

Classical Field Theory-based Design of Green Energy Systems

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ABSTRACT

Novel technologies are often traced back to fundamental science. Green energy, particularly fission-, gamma- and photo-electric (PE) cells, are no exception. Based on the fundamentally sound Lorentz Theory, this article aims to explain how implementation of blackbody-cavity PE cells can greatly increase efficiency of the integrated conventional thermal and photovoltaic systems. Long before quantum mechanics, Lorentz suggested that some disturbances, like waves, travel with particles through a certain medium - motionless ether. The waves are described by the Klein-Gordon equation and dispersion relation $\omega^2 = c^2 k^2 + \omega_c^2$. In hydromechanics, they are known as non-propagating waves and a boundary frequency ω_c is called the cutoff frequency. The group velocity approaches zero and waves are not propagating if their frequency is below the cutoff frequency ω_c . Their group and phase velocity are related by $vu = c^2$, in the infinite k limit $v = u = c$ and the group velocity maximum are c . A quantum object is considered as a vibrating particle or material body with a rest mass m moving in resonance with wave characterized by the cutoff or Compton frequency $\omega_c = mc^2 / \hbar$.

Keywords: Lorentz theory, blackbody-cavity, photoelectric, solar, fission - electric cell, CIGS cylindrical photovoltaic, carbon nano-tube cathode.

INTRODUCTION

The goal of this research article is to offer an innovative approach to current nuclear and solar power systems that would greatly increase their energy output and efficiency. The proposed blackbody cavity design compensates for the loss of energy inherently incurred by solar receivers due to radiation from the absorbing surface. Electron emission in a cavity can be achieved through three common mechanisms: photoelectric (PE), thermionic (TE) and field emission.

The most heavily deployed solar power technologies are photovoltaic (PV) panels and concentrated solar power (CSP) systems. A proposed modification of CSP, flat or CIGS cylindrical PV modules combines solar photoelectric (PE) and thermal systems to efficiently convert solar radiation to electricity and thermal energy (to be stored and/or converted to electricity). Mo, Pt, Al, Ni, or Ag based thin films back contact material for CIGS solar cells can serve as the PE anode. An inverter such as hybrid PE solar panel and thyatron changes the energy from direct current (DC) to alternating current (AC), which is typically used in buildings.

CLASSICAL FIELD THEORY

The two fundamental wave types in the quantum medium are the longitudinal and transverse waves. Classical physics provides the accurate field values (group velocity and intensity of

transverse waves) into Maxwell's field equations, and characterizes antiparticles as longitudinal waves with negative group velocity in Newtonian mechanics. The pairs such as electron-positrons described by the four Klein-Gordon equations are balanced by the energy $2mc^2$ at the distance $d=e^2/(4\pi\epsilon_0 mc^2)=1.4\cdot 10^{-15}\text{m}$. Originally, the energy mc^2 was introduced to stabilize the charged particles by compensating the Coulomb interactions.

Analogy between the acoustic and quantum waves naturally appears when we consider waves on a discrete string of atoms. The frequency of the oscillation should be computed in terms of the mass of the atom M and the string elastic constant βa . Here a is the distance between two neighboring atoms. The length of the string of N atoms is $L=Na$, the material density $\rho=M/a$ and the characteristic speed $c=(\beta a/\rho)^{1/2}$. It can be shown that deviation of the n th atom from the equilibrium position is $z_n=A_n e^{i(\omega t + k n a)}$, where n is integer. The internal energy density $u = 2 \frac{\hbar c}{\pi^3} k_m^2$ and discrete set of k is connected with medium structure.

Then the number of oscillators or traveling wave states between k and dk in the polar coordinates is $dN = \frac{4\pi}{(2\pi)^3} k^2 dk$ and their energy is $\hbar ck$, we have $k_c=10^{16}\text{m}^{-1}$ and $u = 3 \frac{\hbar c \pi}{(2\pi)^3} k_m^4 \approx 10^{37} \text{ N/m}^2$. For wavelengths shorter than mean distance between the atoms (cutoff wave number $k_c=\pi N/L=\pi/a$), propagation becomes impossible.

As $k_c=10^8 \text{ cm}^{-1}$ and $c=3\times 10^5 \text{ cm/s}$, the cutoff frequency of the material oscillations $\omega_c=ck_m\approx 10^{13}\text{s}^{-1}$. If the cutoff frequencies of vacuum oscillations ν_c is $\sim 10^{24}\text{s}^{-1}$, it leads to restriction on its characteristic size $>2c/\nu_c=10^{-16}\text{m}$. For ideal quantum fluid or radiation, pressure of energy density is $P=u/3$.

In 1923, de Broglie suggested that real wave pilots the particle in a vacuum. At that time, the idea was not accepted as conflicting relativity. Instead of a systematic effect analysis, the constancy of light velocity was postulated to justify the result of the Michelson or Sagnac experiment on open paths, in which the Earth appears not to rotate around the Sun.

Mathematically, it was based on the Lorentz transformation that preserves a wave equation in moving frame instead of time. As an algebraic expressions - Lorentz transformation is equally applies to any wave motion, the variable values of light velocity were used in Einstein original manuscript. Moreover, field equations of general relativity do not lead to attraction between material bodies [1-4].

Photoelectric Solar and Radioisotope Systems

In the photoelectric (PE) modules, spacing between transparent or cavity-type anode and cathode allows for greatly improved fundamental properties compared to, photovoltaic (PV) modules. Particularly, a combined photoelectric, photovoltaic and blackbody-cavity thermal solar module converts incident sunlight to both electricity and high-temperature thermal energy. This greatly increases thermal insulation and efficiency of the concentrated solar

power (CSP) systems, green buildings and radioisotope thermal generators (RTG). Even under one sun illumination, PE cathode/gate directional selectivity has the potential to raise receiver efficiency levels to those of concentration systems.

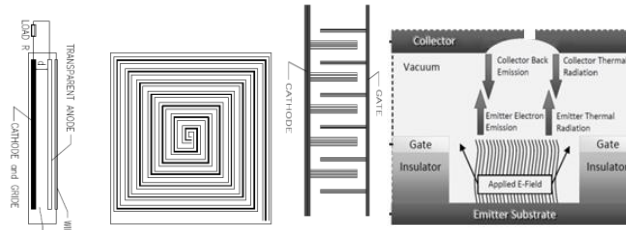


Figure 1: PE panel with in-plane gate and CNT electrodes.

A principal loss mechanism for solar receivers in solar-thermal systems is radiation from the absorbing surface. By the first law of thermodynamics and Planck's law of blackbody radiation, the absorption efficiency of solar absorber is given as

$$\eta = E_{jn} - E_{out} / E_{in} = 1 - \sigma T^4 / DNI * C.$$

Here E_{in} is the absorber input solar power, E_{out} is power loss due to thermal radiation from the absorber, σ is Stefan-Boltzmann constant, T is the temperature of the absorber, DNI is direct normal irradiance of sunlight, and C is concentration ratio of the absorber.

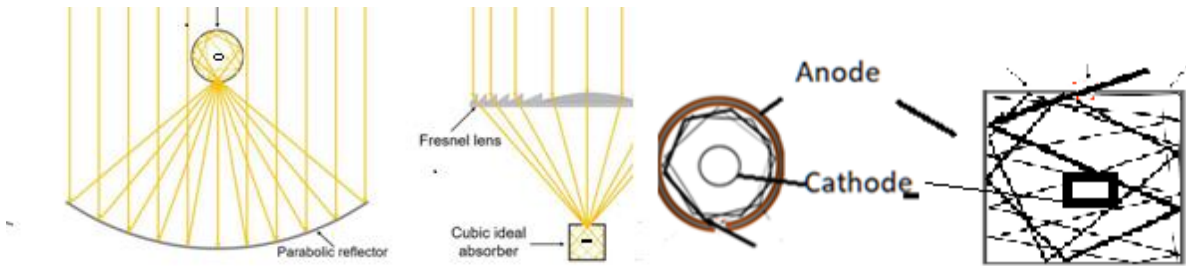


Figure 2: Photoelectric blackbody-cavity CSP plants and PE-cavity converters

The surfaces with high solar absorption and low thermal emission could efficiently convert solar radiation into electricity and useful heat. Ni pigmented anodized Al is one of the typical examples of spectral selective surfaces for efficient photo/thermal conversion of solar energy. Here the metal particles are much smaller than the wavelengths of the electromagnetic radiation

In a typical absorber of a parabolic trough solar receiver with a concentration ratio of 70 and an operating temperature of about 400°C, about 17% of solar energy input would be lost via thermal radiation. The radiation loss can be reduced by using the photoelectric/photovoltaic blackbody-cavity receiver.

In the blackbody-cavity receiver, the maximum enhancement factor for absorption with respect to a single pass absorption is limited to $4n^2$ with n being the refractive index of the absorbing layer. The discharge geometry with Al, thoriated tungsten, phosphorus-doped

polycrystalline diamond, graphene or GaAs photo-cathodes activated by cesium and oxygen surrounded by the Al anode is one of the several possible configurations. Unlike the single-junction Shockley-Queisser limit as a function of band gap, the efficiency of photoelectric solar power improves monotonically as the electrode work functions shrink. The preliminary analyses of the CSP with thermal energy storage (TES) show that the PE/PV blackbody cavity and solar thermal system efficiencies are around 55% and absorber/cathode temperature can be high up to 900°C under 10 suns.

Unlike conventional PV module, the concentrated PV or PE receiver must be continuously aligned with DNI (direct normal irradiance) for continuous power generation. In green buildings, hybrid photoelectric/thermal systems produce electricity and hot water simultaneously. The plasma-enhanced photoelectric PE power module can also serve as a thyatron [5, 6].

The ratio between DNI and global normal irradiance (GNI) can be used to partly identify atmospheric conditions. The solar radiation striking the earth is close to collimated, thus a PE cell facing the sun absorbs direct sunlight at near normal incidence but emits IR radiation in all directions. The PE x-ray or gamma ray radioisotope generator model is very similar to an ideal PE solar power device.

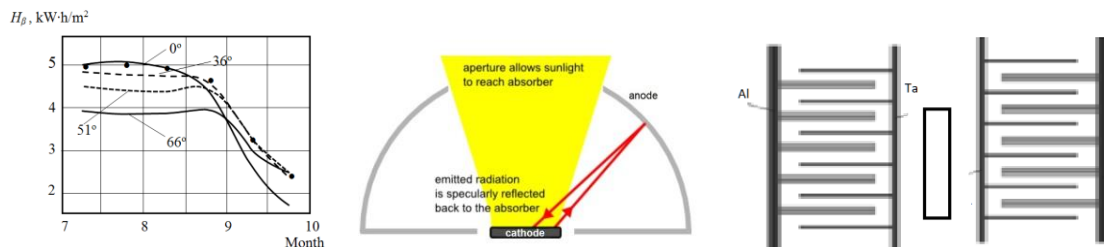


Figure 3: DNI for a month on an inclined surface of the southern orientation of the cylindrical PE/PV solar module and radioisotope photoelectric generator.

The cylindrical PE/PV module can generate higher electric power than the conventional CIGS PV module. Cylindrical panels demonstrated positive proof of their durability against wind of 50 m/s through the field test. As compared with other conventional heat engines, a thermionic energy converter (TEC) offers remarkable advantages due to its compactness, high power density, silent operation, and long operational lifespan. Also, nano-grating comparable with the de Broglie wavelength of the electron can change the electronic and electron emission properties of materials. Studies on the influence of nano-grating structures on the properties of materials have shown that this process may lead to effects similar to those created by doping with donors.

The resistivity values measured in Si-based nano-grating layers, for example, were approximately 10^{-2} Ohm cm, similar to those of Si semiconductors doped with phosphorus impurities having a volume concentration of 10^{18} cm^{-3} .

It is almost independent of initial resistivity of samples: 5000 Ohm cm, 8.5-11.5 Ohm cm, 12-14 Ohm cm.

Nuclear Power Systems

There is a difference between well-tested nuclear pumped lasers and high voltage fission/radioisotope-electric cells. For example, the beta-energy from tritium has an endpoint of 18 keV, though the average beta energy is ~6 keV.

The higher energy electrons are usually slowed down in the material, creating many knock-on electrons along the way in the material. The lower energy (~1 keV) knock-ons are collected by the anode material. The proposed plane, spherical or cylindrical radioisotope unit is composed of alternate layers of high-Z, cathodes with thickness less than electron range and relatively thick low-Z anodes which are insulated by vacuum or other insulating materials. The radioisotope source, such as cobalt 57 or 60, cadmium 109, tin 199m, gadolinium 153, and gold 195 may be used. The X ray or gamma ray sources emit photons up to approximately 200 keV. As an illustration: for a 50 keV gamma ray source, the tantalum layer has a thickness of 5 microns, and the aluminum layer has a thickness of 25 microns with a vacuum spacing between the plates sufficient to avoid breakdown.

It had been determined that each cell, one tantalum and one aluminum layer, will absorb about 5% of the incident photons for a 50 keV gamma ray source. The radioisotope source may be distributed in the central cathode layer and a larger number of layers may be used by coating next Ta layer on Al layer. Up to 20 cells in series can be very efficient.

To integrate electrical-in-nature nuclear energy into green grids, a gas cooled water moderated small modular reactor (SMR) can be used. A fuel cycle converts nuclear waste (depleted uranium (DU) and spent fuel) into an emission-free fuel and medical isotopes. A high reduction of nuclear waste can be realized in the coupled fast-thermal reactor having a near-critical $\Delta k_{11}=10^{-3}$ fast booster with radial legs surrounded by a sub-critical blanket with a breeding ratio of 1.0. The core gain is approximately $A/(1-A \times k_{21})$, where k_{11} , k_{22} , the multiplication factors of the zones 1 and 2 on their own; k_{21} and k_{12} are the coupling coefficients, and $A=k_{12}/(1-k_{11}) (1-k_{22})$ is the gain of the core with $k_{21}=0$.

In the region between fast-thermal zones. dilute lithium deuterioxide LiOD in heavy water or solid LiD with depleted uranium and moderator are used. The fusing of the produced, tritons, with deuterium releases 14 MeV neutrons. The latter high energy neutrons produce direct fission of the fertile material, i. g., depleted uranium, releasing about 3.5 neutrons per fission and 200 MeV. energy.

The core has feedback/vent loops 15 with gas purification system, heat exchangers 17 and inner reflector 28 (layer of water backed by LiD and DU layer). Detectors 12 on the feedback loops provide means for in-core monitoring and detection of a pressure tube leak.

Transfer of delayed neutron, gamma emitters from the blanket 22 and radioisotope-charged coaxial D-T neutron source with a tritium gas or solid distributed target can be used to control the booster 21. The DEC concept could be incorporated into a target-distributed accelerator design, in which an additional electric field compensates for lost beam energy in the target [8, 9].

A very simple estimate of the critical mass can be done. Carbon is an excellent neutron moderator. It also has high strength and good electrical and thermal conductivity. If we fill all the available space exterior to the D-T neutron source with carbon, the ratio of carbon atoms to uranium atoms is approximately 1.4×10^5 . The minimum critical mass of uranium mixed with graphite is approximately 40 kg at this C/ ^{235}U ratio assuming the neutrons are reflected at the outside of a spherical assembly. Other materials such as water or Be or water can be used.

Breed and burn reactor with triode-type fission-electric cell and hydrodynamic test loop concepts are illustrated in Figure 4.

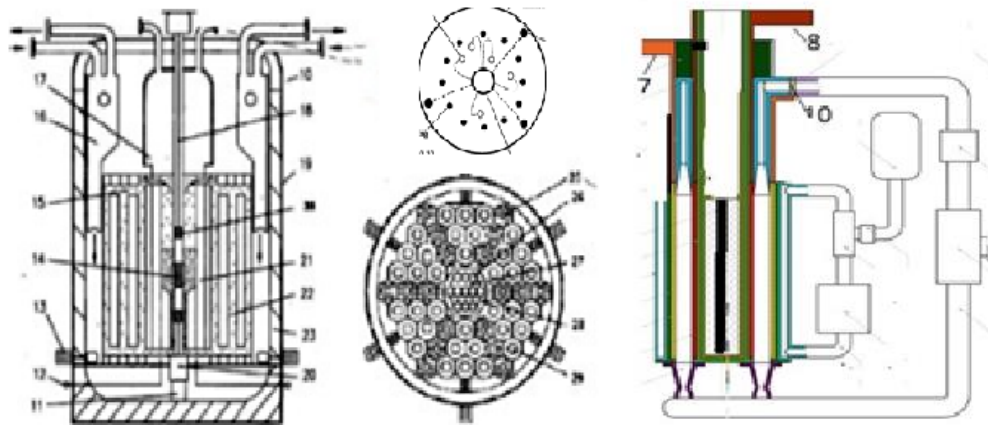


Fig. 4: Breed and burn reactor with in-plane gate FE cells and hydrodynamic fuel channel test loop.

In the fission-electric (FE) cell, the anode is held at a potential of several million volts. The space between the electrodes is evacuated to serve as an electrical insulator. Each fragment has a positive charge of approximately 20 electron charges and thus could be stopped if the anode has a potential of about 4 MV. The cathode is coated with a thin layer of fuel to permit the fission fragments to escape.

Large quantities of low energy electrons are stopped by the surrounding gate at a potential of about -10 kV. The energy density of α -decay isotopes exceeds that of chemical energy storage by 6 orders of magnitude. In the FE/ α cells, α -decay and spontaneous fission Pu 238, Cf 252 or Cm 250 that emit high-energy charged particles can be used. Cf 252 decays by alpha emission (96.91%) and spontaneous fission (3.09%) which results in an overall half-life of 2.645 years. The average neutron energy is 2.13 MeV and the most probable energy is 0.70 MeV. Its neutron energy spectrum is similar to the U 235 and Pu 239 fission sources used in nuclear reactors and weapons.

The spherical or cylindrical FE/ α nuclear battery is composed of alternate layers of heavy nuclei cathodes with thickness less than fission fragment range and thick light nuclei anodes

such as Be which are insulated by vacuum. Output voltage can be increased by cascading several cells in series.

The fuel such as Pu 239, Pu 238, Cf 252 and Am 241 of cathode layers may be deposited on the previous layers of Be moderator/anode. To utilize the decay energy of spent fuel, the photoelectric radioisotope converter can be used as a part of a dry storage cask (DSC) shielding.

CONCLUSION

To improve nuclear and solar energy technologies, we have to go back to the basic science. There are large incentives for FE and cylindrical CIGS photovoltaic/PE cell development because similar technologies are being used. Due to their shape and construction, they have unique features that planar PV panels do not have, including vertical applications and capture sunlight over an angular range of 360°. The optical cavity PE/PV system is capable of achieving receiver efficiencies comparable to an ideal absorber. As emission at large angles is confined, then the IR radiation loss could be reduced without affecting the absorption.

In the PE cavity the absorber is hot, which is compatible with solid state solar-conversion technologies such as solar thermionic or thermoelectric generators. A classical model can be used to design a highly reliable system for remote applications such as the space missions to the outer planets, autonomous well-logging, zero energy buildings or remote military facilities.

The conventional radioisotope thermal generator (RTG), has low efficiency (~4%), low voltage (generally less than 100 volts) and very high operating temperature. Recently, three radioisotope battery technologies (thermo-photovoltaic (TPV) conversion battery using Pu 238 with an 87-year half-life, thermo-electric (TE) conversion battery also using Pu 238, direct-conversion battery using boron-carbide and Po 209 with a 102-year half-life) were analyzed. Using the radiation decay products (α , β , positron, and γ) directly - avoiding the heat cycle - has potential for higher efficiency power sources. The direct-energy-conversion (DEC) method of converting beta-emissions from Po 209 produced a higher conversion efficiency because the heat cycle was avoided.

The energy release per decay of Pu 238 is 5593.2 keV. While not very efficient at generating electrical energy, conventional Pu 238 source is efficient for the heat application. The α -decay of Pu 238 produces heat, which can be also converted to electricity. Target efficiencies of 8.5%, 7.2%, and 10% were predicted. Many alpha, beta and gamma emitters occur naturally in the radioisotopes found in the natural radioactive decay chains of uranium, thorium and actinium.

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