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Energy Harvesting From Solar Wind and Galactic Cosmic Rays

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Abstract: **The human's need for energy is increasing day by day. The search for alternative energy source has made human envision to scavenge energy from outer space. As we know, our universe is full of energies; we can make use of it to meet our energy needs. The most important events in space are solar wind and galactic cosmic rays. These events stream out highly energetic particles like proton, electron, alpha particle and HZE. The energy possessed by proton and electron is usually between 1.5 and 10 keV. This energy can be used to generate electrical energy. This paper describes the possible way of using those energetic particles to harvest energy to fulfill the energy need. In this paper, I've discussed the conceptual method of energy production using static solar sail in which laser is used to beam energy to the collector on space probes, satellites, space station, earth etc. This method can provide huge amount of power to entire humanity.**

Keywords: **Solar sail, cosmic ray, solar wind, power, electric field, high energetic particle**

1. INTRODUCTION

Energy plays a vital role in the economic growth and social transformation of all countries in the world. Literally, everything in the world is depended on availability of energy. With the advancement in technology and global economy, the dependency on energy has been increased even more. Moreover, it is predicted that global energy consumption will be doubled by mid-century.

The use of non-renewable energy sources has deteriorated our environment .The problem like global warming is still lingering. Due to over-exploitation of resources, they are likely to be extinct in coming years. These kinds of energy sources are not sustainable and reliable. So, the future energy demand cannot be fulfilled by non-renewable sources. Hence, alternative way should be searched in order to meet the energy need in future.

There are various renewable energy sources available in recent stage. But the efficiency of those sources is very low to meet the future energy requirements. The quest of alternative energy has enabled human to look out of the box. In this regard, the space comes in the first place. The space is crowded with energetic particles. Solar wind and galactic cosmic rays are the usual phenomenon in the space. These phenomenons bring energy with them. The future energy need can be met by utilizing the energy possessed by space.

2. SPACE RADIATION

Radiation is the energy in form of high speed particles and electromagnetic waves. There are basically two types of radiation; ionizing radiation and non-ionizing radiation. Ionizing radiation has enough energy to knock out electron from atom and make it ionized whereas non-ionizing radiation doesn't have sufficient energy to make the atom ionized. Ionizing radiation includes gamma rays, protons, electrons, neutrons, alpha particle and beta particle and non-ionizing radiation includes microwaves, visible light, infrared and radio waves. Space radiation comes under ionizing radiation. It consists of highly energetic charged particles. The sources of space radiation are basically solar wind and galactic cosmic rays.

2.1 Solar Wind

Solar wind is a stream of charged particles that originates in the upper atmosphere of the sun. It comprises of mostly electrons and protons along with a few heavier ions, and blows continuously from the surface of the Sun [1]. The solar wind may be considered as an extension of the outer atmosphere of the Sun into interplanetary space. The energy possessed by such charged particles ranges from 1.5 to 10 KeV. The source of the solar wind is the Sun's hot corona. The temperature of the corona is so high that they possess high energy because of which the Sun's gravity cannot hold on to it. The mean velocity of these particles is about 145 km/s. This velocity is below the solar escape velocity of 618 km/s. However, a few of the particles are able to achieve energies sufficient to reach the terminal velocity of 400 km/s. Hence, they are allowed to create the solar wind. At the same temperature, electrons reach escape velocity due to their smaller mass which helps to build up an electric field that further accelerates charged particles away from the Sun [2]. The solar wind can travel up to the distance of 75 AU or astronomical units. The density of the

solar wind varies from 1 to 10 particles/cm^3 and decreases with the inverse square of the distance from the Sun.

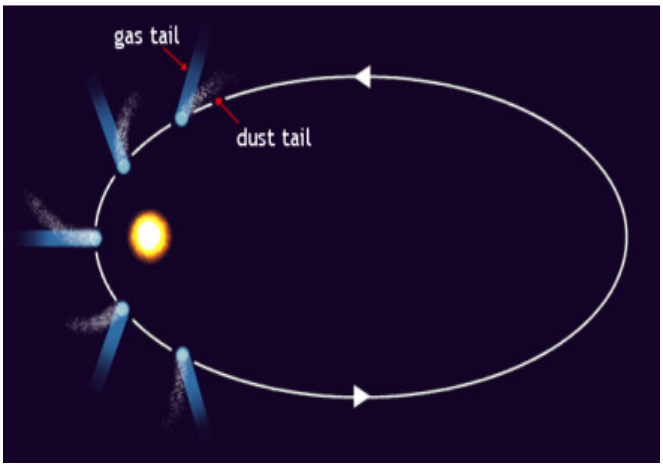

Fig. 1. Tails of comets pointing away from the Sun due to solar wind

"Comet orbit". Licensed under Public domain via Wikimedia Commons

The stream of particles consists basically of fast stream, slow stream and coronal mass ejection. The fast solar wind travels at about 750 km/s and has a composition similar to the sun's photosphere [3]. Similarly, the slow solar wind travels at approximately 400 km/s and has a composition similar to the corona. The temperatures of these two streams are 8×10^5 K and 1.5×10^6 K for the fast and slow winds respectively [4]. The total number of particles carried away from the Sun by the solar wind is about 1.3×10^{36} per second [5]. Hence, the total mass loss each year is about 2.5×10^{-14} solar masses [6]. However, the solar wind has taken away only about 0.01% of the Sun's total mass [7].

2.2 Galactic Cosmic Rays

Cosmic rays are colossally high energy radiation originated at interstellar region. They are mainly composed of high energy protons and interstellar atomic nuclei of atoms, ranging from the lightest to the heaviest elements in the periodic table. They also contain high energy electrons, positrons, and other subatomic particles.About 90% of the cosmic ray nuclei are protons, about 9% are alpha particles and remaining 1% is rest of the elements [8]. The major sources of galactic cosmic rays are thought to be supernovae of massive stars, active galactic nuclei, quasars, and gamma ray bursts. The highly charged particles of cosmic rays travel at nearly the speed of light. Most of the galactic cosmic rays have energies ranging from 100 MeV to 10 GeV. Since, cosmic rays are electrically charged, they are deflected by magnetic fields, and their directions are randomized without giving the exact clue of their origin.

3. ENERGY PRODUCTION BY USING SPACE RADIATION

3.1 Static Solar Sail

Solar sail uses solar radiation pressure to propel. It consists of ultra-thin mirror of different shape. Reflection of solar radiation creates a pressure on the sail. Similarly, some part of the radiation is absorbed. The absorbed energy heats the sail and is re-radiated. This also provides the resultant momentum to propel. The most common material used to make solar sail is aluminized 2 µm Kapton film. It withstands the heat of close Sun without any damage to its structure. The aluminum reflecting film points towards the Sun side.

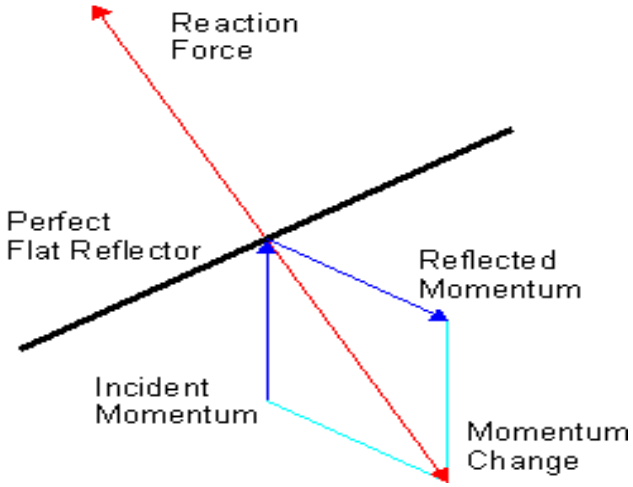

Fig. 2. Mechanism of solar sail

Jerry Wright - http://commons.wikimedia.org/wiki/File:Sail-Force1.gif#mediaviewer/File:Sail-Force1.gif

Static solar sail is the sail which can afloat on the space defying gravitational attraction. Robert L. Forward has pointed out that the static solar sail could generate enough propulsion to counteract gravitational interaction[9].The mirror in solar sail should be adjusted fine enough to get the hovering effect. This helps solar sail to stay stationary and feed uniform amount of charged particles. The stationary solar sail stays in the space with energy harnessing devices. It also consists of other instruments onboard which keeps track of its attitude and can be controlled from ground station. The moderate size of sail can harvest ample amount of energy.

3.2. Electric Field

Static solar sail contains two conducting copper sheet extending up to few centimeters which are charged to generate electric field of high energy .The electric field is maintained as to deflect the incoming electrons and atomic nuclei (see fig.3). When electrons and atomic nuclei from solar wind and

galactic cosmic ray pass through solar sail, they are attracted to the solar sail due to electric field. The electrons are deflected towards anode and positive charges are deflected towards cathode.

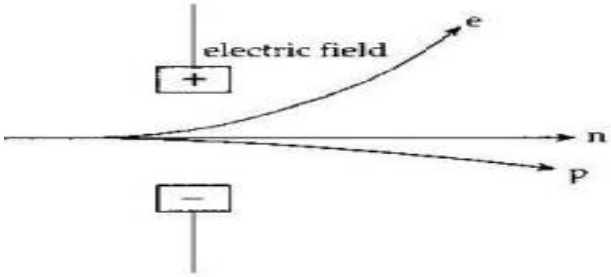

Fig. 3: Deflection of charged particle due to electric field

Source: http://alexteoh.com/orbitals.htm

3.3. Highly energetic electron into electricity

An electric current is the flow of charge. The electron carries charge with them .In electric circuits, the current is produced by the flow of electrons .Solar sail consists of the device to harness energy of electron to electrical energy. The electrons which are deflected by electric field are funneled to the metallic receiver which produces the current .The part of current produced creates metal sheet's electric field. The electrical energy is stored in some devices.

3.4. Highly energetic atomic nuclei into electricity

In a similar way, solar sail also consists of the device which converts energy possessed by atomic nuclei into electrical energy. The atomic nuclei such as protons, alpha particles, HZE etc which are deflected by electric field are also moved to the other chamber which is allowed to strike with PIN junction diode. The single junction PIN diode is made up of silicon and doped with boron and phosphorous which convert high energy positive charges into electricity on bombardment through ionization from electronic stopping in the silicon [10].

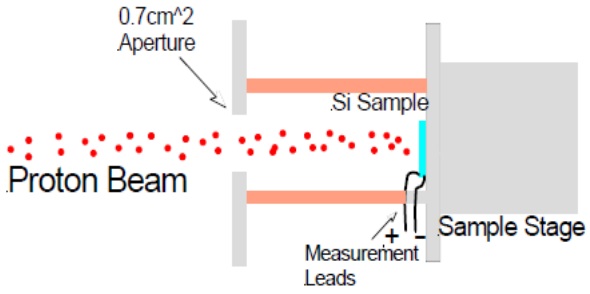

Fig. 4: set up to irradiate the PIN junction diode silicon diodes with 3MeV Proton [10]

This process creates the usable voltage and current in a similar process to photons inducing a voltage and current in a photovoltaic cell.

4. LASER BEAM TO TRANSFER GENERATED POWER

In this system, there is a laser power transmitter. The laser transmitter transmits the energy generated to the respective receiver on space probes, earth, satellites in form of laser. This light energy is sent through air or the vacuum of space onto a photovoltaic receiver where it is converted back into electricity [11]. An infrared laser is appropriate because it has the ability to penetrate the Earth's atmosphere. Since, the laser has to travel million of distance, there will be power loss on the way.

5. PLACEMENT OF ENERGY HARVESTER

The region where the Earth's magnetic field lines extend into space is called the magnetosphere. It influences the flow of the charged solar wind at distances exceeding 10 Earth radii. The solar wind and galactic cosmic rays phenomenon cannot be experienced much in near earth space due to the earth's magnetic field. The earth's magnetic field resists charged particles to enter into the near earth space. So, the static solar sail should be placed far away from the earth's magnetic field. It would need to be kept millions of kilometers away from the Earth where the streaming of charged particles are more.

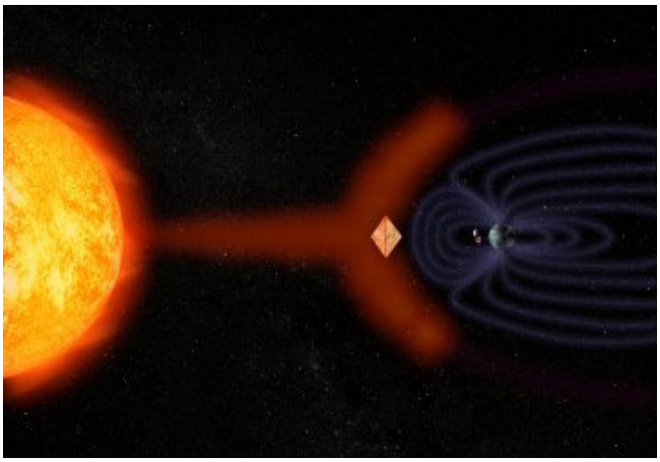

Fig. 5: Solar sail placed between earth and sun beyond earth's magnetic field Image credit: NASA

The static solar sail will be placed at four different places millions of kilometers far from earth. They will act as a dyson ring. They will be opposite to each other where sun will be inbetween.This placement helps to harvest more energy utilizing the scattered charged particles. There is mechanism which will connect adjacent solar sail to each other. Those adjacent solar sail can transfer their power to each other in

case of need. The earth at a time of revolving sun will meet solar sail aligned with it for the four times during one complete revolution. This helps to utilize the maximum energy of the particles.

5.1. Launch of solar sail

The rocket will be used to place solar sail up to low earth orbit. At low earth orbit, the sail will be deployed and start its journey towards sun with the propelling power drawn from solar radiation. The adjustment and control of sail will be done from ground station till it reaches to its destination.

6. PRACTICAL LIMITATIONS

The solar sail technology has not developed in recent times. It's still in an experimental phase. It may take more than a decade to flourish this technology. So; we cannot expect this energy harvester to be placed for next ten years. Similarly, beaming energy from that much distance will create the problem of spreading out of laser beam losing vast amount of energy on its way [12]. This problem can be solved if and only huge lens is kept on the space and a far superior laser is developed.

7. CONCLUSION

The possibilities of energy harnessing from space have been highlighted in this paper. Even though, there are technological hurdles to build such energy harvester at present, it cannot be ruled out .Such energy harvester will be the only source to fulfill the future energy demands. The power generated from space can change the entire world and humanity. The more research has to be done in this field to make the technology accessible and promising.

8. ACKNOWLEDGEMENT

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