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Integrative-design of radio-nuclear source shielded with scintillation crystals for sustainable light-powering of photovoltaic cells

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Abstract

The proposal evaluates the feasibility to develop radioisotope reactors for generation of luminescence. The engineering could be achieved by using the energy of beta (β) and gamma (γ) particle emissions by non-fissionable radioisotopes, to excite scintillation crystals.

The radioisotopes would be covered by a dense shield of scintillation substances, capable by becoming excited to deplete the energy of radiation by emitting light which in turn would be directed by mirrors to power photocells and generate electricity.

This manufacturing approach could minimize the possibility of harmful radiation leaks, allowing the use of rather small quantities of radioisotopes, without having to resort to a heavy lead shielding. This opens the door for many applications, for example to cover the energy needs of a house or building. Safety operating conditions should be implemented: for example, by resorting to keep the chip in a metal box connected by optical fibers, to deliver the light or electric energy, to the places where the energy-using appliances would be located.

Solar sails propulsion by a luminescence-nuclear plant, could achieve continuous acceleration to reach a significant percent of the velocity of light, which would allow interstellar navigation. Light-transfer technology could easily allow miniaturization, with much smaller development costs by permitting toy-sized prototypes. Example by replacing the battery in a model airplane, a radio scintillation-chip, allows the aircraft to fly for months without landing to control weather, crops, etc.

Additionally, this model could be use for the planning and developing of larger airplanes, with reduced fueling needs. Similarly, by decreasing the use of fuels in many applications could prevent considerable CO_2 contamination. The generation of cheap artificial light, not only could improve food production but increasing photosynthesis would also decrease CO_2. These chips also appear to offer considerable advantage, as a suitable energy source for nanotechnology.

Introduction

The designs of nuclear reactors involve large amounts of radioactive materials which require heavy lead shielding. Light-weight radioisotopes could be used as sustainable, long lasting-sources of energy, which do not involve like the heavy radioisotopes, the danger of generating a chain reaction. Lightweight nuclear sources are presently in use, to generate by heat-transfer electrical power.

However, heat-transfer by nuclear reactors, involve engineering mechanical solutions which because of their complexity, could only be scaled to much larger sizes, than it is possible with radioisotopes-scintillation crystals. The heat-transfer is subjected to heat losses greater than light-transfer, because of friction between moving constitutive parts.

The scientific background [(1)(2)(3)] is well established, and the paper only intents to convey the techno feasibility and the relative advantage of its adoption. The improvement of using the scintillation methodology is not only that transfer of light does not require mechanical devices, but also decreases shielding needs, if the scintillation substance is used as a covering shield of the radioisotopes.

Protection by the scintillation enclosure could be enhanced, by designing mirrors to surround the radioactive crystals, allowing only light to emerge. These energy-transducer radioactive crystals could be sized to play the role of nano-reactors.

Theoretical background

Table 1: Scintillation substances and range of fluorescence emission: NaI with 1% Tl (thallium) could be made more efficient by the addition of the scintillation substances some are listed.

- Crystal made of: NaI with 1% Thallium (Tl) plus Dimethyl POPOP, etc.
- Crystal excited by γ and / or $\beta \rightarrow$crystal l*l $\rightarrow h\nu$ (or uν).

Acronym	Scintillation function	Fluorescence emission maximum [nm]
BBOT	**Prim. & sec.**	**425-435**
Butyl-PBD	**Primary**	**360-365**
PBD	**Primary**	**360-370**
PPO	**Primary**	**360-365**
Bis-MSB	**Secondary**	**420-430**
Dimethyl POPOP	**Secondary**	**425-430**

Empirical assay

To prevent radiation leak, an empirical assay can be done; by encasing a core radioisotope fiber into scintillation crystals shaped as cylindrical tubes of progressive larger and larger diameters, until radiation of the core is no longer registered by a Geiger detector. Table 3, allows calculating the remaining energy of any leaking counts, which would be very much decreased by their partial absorption. Direct assay of any energy left-over, in the remaining counts, could be done by the simple methodology of interpolation pages of paper, between the source and the Geiger detector.

The period of half-disintegration allows to express that the fraction of the initial nucleus remaining after n periods is (t $½^n$). Therefore, after 7 periods of half life, the quantity of the remaining radioactive material is less than 1%.

Table 2: Selecting radioisotopes according to a desirable half-life: Curie: 3.10^{10}dissintegrations per second. REM (Radioactive environmental monitoring): 1 rad x Q. Rad: Unit of absorbed radiation dose equivalent to 100 ergs per gram of absorbent matter. Q=Quality factor; Energy captured per unit length. Skin annual dose limit: 50,000 mrem. These radioisotopes should be maintained in sealed sources.

Radioisotope	Half-life	β (MeV)	γ (MeV)	(millirem/hr)**	(millicurie)**
Strontium-89	50.52 (days)	1.481			
Sodium-22	2.6 years	0.55i, 0.58 and 1.8	0.51 and 1.27	370	13.3
Cobalt-60	5.3 years	0.31	1.17 and 1.33	48	14.4
Cobalt-57	271.8 days		<0.13		
Strontium-90 decays →Yttrium-89	29 years 3 days	0.54 2.26		740	0
Cesium-137*	33 years	0.52 and 1.18	0.66	777	4.1

* *Decays to short-lived* ^{133}Ba ** *Dose rate at 30 cm from source.* Cadmium 109, half life 453 days, shows an intermediate period of life.

^{89}Sr and ^{90}Sr are well-known hazards, because replace the physiological function of calcium in the body. Therefore, protection to contamination in addition to radiation is essential, the radioisotope would be sealed in a glass constituted by the scintillating crystal itself or when needed an additional cover of unbreakable glass.

Table 3: Reaching distance of β and γ: The energy of beta decreases by exciting atoms, ionizing molecules and electron slowing-down (bremsstrahlung) which may generate x-rays. The effect of x-rays or γ is to transfer energy to electrons with photoelectric effects ionizing molecules and Compton interaction. If a given scintillation thickness, does not eliminate totally the energy of the particles, but for example retains from 1 MeV only 0.01 MeV, the remaining effects would correspond to this in the table to the lower energy level.

Energy of β [MeV]	Air [m]	Corporal tissue (cm)	Aluminum [mm]
0.01	0.023	0.00027	-
0.5	1.5	0.18	0.59
1	4.2	0.5	1.5
3	12.6	1.5	5.6
Energy of γ [MeV]	-	Corporal tissue (cm)	Lead [mm]
0.01	-	0.131	0.076
0.1	-	4.05	1.2
1	-	9.8	8.9

Table 4: This technology appears to be adequate to replace all sort of long-lasting batteries, and scintillation $^{89}Sr^{39}$ reactor, of similar size than a battery pack for a model airplane (500 g), would allow 24 hours of constant operation for weather, crops, illegal activities, etc., for over a month.

Technology	Consume [W*h*]
Model airplane	**500**
Personal computer	**350**
Laser printed	**100**
Monitor 14''	**75**
TV 14''	**53**
Telephone	**16**
Radio AM/FM	**9**

Calculation of the weight-ratio between radioactive and covering scintillation crystals to minimize harmful radiation leaks

When an energetic particle or a photon (radiation) goes across a scintillation crystal like NaI (molecular weight, mw=150), some of the atoms along the trajectory become excited and thereafter return to their ground state with emission of light.

Each scintillation molecule subtracts from the kinetic energy of the colliding β-particle or excitation by the γ-radiation, an average of 30 to 50 electron volts (eV), as the excitation energy required for the emission of one photon.

It could be calculated if a scintillation crystal contains enough molecules, to match by energy transfer most of the possible trajectories of β-particle or γ-radiation. The steps to calculate: a. Reaction, b. Disintegration per second per mol, c. Scintillation weight to efficiently prevent radiation leak (calculated as that required for photon emission) d. Energy yield.

a. Disintegration reaction for ^{90}Sr

$^{90}Sr^{38} \longrightarrow {}^{90}Y^{39} + {}^{0}e^{-}$ (kinetic energy=0.54 MeV per atom)

$^{1}n^{0}$ (neutron) $\longrightarrow {}^{1}p^{1}$ (proton) + $^{0}e^{-}$ (β-particle)

In a subsequent β-minus reaction:

$^{90}Y^{39} \longrightarrow {}^{90}Zr^{40} + {}^{0}e^{-}$ (2.26 MeV) (Half-life 64 hr).

Total energy per atom= 0.54 MeV+2.26 MeV=2.8 MeV

b. Disintegration per second per mol of $^{90}Sr^{38}$

For both β-particles from $^{90}Sr^{38}$ decay: 2.8 MeV divided by about, i.e., 40eV (transfer energy during each collision) = 7×10^{4} photons per β-particle trajectory, requires an equivalent number of atoms in the scintillation crystal. Half-life: 0.5mol= 3.01×10^{23}disintegrations/29 yrs (28.8 yrs)= 1.05×10^{22}/1yr =1.05×10^{22}/ 3.1536×10^{7}s =3.32×10^{14} disintegrations/s. Hence, multiplied by 7×10^{4} photons yield the number of photons 2.331×10^{19} emitted/s/mol $^{90}Sr^{38}$.

c. Scintillation weight to efficiently prevent $^{90}Sr^{38}$ radiation leak

Assuming collision efficiency of 1 β particle per 4,000 of scintillation molecules during particle trajectory, the relationship would be: 2.3×10^{19} photon emitted×4,000 (correction for collision efficiency) = 9.2×10^{22} n° of required scintillation NaI atoms. Molar ratio of required atoms of NaI: 9.2×10^{22} /6.02×10^{23}=15.3% (molar ratio NaI/$^{90}Sr^{38}$: 150/90=1.66) =25.4% for 90g =23g of NaI will deprive from its kinetic energy and trap the β-particles emitted by 90g of $^{90}Sr^{38}$.

d. Energy yield of $^{90}Sr^{38}$

Total half-life energy per mol=$3.012\times10^{23}\times2.8$ MeV=8.432×10^{23}MeV

$$\frac{8.432\times10^{23}\text{MeV}}{28.8\text{yr}}\times\frac{1\text{yr}}{8.76\times10^{3}h}=\frac{3.342\times10^{18}\text{MeV}}{h}\text{ or }\frac{4.45\times10^{-20}k\text{W}h}{\text{MeV}}\Rightarrow 0.15k\text{W}h/mol$$

a. Disintegration reaction for $^{89}Sr^{38}$

$^{89}Sr^{38} \longrightarrow {}^{89}Sr^{39} + {}^{0}e^{-}$, (β-Radiation ($^{0}e^{-}$) =1.481 MeV/atom).
Half-life: 50.55 days. Activity: ≥ 500 mCi/g at Oak Ridge Nat. Lab. reactor discharge. Radiopurity: 99%.

b. Disintegration per second per mol of $^{89}Sr^{38}$

1.481 MeV/40eV=3.7×10^{4} photons. Half-life: 0.5mol= 3.01×10^{23}disintegrations/ 50.55day= 5.957×10^{21}/day=5.957×10^{21}/ 8.64×10^{4}s =9.89×10^{16} disintegrations/s; multiplied by 3.7×10^{4} photons yield the number of photons 3.66×10^{21} emitted/s/mol $^{89}Sr^{38}$.

c. Scintillation weight to efficiently prevent $^{89}Sr^{38}$ radiation leak

Assuming collision efficiency of 1 β particle per 500 of scintillation molecules during particle trajectory, the relationship would be: 3.66×10^{21} photon emitted×500 (correction for collision efficiency) = 1.83×10^{24} n° of required scintillation NaI atoms. Molar ratio of required atoms of NaI: 1.83×10^{24} /6.02×10^{23}=303% (molar ratio NaI/$^{89}Sr^{38}$: 150/90=1.66) =503% for 89g =450g of NaI. Disposal: after 7 × 50.55 d = 354 days remains only 1% of radioactivity

d. Energy yield of $^{89}Sr^{38}$

Half-life= 223.5 MW*h*/50.52 d.=4.424MW*h*/day=184.3 *k*W*h*/kg of $^{89}Sr^{38}$.

$$\frac{3.0115\times10^{23}\times1.481\text{MeV}}{50.55\text{day}}\times\frac{1\text{day}}{24h}=\frac{3.676\times10^{20}\text{MeV}}{h}\times\frac{4.45\times10^{-20}k\text{W}h}{1\text{MeV}}=16.358k\text{W}h/h/mol$$

A battery of 18 g $^{89}Sr^{38}$ + 90 g NaI=110g theoretical weight for energy source of 3.2 *k*W*h* 20% efficiency: 650W*h*. An additional 300g would be required to complete the battery device. This one could compete with Lithium batteries, which are presently in use to operate the electrical motor of model airplanes (table 4). Its advantage the operative fly-time exceeds one month without need to replace the scintillation battery.

a. **^{60}Co disintegration reaction:** Beta-minus (β = $^{0}e^{-}$) decay:

$^{60}Co^{27} \longrightarrow {}^{60}Ni^{28}$+ (0.31MeV $^{0}e^{-}$) + (1.17MeV γ + 1.33MeV γ), Total energy=2.824 MeV

Production of ^{60}Co: ^{59}Co (not radioactive) + neutron $\longrightarrow$ ^{60}Co + γ (Q = 7.492 MeV). ^{60}Co can not start a chain reaction and since disposal is still unsolved, it may be purchase at lower price than ^{89}Sr. However, ^{60}Co it has to be handed more carefully.

b. Calculation of disintegration per second per mol of $^{60}Co^{27}$.

3.0115×10^{23} / 5.1 yrs=5.90×10^{22}(disinteg./yr)= $5.90\times10^{22}/3.1536\times10^{7}$s =$1.87\times10^{15}$ (disinteg./s) 2.824×10^{6} eV (energy summation of 1β + 2γ/50eV transfer energy per collision) ⇒5.65×10^{4} photons/(1β + 2γ)× 1.87×10^{15} disinteg./s =1.06×10^{20}(photon emitted /s/mol of $^{60}Co^{27}$).

c. Scintillation weight to efficiently prevent $^{60}Co^{27}$ radiation leak

β-particles from $^{90}Sr^{38}$ and $^{89}Sr^{38}$ have greater collision efficiencies than the mixture of β and γ-radiation of $^{60}Co^{27}$. This required introducing a correction factor for the lower efficiency of the NaI scintillation shielding for $^{60}Co^{27}$. Collision efficiency of 1/10000 of radioactive vs NaI. The relationship: 1.06×10^{20} photons emitted/s/mol=1.06×10^{24} ⇒ 264g of scintillation molecules required to absorb the energy of 60g of $^{60}Co^{27}$.

d. Energy yield of $^{60}Co^{27}$

Energy output for full life of 1kg of $^{60}Co^{27}$= 2.63×10^{3} MW*h*; half-life⇒ 1.315×10^{3} MW*h*/5.3yrs = 2.481 MW*h* /yrs=28*k*W*h* per kg of $^{60}Co^{27}$=1.68*k*W*h* per mol of $^{60}Co^{27}$.

Photosynthesis

Figure 1 illustrates a possible design for a long lasting light-emitting lamp. This technology does not require cabling, and could be useful for regions far away from electrical power lines and/or which have not access to trained electrical engineers.

Adding scintillation and fluorescent substances together to melted glass or any convenient translucent material, will allow manufacturing artificial crystals of different efficiency and with light emission of different wavelengths. This, allow to obtain an emission spectra, similar to the one generated by day-light florescent tubes, presently used for plant growing.

For its general use, the lamp has the inconvenience that it cannot be turned off. However, it could be devised a sliding mechanism for the radioactive fiber, that would allow its shifting from a scintillation-translucent container tube to a metal (lead) container tube.

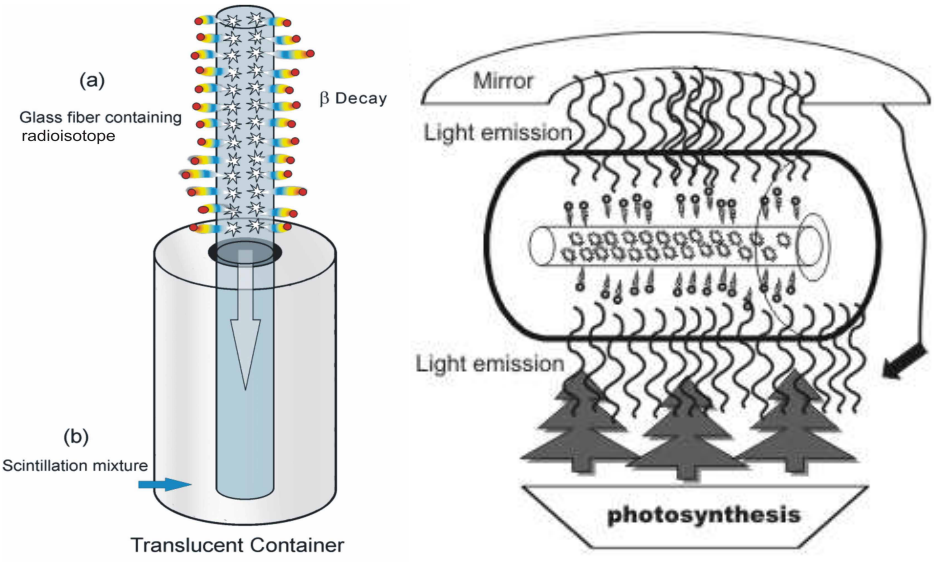

*Fig1.**Radioisotope excited scintillation lamps.** a) Glass fiber chip of encased radioactive isotope and scintillation mixture showing Beta Decay, with atomic disintegration and emitting β particles. b) Being introduced into a translucent cylinder made of additional layers of scintillation substances, like sodium iodine (NaI), after excited molecules return to ground state emit scintillation light and glows like a lamp.*

If the radioactive fiber is manufactured from by-products of nuclear reactor operations, it may require a thicker translucent container cylinder in order to prevent the radiation leak by this waste.

Selection of scintillation systems for photosynthesis

The photon emission during the collision of the beta particle would provide a light source for hydroponics, plant, photosynthetic bacteria, and algae growth, etc.

Plants have two reaction centers for light interaction which are called photo system I (P700) and photo system II (P680). Excitation of the first center generates a strong reducing agent to transfers electrons to NADP. Excitation of the second results in a strong oxidant that from water releases oxygen. Photo system II injects electrons in the chain connecting both systems.

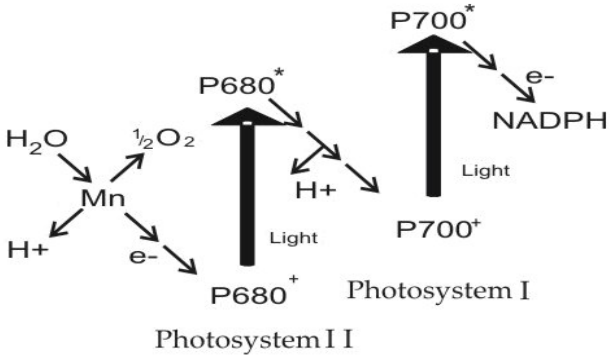

***Figure 2**: Illustrates the z-scheme. A photon converts both chlorophyll complexes (P680 and P700) into powerful reducing agents P680* and P700*. Also shows that input of water interacts with Mn into release of ½ O_2 and protons (H^+) pumped into thylakoid lumen and transfer of hydrogen and electrons (e^-) to reduce NADP from oxidized to NADPH + H^+, the later turnover to oxidized is obtained by transfer of its reducing power in the dark reactions which allows CO_2 fixation (Calvin Cycle).*

Figure 2 shows that excitation of photo systems I and II requires illumination with light from several wave-lengths, development of scintillation mixtures will allow light emission on the range required to cover the full action spectra.

All these systems could be made totally independent of other forms of energy than the radioisotopes themselves, which on the other hand, can substitute for solar panels, which could usually operate for only the 8 hours of sun light [19]. On the other hand if a plantation is divided into 3 lot areas angling 120^{o} each, their artificial light exposition could be triplicates by a rotating a scintillation panel mounted on a pivot to cover each area for 8 hs. Light generated by this technology, could be used to drive photosynthesis to obtain sustainable ecosystems [4-17].

Ecosystem solutions

One of the uses of light-transfer technology may be the replacement of solar panels which could be expected to have a very low efficiency in Polar Regions, by the use of radioisotope lamps manufactured in the shape of panels which could allow the development of agriculture in very cold regions or at least to support the light requirements of greenhouses in Polar Bases.

Integrative techno-concept

This integrative techno-concept should be specifically suitable to meet energy requirements largely independent of existing technologies. The technological impact of this reactor is that it could be scaled down to the size of a battery. By supplying electrical power to an electrical battery charger, it makes unnecessary to change the usual power supply connections or configurations required for instrumental operation.

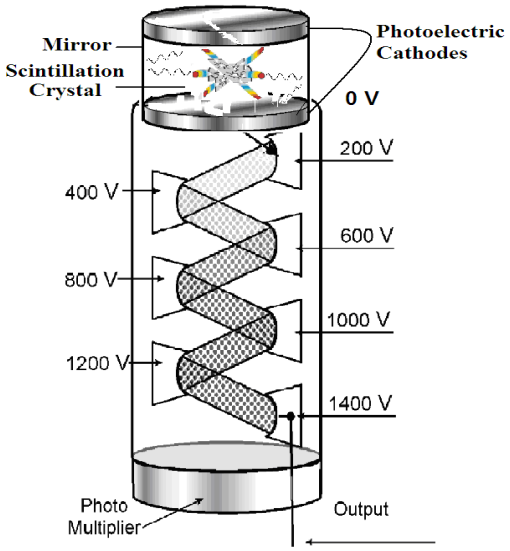

***Fig. 3**: **Scintillation coupled to voltage control** Electric power is supplied by radioisotope operated batteries connected to this voltage amplifier. The figure shows that β-decay particles interact with the scintillation crystal, resulting in photon emission reflected by surrounding mirror. In direct contact with the scintillation crystal is represented the photoelectric cathode of a photomultiplier which releases electrons when stricken by photons. The electrons are accelerated to the first anode, arriving with energy of two hundred electron volts* (V), *releasing secondary electrons from its surface. Subsequent repetition of this process results in an output of electrical current.*

Tandem photovoltaic elements could be use to increase efficiency, if the energy of β particles could be more efficiently capture, by a mixture of scintillation substance generating light of more than one wavelength. The design could be improve by using the energy generated from radioisotopes to generate electric energy in excess, of that to be supplied to the voltage control.

Additionally, research could be extended to find cascade systems which will allow the summation of quantum steps of scintillation, and/or phosphorescent, and/or fluorescent substances. This may allow obtaining summation of the energy of photons of longer wavelength into emission of more energetic photons, or obtaining systems of greater energy efficiency.

More advanced chips could be develop by incorporating boron nitride crystals (hBN) highly resistant to heat with emission of a $\lambda = 215$ nm (nanometers) at room temperature [(19)], UV radiation may be suitable in vacuum to propel solar sails. The design task would be to transfer energy along optical fiber to stimulate laser devices.

One additional example could be that production of light by these lamps may allow generation of electricity from hydrogen gas, or enhance its propulsion power by producing two dissociation pathways, of opposite parity which entangle and lead to correlations in the directions followed by the resulting proton, electron and atom [(20)].

Heat dissipation

These and subsequent electrical power figures had not been corrected for heat-losses decreasing efficiency. The latter should be determined experimentally. Losses by dissipation of energy as heat through a cooling system could be connected to a heat system for maintenance of the environmental temperature within spatial exploratory vehicles.

The material selected to contain the radioisotopes could be given different shapes to facilitate heat-dissipation. It is suggested to manufacture long fibers to be cut accordingly to its end use. For small sizes, heat exchange with surrounding air will provide enough refrigeration. For such a purpose radioactive fibers could be bended and pleated and/or turned around over itself taking care of leaving enough distance in order to allow an easier air-cooling effect.

For a larger radioisotope core, the refrigeration could be achieved by spinning the radioactive fiber around a circulation tube of an attached cooling system. If to match a large radioisotope core requires a large core-enclosing scintillation shielding, this could be made of superimposed crystals leaving between themselves enough space to form air-circulation channels. If the size of the system reaches the need to require a liquid cooling system, this could be installed in such a way that one of the sides has reflecting capability allowing both cooling and focusing of the emitted light.

Engineering solutions will be able to adequate the geometry of radioactive and scintillation crystals to allow for sufficient heat dissipation according to different operative requirements. In the vacuum of space, rather than cooling it may be required to radiate heat into the chambers containing instruments.

Technology adaptable for interplanetary and deep-space exploration

Space exploration and colonization of other worlds requires long-lasting energy supplies [21][22][23]. However, for space agencies purposes, the half life of $^{90}Sr^{38}$ operated photovoltaic battery may be adequate, but its power may be insufficient, and the opposite may be true for $^{89}Sr^{38}$. Hence, it may be more suitable in pursue of space-exploration $^{60}Co^{27}$.

NASA has initiated exploration outside the Solar System using probes which fall into a path of circumvallation of the sun, to confer these spacecrafts the gravitational energy needed to escape the solar system. The thrust thus obtained, allows speeds of the order of tens of thousands of kilometers per hour and would take to these space probes many millenniums in reaching other suns.

For interplanetary navigation, the use of solar sails is under development, as planed aluminum screens would be push by the sun's photons. This type of navigation allows constant acceleration, with a theoretical limit of a fraction of the speed of light. However, if the spacecraft would be moving away from the sun, the number of photons incident on the sail, would diminish until becoming null.

As a result solar propulsion cannot be use to navigate between two solar systems. The considerable dimension of a thermonuclear plant would require solar sails with the sizes of many square kilometers. The solution is to replace the thermonuclear plant by a luminescence-nuclear one, in which the energy of non fissionable radioisotopes like strontium-90 would be transformed by scintillation crystals on light flashing directly on the sails.

The engineering of this system could be expected to result in considerable smaller sails, allowing much smaller development costs by using toy-sized prototypes.

Scintillation lamps in deep space could provide radiation pressure to compensate for the one diminishing from the Sun. If required, two spacecrafts could cross-direct their own laser ray to provide impulse to the other craft's sail, as a solution to requirement of an outside source of power.

These lasers could maintain continuous acceleration, if achieving an increase of 10 meters per second every second, in a few years may allow reaching a significant percentage of the velocity of light. Hence, allowing in not to many years to reach another solar system, at velocities that could never be achieved using gravitational navigation.

Planetary exploratory vehicles may take advantage of atomic reactors of reduced size and weight, which are suitable to be used as batteries with an operative life-spam close to the half-life of a radioisotope. Example: One kg of $^{60}Co^{27}$ plus the weight of the energy generating crystals may weight less than 5kg, providing almost 27 *k*W*h* / *h* decreasing to half after 5 yrs.

If a photovoltaic battery based in $^{60}Co^{27}$ is coupled to an electric motor its lasting operational life and power could be favorably compared to a robot vehicle (about 45kg.), operated by remote control with energy derived from a lithium battery, whose full operative life is only of several hours.

A life support system consisting of a small plant for electrolytic decomposition of water, can be operated by these batteries since about 5Kwh could produce 1m^3 of hydrogen and a ½ m^3 of

oxygen per hour. A system like this could also save weight by converting waste water into an oxygen supply and hydrogen that can be use as a propulsive fuel.

Life-support systems

These are usually based in the use of oxygen tubes and alkaline fixation of CO_2, add excessive weight and have limited life-spam and therefore are not too adequate for long voyages or in supporting human colonies in the Moon or planets. The preceding systems could be replaced by electrolysis generating oxygen or photosynthesis that will produce a renewable atmosphere which will not only restore the level of oxygen but also, concomitantly decrease the level of CO_2. These objectives could also be achieved by the use of Solar Panels, although their size is much greater than the a scintillation lamp, still, these could be easily adapted to provide light for photosynthesis, but become increasingly inefficient when further away from the Sun.

Conclusions

For many radioisotopes shielding by scintillation molecules within the crystal itself could be sufficient to trap most of the β-radiation or γ-radiation covered by a crystal of enough thickness, resulting in negligible radiation leak.
Shielding by scintillation glasses should be considered as an innovative replacement to shielding by lead. Uninterrupted glowing could be an advantage if saving in light expenses is desirable.

Comparative safety

Nuclear reactors could also be used as a source of energy for electrical lamps, but their size and cost may limit their use. Moreover, a spaceship that would be required to travel to planet Mars for a round trip of about 3 year or more may expose the crew to unhealthy and unacceptable levels of radiation unless the atomic reactor is heavily shielded. The long lasting scintillation lamp will add much less weight; because these could be designed to adjust to any scale, moreover the scintillation crystal provides a lighter and more efficient shielding.

Comparative cost

The characteristic previously described allows that a small scintillation nuclear plant could be made significantly cheaper that one similar size heat-transfer atomic reactors and could be easily designed to meet safety and health requirements. The needs of a human colony outside earth will certainly include a nuclear reactor but its operation will yield radioactive waste products, which could be utilized as previously described.

Relation to the present state of knowledge

The world expanding energy needs indicates that is required to engineer ways and means for extensive use of radioisotopes. These could make a significant contribution by adding a supplementary energy source and also by alleviating the difficult problem of radioactive disposal. Expansion of this technology may require studying systems that will allow efficient light transmission through optical fiber-power lines. The development of Photon confinement systems is required to allow storage of electromagnetic radiation to fill the role of capacitors.

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Addendum

Comparative energy yield of radio isotopes vs. carbon combustion

The energy equivalence for each radioisotope calculated as a percentage of $^{235}U^{92}$ to emphasize the large energies involved.
Energy equivalence of 235 g $^{235}U^{92}$ expressed as metric tons of carbon: 2.62×10^3 tons.
1 kg of $^{235}U^{92}$ releases an equivalent (in electric power) ≅ 23,900 M W*h*.

$E_{Sr\text{-}90}$ / E_U per atom decay: $E_{Sr\text{-}90}$: 2.8 MeV / E_U : 2.11×10^2 MeV = 1.32%.
Energy equivalence of 90g of $^{90}Sr^{38}$ in metric tons of carbon: 90.39 tons.
Molar relationship: 235g ($^{235}U^{92}$)/ 90g ($^{90}Sr^{38}$) = 2.61.
Percentage: $E_{Sr\text{-}90}$ / E_U for molar relationships: 1.32%×2.61= 3.45%.
1kg of $^{90}Sr^{38}$ full life: 824.5M W*h.*

$E_{Sr\text{-}89}$ / E_U per atom decay: $E_{Sr\text{-}89}$: 1.481 MeV / E_U : 2.11×10^2 MeV = 0.71%.
Energy equivalence of 89 g of $^{89}Sr^{38}$ in metric tons of carbon: 48.99 tons.
Molar relationship: 235g ($^{235}U^{92}$)/ 89g ($^{89}Sr^{38}$) = 2.64.
Percentage $E_{Sr\text{-}89}$ / E_U for molar relationships: 0.71%×2.64= 1.87%.
1kg of $^{89}Sr^{38}$ full life: 447M W*h*.

Techno idea was previously submitted as Proposals:

"Integrative design for radio nuclear power-transfer by light to batteries"
Transmittal Letter or Prefatory Material
Phase I- Advanced Aeronautical/Space Concept Studies - NIAC CP 05-01. Refer by NASA to DARPA, 03/16, 2007.

Radioisótopos como fuente de energía transferible por centelleo lumínico para operar sistemas fotovoltaicos diseñados para escalas mayores o menores que una batería

Fundacion Argentina de Nanotecnologia (FAN) formulario para la presentacion de ideas-proyectos (convocatoria 2006).

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