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EFFICIENCY OF NEW GENERATION SOLAR PHOTOELECTRIC BATTERIES

Abstract: a solar photo-voltaic battery with a very high efficiency is Developed by dispersing and focusing solar radiation along wavelengths and installing an appropriate solar cell at each wavelength.

This approach allows not only to increase efficiency, but also to increase battery life by eliminating infrared radiation on solar cells. In addition, the design allows cost-effective use of very expensive but highly efficient solar cells.

Key words: sun, photoelectric battery, holographic concentrator, photocell, dispersion and focusing.

At the WSEC-2017 World Congress of Scientists and Engineers "Energy of the Future: Innovative scenarios and methods for their implementation" in the framework of the international exhibition EXPO-2017 held on June 19-20 in Astana, was announced about the possible achievement of efficiency ratio the solar photovoltaic cells up to 25% in the next 2-3 years [1]. At the same time, world science is aimed at increasing the efficiency of solar batteries by increasing the efficiency of solar cells [2].

However, increasing the efficiency of solar batteries can be done in another way, namely, by dispersing (decomposing) solar radiation by wavelengths, focusing them separately (Figure 1 [3]) and installing an appropriate photocell for each wavelength [4]. The possibility of separating infrared radiation allows you to apply to each photocell corresponding radiation up to 1000 suns, in practice, you can limit yourself to several tens or hundreds. This allows you to repeatedly reduce the number of solar cells in solar baterries, thereby reducing their cost.

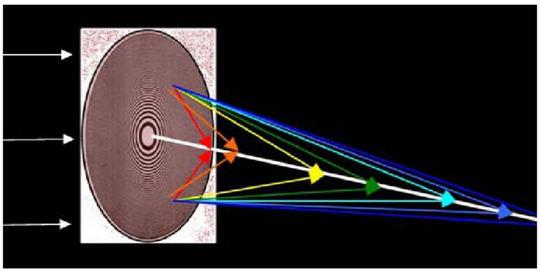
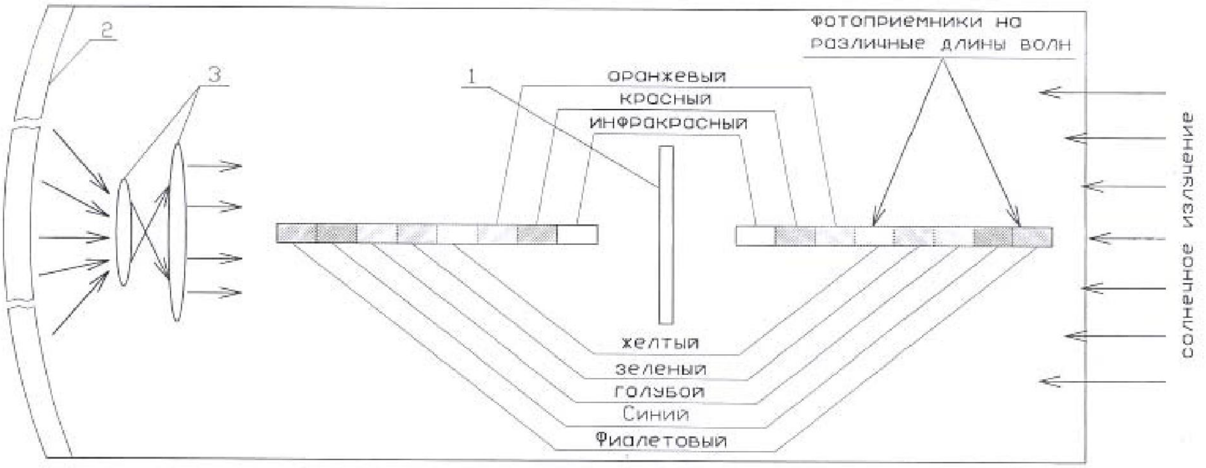


Figure 1 – Holographic concentrator

Figure 2 shows one of the variants of the solar batteries [4], demonstrating a significant increase in efficiency ratio when using industrial-grade photovoltaic cells.

As can be seen in Figure 2, part of the solar radiation directed to the battery hits the holographic concentrator 1. Of this part, about 60% is reflected, dispersed and focused along the main optical axis along wavelengths to the right of the concentrator 1. The remaining 40% penetrate, but also dispersed and focused symmetrically along the main optical axis along the wavelengths to the left of the concentrator 1. Reflected rays from the spherical mirror 2, passing through the collimator lenses 3, hit the holographic concentrator 1 with parallel rays, dispersed and focused similarly. Only the reflected rays are located on the left, and penetrating - to the right of the concentrator 1.



1 – holographic concentrator; 2 – spherical mirror; 3 – collimator lenses.
Figure 2 - Diagram of a new generation solar battery

For each color, as noted above, one can install the appropriate photocell. In this case, the installation of photocells is performed symmetrically on both sides of the holographic concentrator 1.

In this case, the photocells work, practically, in ideal conditions, and the number of suns falling on these photocells is equal to the ratio of the cross-sectional area of solar radiation to the area of the photoelectric cells. Consequently, the need for photovoltaic cells is reduced by as many times as compared with traditional solar panels.

The exclusion of infrared radiation hitting the photocells multiplies their service life and contributes to the achievement of the highest possible efficiency ratio.

Determination of the efficiency ratio of such a solar battery is as follows. Figure 3 shows the scheme and parameters of the distribution of the wavelengths of solar radiation on the right side of the experimental holographic concentrator 1 according to Figure 2 when determining the areas occupied by different colors of solar radiation.

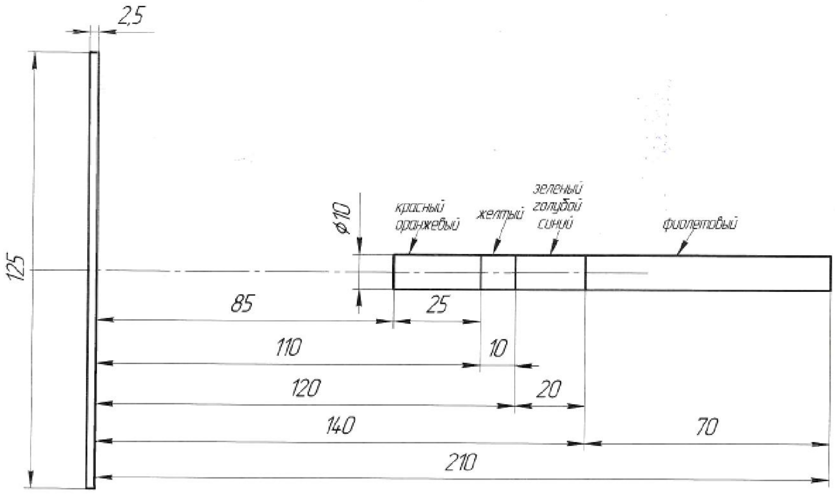


Figure 3 - The layout of the various waves of solar radiation,
reflected from a holographic concentrator with a diameter of 12.5 cm

Previously, we found that the reflected rays from a holographic concentrator are about 60%, and penetrating 40%. Therefore, it can be considered as a full hit of rays of different colors on the corresponding photocells, since solar radiation is involved on both sides of the concentrator (here the insignificant absorption of radiation by the mirror and the concentrator at the entrance is not taken into account).

Different sources give different energy ratios by wavelength, as shown in Figures 4 [5], 5 [6] and 6 [7]. This shows that the power of the energy coming from the Sun for the same wavelength is different. This may be due to several factors, such as geographical location, state of the atmosphere, etc. Thus, Table 1 [8] presents the energy of the spectral regions depending on the position of the Sun relative to the horizon, and Figure 7 presents the radiation power of the visible spectrum depending on the state of the atmosphere [9]. In any case, the efficiency ratio of the considered solar battery, receiving energy from different wavelengths of solar radiation, is an integral value.

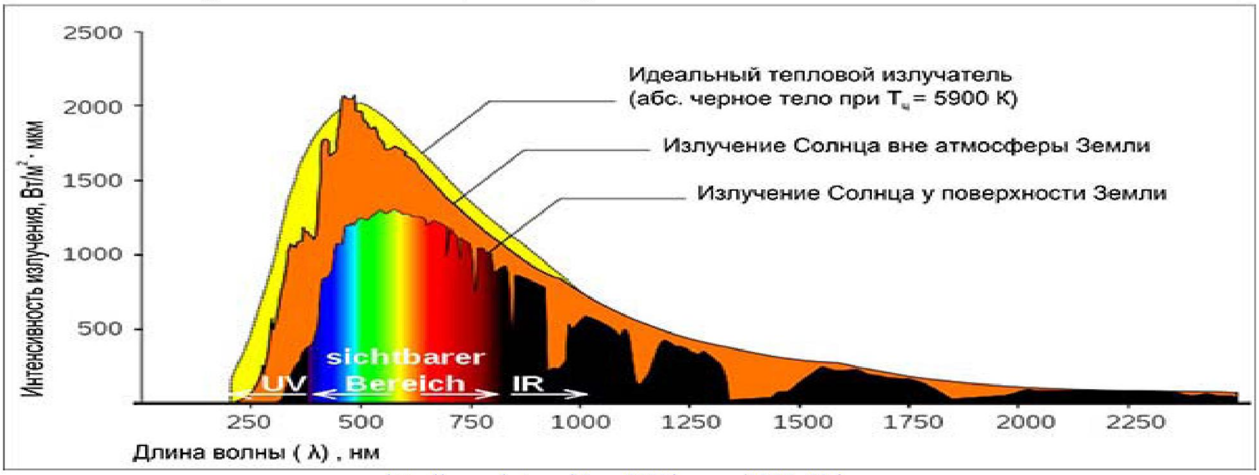


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Figure 4 – Intensity of solar radiation over [7]

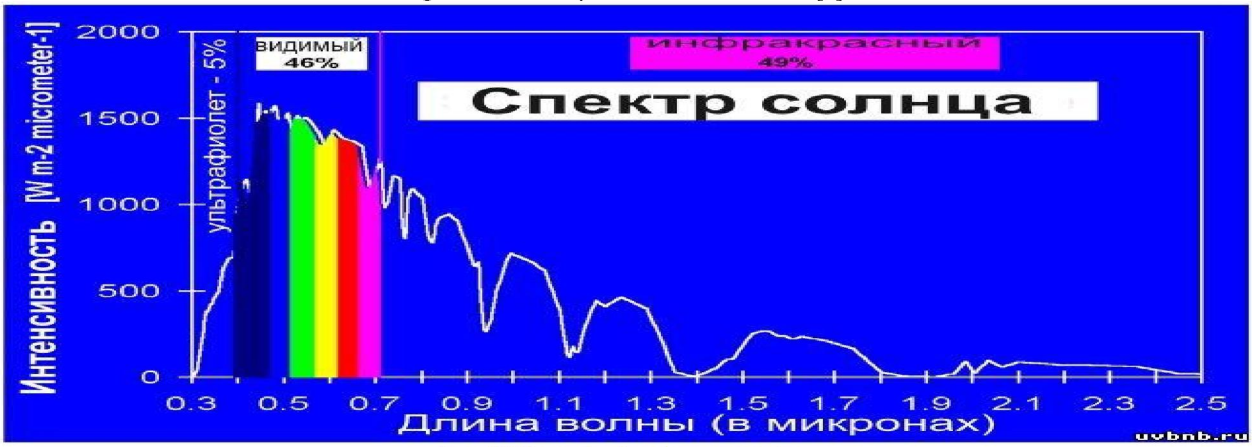

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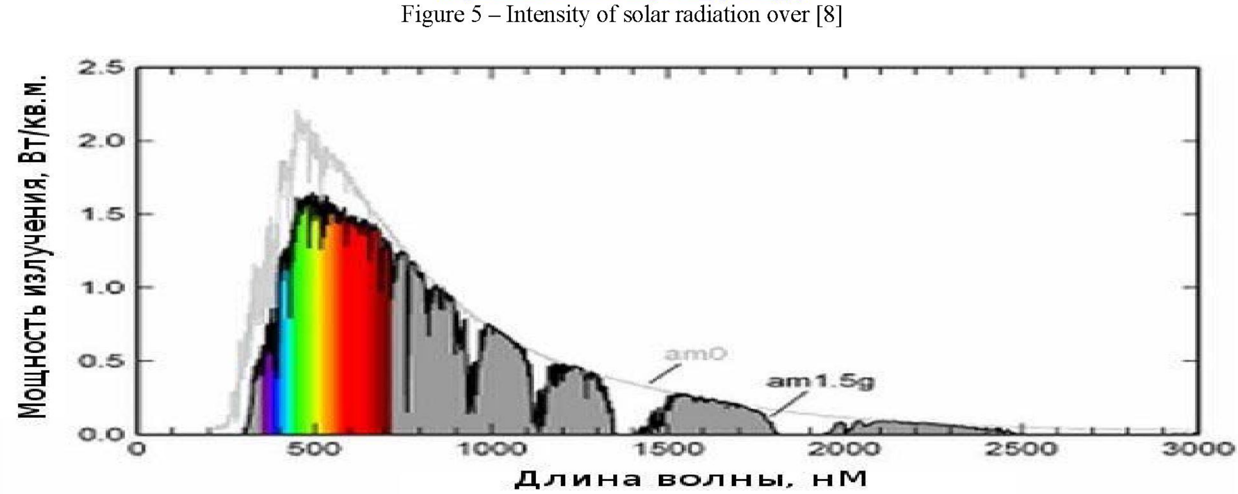
Figure 5 – Intensity of solar radiation over [8]



http://forum.solnechnye.ru/images/batareya/spectr_AM1.5.jpg
Figure 6 – Intensity of solar radiation over [9]

Table 1 – Energy variability from the standing position of the Sun

Источник излучения	Энергия областей спектра, %		
	ультра-фиолетовая	видимая	инфракрасная
Солнце у горизонта	0	28	72
Солнце при высоте стояния 60°	3	44	53
Солнце в зените 90°	4	46	50
Голубое небо	10	65	25

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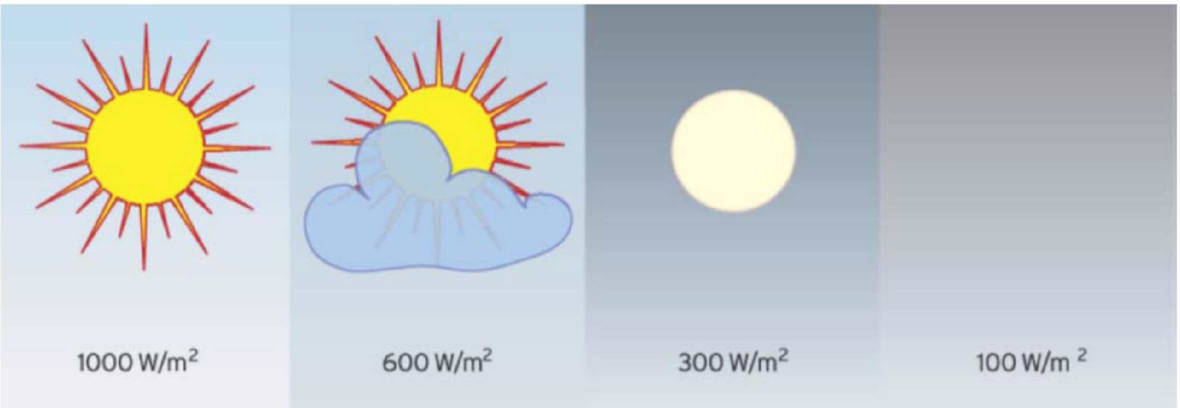

http://2energy.com.ua/images/articles/9.png

Figure 7 - intensity of visible radiation spectrum
depending on the state of the atmosphere

The physical meaning of the integral efficiency value is as follows (Figures 4-6). For example, monocrystalline silicon converts the energy of red, orange and captures, say, a part of yellow. Photovoltaic cells based on gallium arsenide convert the energy of yellow, green, sky blue and partly blue, and amorphous silicon — purple, partly blue, and partly ultraviolet. The elimination of double metering of efficiency ratio in the part in which two photocells operate is produced by the fact that the efficiency value does not add up (not summed up), for example, the efficiency ratio of silicon and the efficiency ratio of gallium arsenide on the yellow color, etc.

In fact, in this example of a solar battery (Figure 2) monocrystalline silicon is set only to red and orange, yellow, green, sky blue and blue — a photocell based on gallium arsenide, and purple — amorphous silicon. Consequently, the integral value of the efficiency ratio would be 20 + 40 + 6 = 66%, and if we install a photocell based on gallium arsenide instead of monocrystalline silicon, then the efficiency would be 86%.

However, the power of different wavelengths of solar radiation is different, so it is necessary to take into account the contribution share of each wavelength. According to Figure 5, where the colors are more clearly separated, red and orange colors will be 1250 W/m2, yellow 1400, green 1450, sky blue and blue - 1500 and purple 1500 W/m2. The area of the colored portion of the visible spectrum corresponds to the power of the visible radiation spectrum, and the area of each color corresponds to the energy contribution of a given wavelength.

Table 2 [10] presents the wavelength range of various colors of solar radiation. In this case, the area bounded by the wavelength range and the radiation intensity according to Figure 5 for each wavelength will be:

red 1250 x (740-625) = 143750,

orange 1250 x (625-590) = 43750,

yellow 1400 x (590-565) = 35,000,
green 1450 x (565-500) = 94250,
sky blue 1500 x (500-485) = 22500,
blue 1500 x (485-440) = 67500,
violet 1500 x (440-380) = 90000.

Table 2 – Characteristics of visible light

Цвет	Диапазон длин волн, нм	Диапазон частот, ТГц	Диапазон энергии фотонов, эВ
Фиолетовый	380 - 440	790 - 680	2,82 - 3,26
Синий	440 - 485	680 - 620	2,56 - 2,82
Голубой	485 - 500	620 - 600	2,48 - 2,56
Зелёный	500 - 565	600 - 530	2,19 - 2,48
Жёлтый	565 - 590	530 - 510	2,10 - 2,19
Оранжевый	590 - 625	510 - 480	1,98 - 2,10
Красный	625 - 740	480 - 400	1,68 - 1,9

The total area of 496750 is proportional to the power of the solar radiation of the visible spectrum, and the area of each color is proportional to the contribution of a given wavelength to the total power of the visible spectrum. The ratio of these individual areas to the total area shows the proportion of power that falls on a particular wavelength. Thus, the share of red will be 143750/496750 = 0.29; orange - 0.09; yellow - 0.07; green - 0.19; cyan - 0.05; blue - 0.14; purple - 0.19.

The efficiency ratio of a monocrystalline silicon solar cell is 22.5% [11], photovoltaic cells based on gallium arsenide 40% [14], amorphous silicon 6% [11].

Consider an option, for example, when monocrystalline silicon is set to red and orange. Yellow, green, sky blue and blue are photo cells based on gallium arsenide, and purple is amorphous silicon. In this case, the overall efficiency will be $0.29{\cdot}0.225 + 0.09{\cdot}0.225 + 0.07{\cdot}0.4 + 0.19{\cdot}0.4 + 0.05{\cdot}0.4 + 0.14{\cdot}0.4 + 0.19{\cdot}0.06 = 0.277$. If instead of monocrystalline silicon we put a photocell based on gallium arsenide and leave the rest unchanged, then the efficiency ratio = 0.34.

Since infrared radiation is not supplied to photovoltaic cells in the solar battery, moreover, the design allows to significantly increase the number of suns, you can use AlGaInP/ AlGaInAs/GaInAs/Ge with an efficiency of 57% [15].

The area of all photocells according to Figure 3 is 39.25 cm2, the total area on both sides of the concentrator will be 78.5 cm2. The projected area of a spherical mirror with a diameter of 60 cm is 2826 cm2. Consequently, 36 suns fall on solar cells, with a 80 cm mirror diameter there will be 64 suns, and with a diameter of 2 m - 400. Thus, it is possible to repeatedly and safely increase the number of suns falling on solar cells, thus the use of very expensive solar cells will be economically justified. This means that on the area of 31,400 cm2 (mirror diameter 2 m) only 78.5 cm2 of photocell will be involved. Consequently, to convert solar radiation into electrical energy from an area of 31,400 cm2, 400 times fewer expensive photovoltaic cells will be required.

Separately focused infrared radiation can be used in three directions: generation of thermal energy, conversion into electrical energy by means of a thermogenerator or photocell for infrared rays developed in Spain [12, 13]. Then the efficiency will increase, for example, if the efficiency ratio is 0.2 for infrared radiation, then $0.2 \cdot 0.49 = 0.1$, where 0.49 is the fraction of infrared radiation (Figure 5) [8], i.e. efficiency increase by 10%. Similarly, when using a thermogenerator, the efficiency of a solar battery will increase by at least 3%.

Conclusions: **increasing the efficiency of solar cells is possible by not only increasing the efficiency of solar cells, but also by dispersing and focusing solar radiation along wavelengths and installing a corresponding solar cell at each wavelength.**

The separation of infrared radiation not only increases the efficiency, but also increases the service life of solar photo-voltaic cells, since the degradation of solar cells due to thermal effects is eliminated.

The design of the solar battery allows utilizing infrared radiation in the form of electric or thermal energy.

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ЖАҢА БУЫННЫҢ КҮН ФОТОЭЛЕКТРЛІК БАТАРЕЯЛАРЫНЫҢ ТИІМДІЛІГІ

Аннотация: Толқындардың толқын ұзындығы бойынша күн радиациясын диспергациялау мен фокусына және әрбір толқын ұзындығына тиісті фотоэлементтердің орнатылуына байланысты өте жоғары тиімділігі бар күн батареясы әзірленді.

Бұл тәсіл тиімділікті арттырып қана қоймай, сонымен бірге инфрақызыл сәулені фотоэлементке түсірмей батареяның қызмет ету мерзімі артады. Сонымен қатар бұл құрылым өте қымбат, тиімділігі жоғары фотоэлементтерді экономикалық тиімді пайдалануға мүмкіндік береді.

Түйін сөздер: күн, фотоэлектрлік батарея, голографиялық концентратор, фотоэлемент, диспергациялау және фокустау.

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ЭФФЕКТИВНОСТЬ СОЛНЕЧНЫХ ФОТОЭЛЕКТРИЧЕСКИХ БАТАРЕЙ НОВОГО ПОКОЛЕНИЯ

Аннотация: Разработана солнечная фотоэлектрическая батарея с весьма высоким коэффициентом полезного действия за счет диспергирования и фокусировки солнечного излучения по длинам волн и установки на каждую длину волны соответствующий фотоэлемент.

Данный подход позволяет не только повысить эффективность, но и увеличить срок службы батарей за счет исключения инфракрасного излучения на фотоэлементы. Кроме того конструкция позволяет экономически выгодно использовать весьма дорогие но высокоэффективные фотоэлементы.

Ключевые слова: солнце, фотоэлектрическая батарея, голографический концентратор, фотоэлемент, диспергирование и фокусировка.

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