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Stimulated Plasma by Positron Injection into the Media Cross Sections and Wall Interaction Calculation

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Author's contribution

The only above mentioned author performed the whole research work. She only wrote the first draft of the paper. And she read and approved the final manuscript.

Research Article

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ABSTRACT

Because of the technical complexities involved in the plasma heating process in most reactions a simple method has been introduced by this author in ITC/12 conference, Japan. In the present approach rather colder plasmas are stimulated by using positronium atoms as stimulus element into the plasma media (The formation of positronium atoms are plausible through injection positrons from Ring storage into plasma media which immediately tends to pair annihilation then leading to gamma emission in singlet and / or triplet forms referred to the spins of pairs (Table 1)). The energy obtained by these rays would thermalize the plasma particles even if they should be used in nuclear reaction. In the present paper the interactions between gamma rays with the plasma particles including electrons, ions and neutral species through different mechanism are investigated, ultimately all interaction cross – sections are taken into account and the possible wall interactions calculated.

***Keywords**: Positron particle; gamma rays; plasma particles; cross section.*

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1. INTRODUCTION

The main scope of this study is presenting as a new way of plasma heating[1] trend through investigating the interaction of plasma particles and electromagnetic radiation applied inside the plasma without the needs of external supplementary devices to launch the waves into the plasma media. Indeed, the positrons produced, in Ring storages would be injected into the fuel part of the reactors (viz; tokamaks) and the interaction between them and the plasma electrons leads to positronium atoms formation. Then pair annihilation takes place that leads to singlet and/ or triplet linearized, mono chromatic gamma radiation (refer to the spin of pair) with the proper life time of $\tau_s = 10^{-10}\,s$ and $\tau_t = 10^{-7}\,s$, respectively. The gamma rays features are tabulated in Table 1. Obviously with the proper life time of singlet and triplet gamma radiation coincide in the excited inert – gas transition time in the relevant lasers ($10^{-7} - 10^{-10}$)[2]. Therefore, the above mentioned rays could act as excimer short pulse high energy productive elements of the same lasers interact with plasma particles in the case of laser application. Then the absorption or the scattering of the gamma rays from pair annihilation with $\lambda\,(= \frac{hc}{\varepsilon} = \frac{hc}{0.51 Mev}$ *where* ε *is the rest mass of pairs*$) =$ $0.012 A^{\circ} - 0.024 A^{\circ}$ would thermalize the plasma particles in one extreme lead to the increasing the particles energy high enough in the other extreme.

Also spatially non homogenous plasmas with the variation of dielectric constant and undulation of the fluid point of view, together with the dispersion relation variation, lead to scattering of the rays with different mechanisms [3] which are considered in this paper.

Table 1. Pair annihilation gamma rays features

Feature		
State	**Singlet**	**Triplet**
spin	↑↓	↑↑
proper life time	$\tau_s = 1.25 \times 10^{-10}\,s$	$\tau_t = 104 \times 10^{-7}\,s$
decay type	2γ	3γ
share %	25	75
total radiation power	$0.653\ mw$	0.0389 *mw*
free distance that ray travel	$L_s = 3.75\ cm$	$L_t = 42\ m$

Noticeably the simple elastic scattering of the photon rays in the medium is not the case, otherwise our interested cases are restricted to inelastic scattering with the attention paid on their cross – sections, viz; the following mechanism:

Free electrons (in the plasma) interaction with gamma rays should fulfill the Compton Scattering condition i .e, $h\nu = m_{\circ}c^2$ or Compton classical scattering formula as [4]:

$$\Delta\lambda = \lambda_c(1 - Cos\theta)$$
$$\lambda_c = 0.0242A^{\circ} \quad (1)$$
$$K_e = h\nu \frac{\frac{h\nu}{m_{\circ}c^2}(1 - Cos\theta)}{1 + \frac{h\nu}{m_{\circ}c^2}(1 - Cos\theta)}$$

In our case: $h\nu = m_{\circ}c^2$

And: $K_e = \frac{h\nu(1 - Cos\theta)}{2 - Cos\theta}$

At $\theta = 0 \quad K_e = 0, \; \theta = \frac{\pi}{2}, \; K_e = \frac{h\nu}{2}$, at $\theta = \pi$, $K_e = \frac{2}{3}h\nu$ and at $\theta = \frac{3\pi}{2}$, $K_e = \frac{h\nu}{2}$ (and $h\nu = m_{\circ}c^2 =$ rest mass of pairs) = 0.51 Mev

As is obvious from above calculations, through Compton classical scattering of the gamma rays and the electron species of the plasmas, the submission of the γ rays energy to electrons would lead to the increasing the particles energy high enough about 0.51 *Mev*- $\frac{2}{3}0.51Mev$. Compton scattering cross – section is measureable through Klein – Nishina formula [5]:

$$\frac{d\sigma(\theta)}{d\Omega} = \frac{1}{2}r_0^2\frac{\nu'^2}{\nu^2}\left(\frac{\nu}{\nu'} + \frac{\nu'}{\nu}Sin^2\theta\right) \quad (2)$$

In our case:

$$\frac{\nu'}{\nu} = \frac{1}{1 + \gamma(1 - Cos\theta)}, \; \gamma = \frac{h\nu}{m_{\circ}c^2} = 1 \quad (3)$$

So as: $\frac{d\sigma(\theta)}{d\Omega} = r_0^2$

And $Z(\theta) = 4\pi r_0^2$ maximum value at $\theta = 0$

At $\theta = \frac{\pi}{2} \quad \frac{d\sigma(0)}{d\Omega} = \frac{3}{16}r_0^2$ and $\sigma(\theta) = 4\pi\frac{3}{16}r_0^2$ (4)

At $\theta = \pi \quad \frac{d\sigma(\theta)}{d\Omega} = \frac{5}{2^7}(r_0^2)$ and $\sigma(\theta) = 4\pi\frac{5}{2^7}(r_0^2)$

Where $r_{\circ}$ is electron classical radius

2. RESULTS

In this work the main question was to achieve a new technique to heat the cold plasmas with least technical difficulties, ever faced with plasma works as in tokamaks. With using an internal agent to heat the plasma in one extreme lead to rather fully ionization of the plasma, in other extreme with least damages was the other scope of the work. The injection of positrons into the plasma media from some devices as Ring storages tend to positronium atoms formation, proceed to pair annihilation with γ ray radiation that contribute to the release of energy about the rest mass of the pairs (=2*0.511Mev) to the plasma particles. The cross – sections of different photon – matter interaction inferred through mentioned below, cases, with the relevant probability of reactions occurrences are also deduced. The fruitfulness of the method (theoretical) is partially because of the very little vessel damage together with using the colder plasmas, with least confinement time about $10^{-10} - 10^{-7} s$ of that of the proper life times of gamma – rays entered into the reactions.

From diagnostics point of view in this method with not only using a simple bolometer is capable to follow the internal situation of the reactor, but it is clear that also the achievements of the sufficient heating of the plasma particles would be another key roll to pursue the diagnostic problems inside the fuel part vessel during the plasma works which is another view point of the work that we should mentioned it in another paper. Except that the Compton interaction mentioned above there should be mentioned another possible interaction between matter – gamma ray as below:

2.1 Rayleigh Scattering

The second important case in this paper that is taken into account is Rayleigh scattering. The absorption and scattering of γ radiation with atoms and molecules in the plasma should be considered as the following [6]:

The reaction cross- section is:

$$\sigma_{sc}(\omega) = \frac{8\pi r_0^2}{3} \frac{\omega^4}{(\omega^2 - \omega_i^2)^2 + \omega^2 \gamma^2} \tag{5}$$

At $\omega << \omega_i \ \ and \ \ |\omega - \omega_i| \leq \gamma$

Then $\sigma_{sc} = 6\pi \frac{r_0^2}{3} (\frac{\omega}{\omega_i})^4 \cong 8\pi \frac{r_0^2}{3} (\frac{\lambda_i}{\lambda})^4$ (6)

If the interaction lead to resonant absorption then the cross section is:

$$\sigma_{sc}(\omega) = \frac{\delta \pi r_i^2}{3} (\frac{\omega_i}{\gamma})^2 \tag{7}$$

Refer to classical γ amounts:

$$\gamma = \frac{e^2 \omega_i^2}{6\pi\varepsilon_\circ mc^3} \tag{8}$$

$$\sigma sc_{\max} = \frac{6\pi c^2}{\omega^2} = 6\pi\chi^2 \tag{9}$$

2.2 Inelastic Absorption

About resonant frequency ω_i the interactive absorption occurs and the cross- sections are[7]:

$$\sigma_{sc}(\omega) = \pi r_0^2 f_{ei}^2 \frac{\omega_i^2}{(\omega - \omega_i)^2 + (\frac{\gamma_i}{2})^2} \tag{10}$$

Where f_{ei} is the scattering power in electron transition from the lowest state of atoms:

$\sigma sc_{\max} = 2\pi\chi^2$

The fulfillment of the classical relation completely is:

$$\sigma sc_{\max} = \frac{6\pi C^2}{\omega^2} = 6\pi X^2 \tag{11}$$

2.3 Raman Scattering

At this moment the last photon- mater interaction cross – section calculation for the Raman scattering in the classical scheme presented. Here for the50% hydrogen (ionized hydrogen) plasma we have [8]:

$$\sigma = \frac{e^2}{4\tau m\varepsilon_\circ c((\omega - \omega_\circ)^2 + (\frac{1}{2\tau})^2)} \tag{12}$$

Then, $\gamma = \frac{e^2 \omega_0^2}{6\pi\varepsilon_\circ mc^3}$ and if $\gamma << \omega_\circ$, $\gamma = 0$

$$\sigma = \frac{e^2}{4\tau m\varepsilon_\circ c(\omega - \omega_\circ)^2} = 4\frac{r_0^2}{6}(\frac{\omega_\circ}{\omega}) \cong \frac{2\pi r_0^2}{3}(\frac{\omega_\circ}{\omega})^2 = \frac{\sigma T}{4}(\frac{\lambda}{\lambda_\circ})^2 \tag{13}$$

$$\lambda_\circ = \lambda_{H\alpha} = 6562.8A^\circ$$

Such that:

$\lambda c = 0.024A^\circ = 1.1\times 10^3 r_\circ$

And total interaction cross-section is $\sigma \cong 0.4\sigma_T \times 10^9$ which is not considerably high.

3. DISCUSSION

Obviously the probability of interaction occurrences for all direction is [9]:

$$F(\omega)=\frac{d\sigma(\theta)}{d\Omega}$$

$$\sigma(\theta)=\int d\sigma=\int F(\omega)\,d\Omega=4\pi F(\omega) \quad (14)$$

$$F(\omega)=\frac{\sigma}{4\pi}$$

$$and\ \sum\frac{\sigma}{4\pi}=\frac{1}{4\pi}(\sigma_{com}(=\frac{r_0^2}{at\theta=0})+(\frac{3}{2}\lambda_{Ra}^2))=\frac{1}{4\pi}(\frac{3}{2}\lambda^2+\frac{3}{2}\lambda_{Ra}^2+\pi\frac{r_0^2}{6}(\frac{\omega_\circ}{\omega})^2) \quad (15)$$

$$\cong 7.95\times10^{-30}+0.60\times10^{-24}+0.187\times\frac{10^{-40}}{pholon}$$

$$=7.95\times10^{-30}+3(0.20\times6^{-24})+\frac{1}{6}(1.12\times10^{-40})$$

The probability of photon – wall interaction is directly proportional to:

$P_w=\frac{total\ reaction\ cross-\sec tions}{total\ device\ \mathrm{int}ernal\ surface}$ (Multiplying the number density of confined plasma particles).

In experimental small tokamak like that of Iran viz, IR-T1 if n=$10^{20}\,cm^{-3}$ is number plasma density and total internal device surface ($2\pi R\ \ 2\pi a$ where R is the mid value of torus radius and α, the circular cross section radius of the device namely: R= 46.00 *cm*
$a=12.60\,cm$) $for\ \ n_e=0.7-3\times10^{20}$
$P_w=0.85\times10^{-8}$ Which is the least possible value.

On the other hand the photon – particle reaction probability is about:
$P_{Ph}=1-P_w=1.$

4. CONCLUSION

In this paper a new method for stimulation the plasma particles presented, so that the plasma media necessarily could not be also too heated. The stimulus agent are positron particles that are obtained from some devices as Ring storage. The injection of these particles into the plasma vessel would led to positronium atoms formation with short term life time then in turn tend to annihilation of pairs. Submission of the released energy from this reaction into the plasma media as mentioned earlier could heated the plasma particles(pair annihilation could produced 2-3 gamma photon refer to the spin of the pairs (singlet and or triplet gamma rays)). It expected that during these process wall and gamma rays interaction take place in the plasma vessel, but calculation showed that the possibility of this to be occurred is rather regardless. The possible gamma photon - matter particles (electrons and massive protons) reactions including Compton, Rayleigh and Raman scattering and last but not least inelastic absorption of the rays in free electrons should be mentioned.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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