World Journal of Nuclear Science and Technology, 2018, 8, 190-196
http://www.scirp.org/journal/wjnst
ISSN Online: 2161-6809
ISSN Print: 2161-6795

A Way to Realize Controlled Nuclear Fusion by γ-Laser or γ-Ray

Shihao Chen[1], Ziwei Chen[2]

[1]Institute of Theoretical Physics, Northeast Normal University, Changchun, China
[2]Key Laboratory of Microwave and Electromagnetic Radiation, Institute of Electronics, Chinese Academy of Science, Beijing, China

Email: shchen@nenu.edu.cn

How to cite this paper: Chen, S.H. and Chen, Z.W. (2018) A Way to Realize Controlled Nuclear Fusion by γ-Laser or γ-Ray. *World Journal of Nuclear Science and Technology*, **8**, 190-196.
https://doi.org/10.4236/wjnst.2018.84016

Received: September 3, 2018
Accepted: October 21, 2018
Published: October 24, 2018

Abstract

A way is proposed to realize controllable-nuclear fusion by γ-laser or γ-ray and ordinary laser with their certain frequencies and large enough intensities to irradiate a target ball. The function of ordinary laser is to heat the target nuclei and to realize the inertial confinement for the target nuclei. The target nuclei absorbing γ-photons will be in a certain excited state. The scattering cross-sections will be larger and the ignition temperature will be lower to realize fusion of the nuclei in their excited states than those of the nuclei in their ground states. In contrast with the nuclei applied in conventional fusion, e.g., deutons and tritons, according to the way, the nuclei applied to fusion should have the following characters: the nuclei have their excited states, one of the excited states has higher energy and longer lifetime, and the masses of the nuclei are lesser. Thus, the Lawson conditions can more easily be realized so that the controllable nuclear fusion is possibly realized by the way.

Keywords

Controlled Nuclear Fusion, Excited States of a Nucleus, Laser, Interaction of Laser with Matter

1. Introduction

γ-ray has been produced by electron-laser back-scattering. The way to realize γ-laser whose wavelength is continuously adjustable has been presented [1] [2] [3].

To date, controlled nuclear fusion has a important progress [4], but not the ultimate realization. A necessary condition for nuclear fusion is that the Lawson coditions must be satisfied. One of the conditions is that the distance between two target nuclei must be lesser than the radius of the strong interaction. This means that the nuclear kinetic energy must be large enough to overcome the electrostatic potential barrier between two nuclei. The ignition temperature is not easily achieved by traditional methods.

This paper presents a way to realize nuclear fusion at lower temperature by γ-laser or strong enough γ-ray and ordinary laser to irradiate target atoms. The ignition temperature of nuclear fusion of the excited nuclei is lower, and the scattering cross-section of the excited nuclei is larger. Thus, the Lawson conditions can easily be realized.

The effect of γ-laser or γ-ray is essntially different from the ordinary laser. The energy of a γ-photon can be the same as the difference between these two energy states. Hence a nucleus can transit to its excited state after it absorbs a γ-photon.

In Section 2 the way to realize nuclear fusion by γ-laser is presented; in Section 3, the features of the way are explained; Section 4 is discussion; Section 5 is the conclusion.

2. The Way to Realize Nuclear Fusion by γ-Laser or γ-Ray

1) The Way to Realize Nuclear Fusion by γ-Laser or γ-Ray with Their Large Enough Intensities

Let it have been ready that a target atom ball composed of A and B sorts of atoms, many (such as 36) γ-laser beams or many γ-ray beams with their certain frequency $\omega_{\gamma i}, i = A, B$ and their large enough intensities, and many (such as 192) ordinary laser beams with certain frequencies ω_{oi} and their large enough intensities. The laser beams distribute symmetrically about the target ball and irradiate the target ball. A nucleus absorbing a γ-photon with its energy $E_{\gamma i} = \hbar\omega_{\gamma i}$ will be in its excited state with its energy eigenvalues E_{ei}. Considering the Mossbauer Effect, *i.e.* the recoil effect of the nucleus, we obtain the energy of the photon to be

$$E_{\gamma i} = \left(E_{ei} - E_{gi}\right) + \left(E_{ei} - E_{gi}\right)^2 \Big/ 2m_i c^2, \; E_{ei} \gtrsim T_{eF}, \tag{1}$$

where E_{ei}, E_{gi}, m_i and T_{eF} are the energy of the excited state, the energy of the ground state, the mass of the ith sort of the target nuclei in the static state, and the fusion temperature of the A-nuclei and the B-nuclei in their excited states. In general, the condition $E_{ei} > T_{eF}$ can be satistied. The function of the ordinary laser is to strip the electrons about a nucleus and to realize the inertial confinement for the nuclei in the target ball. In the period of the inertial confinement for the nuclei, γ-laser or γ-ray irradiates the target ball from beginning to end.

It is also possible that the target ball is composed of only the the A sort of atoms. Because of γ-laser or γ-ray irradiation, the target ball becomes a plasma composed of the A-nuclei in their excited states and electrons. When the temperature of the plasma $T_p \lesssim T_{eF}$, incident B-nuclei (e.g. a beam of protons) with a certain momentum will react with the A-nuclei, the fusion of the A-nuclei and B-nuclei can occur in the plasma.

The reaction of the two nuclei in their excited states has the following features.

The ignition temperature will be lower and the scattering cross-sections will be larger to realize fusion of the nuclei in their excited states.

2) The distance of the nucleons in the outermost shell of a nucleus in its excited state to its nuclear centre is larger than that of the nucleus in its ground state to its nuclear centre

The volume of a nucleus when it is in its excited states is approximately equal to that when it is in its ground state, because a nucleus cannot be compressed. Although the volume of a nucleus is invarient, its shape can change. Because of the stretching action of the nucleus in the outermost shell when a nucleus is in an excited state, a spheric nucleus can become an ellipsoid nucleus when it transits from its ground state to an excited state. In other words, the ratio of the ellisoid long axis to the short axis becomes bigger when the nucleus changes from its ground state to an excited state. Let the long axis and short axis of the ith sort of nuclei in its ground state be r_{gli} and r_{gsi}, the long axis and short axis of the ith sort of nuclei in an excited state be r_{eli} and r_{esi}, respectively, then it is necessary

$$r_{eli} > r_{gli},\ r_{eli}/r_{esi} > r_{gli}/r_{gsi}, \tag{2}$$

Because of (2), there should be

$$l_e > l_g,\ \mu_e > \mu_g, \tag{3}$$

where l_e and μ_e are the orbital angular momenta and the orbital magnetic moments of the nucleus in an excited state, and l_g and μ_g are the orbital angular momenta and the orbital magnetic moments of the nucleus in its ground state.

3) Scattering cross-sections of the strong interaction of the nuclei in their excited states will be larger than that of the nuclei in their ground states

The strong interaction of two nucleons by exchange virtual π-mesons is attractive interaction. Let the strong interaction radius of a nucleon be R_0, then the strong interaction radius of the A-nucleus and B-nucleus in their excited states is $R_e = R_0 + r_{elA} + r_{elB}$, and the strong interaction radius of the A and B nuclei in their ground states is $R_g = R_0 + r_{glA} + r_{glB}$. It is necessary that

$$R_e > R_g, \tag{4}$$

because $r_{elA} > r_{glA}$ and $r_{elB} > r_{glB}$.

On the other hand, the surface area of a nucleus in an excited state is bigger than that of the nucleus in its ground state, because their volumes are the same, but $r_{eli} > r_{gli}$. Let σ_g and σ_e are the scattering cross sections of strong interaction of the A-nucleus and B-nucleus when both are in their ground and when both are their excited states, respectively, then it is necessary

$$\sigma_e > \sigma_g. \tag{5}$$

Increase of scattering cross section is equivalent to increase of the number density n of nuclei.

4) The temperature to realize fusion reaction of the nuclei in their excited states will be lower than that of the nuclei in their ground states

When the distance R_{AB} of the A-nucleus and B-nucleus in their ground states is larger than R_g, *i.e.* $R_{AB} > R_g$, or $R_{AB} > R_e$, the stong interaction between the A-nucleus and B-nucleus may be neglected, When $R_{AB} > R_g$ or $R_{AB} > R_e$, the electromagnetic interaction is dominative. In order to realize the nuclear reaction, $R_{AB} \lesssim R_g$ or $R_{AB} \lesssim R_e$ is necessary. Let Q_A and Q_B are the charges of the A-nucleus and the B-nucleus, respectively, the electromagnetic potential energy between the A-nucleus and the B-nucleus is

$$V_{AB} = Q_A Q_B / R_{AB}. \tag{6}$$

Let E_g be the relative kinetic energy of the A-nucleus and the B-nucleus in their ground states, and E_e be the relative kinetic energy of the A-nucleus and the B-nucleus in their excited states, then only when

$$E_g \gtrsim V_g \equiv Q_A Q_B / R_g, \tag{7}$$

or

$$E_e \gtrsim V_e \equiv Q_A Q_B / R_e, \tag{8}$$

the nuclear reaction of the A-nucleus and B-nucleus can occur. It is obvious that

$$E_g > E_e. \tag{9}$$

In fact, when nuclei are in excited states, the internal energy of the nuclei increase. The internal energy will release out when nuclear reaction occurs. Increase of the internal energy is equivalent to increase of of kinetic energy of the nuclei. Hence the temperature T_e to realize fusion reaction of the nuclei when they are in their excited states will be lower than that when they are in their ground states, *i.e.*

$$T_g > T_e. \tag{10}$$

It is seen from (3), (5) and (10) that the nuclei in an excited state can more easily confined than the nuclei in their ground state. In other words, under the same conditions, the confined time

$$\tau_{ec} > \tau_{gc}.$$

where τ_{ec} and τ_{gc} are the confined times of the nuclei in an excited state and in their ground state, respectively. Consequently,

$$n\tau_e > n\tau_g. \tag{11}$$

Here it is considered that increase of scattering cross section is equivalent to increase of the number density n of nuclei. It is seen that according to the way, the Lawson conditions can easier be realized so that the controlled nuclear fusion can easier be realized.

5) Choice of nuclei applied to fusion and an example

In contrast with the conventional choice of fusion nuclei, it is possible that deutons and tritons are not optimal nuclei for fusion. It can been seen from above mentioned that the nuclei applied to fusion should have the following characters: the nuclei have their excited states; one of the excited states has higher energy and longer lifetime; and the masses of the nuclei are lesser.

For example, ^{11}B and ^{1}H nuclei may be chosen. The target ball is composed of the $^{11}B_{10}H_{14}$ molecules. Because of irradiation of ordinary laser, the $^{11}B_{10}H_{14}$ molecules is dissociated to plasma composed of ^{11}B's, p's and electrons. It is also possible that the target ball is composed of only the ^{11}B atoms, but proton beams with their large enough momenta impact the target ball. There is the following reaction [5]

$$^{11}\mathrm{B}+\mathrm{p}\to{}^{12}\mathrm{C}^{*}\to{}^{12}\mathrm{C}+\gamma,\ {}^{8}\mathrm{Be}+\alpha+E'_g,\ 3\alpha+E_g. \tag{12}$$

$$^{11}\mathrm{B}+\mathrm{p}\to{}^{11}\mathrm{C}+\mathrm{n},\ {}^{10}\mathrm{B}+\mathrm{d},\ {}^{11}\mathrm{B}+\mathrm{p}, \tag{13}$$

where $^{12}\mathrm{C}^{*}$ is an intermediate state or an excited state of ^{12}C, E'_g and E_g are the energies released in the reaction. Let E_{gp} be the relative kinetic energy of an incident proton and ^{11}B be in its ground state, then when $E_{gp}\lesssim 3\,\mathrm{MeV}$ [5], the reaction

$$^{11}B+\mathrm{p}\to 3\alpha+E_g,\ E_g=8.7\ \mathrm{MeV}, \tag{14}$$

is dominate. There is no neutron to release in the reaction, hence this is a clean fusion-energy sources. But this reaction cross-section is lower and this ignition temperature is higher than those of a deuton and a triton. In order to overcome the two shortcomings, we suggest to irradiate the ^{11}B target nuclei by γ-laser or γ-ray. There is the excited state $^{11}\mathrm{B}^{*}$ of ^{11}B whose energy $E^{*}_{eB}=2.124693\,\mathrm{MeV}$ (let the energy of its ground state be zero), lifetime is 3.8 fs, and spin and parity is $(1/2)^{-}$ [5]. The energy of the γ-photon is

$$E_\gamma=E^{*}_{eB}+E^{*2}_{eB}\big/\left(2m_Bc^2\right). \tag{15}$$

E^{*}_{eB} is the transition energy of the ^{11}B nucleus from its ground state with its spin and parity $(3/2)^{-}$ to the excited state $^{11}\mathrm{B}^{*}$ when the ^{11}B nucleus is static [5], and m_B is the mass of a ^{11}B nucleus. A ^{11}B target nucleus absorbing a γ-photon with its energy E_γ will be in its excited state $^{11}\mathrm{B}^{*}$ by the interaction of its magnetic dipole *M*1.

$$\gamma+{}^{11}\mathrm{B}\to{}^{11}\mathrm{B}^{*}. \tag{16}$$

To impact a $^{11}\mathrm{B}^{*}$ nuclei by such proton with the energy

$$E_{ep}\lesssim(3-2.124693)\,\mathrm{MeV}=0.875307\ \mathrm{MeV}, \tag{17}$$

a reactions analogous to (14) will occur, *i.e.*

$$^{11}\mathrm{B}^{*}+\mathrm{p}\to 3\alpha+\tilde{E}. \tag{18}$$

It is seen the ignition temperature will be lower because the relative kinetic energy of a proton and the $^{11}\mathrm{B}^{*}$ nucleus reduces from $E_{gp}\sim 3\,\mathrm{MeV}$ to $E_{ep}\sim 0.875307\,\mathrm{MeV}$. Consequently, the fusion temperature will significantly reduce.

The particles in the final states of (18) are the same as those of (14). But The reaction cross-section of $^{11}B^{*}$ + p is larger and this ignition temperature of $^{11}B^{*}$+p is lower than those of ^{11}B+p. When $E_{gp} \lesssim 3\,\mathrm{MeV}$ and ^{11}B in its ground state or when $E_{ep} \lesssim 0.875307\,\mathrm{MeV}$ and ^{11}B in the excited state $^{11}B^{*}$, the probability of the reaction (13) is very small [6]. Especially, there is no neutron to release out in the final states.

It is possible that there are the results analogous to (18) for other nuclei, e.g. $^{11}B^{*}$ + p or $^{9}Be^{*}$ + ^{3}He, here $^{11}B^{**}$ is another excited state of ^{11}B and $^{9}Be^{*}$ is an excited state of ^{9}Be.

Another example is to choose ^{10}B's and neutrons. There are the following reactions

$$^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{11}\mathrm{B} + E'_{gn}, \tag{19}$$

$$^{10}\mathrm{B}^{*} + \mathrm{n} \rightarrow {}^{11}\mathrm{B} + E'_{en}, \tag{20}$$

It is seen from above described that the reaction (20) is more easilly realized that (19), and the fusion temperature of (20) is significantly smaller than that of (18), because there is no electrostatic potential energy to be overcomed.

3. Discussion

It is possible that the lifetime τ_e of the excited state of target nuclei is shorter than the period τ_{ec} in which the nuclei are confined. For example, the lifetime of the excited state $^{11}B^{*}$ is only 3.8 fs. Thus, it is possible that the nuclei have decayed in the period τ_{ec} so that the nuclei are not in their excited states when two nuclei impact. Thus, it is necessary that γ-laser or γ-ray irradiates the nuclei from beginning to end in the period τ_{ec}. The process in which the nuclei can be in excited states is a dynamic balance process. In order to the $n_e/n_g \gg 1$, the intensity of γ-laser or γ-ray to irradiate the target nuclei should be large enough. It is seen from the process that such excited states which have longer lifetime should be chosen.

The electric field intensity of a laser tail wave. is very strong and variational. When a plasma composed of A-nuclei, B-nuclei and electrons is confined by a strong magnetic field and is acted by the laser tail wave, the temperature of the plasma will fastly increase. This is because the differences among the mass of a A-nucleus, the mass of a B-nucleus and the mass of an electron are very large, the differences among the velocities of the A-nuclei, the velocities of the B-nuclei and the velocities of the electrons and the differences among the accelerations of the A-nuclei, the accelerations of the B-nuclei and the accelerations of the electrons are all very large so that collision among the A-nuclei, the B-nuclei and the electrons is very frequent and strong. Consequently, the temperature of the plasma must fastly increase.

4. Conclusion

This paper proposes a way to realize controllable-nuclear fusion by γ-laser or

γ-ray and ordinary laser with their certain frequencies and large enough intensities to irradiate a target ball. The function of ordinary laser is to heat target nuclei and to realize the inertial confinement for the plasma composed of the nuclei and electrons. The target nuclei absorbing γ-photons will be in a certain excited state. The scattering cross-sections will be larger and the ignition temperature will be lower to realize fusion of the nuclei in their excited states than those of the nuclei in their ground states. In contrast with the nuclei applied in conventional fusion, e.g., deutons and tritons, according to the way, the nuclei applied to fusion should have the following characters: the nuclei have their excited states, one of the excited states has higher energy and longer lifetime, and the masses of the nuclei are lesser, for example, ${}^{11}_{5}\mathrm{B}$ and p. On the other hand, it is easier to confine the target nuclei in their excited state because the ignition temperature is lower, and the scattering sections and nuclear magnetic moments are larger. Thus, the Lawson conditions can more easily be realized so that the controllable nuclear fusion is possibly realized by the way.

Acknowledgements

This work is supported by tau-charm physics research KJ (x2-yw-N29) and National Natural Science foundation of China 11075064.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Chen, S.-H. and Chen, Z.W. (2014) Electron-Photon Backscattering Lasers. *Laser Physics*, **24**, 6.

[2] Chen, S.-H. and Chen, Z.W. (2015) A Discussion on Electron-Photon Backscattering Lasers and the Electron-Photon Backscattering Laser in a Laser Standing Wave cavity. *Laser Physics*, **25**, 5.

[3] Chen, S.-H. and Chen, Z.W. (2016) Coherent Conditions of Electron-Photon Backscattering Light in a Wiggle Magnetic Field. *Laser Physics*, **26**, 5.

[4] Hurricane, O.A., Callahan, D.A., Casey, D.T., *et al.* (2014) Nature, Fuel Gain Exceeding Unity in an Inertially Confined Fusion Implosion. **506**, 343-348.

[5] Firestone, R.B., Shirley, V.S., Frank Chu, S.Y., *et al.* (1996) Table of Isotopes, Eighth Edition, Weily Interscience, Hoboken, 285-313.

[6] Yang, F.J., Wang, Y.S. and Lu, F.Q. (2006) Nuclear Physics. 2nd Edition, Fudan University Press, Shanghai, 295-296. (In Chinese)