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PULSED FUSION NEUTRONS PRODUCTION BY ENHANCING THE DTμ FORMATION USING LASER IRRADIATION

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Abstract

By irradiating a gas mixture of d+tμ with a high-intensity laser, the high intensity of 14 MeV fusion neutrons can be created. Using a properly chosen short-pulse laser, the space dependent and time dependent source of high intensity neutrons is created which is suitable for neutron-scattering experiments.

1. Introduction

Muon-catalyzed fusion occurs through dtμ molecular formation, which is the resonance reaction of shallow binding energy (v=1, J=1) above the ground state of tμ+d [1]. The dt fusion occurs as soon as a dtμ molecule is formed. At liquid density, dtμ molecular formation occurs in the rate of 10^8/sec.

2. Laser enhancement of dtμ formation

When the dt target density is 10^{-3} of liquid dt density, the formation rate is reduced to 10^5 /sec . Muons injected into this density of a dt target can create fusion only once during a muon decay-time of 2.2 μsec. If we irradiate the dtμ mixture with a laser intensity of 10^{12} watt/cm^2, the formation rate is increased by 10^3 times [2], it becomes 10^8 /sec; hence, by radiating with this high-intensity laser, we can make fusion reactions during 10^{-8} sec. Figure 1.a shows the (dtμ) molecular formation rate as function of laser intensities with the angular frequencies of ω =7.6 to 22.8×10^{13} rad/sec; Figure 1.b shows one for the (ddμ) molecular formation rate. Thus, by irradiating the d+tμ target with laser intensity of 10^{12} /cm^2 , in a duration of only 10^{-8} we can generate a dtμ fusion reaction and produce the 14 MeV fusion neutrons with a pulse width of 10^{-8} sec. The energy consumed for laser irradiation is 10^4joule/cm^2. By focusing the laser beam, the fusion reaction occurs only small regions, and the diffusion of the muon is so small that high-intensity 14 MeV fusion neutrons are produced. It is an ideal source of neutrons for high-energy-neutron scattering experiments. Use of the thermal neutron scattering requires some slowing down , and the neutron source will be spread somewhat, but comparing the thermal neutron source from a reactor and spallation neutron source, for the former is much better collimated and has smaller energy spread. When a high intensity laser focused in the 10^{-2} cm^2 is used , a small part of dtμ mixture will generate the fusion. The 14 MeV energy neutrons with short pulse of 10^{-8} sec can be created in these small regions of 10^{-2} cm^2.

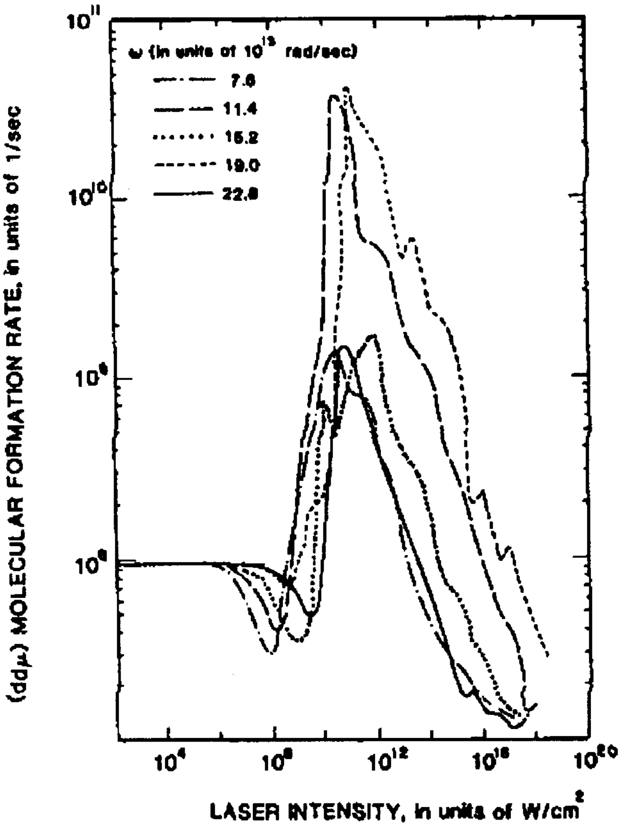

Figure 1.a Molecular formation rate of (dtμ) as the function of laser intensities with the angular frequencies of $\omega = 7.6 \times 10^{13}$ rad/sec to 22.8×10^{13} rad/sec.

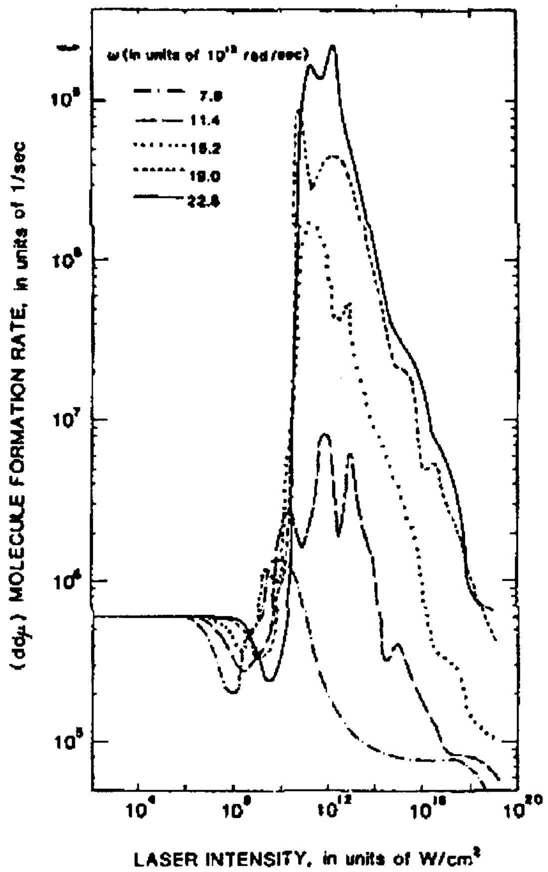

Figure 1.b Molecular formation rate of (ddμ) as the function of laser intensities with the angular frequencies of $\omega = 7.6 \times 10^{13}$ rad/sec to 22.8×10^{13} rad/sec.

3. Neutron source density

Assuming 3 GeV proton is injected into some target, it will create the negative muon per 6 GeV; thus 1 proton produces 0.5 negative muons. When a 3.3 mA proton is used, a negative muon of $6 \times 10^{18} \times 3.3 \times 10^{-3} \times 0.5 = 10^{15}$ is created. If it is assumed that the whole negative muon is stopped in a target with length of 10 cm and area of $1\text{cm}^2 = 10$ cc volume, the density of the negative muon will be $n\mu = 10^{14}$/cc during 2.2 μsec, and the density of d+tμ mixture gas will be 10^{14}/cc the same as the negative muon. When a short pulsed laser beam with pulsed width of 10^{-8} sec which is focused with 1mm^2 radiates the gas target from the side as shown in the figure 2, we can create the fusion reaction in each 0.1 cc (:assume 10 cm $\times$ 0.01cm^2) from this volume of the regions generated by the fusion reaction, and produce the 14 MeV monochromatic neutrons from these small irradiation regions in the very short time of 10^{-8} sec. The high density neutrons source with $10^{14} \times 0.01/10^{-8} = 10^{20}$ neutron/cc/sec will be

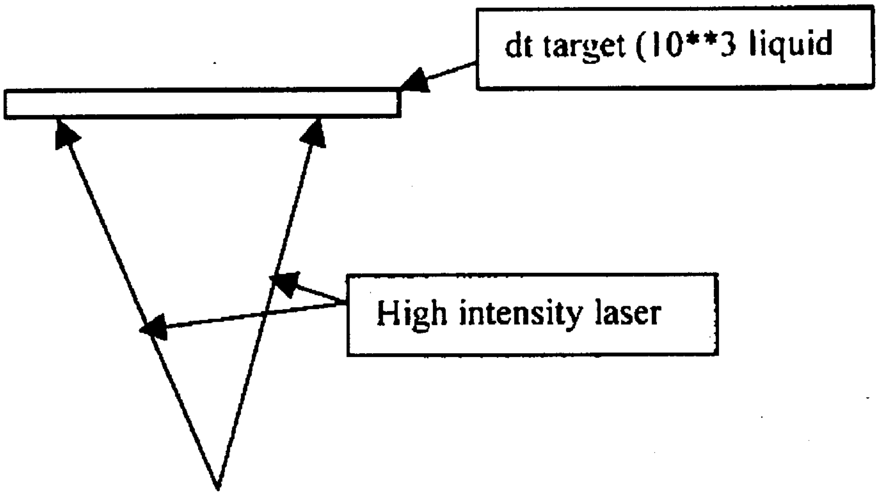

Figure 2 Laser irradiation to d+tμ gas target to create time and space dependent 14 MeV neutron source.

obtained. By subsequently irradiating a different part of the dtμ target, the fusion neutrons will be generated. For each shot, these pulsed neutron are created, so that we can make a time-dependent and spatial-dependent correlation (Figure 2). Since the neutrons are produced where laser field is applied, the neutron source is time-dependently and spatial-dependently generated. Many kinds of neutron scattering experiments can be carried out using this high-intensity neutron source which is spatially-and time-dependent. In the above calculation, an enhancement factor of 10^3 by laser irradiation is used, but, as shown in figure 1.b, in the case of ddμ molecular formation, an enhancement factor of 5×10^4 can be obtained with the proper choice of the laser wavelength and intensity. Therefore, a higher intensity and shorter neutron source can be achieved .

Acknowledgment

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Reference

[1] S.S.Gerstein and L.I.Ponomarev, Phys.Lett. 72B (1977), 80
[2] H.Takahashi Muon Catalized Fusion 2 (1988) 295-302
Laser Enhancement of Resonance [dtμ, d2e]*([ddμ, d2e]*) Formation