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Analysis of Maximum Possible Utilization of Solar Radiation on a Solar Photovoltaic Cell with A Proposed Model

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Abstract: *The paper proposes a possible solution to absorb and utilize all the solar radiation spectrum including ultravioletand infrared along with the visible radiation. A typical solar PVcell usually absorb only the visible solar radiation to covert to electricity which is 46% of the total solar radiation but it can't use the other non-visible spectrum like infrared (longer wavelength) and ultraviolet (shorter wavelength) which consists of the other 54% of solar energy. This non-visible solar radiation is either absorbed by the earth surface and atmosphere or reflected back to the space and it is wasted as faras the solar cell absorption is concerned. There are lots ofresearches going on in the semiconductor level to design a solarcell which can absorb the solar radiation in non-visible region using band-gap engineering but if we could somehow convert the non-visible solar radiation into visible range before it comesto the solar cell (semiconductor level) then the overall efficiencyof a solar PV system would surely be increased to a satisfactoryamount. After converting the non-visible spectrum into visible spectrum, we will then incident this radiation on a typical solarPV cell. In this paper the possible arrangement for such conversion is proposed which is still at a preliminary stageconcept and yet to be implemented.*

Keywords: solar radiation, infrared radiation, ultravioletradiation, virtual earth surface, solar PV cell

I. INTRODUCTION

Utilization of renewable energy resources has been the most important & prospective field to seek new energy sources to meet up the increasing demand in power all over the world. Among the renewable resources, solar being the most popular one due to abundant, ease of accessibility and convertibility to the electricity. There is a growing interest in harnessing renewable energy sources since they are naturallyavailable, pollution free and inexhaustible. The amount of solar radiation that we receive on earth, we actually make use very few of that in converting to electricity. Again conversion efficiency of the typical solar cell is very low andhence not cost effective at all. The one of the solutions can be absorption of all the solar radiation rather only visible spectra along with designing the solar cell by band-gap engineering.The later one is being done by many researchers from different sides of the world.

One of the basic processes behind the photovoltaic effect, on which the operation of solar cells is based, is generation of the electron-hole pairs due to absorption of visible or other electromagnetic radiation by a semiconductor material. The solar PV cells consist of a junction between two thin layers ofdissimilar semiconducting materials. One is the positive typesemiconductors or 'p' type and the other is the negative typesemiconductors or 'n' type. Semiconductor materials like Silicon, Gallium Arsenide, Indium Phosphide, Cadmium Tellurium etc are usually used to make solar cells.

II. SOLAR RADIATION SPECTRUM

Solar radiation is an electromagnetic wave emitted by the Sun's surface that originates in the bulk of the Sun where fusion reactions convert hydrogen atoms into helium. Every second about 3.89.1026J of nuclear energy is released by theSun's core. This nuclear energy flux is rapidly converted intothermal energy and transported toward the surface of the starwhere it is released in the form of electromagnetic radiation. The power density emitted by the Sun is of the order of 64MW/m2 of which ~1370W/m2 reach the top of the Earth'satmosphere with no significant absorption in the

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space. The latter quantity is called the *solar constant*. The spectral range of the solar radiation is very large and covers from ultraviolet(UV) radiation (λ<400nm) accounts for 6% to infrared (IR) radiation (λ>700nm) for 46% including the visible (400<λ<700nm) spectra for 48%. The spectral distributions of solar energy for both the cases: radiation leaving the sun and radiation arriving at earth's surface have been shown in figure 1 & figure 2 respectively.

The solar radiation incident on the solar panel in three ways: direct radiation, diffuse radiation and reflected from the earth surface (Albedo). So the global radiation consists of all these three type of radiation that is described below and shown in figure 3.

Direct or beam radiation

Radiation that is not reflected or scattered and reaches the earth's surface directly in line from the sun is called direct or beam radiation. The scattered radiation which reaches the ground is called diffuse radiation

Diffused radiation

The radiation that is scattered by dust, aerosols, moleculesetc and has no preferred direction is diffused radiation.

Albedo

The part of radiation reflected from the ground is called Albedo.

Global radiation

Global radiation is the combination of all above three radiation mentioned i.e. Beam radiation, Diffuse radiation and Albedo.

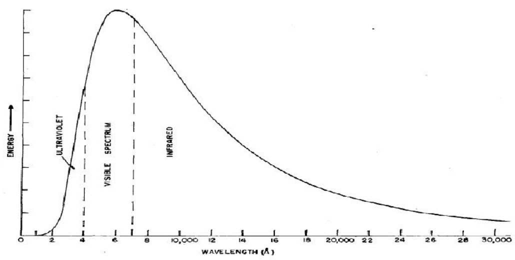

FIGURE 1. The spectral distribution of energy leaving the sun.

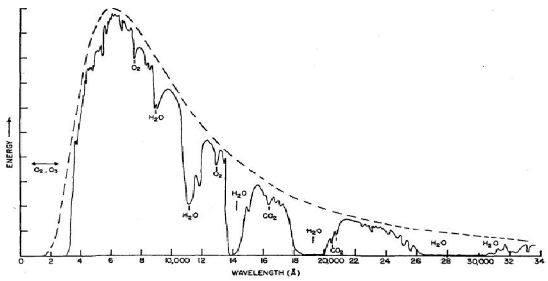

FIGURE 2. Spectral distribution of sunlight arriving at earth's surface.

III. PROPOSED MODEL

The block diagram of our proposed model for maximum solar absorption and utilization is shown in figure 4. Our main concern is to convert the non-visible solar radiation intovisible spectra before it is applied on the solar cell. The Infrared radiation is being received by an IR antenna which then converts the IR electromagnetic wave into electrical voltage and current. The wavelength of the infrared radiationis higher than the visible radiation or alternatively we can saythat the frequency is lower, so the energy being lower as well.

This lower photon energy (h_f<Eg) is not enough to bring electron from valence band to conduction band and hence it is needed to convert the frequency to higher level which is done by a frequency up-converter. Then the higher frequency signal is then applied to the solar cell to excite the electron after creating the electron-hole pair.

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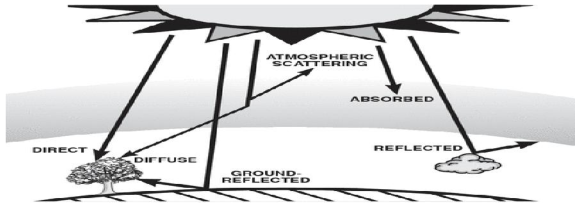

Figure 5. Different form of solar radiation arriving on earth's surface

On the other hand to utilize the UV radiation having lower wavelength or higher frequency (hf>Eg) we need to covert it's frequency to a lowerlevel such that it then becomes into visible range.

Now we know the working principle of greenhouses where the incoming solar wavelength is converted to higher one after reflecting back from earth surface. Here we are going toapply the same principle by using a virtual parabolic earth surface to concentrate the UV radiation where the solar panelis placed in the receiver position at the top centre of the concentrator like the dish antenna arrangement which is shown in figure 5. So we make a virtual environment like greenhouse to utilize the UV radiation.

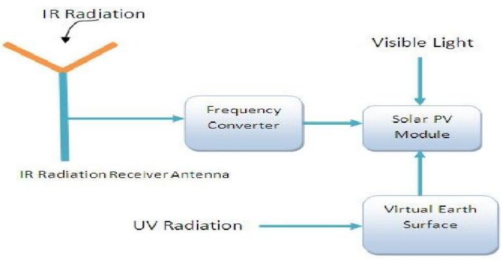

Figure 6. Proposed Model for max solar absorption

IV. INFRARED TO VISIBLE WAVE CONVERSION

The conversion of infrared radiation into visible can be accomplished by means of few proposed non-empirical methods those have been yet to be tested in real scenario for this special purpose.

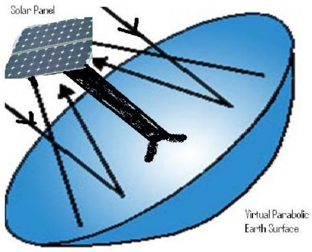

Figure 7. Virtual Parabolic Earth Surface for UV Radiation Concentration

First possible method

The first method has been proposed in reference [3] where the conversion is considered of infra-red radiation into visible in a proustite crystal with the pump and signal waves perpendicular to each other. As described in this reference, the dependence of the conversion spectral bandwidth on the angle α between the pump and signal wave directions is givenin figure 6.

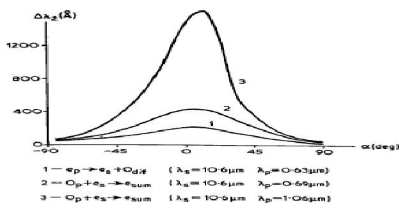

Figure 8. The dependence of the conversion spectral bandwidth on the angle α between the pump and signal wave directions

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Now we can also take a look at the experimental setup thatis described in this reference [3] which is given in figure 7.

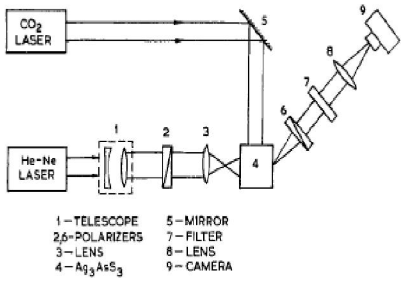

Figure 9. Experimental set-up used to investigate the angular parameters ofan infra-red up-converter with perpendicular signal and pump beams.

Second possible method

The second proposed method was described in paper [4] where an investigation was made of the conversion of infrared into visible radiation in an LiNbO3 crystal. This wasdone by mixing infrared radiation with that produced by a pulse ruby laser. The Figure 8 gives the calculated dependence of the wavelength of the infrared radiation beingconverted (**λi**) on the phase-matching angle at roomtemperature in the case of the *ooe* interaction reported in ref.[4].

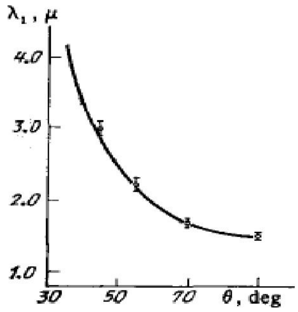

Figure 10. Dependence of the wavelength of the converted infrared radiation **λi** on the phase-matching angle **θ**.

Here [4] they investigated the conversion of infrared radiation in an LiNbO3 crystal in the wavelength range 1.6-3μ and the quantum efficiency of the conversion process was close to unity. It was found that at pump power densities of ~ 3 MW/cm2, the nonlinear crystal emitted a continuous luminescence spectrum and it was difficult to separate the converted radiation.

Last proposed method

The last proposed method is kind of a traditional one to convert low frequency signal (IR wave) to high frequency signal (visible range). Now for this to happen we have to first all transfer to the electrical domain from the electromagneticdomain. So we propose an IR antenna which will receive theIR radiation from the sun and convert to the corresponding electrical current. After that this signal can be boost up to thehigher frequency by using the frequency converter. The typical basic frequency converter circuit for conversion of low frequency to high frequency is given in figure 9.

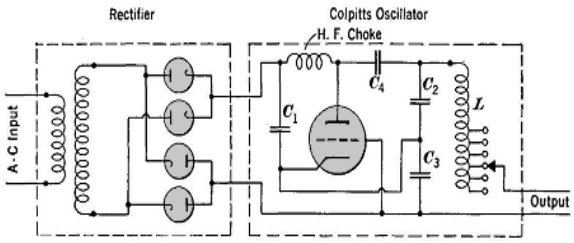

Figure 11. Fundamental Circuit With Colpitts Oscillator for ConvertingLow-Frequency Power to High-Frequency Power

V. ULTRAVIOLET TO VISIBLE WAVE CONVERSION

Like greenhouse glass, we can make use of the UV radiation from sun by converting into visible range similar tothe principle used in growing of plants in winter seasons by making green house where short wavelength radiation from the sun can pass through the glass but after reflecting from plants the higher wavelength are trapped inside the glass house. So we have make such kind of environment artificially to acomplish such conversion. So we proposed a virtual earth surface where UV radiation is incident and reflected back to the solar pannel as after reflection the wavelength has been higher than the incident wave. So in that way we can convertthe UV into the visible wave so that it can be utilized by the solar PV cell. The principle of greenhouse is obvious from the figure 10.

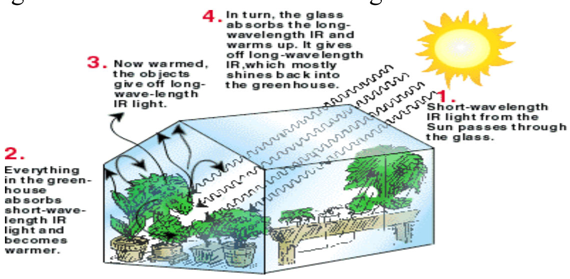

Figure 12. The working principle of greenhouse

VI. CONCLUSION

This proposed method for converting IR radiation into lower wavelength and UV radiation into higher wavelength in such a way that both non-visible spectra fall into visible spectra which the typical solar cell can make use of it to produce electrical energy like it does with the visible solar radiation. This is simply an idea which may require lots of modification and we are still working on it to make it feasibleand practicable. We think this concept may lead to a very good prospect in harnessing solar energy with a great efficiency and the researcher working on solar cells or renewable energy may get an inspiration from it to make the solar PV system lot more cost effective and thus it can solve the energy crisis of our world. The model presented here canbe further extended if we consider the IR nano-antenna to capture the solar radiation of the infrared region for which theresearch is going on [11, 12].

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