Such quantum electrodynamic modeling typically assumes relatively simple atoms, such as hydrogen.[7] Atoms of monatomic noble gases such as neon, argon, krypton and xenon, with numerous outer electron orbitals, may more readily yield radiation in our process due to those available orbitals; but the multiple orbital energy levels significantly complicate the modeling. Existing electrodynamic modeling of Lamb shifts suggest that the technology readiness level ("TRL") of this area is at TRL-3. We will extend such modeling to more complicated noble gases.

(2) Precise Fabrication of Casimir Cavities. Casimir cavities for our use will have gap sizes ranging from approximately 0.1 to 0.3 microns. The precise dimensions of the cavity gap are critical to appropriate suppression of quantum vacuum electromagnetic wavelengths. The gaps must be bordered by conductive surfaces which are fabricated economically, precisely and smoothly to fine tolerances. Candidate surface materials for the cavity boundaries include metals such as aluminum, silver, gold, palladium and platinum. The surfaces must be etched or deposited over a suitable substrate by means such as sputtering or a combination of processes. We will fabricate Casimir cavities in collaboration with the Quantum Engineering Lab. of the Dept. of Electrical, Computer & Energy Engineering of the University of Colorado at Boulder.

Based upon previous investigation of a variety of fabrication techniques for Casimir cavities, our current approach is to use nanopore filters, with nanopores of sufficient strength and uniformity to sustain the gas flow. We can adjust the nanopore diameter precisely by depositing metal layers of specified thickness onto them, measuring it with a scanning electron microscope. After initially verifying emitted radiation, we will investigate other

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[7] Modeling of the stochastic motions of the electrons reproducing the probability density distribution of the Schrödinger wave function is reported, for example, in Cole, D. & Yi Zou, *Quantum Mechanical Ground State of Hydrogen Obtained from Classical Electrodynamics*, Physics Letters Vol. A 317, No. 1-2, 14 (2003). Cole and Nickisch have simulated vacuum fluctuations acting on the single electron in hydrogen, showing that the electron orbital is influenced by quantum vacuum fluctuations. This suggests that Casimir cavity suppression of the vacuum at appropriate frequencies will result in orbital energy shifts while in transit through the cavity; but should not be confused with claims of supposedly stable "sub-Bohr" hydrogen atoms (so-called "hydrinos"). There is no permanent change in the atoms cycling through the system, merely transient orbital shifts while passing through the Casimir cavity. It also has been objected that even if energy is released during an atom's entrance into a Casimir cavity, that same energy will simply be recaptured on exit with no net gain. This cannot happen. The energy released upon entrance into the cavity does not come directly from the quantum vacuum, but rather from a change in electron orbital energy, such as in ordinary photon-emitting line transition. Therefore it is not stored "as is" awaiting reinsertion into the quantum vacuum upon exit of the atom from the cavity.

techniques for forming gap cells, such as by etching out buried oxide layers in silicon, or by bonding together silicon wafers with precise spacers deposited across the entire surface. With accumulated experience in engineering the geometry of the Casimir cavity devices, we consider this area of research to be at TRL-3.

(3) Signal Detection Apparatus. Optimizing our process for energy generation requires precise detection and characterization of the electromagnetic energy emitted. Even careful modeling may misapprehend the real-world spectral characteristics of the emitted photons. Characterizing the emission thoroughly will put us in a position to design configurations in which the gas makes multiple passes through the nanopores to multiply the radiation intensity, and to measure power input/output for the entire system. We will conduct signal detection tests at the Quantum Engineering Laboratory at the University of Colorado, Boulder. In order to accommodate the various possible radiation wavelengths, we will test across a broad spectrum, using a pyroelectric detector with an absorption spectrum extending from the near UV through the far infrared and into terahertz bands. Such a broadband detector is highly susceptible to background radiation and noise. Therefore, in order to facilitate the necessary lock-in detection, we will use a vacuum chamber of sufficiently small volume to allow us to pulse the gas at a frequency of 1 Hz or higher. After we confirm and determine the range of wavelengths of the emitted radiation, we can use a spectrometer to examine the emitted spectrum more precisely.

(4) Spectroscopic Demonstration of the Casimir-Lamb Shift. The Casimir-Lamb shift itself could be demonstrated simply and powerfully with spectroscopy to validate a key scientific element of our technological approach, using the well-known Balmer series of hydrogen.[8] The electron orbitals should be diminished within a Casimir cavity due to the suppression of quantum vacuum fluctuations, resulting in the Casimir-Lamb shift. To measure this, we would dissociate naturally occurring H_2 molecules with sufficient energy to simultaneously ionize the hydrogen atoms. The recombining atoms would then be made to enter Casimir cavities, where we will measure the resulting recombination spectrum for line shifts due to Casimir-induced changes in the orbital energies. The task is simple in concept, but requires subtle architecture in order to ensure that the spectrum being measured is restricted to hydrogen ions within the small dimensions of the Casimir cavities. We will retain expert consultants in appropriate spectroscopic techniques and instrumentation to help design the protocol for this innovative attempt to measure the recombination spectrum of hydrogen in a Casimir cavity environment. We estimate this area of research to be at TRL-2, with the objective of reaching TRL-3 in this area by validating the analytical predictions of the Casimir-Lamb shift.

(5) Integrated System. After detecting and characterizing electromagnetic energy emitted in simple bench devices, we would seek to amplify the effect in a simple integrated system featuring recirculation of gas through multiple Casimir cavities. Although separate elements of our proposed research may now be as high as TRL-3, the operation of an integrated system is formulated in concept only, and therefore no higher than TRL-2. Our objectives for the integrated system in this initial research endeavor extend only to proof of concept or low-fidelity function of a simple bench device, reaching TRL-3 or at best TRL-4.

[8] The Balmer series spectral lines appear at 410 nm, 434 nm, 486 nm, and 656 nm in the visible light spectrum.

Distinctions of Our Technology.

Unlike combustion processes, energy devices using this technology would generate neither greenhouse gases nor other waste products. The process would be highly energy-efficient, the only energy consumed in the process being the modest amount of pressure to move inert gases through nano-scale apertures. The electromagnetic energy released in the process would be controllable, with no harmful toxic or radioactive effects. The materials involved need not be highly costly, and manufacturing of devices should be amenable to simple etching and stamping technologies like those used for making digital video recordings on plastic diskettes. Devices with such advantages demand investigation.

The exotic notion of "zero point energy" tantalizes the popular imagination and has attracted notoriety as well as some investigation in the United States and abroad. The range of schemes to harvest zero point energy fluctuations developed over the last 25 years fall into three main categories: (i) using the attractive force between the plates of Casimir cavities[9]; (ii) applying resonators to down-convert zero point energy to usable frequencies[10]; and (iii) employing diodes to rectify the ambient zero point energy.[11] All of these harvesting schemes fall prey, however, to variations on "Maxwell's demon," in that they attempt to ratchet ambient energy.[12] Our fundamentally different method is based on the fact that zero point energy is not a constant in the universe, but changes with boundary conditions.[13] This allows us to make us of the Casimir cavity, in which quantum vacuum energy density is lowered, to tease energy from the ambient quantum vacuum field. We know of no other approach to access the electromagnetic fluctuations that comprise the vast energy of the quantum vacuum field[14] in order to perform work. We therefore believe that, if any consideration is given to attempting to access zero point energy, our proposal is the only methodologically rigorous and potentially feasible pathway for pursuing it. Systems using the approach discussed in this concept paper are covered by U.S. Patent No. 7,379,286 (issued May 27, 2008), assigned to the University of Colorado.

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[9] Forward, *supra* note 4; Pinto, F., *Engine cycle of an optically controlled vacuum energy transducer*, Physical Review Vol. B 60, 14740 (1999).

[10] Mead, F., "System for converting electromagnetic radiation energy to electrical energy," U.S. Patent No. 5,590,031 (1996).

[11] Valone, T. *Proposed Use of Zero Bias Diode Arrays as Thermal Electric Noise Rectifiers and Non-Thermal Energy Harvesters*, Proc. Space, Propulsion and Energy Sciences International Forum (SPESIF), Workshop on Future Energy Sources, AIP, Huntsville, AL (Feb. 24, 2009).

[12] Einstein showed by a detailed balance argument in 1917 that no asymmetry can exist in the rates of energy flowing between two points in a system in equilibrium. Ambient zero point energy is in a state of genuine equilibrium, and therefore the detailed balance argument applies to these harvesting methods as it does to Einstein's radiation emitted and absorbed by atoms. See *e.g.,* Couture, L. & Zitoun, R., Statistical Thermodynamics and Properties of Matter, transl. E. Geissler (Overseas Publishers 2000), p. 229.

[13] Puthoff, H., *The energetic vacuum: implications for energy research*, Speculations in Science and Technology, Vol. 13, 4, 247 (1990).

[14] Estimates of the density of energy in the ambient quantum fluctuations range from 10^{35} joules/meter^3 to as high as 10^{113} joules/meter^3. These seemingly absurd values would clearly require near cancellation with the Dirac sea of particles insofar as the combined effect of the photon and particle energies on cosmological gravitation, but that would not preclude tapping electromagnetic vacuum processes, i.e. A and B canceling gravitationally may still allow tapping specific other attributes of A or B.