Diode Energy Array Converter (DEAC) Solid State Electricity Generation Project

Thermal, Environmental and Non-Thermal Energy Harvesting in One Compact Device

Version 8.0

2016

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Project Director

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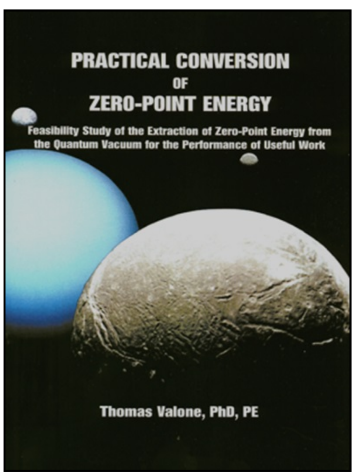
Summary

The Diode Energy Array Converter (DEAC) Project will design, develop, produce and test a number of sample IC array's to prove the viability of using massive arrays of zero-bias, backward tunnel Schottky diodes to harvest minute levels of Johnson noise and other RF and thermal energy from the atmosphere. Although relatively small, this power level is sufficient for powering many low power devices like smart phones, MP3 players, sensors, flashlights, and many other electronic devices. Use of the resultant high density IC's would obviate the need for batteries or recharging of cell phones and other low power devices, dramatically expanding the growth of communications and cell phone use across the planet, particularly in third world countries. It would also allow us to replace the kerosene lantern used across the planet for illumination and student reading, breathing in the fumes and carbon emissions.

This effort has been under exploration at IRI since the **discovery in 2003 that semiconductor junctions exhibit measurable Johnson noise at any temperature,** including microdegrees above absolute zero. This discovery has been explored by the project director and other scientists, for the purpose of developing a new, **low cost solid state renewable energy source**, and confirmed by independent lab testing. Though the evidence of this phenomenon has been in the literature for years, only a twenty-year-old patent by Charles Brown, US #3,890,161, teaches the basic technique for creating a suitable array of diodes for harvesting this energy. These massive arrays of diodes effectively rectify this noise to create a sustaining, self powered solid-state electricity source worthy of 21st century energy demands. (Note: "rectification" in electrical terms is the process of converting AC electrical oscillations, including random noise and other oscillations, into usable DC electricity.)

Selection of Certain Diodes for Energy Conversion



In response to the inquiry from Chief Scientist Dennis Bushnell of NASA-Langley who recently asked Tom Valone about the extraction of energy from the quantum vacuum, after becoming aware of his book, ***Zero Point Energy: The Fuel of the Future***, He replied that *the main discovery that he made is that there exists a class of diodes (rectifiers) that operate at "zero-bias" (no voltage applied to make them work) and operate up into microwave frequencies. These Schottky type diodes are suitable for generating minute levels of electrical current from thermal fluctuations, environmental electromagnetic field (EMF) pollution, and from the 'zero point energy' quantum vacuum because of natural nonthermal electrical fluctuations (Johnson noise).*

Peer-reviewed journal articles already document electron tunneling at zero voltage ("zero bias"). Several microwave diodes also exhibit this feature. Looking in the noise level (1/f noise or Johnson noise) is where thermal and non-thermal energy manifests. As to the nonthermal fluctuations, ***Practical Conversion of Zero Point Energy from the Quantum Vacuum for the Performance of Useful Work*** is a useful reference.[1] Nature has also been helpful since

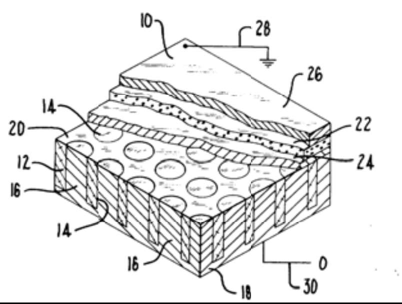
[1] Valone, Thomas. *Practical Conversion of Zero Point Energy: Feasibility Study of the Extraction of Zero Point Energy from the Quantum Vacuum for the Performance of Useful Work*, Integrity Research Institute, 2003, ISBN 0-9641070-8-2

Johnson noise in the diodes is also generated at the junction itself and therefore, requires no minimum signal to initiate the conduction in one direction.

Relevant Patent Search

The following US patents are the most significant in conversion of thermal and non-thermal (zero point quantum vacuum energy or ZPE): "Rectifying Thermal Electric Noise" by **Charles Brown #3,890,161**, whose integrated micron-sized diode array is seen below, and **#4,704,622 by Capasso**, which actually acknowledges ZPE for its functional contribution.[2] Capasso is an IBM engineer and indicates that his tunneling device only works if ZPE is present, much like what Planck discovered a century ago and Koch detected decades ago in the lab (Koch, 1982). I tend to think that metal-metal nanodiodes probably will be a popular brand for ZPE usage with millipore sheet assembly, as Brown suggests. I also cite the work of Yasamoto, et al. (2004, Science, 304:1944) covering peptide molecular photodiodes just 1 nm across -- another example of a molecular tool for studying this zero point energy that shows up on the molecular level.

Dr. Peter Hagelstein, who worked with Eneco, Inc. was thinking along the same lines when in 2002 he patented his "**Thermal Diode for Energy Conversion" (US Patent #6,396,191),** which uses a thermopile bank of thermionic diodes. These are slightly different, more like thermocouples, than the diodes that is presented in this proposal. However, Hagelstein's diodes are so efficient that he predicts that, with only a 10C temperature difference, a water pool of six meters on a side could supply the electricity for a house. He also suggests their use as "efficiency boosters" for augmenting the performance of electric or hybrid cars.



Brown #3,890,161 patented diode array using Millipore sheets

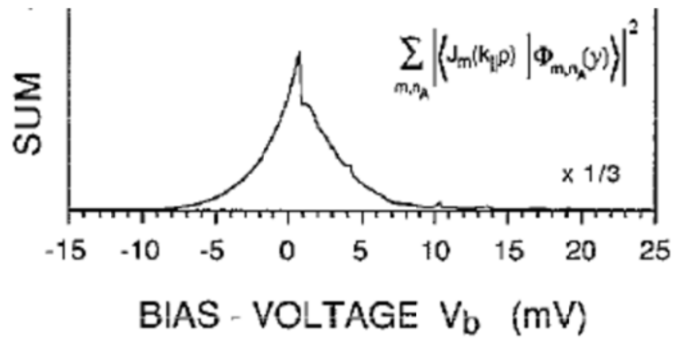
Other diodes which exhibit the ability to rectify EMF energy include the class of "backward diodes" which operate with zero bias (no external power supply input). (See US patent #6,635,907 "Type II Interband Heterostructure Backward Diodes" and also US patent #6,870,417 "Circuit for Loss-Less Diode Equivalent") These have been used in microwave detection for decades but have never been tested for thermal or nonthermal fluctuation conversion depending on their operating frequency range. There is every reason to presume they include such ZPE radiation conversion in their everyday operation but it is unnoticed with other EMF energy being so much larger in amplitude. US Patent 6,635,907 from HRL Laboratories describes a diode with a very desirable, "highly nonlinear portion of the I-V curve near zero bias." These diodes produce a significant current of electrons when microwaves in the gigahertz range are present. Another example is US Patent #5,930,133 from Toshiba entitled, "Rectifying device for achieving a high power efficiency." They use a 'tunnel diode' in the backward mode so that "the turn-on voltage is zero." Could there be a better device for small voltage ZPE fluctuations that don't like to jump big barriers?

Custom Made Zero Bias Diodes

In 1994, Smoliner reported, for the first time, resonant tunneling while applying no voltage at all to the one-dimensional quantum wells that his team had created. They used "anharmonic oscillation" to

[2] Note: www.google.com/patents is a good source of printable patents in PDF format.

substitute for zero point energy, which they ignored "for simplicity" though it was powering the tunneling of their electrons in each well. The figure below shows the remarkable German achievement, where the electrons prefer a zero voltage bias for the best results.

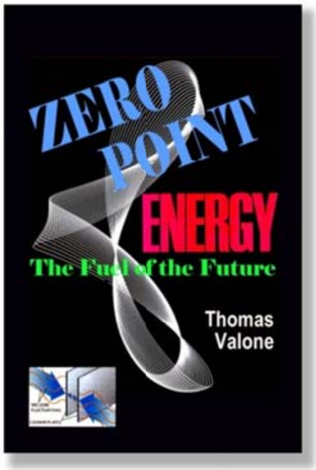


A completely passive, unamplified zero bias diode converter/detector for millimeter (GHz) waves was developed by HRL Labs in 2006 under a DARPA contract, utilizing an Sb-based "backward tunnel diode" (BTD). It is reported to be a "true zero-bias diode" that does not have significant 1/f noise when it is unamplified. It was developed for a "field radiometer" to "collect thermally radiated power" (in other words, 'night vision'). The diode array mounting allows a feed from horn antenna, which functions as a passive concentrating amplifier. The important clue is the "noise equivalent power" (NEP) of 1.1 pW per root hertz (picowatts are a trillionth of a watt) and the "noise equivalent temperature difference" of 10K, which indicate a sensitivity to Johnson noise, the source of which is known to be ZPE. Perhaps HRL Labs will consider adapting the invention for passive thermal and nonthermal zero-point energy generation (Lynch, et al., 2006).

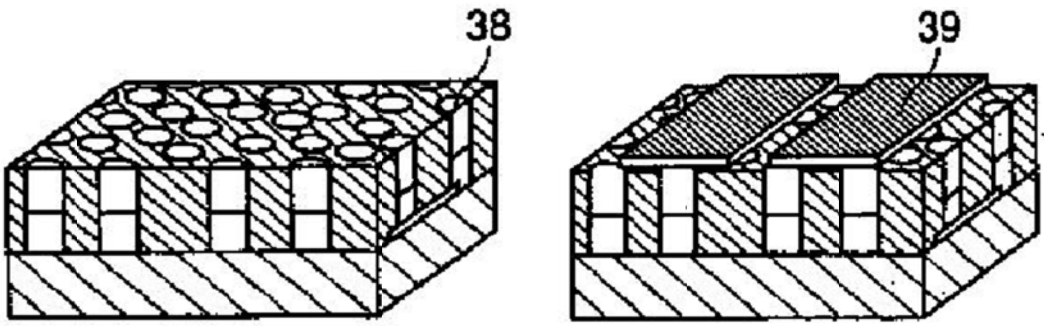
Another invention developed in 2005 by the University of California Santa Barbara is the "semimetal-semiconductor rectifier" for similar applications, to rival the metal-semiconductor (Schottky) diodes that are more commonly known for microwave detection. These zero bias diodes can operate at room temperature and have a NEP of about 0.1 pW but a high "RF-to-DC current responsivity" of about 8 A/W (amperes per watt). Most importantly, the inventors claim that the new diodes are about 20 dB more sensitive than the best available zero-bias diodes from Hewlett-Packard (Young et al., 2005).

There also have been other inventions such as "single electron transistors" that also have "the highest signal to noise ratio" near zero bias. Furthermore, "ultrasensitive" devices that convert radio frequencies have been invented that operate at outer space temperatures (3 degrees above zero point: 3K). These devices are tiny nanotech devices so it is possible that lots of them could be assembled in arrays to produce ZPE electricity and thermal fluctuation electricity with significant power density (Brenning et al., 2006).

Other devices which also will provide the fuelless electrical energy for cars, planes and homes by simply using zinc oxide or titanium oxide films that can convert ambient heat into electricity, as used in photovoltaic panels. A few reports indicate that these work reliably for years. Such solid-state diode converters will also grab the thermal fluctuations and nonthermal ZPE in the process and therefore can work in outer space, even without solar exposure, for spaceships and extraterrestrial settlements during dust storms and overnight. More information on ZPE and alternate energy conversion methods is contained in Valone's second book, *Zero Point Energy: The Fuel of the Future*.



Recent developments in nanotechnology assure us that the contemplated diode array can be significantly shrunk in size with no loss of power density, as compared to the Brown patent estimate for example (**Charles Brown #3,890,161**) from thirty years ago. Brown suggests that metal-metal diodes probably will be a popular brand for ZPE usage with millipore sheet assembly. While Brown patented his invention back in 1975, his idea has been revived and rejuvenated by **Kuriyama's "Method for Manufacturing a Semiconductor Device" US Patent #7,183,127** which cites Brown's patent and others with similar cylindrically shaped pores for p-n junction design. It is encouraging to note that Kuriyama's preferred range of diameter for each cylindrical diode is not smaller than 1 nanometer (nm) and not larger than 10 nm, an order of magnitude smaller than Brown.



Updated version of a Brown's p-n junction (a) diode array (38) and (b) with parallel conductors (39) added (Kuriyama, A., Miyata, H., Otto, A., Ogawa, M., Okura, H., Fukutani, K., and Den, T., "Method for Manufacturing a Semiconductor Device", U.S. Patent 7,183,127, Feb. 27, 2007, Fig. 4D and 4E).

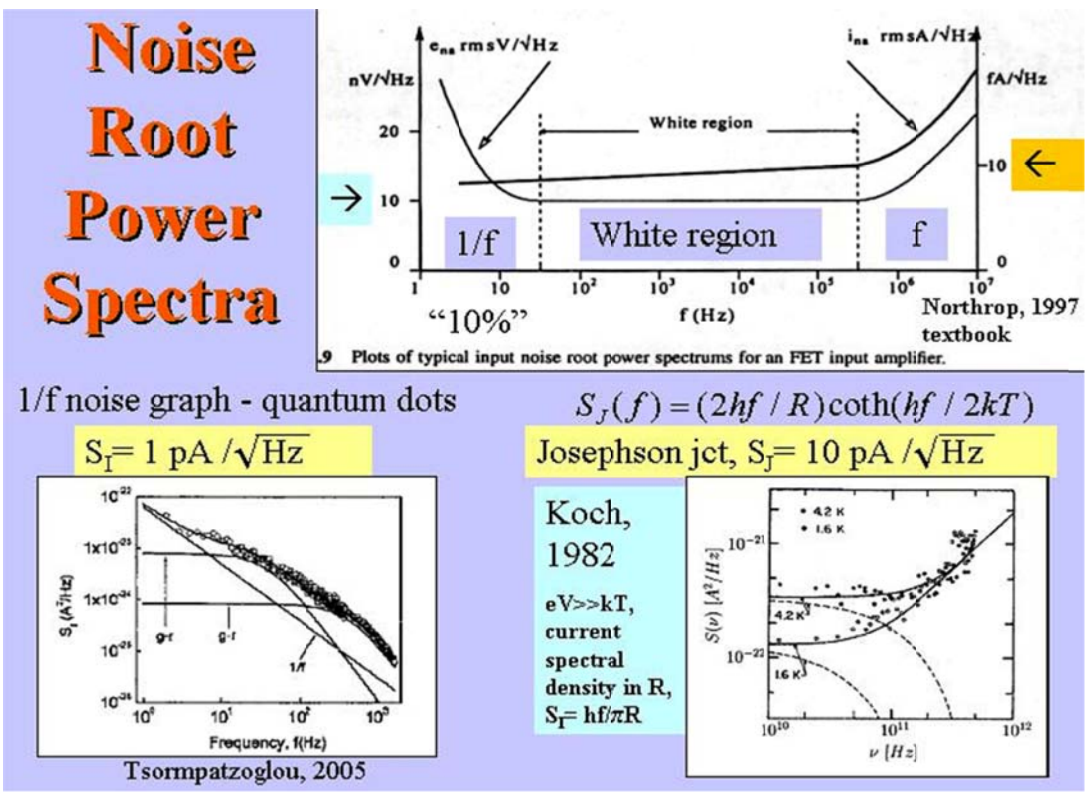
In addition, several references are cited for nano-hole and nano-wire construction techniques, especially with regard to p-n or p-i-n junctions. A typical example of aluminum-silicon nano-structures has achieved an average diameter of 3 nm per cylinder with a 7 nm spacing between them, with a length of 200 nm per cylinder. Kuriyama also notes that these dimensions also hold if germanium is substituted for silicon. He also includes the important option of an electrode plate on the top and bottom of the diode array, or an electro-conductive substrate for the bottom common conductor. The smallest diameter that Kuriyama cites as a practical example has a <u>1 nm cylinder width with a 3 nm spacing</u> between the diodes in 1000 nm square semiconductor dies, as seen in the Figure on this page. This creates a diode density of approximately 10^{12} diodes per cm^2 that is on the order of self-assembled quantum dot GaAs Schottky diodes grown by atomic layer molecular beam epitaxy (ALMBE) with InAs dots which have a diode density of 10^{11} per cm^2 (Hastas, 2003).

Potential Product Development

We are developing 3-4 initial product sizes, targeted for different power levels and applications. The first device might be a single layer VLSI chip, with approx. 10-50 M junctions to validate the concept and provide a test device for further development and selection of the best diodes, and their series length. This would likely only produce milliwatts to watt levels of power, but will be easy to produce test IC's and measure the results in a variety of environments, including in a faraday cage, and at varying temperature levels. The second device would be a larger die, to optimize the diode density, with a target of 200-500M diodes per IC, that might produce an output level of 50-100mw, which have significant market potential for sensors and other apps, like RFID tags, defense use, etc. Of concern also is whether the physical junction area per diode will be a factor in power generation which will be tested with micron-sized diodes versus nano-sized diodes.

The next level product would be to 'stack' multiple layers of the device design in order to attempt to achieve a power level that could be sufficient for powering devices like sensors, MP3 players, and some simple low power cell phones. Several of these devices might be used in tandem to power a typical 'Smartphone'. This application would be of interest to all Cell phone manufacturers, as it would obviate the need for recharging of any cell phones using this approach. This could dramatically expand the cellphone market, particularly in third world countries. The most interesting arrangement of diode arrays might be a convenient <u>10 cm^3</u> (10 cc with 2.1 cm per side), containing up to a hundred of the Phase 3 stacked arrays, which might yield a **power source of over 100W** !

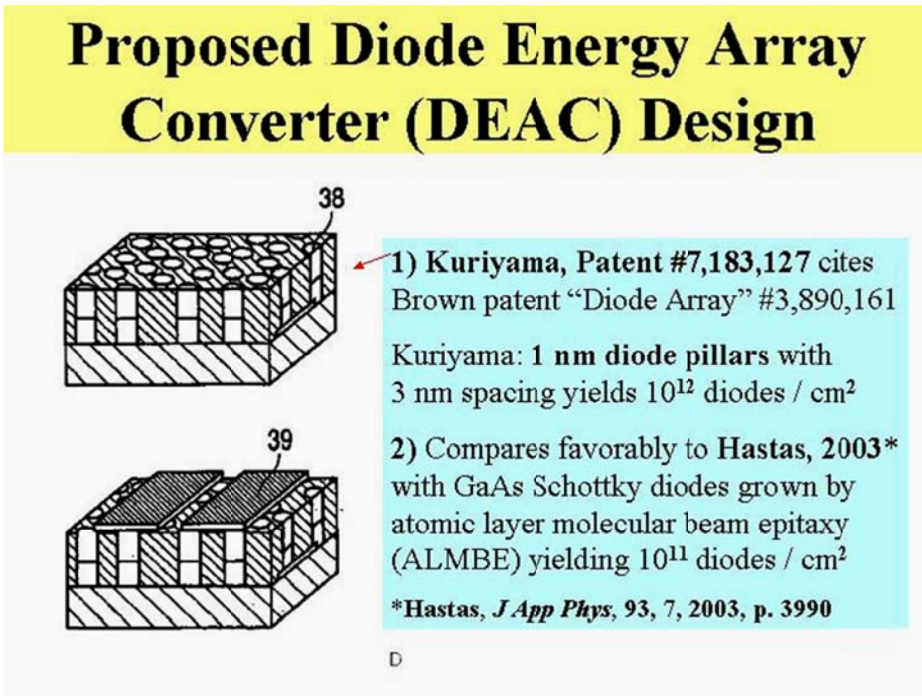
Below is a slide that estimates Johnson noise (ZPE) nonthermal energy per frequency band and the beginning of the thermal range which has an "f" proportionality instead of 1/f dependency.



Both are estimated to be in the range of 10^{11} per cm^2 diode density. Using a conservative packing density of 2 mm per layer (with 1.1 mm substrates), we can pack 5 diode array layers in 1 cc and therefore, 50 diode layers in 10 cc. This raises the diode density **to 5 x 10^{12} diodes** (*5 trillion diodes*) in a 10 cc box. This is a favorable quantity which could yield a potential estimated <u>50 Watt DC generator</u> from thermal and nonthermal noise combined, for the estimate of 10 pW per diode.[3] It is

[3] For comparison, see Haish, Bernard et al., US patent #7,379,286 "Quantum Vacuum Energy Extraction" which has a very <u>similar estimate for energy output</u> from a different, Casimir cavity device of the <u>same size</u> box (10 cc).

worthwhile noting that an array of a trillion molecular switches has been proposed using less than 100 zJ (100 x 10^{-21} joules) per switch based on direct experimental measurement of a single molecule (Loppacher, 2003). Loppacher et al. also note that it requires "less than a femtojoule of energy" to switch a solid state transistor, which may be useful in an advanced design of a switching DEAC for AC output. (Two samples of the slideshow from the March, 2009 SPESIF meeting are below.)



Prototype Development Stages

Phase 1 prototype involves hand assembling several 500 – 2000 diode arrays of an optimal zero bias diode, tested in a shielded enclosure and without the shielded enclosure for comparison, similar to the Tom Schum proof-of-principle diode array with capacitors for charge storage. SWI www.swri.org This effort is being expanded at this time, with limited funding.

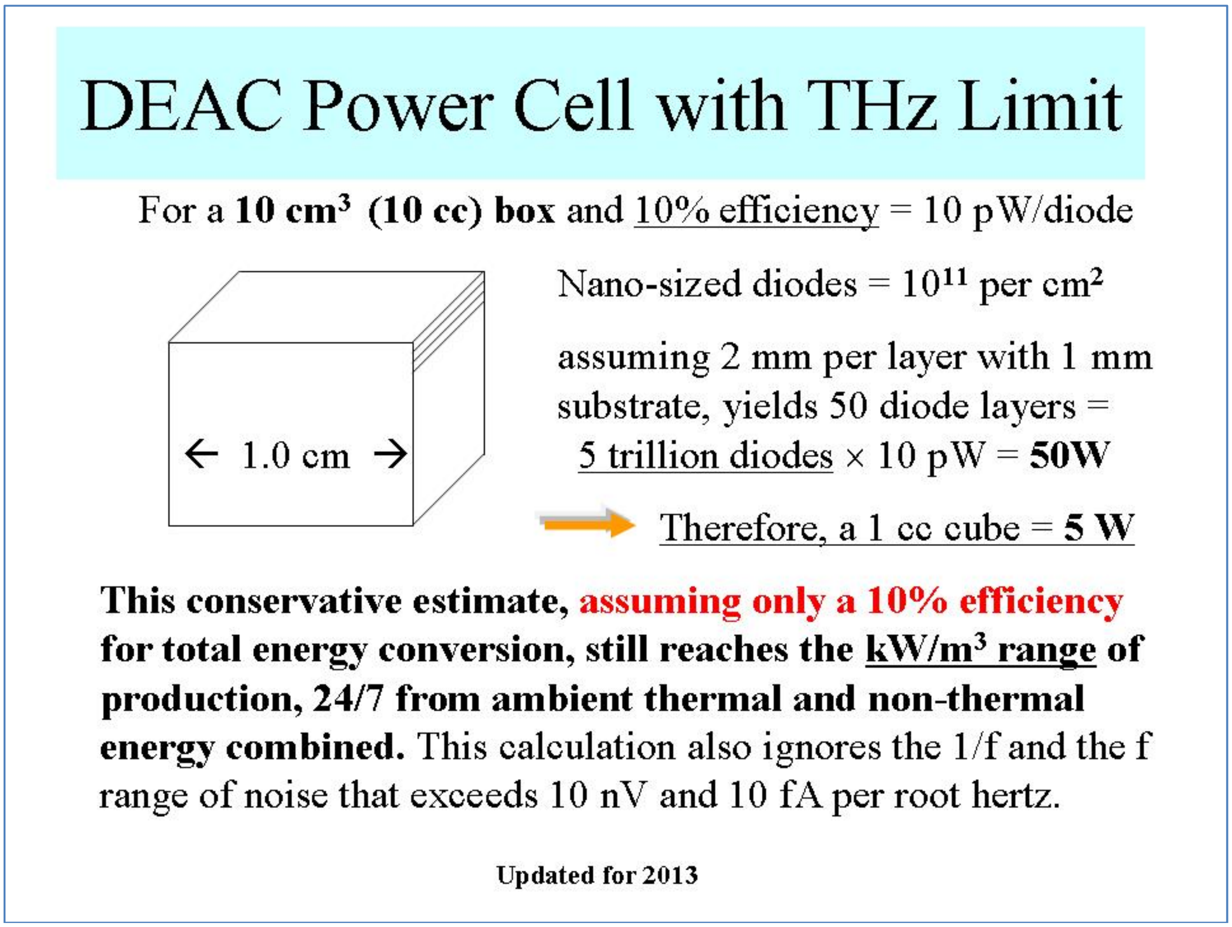
Phase 2 prototype is the next step, to design, build, and test **a one hundred thousand to 5 million diode array** with groups like www.MOSIS.com for fabrication and design for voltage, current and power output. CNSE-Albany, the Center for Nanoscale Sci and Tech, and NIST (CNST NanoFab) are suitable design/test facilities that we may work with. This special large scale diode array is expected to continually produce at least the minimum amount of electricity for useful purposes.

Phase 3 will be to manufacture a single layer of microdiodes, estimated to be in the range of **10-100 million diode density**. It is expected to confirm the expected 100 mW output (at zero degrees) from the conservative estimate of a single layer of 1 cm^2. The very large scale integration (VLSI) stage of 10^9 on a chip and 10^{11} per cm^2 diode density will very likely require additional funding.

Phase 4 - This phase is designed to perform a series of field tests with any interested partners, who might have suitable applications in the sub watt range, while determining the optimum product design and configurations, and ancillary components like ultracapacitors.

Potential Options and Methods for Commercialization

A one centimeter cube (1 cc) estimate of power generation is calculated below for a 10% efficiency. It should be noted that such a volume can conveniently be flattened to fit into a cell phone with dimensions on the order of 0.5 cm x 4 cm x 0.5 cm for example. Adding an ultracapacitor to the power circuit will allow deeper current draw and a charging up of the cap overnight.



The final stage of the DEAC box development will involve a choice of

1) the Hastas self-assembled GaAs Schottky diodes or
2) the Kuriyama high density nano-size cylinder-shaped diodes.

Note - The University of Wisconsin-Madison reported in 2010 as working on utilizing noise with zinc oxide crystals immersed in water to create energy with a 20% efficiency (J. Phys. Chem. Ltrs., DOI:10.1021/jz100027t). The University of Maryland has a "rectenna" diode array project under Professor Dagenais and the University of Colorado at Boulder also has a rectenna terahertz/petahertz project under the direction of Professor Moddel. In addition, the IRI Future Energy eNews has reported on enhanced antennas that concentrate the ambient available electromagnetic energy which can be converted into electricity. The latest in the series is November 2013 edition reprinting the Duke University 37% efficient power-harvesting, rectifying metamaterial capturing "various forms of electromagnetic wave energy" to convert them into useful electricity.

Textbook Noise Estimate

Intro. to Instrumentation and Meas., CRC Press, Northrop, 1997

Voltage fluctuation noise: nanovolt (nV) per root hertz*

Current fluctuation noise: femtoampere (fA) per root hertz

(background thermal noise and light scatter may add to this estimate)

Using Koch's measured frequency **THz upper limit** for current noise:

$$(10\ \mathrm{nV/Hz^{1/2}})(10\ \mathrm{fA/Hz^{1/2}})(10^{12}\ \mathrm{Hz}) = 0.1\ \mathrm{nW} = 100\ \mathrm{pW}$$

Assume a 10% efficiency yields **10 pW per diode** for a conservative estimate

*Also see Luukanen, NIST Quantum Electrical Metrology Division, Proc. of SPIE, V. 5410, 2004 (eq. noise **$\mathbf{nV/Hz^{1/2}}$**)

Financial Plan

IRI-VALONE DEAC
PROJECT BUDGET

PERSONNEL COSTS

PROJECT DIRECTOR	$ 80,000
TRAVEL	$ 5,000
ENGINEER	$ 10,000
SUBCONTRACTOR	$ 25,000
CNST NANOFAB AT NIST LAB	$ 5,000
TOTAL OF PERSONNEL COSTS	**$125,000**

OTPS (Other Than Personnel Services)

FACILITY RENT (TWO-YEAR)	$ 10,000
LABORATORY EQUIPMENT	$ 50,000
MOSIS FABRICATION	$ 50,000
DIODES	$50,000
INSTRUMENTATION	$40,000
ELECTRICAL SUPPLIES	$ 5,000
SUB-CONTRACTING DESIGN	$10,000
MAINTENANCE & SUPPLIES	$5,000
SOFTWARE	$5,000
TOTAL OF OTPS COSTS	**$225,000**
TOTAL BUDGET	**$350,000**

References

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Hastas, N. A., and Dimitriadis, C. A., "Low frequency noise of GaAs Schottky diodes with embedded InAs quantum layer and self-assembled quantum dots", *J. App. Phys*., V. **93**, N. 7, April 1, (2003), p. 3990.

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Jeong et al., On the non-Arrhenius temperature dependence of the interwell electron tunneling rate in quasi two dimensional organic quantum wells, *J. of Chem. Phys.*, Vol. 113, No. 17, November, 2000, p. 7613

Koch et al., Measurements of quantum noise in resistively shunted Josephson junctions, *Physical Review B,* Vol. 26, No. 1, July, 1982, p. 74

Lynch, Jonathan et al. "Unamplified Direct Detection Sensor for Passive Millimeter Wave Imaging" Passive Millimeter-Wave Imaging Technology IX, edited by Roger Appleby, Proc. of SPIE, V. 6211, 621101, 2006 - Also see: Schulman et al. "Sb-heterostructure interband backward diodes" IEEE Electron Device Letters 21, 2000, p. 353-355

Pinto, F., "Engine cycle of an optically controlled vacuum energy transducer" *Phys. Rev. B*, Vol. 60, No. 21, 1999

Smoliner et al., Tunnelling spectroscopy of 0D states, Semicon. *Sci. Tech.* Vol. 9, 1994, p. 1925

Valone, Thomas, "Proposed Use of Zero Bias Diode Arrays as Thermal Electric Noise Rectifiers and Non-Thermal Energy Harvesters", *Proceedings of Space, Propulsion and Energy Sciences International Forum* (SPESIF), Workshop on Future Energy Sources, American Institute of Physics, American Institute of Aeronautics and Astronautics, Huntsville AL, February 24, 2009

Young, A.C. et al. "Semimetal-semiconductor rectifiers for sensitive room-temperature microwave detectors", *App. Phys. Letters*, V. 87, 2005, p.16350

DEAC Slideshow presented to public audiences including the Naval Strategic Studies Group in 2009

Diode Energy Array Converters

Thermal and Nonthermal

Thomas Valone, PhD, PE

Integrity Research Institute

Navy Strategic Studies Group, Nov. 12, 2009

SPESIF-AIP Conf. Proc. Vol. 1103, 2009

Updated for 2013

Two Types of Energy Input for Ambient Harvesting Diode Energy Array Converters

1. ***Thermal Fluctuations*** and Ambient RF Noise
2. ***Nonthermal Noise Fluctuations*** Associated with Quantum Vacuum

1. Thermal Rectification with Tunnel Diodes

Fluctuation-Induced Tunneling Conduction in Carbon-Polyvinylchloride Composites

Ping Sheng, E. K. Sichel, and J. I. Gittleman
RCA Laboratories, Princeton, New Jersey 08540
(Received 13 February 1978)

PRL, V. 40, No. 18, 1978

We present evidence that in carbon-polyvinylchloride composites, consisting of aggregates of carbon spheres (100–400 Å) dispersed in the insulating matrix, the electrical conductivity can be ascribed to a novel mechanism of tunneling with potential-barrier modulation by thermal fluctuations. Theoretical consideration of the tunneling-probability modification by thermal fluctuating electric field across tunnel junctions yields expressions for the temperature and the field dependences of the conductivity in excellent accord with experimental results.

Thermal Noise Voltage $V_N = 4kTRF_{BW}$ where R = resistance, T= absolute temp., k= Boltzmann const., and F_{BW}= frequency bandwidth in Hertz

JOURNAL OF APPLIED PHYSICS **113**, 193509 (2013)

Efficiency limits for the rectification of solar radiation

Heylal Mashaal[a] and Jeffrey M. Gordon[b]
Department of Solar Energy and Environmental Physics, Jacob Blaustein Institutes for Desert Research, Ben-Gurion University of the Negev, Sede Boqer Campus 84990, Israel

(Received 25 February 2013; accepted 1 May 2013; published online 20 May 2013)

Efficiency limits for rectifying (converting AC to DC) incoherent broadband radiation are presented, prompted by establishing a fundamental bound for solar rectennas. For an individual full-wave rectifier, the bound is $2/\pi$. The efficiency boosts attainable with cascaded rectifiers are also derived. The derivation of the broadband limit follows from the analysis of an arbitrary number of random-phase sinusoidal signals, which is also relevant for harvesting ambient radio-frequency radiation from a discrete number of uncorrelated sources. © *2013 AIP Publishing LLC.* [http://dx.doi.org/10.1063/1.4805819]

Efficiency of Rectification

Marshaal (JAP 113, 2013) calculates thermal fluctuation's white noise probability, including harvesting ambient RF radiation, using full wave rectification of rectennas a 64% efficiency (half-wave diodes are ¼ as efficient)

$$\langle y \rangle = 2\int_0^\infty y \cdot P(y)dy = \frac{2}{\sqrt{2\pi}}\int_0^\infty y \cdot e^{-\frac{y^2}{2}}dy = \sqrt{\frac{2}{\pi}}$$

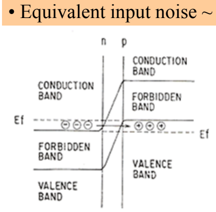
for which the rectification efficiency is

$$\eta = \langle y \rangle^2 = 2/\pi \approx 0.6366.$$

Even higher efficiencies are predicted with more rectification stages up to 98%

Tunneling Diode Currents

- HRL Labs, 2006, DARPA contract[1] developed BTD[2] for field radiometer with a noise equivalent power (NEP) of 1.1 pW/√Hz
- Thermal noise $V_N = 4kTRF_{BW}$ is the biggest contribution
- Equivalent input noise ~ 1 nV/Hz½ (Luukanen, NIST Boulder)



Thermal energy → can be rectified

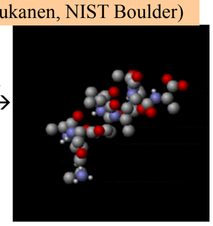
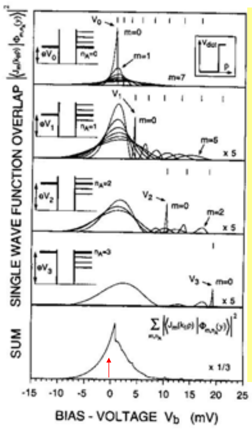


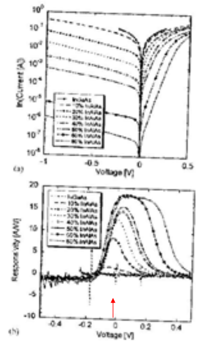
Diagram showing quantum tunneling

[2]BTD = Backward Tunnel Diode

[1]Lynch, Proc. of SPIE, 2006, p. 621101



Pillar shaped tunnel diodes - Smoliner, 1996

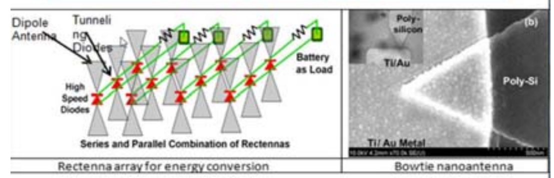


Noise eq. power = pW/Hz½
semimetal-semiconductor

Diode developed at UC Santa Barbara

Modified Schottky RF-DC diode – Young, 2005

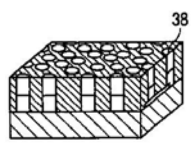
Nanorectifiers and Nanorectennas

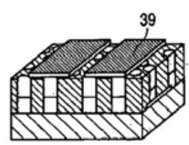


Principal Investigator(s): Dagenais, Mario
Invited Plenary Speaker for SPESIF
University of Maryland, ECE Dept.
http://www.umerc.umd.edu/projects/solar09

IRI is collaborating with Prof. Moddel – U of Colorado on the same rectennas

Diode Energy Array Converter (DEAC) Possible Design





1) Kuriyama, Patent #7,183,127 cites Brown patent "Diode Array" #3,890,161

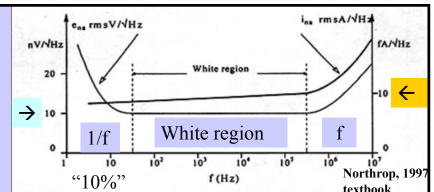
Kuriyama: **1 nm diode pillars** with 3 nm spacing yields 10^{12} diodes / cm²

2) Compares favorably to **Hastas, 2003*** with GaAs Schottky diodes grown by atomic layer molecular beam epitaxy (ALMBE) yielding 10^{11} diodes / cm²

Hastas**, ***J App Phys, **93, 7, 2003, p. 3990**

Series and parallel arrangement of diode groups to be optimized

Noise Root Power Spectra



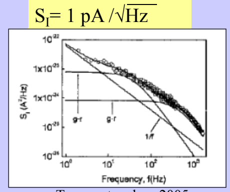
"10%"

Northrop, 1997 textbook

9 Plots of typical input noise root power spectrums for an FET input amplifier.

1/f noise graph - quantum dots

S_I= 1 pA /√Hz



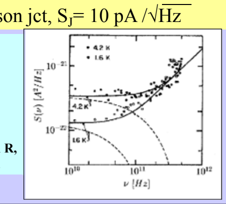
Tsormpatzoglou, 2005

$S_J(f) = (2hf / R)\coth(hf / 2kT)$

Josephson jct, S_J= 10 pA /√Hz

Koch, 1982

eV>>kT, current spectral density in R, S_I= hf/πR



PRL 96, 210601 (2006) PHYSICAL REVIEW LETTERS 2 JUNE 2006

Brownian Refrigerator

C. Van den Broeck
Hasselt University, B-3590 Diepenbeek, Belgium

ternative, and arguably more promising approach, would be to utilize thermal fluctuations rather than fighting them. A well-documented example is the Brownian motor [1,2], which generates power through the rectification of thermal fluctuations. In this Letter, we present a novel method of microscopic cooling based on a Brownian motor in which, almost paradoxically, thermal fluctuations themselves can be harnessed to reduce the thermal jitter in one part of the system.

PHYSICAL REVIEW B 67, 035301 (2003)

Full-frequency voltage noise spectral density of a single-electron transistor

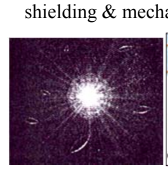
Andreas Käck and Göran Wendin

We calculate the full-frequency spectral density of voltage fluctuations in a single-electron transistor (SET), used as an electrometer biased above the Coulomb threshold so that the current through the SET is carried by sequential tunneling events. We consider both a normal-state SET and a superconducting SET. The whole spectrum, from low-frequency telegraph noise to quantum noise at frequencies comparable to the SET charging energy ($E_C/\hbar$) to high-frequency Nyquist noise, is described. We take the energy exchange between the SET

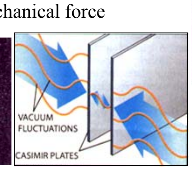
2. Nonthermal Energy

Quantum fluctuations of the vacuum create virtual particles (real for an instant) that produce shielding & mechanical force

- Zero-point energy is not conserved
- Helium stays liquid < 1°K
- ZPE density = 220 erg/cc in optical region

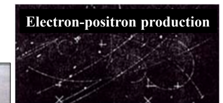


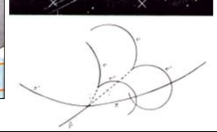
Koltick experiment



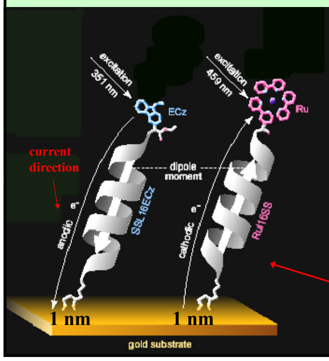
Casimir force pushes

Electron-positron production



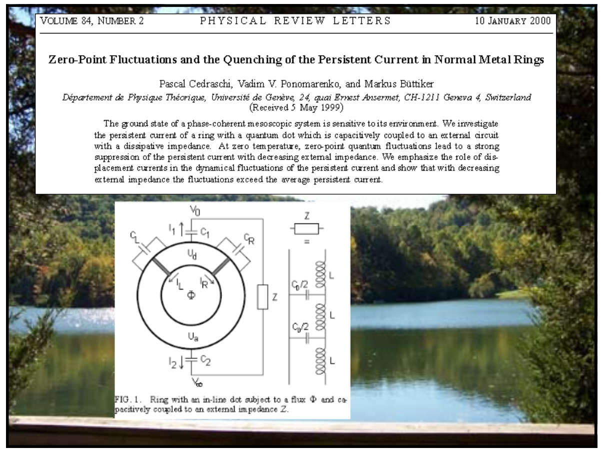


Rectifying Thermal and Nonthermal Electric Noise



- Brown patent, metal-metal diodes #3,890,161
- Single electron transistors (SET) high noise at zero bias
- High resistance good for more thermal noise
- Not related to Peltier effect that needs current flow
- Self-assembled diodes
- Peptide molecular photodiodes 1 nm across

Yasutomi et al. 2004 *Science* 304 1944



VOLUME 84, NUMBER 2 PHYSICAL REVIEW LETTERS 10 JANUARY 2000

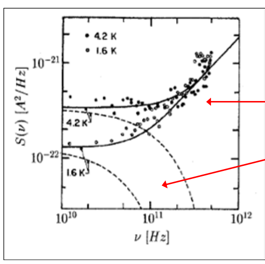
Zero-Point Fluctuations and the Quenching of the Persistent Current in Normal Metal Rings

Pascal Cedraschi, Vadim V. Ponomarenko, and Markus Büttiker
Département de Physique Théorique, Université de Genève, 24, quai Ernest Ansermet, CH-1211 Geneva 4, Switzerland
(Received 5 May 1999)

The ground state of a phase-coherent mesoscopic system is sensitive to its environment. We investigate the persistent current of a ring with a quantum dot which is capacitively coupled to an external circuit with a dissipative impedance. At zero temperature, zero-point quantum fluctuations lead to a strong suppression of the persistent current with decreasing external impedance. We emphasize the role of displacement currents in the dynamical fluctuations of the persistent current and show that with decreasing external impedance the fluctuations exceed the average persistent current.

FIG. 1. Ring with an in-line dot subject to a flux Φ and capacitively coupled to an external impedance Z.

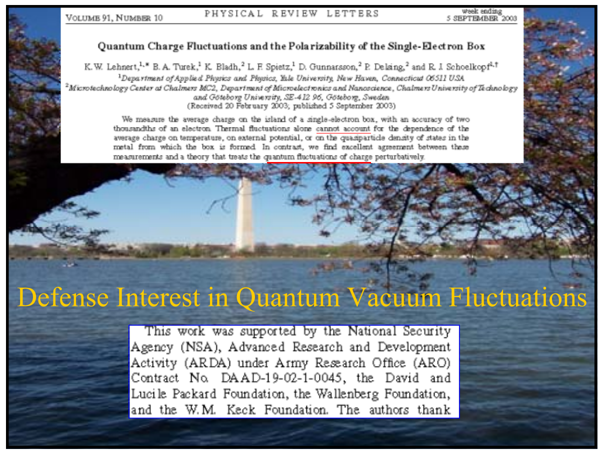
Nonthermal Energy in the Lab



"Laboratory Tests on Dark Energy"
Christian Beck, U of London, Jour. of Phys., Confer. Series 31, 2006, p. 123-130

- Josephson junction meas. at 10 GHz to 500 GHz (f_J = 2eV/h)
- Spectral density is Planck's 2nd radiation law for ZPE (h f_J > kT)
- Dashed line is Planck's first law for oscillators w/o ZPE (eV<kT)
- Dark energy = vacuum fluctuations directly affects electrons and other charges
- Beck analyzed Koch results
- Koch, UC Berkeley, Phys. Rev. B, 26, 1, 1982

- Valuable for space travel -



VOLUME 91, NUMBER 10 PHYSICAL REVIEW LETTERS week ending 5 SEPTEMBER 2003

Quantum Charge Fluctuations and the Polarizability of the Single-Electron Box

K. W. Lehnert,[1,*] B. A. Turek,[1] K. Bladh,[2] L. F. Spietz,[1] D. Gunnarsson,[2] P. Delsing,[2] and R. J. Schoelkopf[1,†]
[1]*Department of Applied Physics and Physics, Yale University, New Haven, Connecticut 06511 USA*
[2]*Microtechnology Center at Chalmers MC2, Department of Microelectronics and Nanoscience, Chalmers University of Technology and Göteborg University, SE-412 96, Göteborg, Sweden*
(Received 20 February 2003; published 5 September 2003)

We measure the average charge on the island of a single-electron box, with an accuracy of two thousandths of an electron. Thermal fluctuations alone cannot account for the dependence of the average charge on temperature, on external potential, or on the quasiparticle density of states in the metal from which the box is formed. In contrast, we find excellent agreement between these measurements and a theory that treats the quantum fluctuations of charge perturbatively.

Defense Interest in Quantum Vacuum Fluctuations

This work was supported by the National Security Agency (NSA), Advanced Research and Development Activity (ARDA) under Army Research Office (ARO) Contract No. DAAD-19-02-1-0045, the David and Lucile Packard Foundation, the Wallenberg Foundation, and the W.M. Keck Foundation. The authors thank

Nonthermal Spectral Density

Picojoules per second (pJ/s) = picowatts (pW)

Vacuum Fluctuations Spectral Density Equation*

Compare to 10^{17} Hz using 1 nm = λ resonant wavelength of diode junction and c/λ = f, put into

$$\int_{\omega_1}^{\omega_2}\rho(\omega)d\omega=\frac{\hbar}{8\pi^2c^3}\left(\omega_2^4-\omega_1^4\right) \quad \text{eV/m}^3$$

Einstein's E=hf

390 eV/nm³ = 10^{-15} J/nm³ = 10^{12} J/m³

Same order of magnitude

keV or femtojoule (10^{-15} J)

Now use gamma ray (10^{23} Hz) as upper frequency limit. ZPE density = 390 MeV/fm³ and an electron is a few femtometers in size, so vacuum energy density is 60 pJ per electron

*Milonni, ***The Quantum Vacuum***, Academic Press, 1994, p. 49

Combined Noise Estimate

Intro. to Instrumentation and Meas., CRC Press, Northrop, 1997

Voltage fluctuation noise: nanovolt (nV) per root hertz*

Current fluctuation noise: femtoampere (fA) per root hertz

(thermal noise, RF and light scatter all contribute to this estimate)

Using Koch's measured frequency **THz upper limit** for current noise:

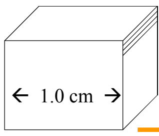
($10\ nV/Hz^{1/2}$)($10\ fA/Hz^{1/2}$)(10^{12} Hz) = 0.1 nW = 100 pW

Assume a 10% efficiency yields **10 pW per diode** for a conservative estimate

*Also see Luukanen, NIST Quantum Electrical Metrology Division, Proc. of SPIE, V. 5410, 2004 (eq. noise **nV/Hz** ½)

DEAC Power Cell with THz Limit

For a **10 cm^3 (10 cc) box** and <u>10% efficiency</u> = 10 pW/diode



Nano-sized diodes = 10^{11} per cm^2

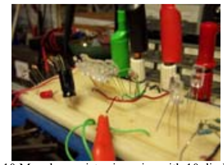
assuming 2 mm per layer with 1 mm substrate, yields 50 diode layers = <u>5 trillion diodes</u> × 10 pW = **50W**

<u>Therefore, a 1 cc "sugar" cube = **5 W**</u>

This conservative estimate, assuming only a 10% efficiency for total energy conversion, still reaches the <u>kW/m^3 range</u> of production, 24/7 from ambient thermal and non-thermal energy combined. This calculation also ignores the 1/f and the f range of noise that exceeds 10 nV and 10 fA per root hertz.

Updated for 2013

IRI Diode Energy Converter Research

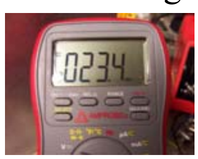


10 Megohm resistor in series with 10 diodes

Keithley 486 Picoammeter reads 2.27 nanoamps constant current with or w/o resistor in series

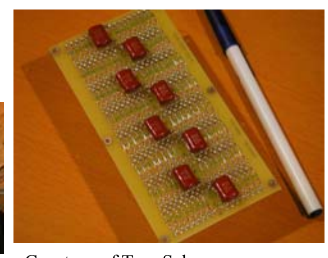
Voltage Readings with 10 Meg

23 mV across 10 MΩ = 2.3 nA



Two views of IRI Electromagnetics Research Lab

Diode Array Example



Courtesy of Tom Schum

Nonthermal Energy Summary

	Microsphere	Nanosphere	Picosphere	Femtosphere
Photon energy	infrared 1 eV	optical 1keV	X-rays 1 MeV	Gamma rays 1 GeV
E = mc^2	Si: 10^{44} eV	Ag: 10^{17} eV	Pt: 10^{11} eV	p: 940 MeV
ZPE energy	390 meV/μm^3	390 eV/nm^3	390 keV/pm^3	390 MeV/fm^3
Physical cross sectional area	3 x 10^{-12} m^2	3 x 10^{-18} m^2	3 x 10^{-24} m^2	3 x 10^{-30} m^2
Scattering cross section	10^{-8} m^2	10^{-15} m^2	10^{-21} m^2	10^{-30} m^2

Highest energy Density: picojoules

***Classical electron radius e^2/mc^2 = 2.8 fm**

Electromagnetic	Mechanical	Fluid Dynamic	Thermodynamic
Dual sphere - Mead	Casimir engine - Pinto	Inertia Effects - Froning	Quantum coherence - Allahverdyan, Scully
Focusing ZPE - Ford	Cavity QED - Haroche	Hydrodynamic model – Bohm	Brownian motors - Astumian
	Spatial squeezing- Hu	Casimir cavity - Maclay	Transient fluctuation theorem - Crooks
	Casimir cavity optimized design - Maclay		Thermal fluctuation rectifiers – Brown, Ibarra-Bracamontes, Engel
	Vibrating cavity photon emission - Hizhnyakov		Quantum Brownian nonthermal rectifiers - Goychuk

Valone, ***Practical Conversion of ZPE***, 2003

Further Research Details

- Single layer series testing to be pursued for next paper
- Two independent verifications of zero bias diode array already have surfaced
- Refrigeration effect is expected
- Hastas (GaAs Schottky diodes) measured 100 pA of forward current at zero bias
- Hundreds of kW/m^3 is possible even without RF energy harvesting and 1/f and f contributions
- Noise amplification is well known, enhancement of shot noise is an example that resulted in charge accumulation

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301-513-5242

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EXPERIENCE HIGHLIGHTS

1996-Present U. S. PATENT & TRADEMARK OFFICE Alexandria, VA
Primary Examiner,
Physics, Measuring, Testing, Instrumentation Class 324, Art Unit 2858, GS-14. Electric and nonelectric properties, testing in specific environments, calibrating electric meters, sensing electricity, internal combustion engine ignition system, electromechanical switching devices, thermoelectric properties, electrostatic field sensing, fault detection, impedance/admittance testing, power measurement, motors/generators. Elected as Board member of the PTO Society, 1999. Organized Art Unit trip to NIST Conference with 16/40 time included, 1998.

1991-Present INTEGRITY RESEARCH INSTITUTE Washington DC
Professional Engineering, Energy Research Scientist, Physicist
Technical consultation for companies, law firms, authors, video production. Clients include Global Atomics, Inc., Lightworks AV, Alternative Energy Institute, Starburst Foundation, The Magnetizer Group, Saladoff and Associates, ELF International, Sachs-Freeman Associates, AquaQueen, Newline Investments. Services provided: Electrical product design/development, energy, propulsion, bioenergetics, expert testimony and opinion, electromagnetic field/energy consulting, report writing, book publishing.

1987-1990 INTEGRITY RESEARCH CORPORATION Buffalo, NY
Engineering Manager
Responsible for Engineering Department instrumentation projects, managed engineers and technicians, initiated several magnetic field instrument lines, trained engineering industrial student interns from SUNY at Buffalo for several years, designed 2% accuracy calibration procedures, designed specification sheets and training manual, represented company at shows, conferences.

1981-1986 ERIE COMMUNITY COLLEGE (SUNY-ACCREDITED) Buffalo, NY
Instructor
(Physics, Robotics, & Electrical Tech Depts.) Courses taught included Engineering Physics, Technical Physics, Introductory Physics, AC Electricity, Electronics, Digital Logic, Microprocessors (6502), Environmental Science, as well as laboratory sessions for above courses. Designed Instrumentation & Process Control Curriculum at direction of College President. Participated in Project Outreach by teaching SUNY-contract microprocessor courses (6800) at Chevrolet Plant, Tonawanda, NY.

1976-1980 SCOTT AVIATION, DIV. OF ATO, INC. Lancaster, NY
Research Scientist
(Research & Development Department) Developed gas detection linearization circuit for Series 9000 instruments, directed planning/installation of computerized test facility for catalytic sensors, performed feasibility study of non-pressurized zeolite oxygen tank for firemen, published design articles, managed acquisition and installation of computer network, numerous sensor circuit design and testing projects. Advanced to Director of R & D by fourth year.

MEMBER: Institute of Electrical and Electronic Engineers, Union of Concerned Scientists, World Innovation Foundation, and formerly, American Institute of Aeronautics and Astronautics, Bioelectromagnetics Society, World Future Society.

Awards and references available upon request.

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James Dunn, CEO, NASA Center for Tech Development, Westborough MA, 508-870-0042
Paul Werbos, PhD, Space Solar, National Science Foundation, Arlington VA, 703-292-8339

RECTENNA SOLAR CELLS, METAL-INSULATOR TECHNOLOGY & GEOMETRIC DIODES

Optical Rectennas: Quantum theory of operation & experimental results
Ultra-high-speed metal-insulator device technology
Ultra-high speed, low capacitance, low resistance diodes for rectenna solar cells and more

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Phiar Corporation

- Whatever happened to Phiar Corporation?

Popular Press

- New Scientist: Is night falling on classical solar cells?
- Scientific American
- IEEE Spectrum

Overview

- Metal-insulator electronics

CNO STRATEGIC STUDIES GROUP
686 CUSHING ROAD
NEWPORT RI 02841-1207

14 September 2009

Mr. Thomas Valone, PhD, PE
Integrity Research Institute
5020 Sunnyside Avenue, Suite 209
Beltsville, MD 20705

Dear Dr. Valone,

I am writing in follow-up to your conversations with CDR Keith Gordon and am delighted that you can meet with the CNO Fellows. We're all set for the afternoon session 1330-1630 on Tuesday, 12 November 2009 at Sims Hall in the SSG Innovation Center. We anticipate about half the time for presentation and half for discussion over a two part session. I am sure the Group will benefit from your presentation on "Zero Point Energy and the Future."

You are part of our Fall Program which provides insights on key trends and technologies that may contribute to future warfighting concepts. In addition to Zero Point Energy, topics will focus on innovation, mind stretching, future conflicts and threats, future warfare concepts, operational art, team-building synthesis and planning, and science and technology. In your important area, you will assist the Group in shaping their work and in their concept formulation.

CDR Gordon is the coordinator for your visit; his phone number is 401-841-3355, e-mail keith.gordon@usnwc.edu. Please contact Laura Krue for assistance on administrative issues; her phone number is 401-841-2625, e-mail laura.krue@nwc.navy.mil, and fax number is 401-841-4783.

We look forward to seeing you in November!

Sincerely,

Jim H

JAMES R. HOGG
Admiral, U.S. Navy (Ret)
Director

Encl:
SSG XXIX Roster

2009 - 2010 (May 09)

CHIEF OF NAVAL OPERATIONS
STRATEGIC STUDIES GROUP

GENERARE FUTURUM

SSG XXIX

CAPT Thomas H. Bond, USN, 1600

CAPT James D. Davis, USN, 3100

CAPT Daniel H. Fillion, USN, 1310

CAPT Allan G. Galsgaard, USN, 1440

CAPT Fernandez L. Ponds, USN, 1110

CAPT Michael W. Selby, USN, 1110

Col James J. Tabak, USMC

CAPT Edward L. Takesuye, USN, 1120

CAPT Paul F. Thomas, USCG

Col Mark E. Weatherington, USAF

Dr. Valone with a handful of the full house of Navy Commanders who were briefed (below) for three hours on the applications for zero point energy converters for practical use in 2009

From: Jim Dunn <jpdunn1@charter.net>
Sent: Monday, April 01, 2013 10:40 AM
To: iri@erols.com; 'Rick Payne'
Subject: intro for the massive diode array project

Tom - I have discussed the massive diode array project with several people in the IC business, including Rick Payne at TI.

He is prepared to discuss this further with some fab. engineers at TI, and has some questions for you.

I think that what we want to do can be done fairly easily, with very high junction densities, but we need to pick the proper diode devices.

Thanks,

Jim Dunn
Future Solar Systems, LLC
508-560-9421

Thomas Valone

From: Jacqueline & Thomas Valone <jtvalone@gmail.com>
Sent: Sunday, May 15, 2011 8:10 PM
To: Thomas Valone
Subject: Fwd: Aloha from Hawaii

Follow Up Flag: Follow up
Flag Status: Flagged

xxx

---------- Forwarded message ----------
From: **hyson@planetpuna.com** <hyson@planetpuna.com>
Date: Tue, May 10, 2011 at 7:31 PM
Subject: Aloha from Hawaii
To: IRI@starpower.net, adrainbarber1@gmail.com

Aloha Dr. Valone,

Thanks for talking with me. We are interested in helping to developing the zero bias diode.

In particular, my colleague Adrian Barber is most interested in speaking with you about all this.

Contact information:

Adrian Barber email: adrainbarber1@gmail.com

Michael Hyson email: michaelhyson@yahoo.com
(profile at: www.planetpuna.com/hyson)

Please let us know a good time to call. We are Greenwich -10

Mahalo,

Dr. Michael Hyson

--
Jacqueline Valone

Wireless Device Converts "Lost" Energy into Electric Power

By Karyn Hede, Duke University, Nov. 7, 2013, http://www.pratt.duke.edu/news/wireless-device-converts-lost-energy-electric-power

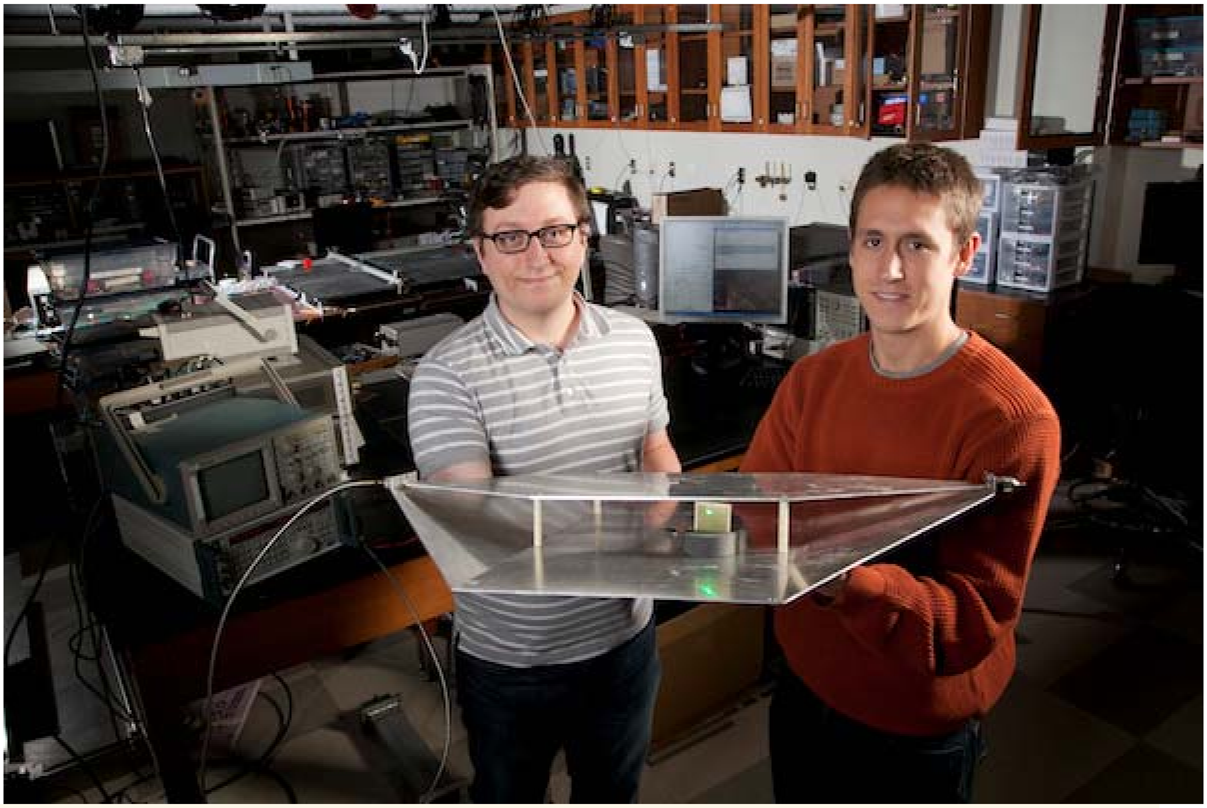
Using inexpensive materials configured and tuned to capture microwave signals, researchers at Duke University's Pratt School of Engineering have designed a power-harvesting device with efficiency similar to that of modern solar panels.

The device wirelessly converts the microwave signal to direct current voltage capable of recharging a cell phone battery or other small electronic device, according to a report appearing in the journal *Applied Physics Letters* in December 2013. (It is now available online.)

It operates on a similar principle to solar panels, which convert light energy into electrical current. But this versatile energy harvester could be tuned to harvest the signal from other energy sources, including satellite signals, sound signals or Wi-Fi signals, the researchers say.

The key to the power harvester lies in its application of metamaterials, engineered structures that can capture various forms of wave energy and tune them for useful applications.

Undergraduate engineering student Allen Hawkes, working with graduate student Alexander Katko and lead investigator Steven Cummer, professor of electrical and computer engineering, designed an electrical circuit capable of harvesting microwaves.



Duke engineering students Alexander Katko (left) and Allen Hawkes show a waveguide containing a single power-harvesting metamaterial cell, which provides enough energy to power the attached green LED.

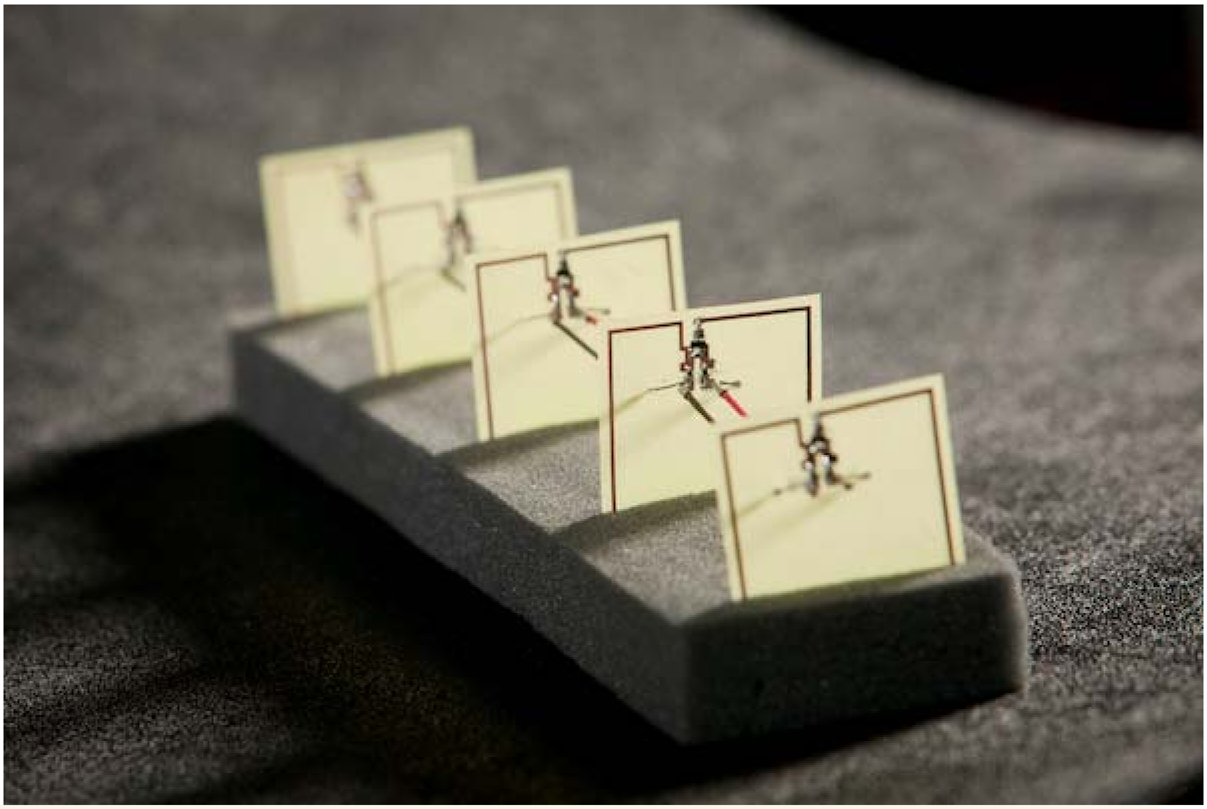
They used a series of five fiberglass and copper energy conductors wired together on a circuit board to convert microwaves into 7.3V of electricity. By comparison, Universal Serial Bus (USB) chargers for small electronic devices provide about 5V.

“We were aiming for the highest energy efficiency we could achieve,” said Hawkes. “We had been getting energy efficiency around 6 to 10 percent, but with this design we were able to dramatically improve energy conversion to 37 percent, which is comparable to what is achieved in solar cells.”

“It’s possible to use this design for a lot of different frequencies and types of energy, including vibration and sound energy harvesting,” Katko said. “Until now, a lot of work with metamaterials has been theoretical. We are showing that with a little work, these materials can be useful for consumer applications.”

For instance, a metamaterial coating could be applied to the ceiling of a room to redirect and recover a Wi-Fi signal that would otherwise be lost, Katko said. Another application could be to improve the energy efficiency of appliances by wirelessly recovering power that is now lost during use.

“The properties of metamaterials allow for design flexibility not possible with ordinary devices like antennas,” said Katko. “When traditional antennas are close to each other in space they talk to each other and interfere with each other’s operation. The design process used to create our metamaterial array takes these effects into account, allowing the cells to work together.”



This five-cell metamaterial array developed by Duke engineers converts stray microwave energy, as from a WiFi hub, into more than 7 volts of electricity with an efficiency of 36.8 percent—comparable to a solar cell.

With additional modifications, the researchers said the power-harvesting metamaterial could potentially be built into a cell phone, allowing the phone to recharge wirelessly while not in use. This feature could, in principle, allow people living in locations without ready access to a conventional power outlet to harvest energy from a nearby cell phone tower instead.

“Our work demonstrates a simple and inexpensive approach to electromagnetic power harvesting,” said Cummer. “The beauty of the design is that the basic building blocks are self-contained and additive. One can simply assemble more blocks to increase the scavenged power.”

For example, a series of power-harvesting blocks could be assembled to capture the signal from a known set of satellites passing overhead, the researchers explained. The small amount of energy generated from these signals might power a sensor network in a remote location such as a mountaintop or desert, allowing data collection for a long-term study that takes infrequent measurements.

The research was supported by a Multidisciplinary University Research Initiative from the Army Research Office (Contract No. W911NF-09-1-0539).

An open access copy of the original report is freely available from Duke University for those who do not have access to *Applied Physics Review.*