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Discovered Solar Positronium

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Abstract

I describe a method for the observation of Positronium (Ps) involvement in the solar radiation spectrum. In this method, Rydberg-Ritz's principle and Planck's radiation formula are used to acquire information of the atomic transitions of Ps alike Hydrogen and Helium. In order to perform this experiment, an advanced solar spectrum monitor is constructed by utilizing light emitting diodes (LED) of various colors. A detailed study on this method provides qualitative agreement with experimental data, giving insight to the physical process involved in the solar radiation spectrum and confirming the existence of solar Ps.

Keywords

LED, Light, Positronium, Simulation, Spectrometer

1. Introduction

Living creatures can sustain only in the third planet of the solar system and maximum energies consumed by it are being received from the Sun. *Positronium* (Ps) is a purely *leptonic* H-like atom formed from an electron (e^-) and its anti particle the positron (e^+). Particle antiparticle interaction is an electromagnetic process and a good test of QED leading to discover the similar phenomena in the environment of Sun by studying the chromaticity of the solar spectrum [1]. It is thought that solar energy produced by the radiation consisting of atomic transitions of H and He, and what maximum of us did not aware of Ps which is one of the important ingredient of solar radiation. From the best of my knowledge on the experimental and the theoretical literature survey, solar Ps spectrum is being demonstrated here for the first time. Radioactive isotope, pair production and fusion reac-

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tion are the major sources of e^+. The huge applications for e^+ include atomic, nuclear, astrophysics experiments [1]-[5], positron emission tomography (*PET*) [6] [7], studies of defects, surfaces, electron momentum of materials [8] [9] and material with medicinal values [10]. With the advent of sophisticated technology scientists are capable to produce high intense pulsed positron beam, accumulation of e^+ and Ps, production of Ps_2 molecule, intensive studies of Ps laser cooling for the achievement of Ps Bose-Einstein Condensation (PsBEC) [11]-[15]. Short pulses of Ps atoms is suitable for laser spectroscopy of the *Lyman-*α -like transition in the dipositronium (Ps_2) molecule at a UV wavelength of 251 nm [16], as well as Ps formation and dynamics in various target materials and efficient production of *Rydberg* Ps (binding energy −6.8 eV which is just half of the H due to the reduced mass of Ps) atoms. A. P. Mills and co-workers succeeded to make the e^+ beam intensity ~10^{10} to ~10^{11} per cm^2 by adding Ps-forming target and a pulsed magnet and Ps-*Lyman-*α spectroscopy can be found elsewhere [17]. Dipositronium and Ps can be produced simultaneously on the metal surface by the highest intense slow e^+ beam bombardment which is significant for studying the *Rydberg* Ps atoms and observing the PsBEC state. Hence laboratory based e^+ and Ps studies enrich our knowledge that helps me to unearth the solar Ps and find out its characteristics in the enormous temperature of the Sun. The detection of Ps outside the laboratory experiments were first observed by Chuup *et al.* (1973) [18] and first identified by Levethal *et al.* (1978) from the Galactic centre [19] via detection of the Ps annihilation, but innovation of the solar light color spectroscopy did not exist. Recent novelty of light emitting diodes (*LED*) for which "Nobel Prize-2014" is conferred to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura for their greatest contribution in social, industrial and entertainment applications. How *LEDs* can play a crucial role in science & technology development and pave the way of discovering the solar Ps will be illustrated in the following sections.

2. Theoretical aspect of Solar Positronium

2.1. Formation of Solar Positronium

The fusion reaction [1] is a source of solar Ps production that persistent in thermal plasma at $T \le 10^5$ K [20] for a while that is good enough to measure the transition energies between the quantum states. Since the reduced mass of Ps is $m_e/2$ just half of that of H atom and hence the binding energy of *Rydberg* Ps is −6.8 eV. Correspondingly Ps-Lyman-α has a wavelength of 243 nm and was observed by Canter *et al.* [21]. The total wave function of the Ps state is the product of three wave functions depending on the spin, space and charge coordinates:

$$\varphi(\text{total}) = \varphi(\text{space})\alpha(\text{spin})\beta(\text{charge})$$

This is a symmetric-antisymmetric wave function depends on the spin functions for a combination of two spin-1/2 particle-antiparticle (e^+ and e^-) can be expressed in the following four possible blends [22]:

$$\alpha(1,1) = \varphi_1\left(\frac{1}{2},\frac{1}{2}\right)\varphi_2\left(\frac{1}{2},\frac{1}{2}\right),$$

$$\alpha(1,0) = \frac{1}{\sqrt{2}}\left[\varphi_1\left(\frac{1}{2},\frac{1}{2}\right)\varphi_2\left(\frac{1}{2},-\frac{1}{2}\right) + \varphi_2\left(\frac{1}{2},\frac{1}{2}\right)\varphi_1\left(\frac{1}{2},-\frac{1}{2}\right)\right],$$

$$\alpha(1,-1) = \varphi_1\left(\frac{1}{2},-\frac{1}{2}\right)\varphi_2\left(\frac{1}{2},-\frac{1}{2}\right),$$

$$\alpha(0,0) = \frac{1}{\sqrt{2}}\left[\varphi_1\left(\frac{1}{2},\frac{1}{2}\right)\varphi_2\left(\frac{1}{2},-\frac{1}{2}\right) - \varphi_2\left(\frac{1}{2},\frac{1}{2}\right)\varphi_1\left(\frac{1}{2},-\frac{1}{2}\right)\right],$$

where the first three form a spin triplet $\left({}^3S_1\right)$ of $S=1$ and $S_z = 1$, 0, −1 states have the property that they are symmetric under particle interchange, and the last one is a singlet $\left({}^1S_0\right)$ of $S = S_z = 0$ state has the property of antisymmetric. The symmetry of the spin function α under particle interchange is $(-1)^{S+1}$, where S is the total spin. Particle interchange is equivalent to space inversion, introducing a factor $(-1)^l$, where l is the orbital angular momentum of the system. The charge wave function β acquire a charge conjugation factor $C = (-1)^n$ where n is the number of photons under particle interchange. The product of the factors applying to the separate spin, space, and charge function must then be that of the total wave function φ, which we denote by K, so that $K = C(-1)^{S+1}(-1)^l$. Individuality of the singlet and the triplet states Ps are presented in

Table 1.

2.2. Comparison of Exotic and Non Exotic Atoms

Since most of the previous studies have focused on the Galactic centre as the most promising source of Ps, although visual extinction is very high. However, detection of Ps recombination line made by Puxley & Skimer (1996) who searched for Ps *Paschen*-β from the Galactic centre but undetected [23]. Very recently study chromaticity of solar spectrum lead me to discover the solar Ps which is described in the following sections. This renewed interest is motivated by several recent and imminent advances in technology. From the literature survey it is found that Ps formation, recombination and quenching largely take place at temperature <10^6 K. Therefore, most astrophysical environments (~10^3 - 10^6 K) for Ps formation will be the dominant process leading to annihilation [24]. A comparative study of Ps, H and He are shown in **Table 2**.

The spectral lines (wavelength) of solar radiation spectrum are achieved from the *Rydberg-Ritz* formula:

$$\lambda = \left(\frac{hc}{R_\alpha}\right)\left(\frac{n_i^2 n_f^2}{n_f^2 - n_i^2}\right) \tag{1}$$

where h is the Planck's constant, c is the speed of light, R_α is the *Rydberg* energy (shown in **Table 2**). Hence, wavelength of each atom will be different *i.e.*, different color bands in the spectrum. The quantum numbers n_i and n_f respectively are the initial and final states of the atomic transition. For the *Lyman* series $n_i = 1$ and $n_f = 2, 3, 4, \cdots$; for the *Balmer* series $n_i = 2$ and $n_f = 3, 4, 5, \cdots$; for the *Paschen* series $n_i = 3$ and $n_f = 4, 5, 6, \cdots$; and for the *Brackett* series $n_i = 4$ and $n_f = 5, 6, 7, \cdots$, ... etc. The intensity of each color bands will be distributed according to the *Planck*'*s* radiation formula which is given below and details of this formulation can be found elsewhere [25].

$$\frac{\mathrm{d}R(\lambda)}{\mathrm{d}\lambda} = \frac{2\pi hc^2}{\lambda^5} \frac{1}{\mathrm{e}^{\frac{hc}{\lambda KT}} - 1} \tag{2}$$

where K is the Boltzmann constant and T is the temperature of the photosphere (5800 K). The wavelength λ of the corresponding H, He and Ps can be obtained from Equation (1).

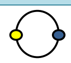
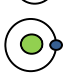
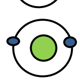
3. Detector Development and Data Acquisition

In order to study the solar Ps an advanced Solar Spectrum Monitor (*SSM*) development is extremely vital. Using the various colored *LEDs* (keeping in mind of *VIBGYOR* in the solar spectrum Red, Orange, Yellow, Green and White *LEDs* are taken into account) and a *Freeduino* the *SSM* detector is constructed. *LEDs* which are commer-

Table 1. Properties of singlet and triplet states Ps.

Ps states	Particle-antiparticle interactions				
	$S = J$	l	C	K	Lifetimes (s)
Singlet $({}^1S_0)$ 2γ (antisymmetric)	0	0	+1	−1	1.25×10^{-10}
Triplet $({}^3S_1)$ 3γ (symmetric)	1	0	−1	−1	1.42×10^{-7}

Table 2. Comparison among the Ps, H and He atoms.

Atoms	Properties					
	Ground state	Mass energy (MeV)	Rydberg energy (eV)	Lyman-α (nm)	1S-2P transition energy (eV)	Stability
$\mathrm{Ps}(\mathrm{e}^+\mathrm{e}^-)$		1.02	−6.8	243.0	5.1	Unstable (no nucleus)
$\mathrm{H}(p, \mathrm{e})$		938.00	−13.6	121.5	10.2	Stable (nucleus exist)
$\mathrm{He}(2p, 2n, 2\mathrm{e})$		3756.00	−54.6	58.4	21.2	Stable & inert (nucleus exist)

cially available in the public market are collected, hence manufacture's quote of each colored wavelength of *LEDs* are unavailable. *Freeduino* is a tool for the interfacing of data to a computer from the physical parameters, e.g., sound, light etc. It is based on the Atmel's *ATMEGA*328 micro controller systems. The size, shape and number of each colored *LEDs* are kept equal and connected in series to each group. The size of the Vero-board is 15 × 10 cm^2 and each colored section is about 4 × 4 cm^2. There are five channels of the color group. The analogue output signals from the *SSM* are fed into the *Freeduino* digital microprocessor unit 0 - 4. The *Freeduino* gets its input *i.e.*, analogue signals from the *SSM* detector when it is directly exposed to the ray of Sun for an hour. These signals are digitized by the *ADC* (1024 Channels) of the board that is interfaced with a *PC* via *USB* ports and output data is scrutinized in the monitor by using external software. This data is now displayed and stored in the *ASCII* format for further analysis. In order to take the background data *SSM* detector is covered with a piece of thick black cloth and data are taken for the same time. A schematic diagram of the *SSM* detector is shown in **Figure 1**.

4. Results and Discussions

Data obtained by different colored *LEDs* are compared with the results of the simulation considering the model based on *Rydberg-Ritz-Planck* principle rigorously.

4.1. Simulation

In order to understand the solar radiation spectrum intensively, an extensive simulation is carried out for the atomic transitions of He, Ps and H according to the *Rydberg-Ritz* principle (see **Equation (1)**). Simulation results are shown in **Figures 2(a)-(c)** and solar spectrum (sum of **a**, **b** and **c**) is depicted in (**d**) where components of each atomic transitions are clearly exhibited with the colour bands, but data do not illustrate the distribution of solar radiation spectrum.

Hence wavelengths which are obtained by the *Rydberg-Ritz*'*s* formula stated in **Equation (1)** are fed into the *Planck*'*s* radiation formula. The wavelength distributions are shown in **Figures 3(a)-(c)**. After combining those data of Ps, He and H the solar radiation spectrum is achieved and that is revealed in (**d**) and consequently the area of interest (720 - 830 nm, Ps-*Balmer* series) is illuminated.

Theoretical contribution of H-(Balmer+Paschen), He-(Paschen+Brackett) and Ps-(Balmer) spectra in visible range of solar radiation respectively are estimated to be 37%, 41% and 22%.

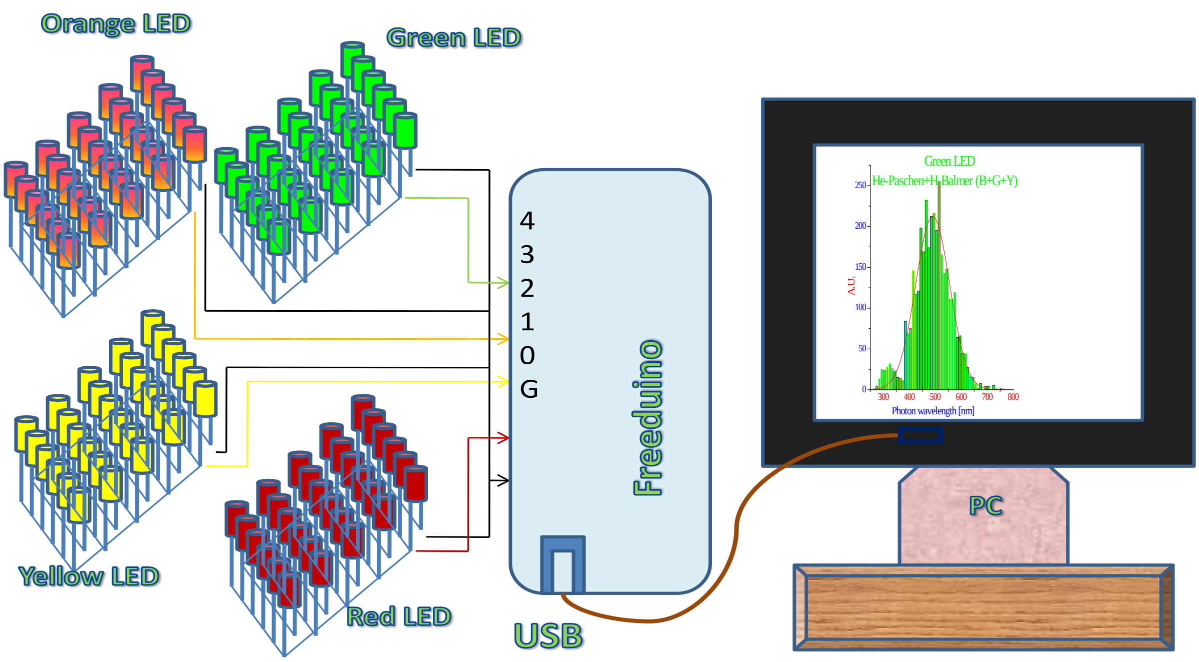


Figure 1. Experimental arrangement of solar spectrum monitor.

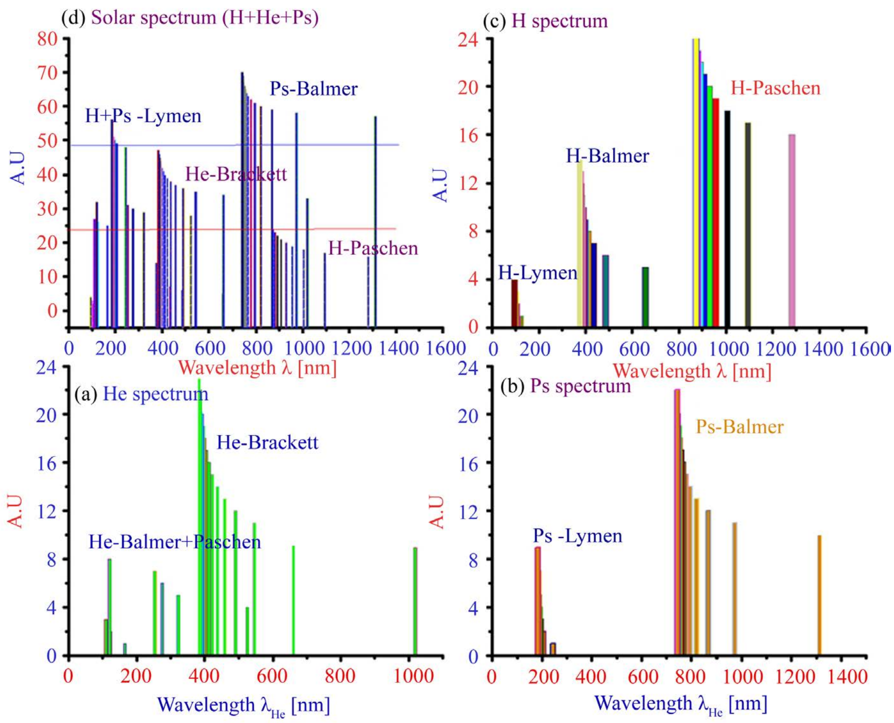


Figure 2. Origin of the solar spectrum.

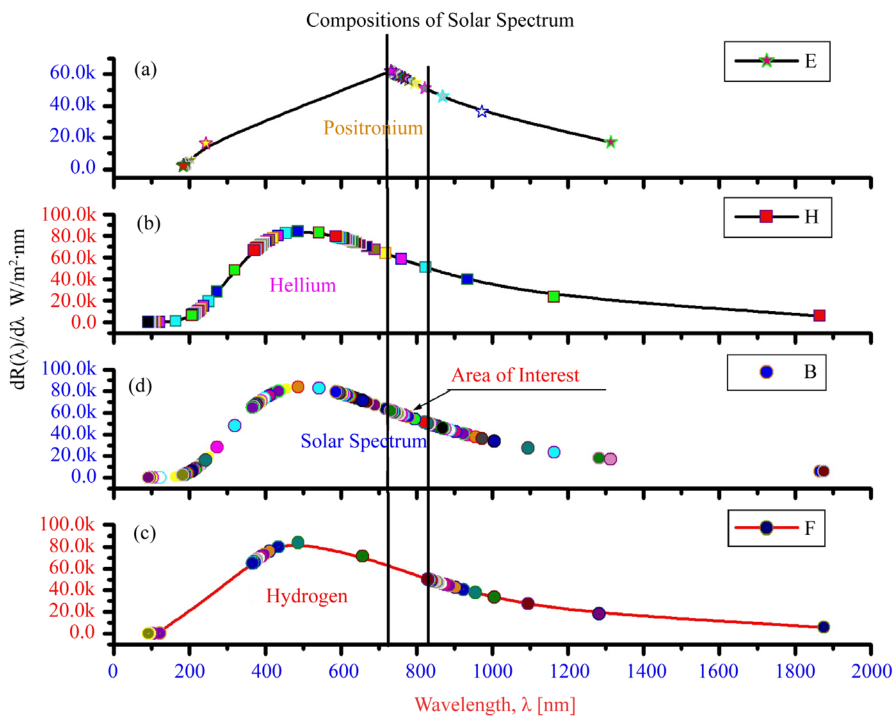


Figure 3. Distribution of solar radiation with other constituent spectra.

4.2. Experimental Results

Similarly experimental data are analyzed by subtracting each background from the respective colored bands and converted energy (eV) to wavelength (nm) which is depicted in **Figures 4(a)-(d)**. In order to see the contribu-

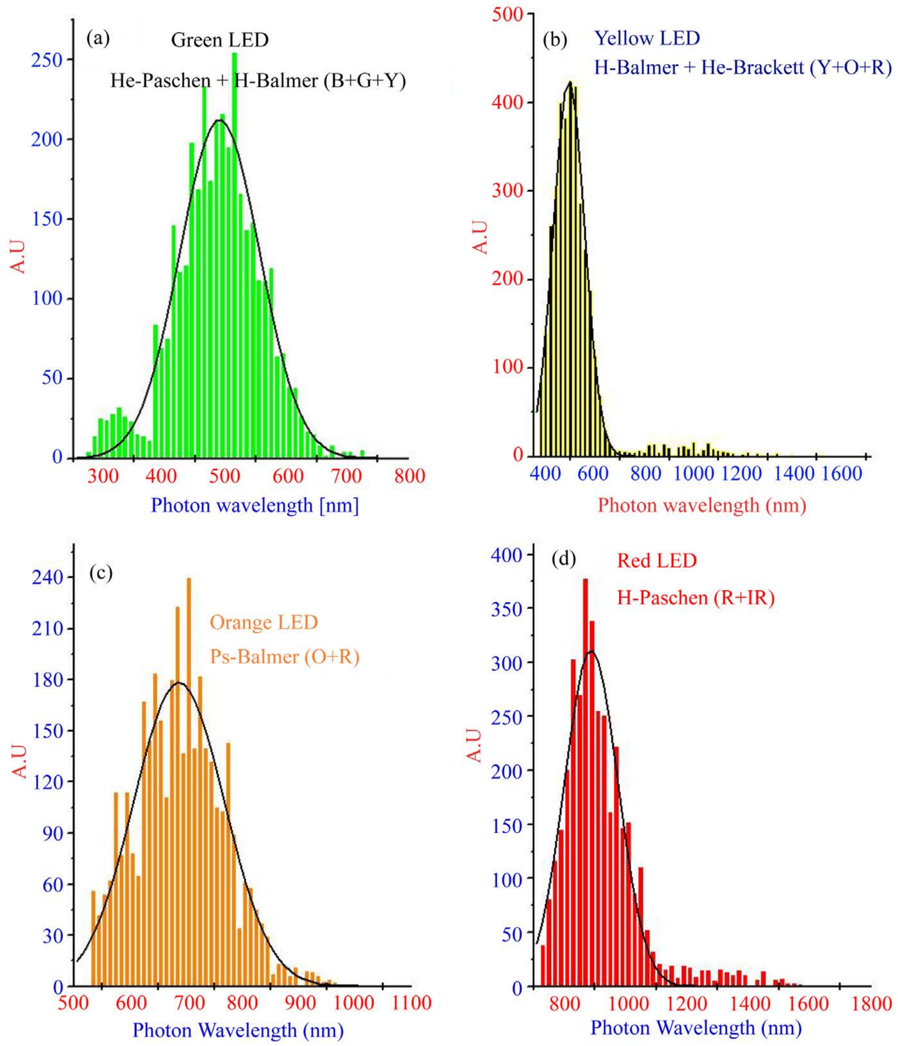


Figure 4. Observation of solar radiation by coloured *LEDs*.

tion of each component in the solar radiation spectrum data are fitted with *Gaussian*. The mean and *FWHM* $(= 2.35 \times \sigma)$ of the Gaussian are shown in **Table 3** and considered for the evaluation with a *LED* manufacturer's quoted values found elsewhere [26] for better understanding.

Contribution of H-Balmer 54% in Green, H-Paschen 4.2% in Orange and 66% in Red spectra are estimated from the fitted frequencies. Similarly He-Paschen 8% in Green, 2.34% in Yellow, and He-Brackett 34% in Green, 93% in Yellow; and Ps-Balmer 1% in Yellow, 41% in Orange and 26% in Red are estimated. In total contributions of H-(Balmer + Paschen), He-(Paschen + Brackett) and Ps-(Balmer) respectively are determined to be 31%, 52% and 17% in the visible range of solar radiation spectrum.

The extremity at right hand side of each spectrum shows the temperament of *Planck*'*s* radiation formula. In order to find exact distribution of *this* formula more colored *LEDs* (Violet, Indigo and Blue) data are required. However reported results confirm a good agreement with the theoretical achievement of *Ridberg*-*Ritz*-*Planck*'*s* principle within this constraint. The differences what are merely appeared due to the diverse transitional times among H, He and Ps in the solar environment, refraction and reflection of light due to solar and earth atmospheres and statistical error due to electronics fluctuations which are not determinative. The *FWHM* of each Gaussian distribution represents the wide range of colors originated from the respective atoms of different transition series. The *FWHM* of Red spectrum shows maximum due to the widest range of different series and the highest contribution of H-*Paschen* (66%) series. Yellow spectrum shows minimum because of the shorter range and maximum contribution of *He-Brackett* (93%) series. The contribution of the He atom is maximum because

Table 3. Evaluation of experimental results with manufacturer's quoted value.

Chemical composition of LEDs	Wavelengths (nm)			
	Manufacturer's quoted values[a]		Experimental values	
	Mean wavelength	FWHM	Mean wavelength	FWHM
GaP-GaP	555 (Green)	25	490 (Green)	154
GaAsP-GaP	610 (Orange)	35	492 (Yellow)	150
GaAlAs-GaAlAs	660 (Red)	25	687 (Orange)	190
GaAlAs-GaAs	700 (Red)	25		
GaAlAs-GaAlP	880 (Near IR)	80	887 (Red)	205
GaAs-GaAs	940 (IR)	45		

[a]. Reference [26] is not the same manufacture of LEDs which are used in this experiment.

it is stable and inert. On the other hand, higher ionization probability leads H for taking part in the fusion reaction. Ps is unstable, quenching in the huge magnetic field and have the shortest lifetimes; as a result transitional probabilities of *Ps* are fewer than H and He. In the Orange spectrum (600 - 700 nm), around 40% contribution comes from the He-*Pfund* series. But I suppose this probability is very low in compare to He-*Brackett* and He-*Paschen* series in the range of visible light. Hence, it is better to think other type of lighter atoms forming in the fusion mechanisms whose binding energy (~8.25 eV) is fewer than H and greater than Ps atom. That hypothetical atom (presume Nm) will provide the color band of wavelength (600 - 700 nm) from the transition of Nm-*Balmer* series.

5. Conclusion

The data of Solar Spectrum Monitor conclude the existence of solar Ps which is one of the main constituent of solar radiation spectrum. By monitoring and characterizing the colored radiation spectra solar Ps will be estimated and that will tell us the present, past and future of the astrophysical phenomena. If *SSM* detector is possible to send in the outer space with necessary modification and collect the γ-rays of e^+e^- annihilation more precisely and those analyzed data will provide intense information about the space, extra galactic solar system and their circumstances, celestial Ps, *dark matter* and possibly the giant source of PsBEC. Hence, solar Ps spectroscopy plays a crucial role for the determination of sun's environment, fusion reaction in various cells and constituents. The intensity distribution of the solar spectrum and associate color bands exactly tell us the nuclear and fusion reaction mechanisms, radiation energy and particle-antiparticle plasma in the colossal magnetic fields.

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