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Research Article

Features and Giant Acceleration of "Warm" Nuclear Fusion at Interaction of Moving Molecular Ions (D-...-D)$^+$ with the Surface of a Target

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Abstract

The nuclear interaction mechanism and optimization methods of (dd) synthesis under bombardment of solid targets by linear oriented molecular ions consisting of a few deuterium atoms (nano-clusters) are discussed. Preliminary results on observation of optimized $d + d = He^3 + n$ reaction during collective interaction are presented.

Keywords: Moving nano-clusters, Correlated states, Neutron generation, Warm nuclear fusion

1. Introduction

The search for optimal systems to produce nuclear fusion effectively is one of most important problem in science today. About two decades ago the abnormally high yield of synthesis products (p, t and He^3) was observed experimentally under collisions of single charged cluster ions of heavy water $(D_2O)_N$ with energy 0.12–6 keV/nucleus with TiD target. Every cluster consisted of a big group of identical molecules (e.g. D_2O) connected by hydrogen bonds.

It was found that the synthesis efficiency depended on the number of nuclei N in the clusters: $25 < N < 1300$ [1].

In the absence of D in cluster ions (i.e. at light water use $(D_2O)_N \rightarrow (H_2O)_N$) or when using targets formed on the basis of hydrogen (D $\rightarrow$ H), the reaction products were not observed.

A mechanism leading to the enhanced yield was not revealed in [1]. However, it has been suggested in [2] that the anomalies can arise due to collisions between cluster components. Moreover, the environment surrounding moving cluster ions in a solid influences these collisions.

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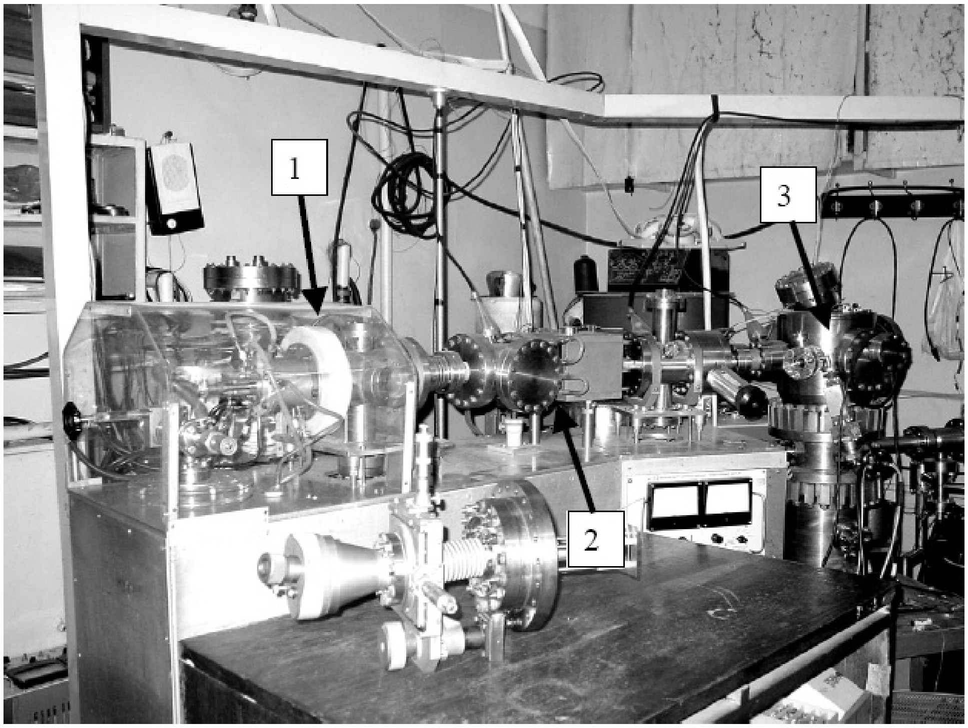

Figure 1. A general view of experimental installation.

Since a detailed dynamic calculation for a system with $N \gg 1$ is impossible, the main objective of the present work is to study mechanisms of this phenomenon for nano-clusters with $N = 2$ and 3.

In this report new experiments and theoretical models are discussed.

2. Experiments on Controlled Warm dd-fusion

Experiments were done with beams of accelerated molecular ions (D_2^+ and D_3^+ with energy 3.3 keV/nucleon) bombarding a stainless steel target. The analysis and calculation of processes in this system were carried out. The current of the ion beam was $J_D \le 5\ \mu$A, and the diameter of beam was about 2.5 mm.

These ions were formed at single ionization of gas molecules D_2 and D_3 in duoplasmatron (see Fig. 1).

A duoplasmatron ion source (Fig.1, item 1) of different atomic and molecular ions ($D^+ \equiv d$, D_2^+ and D_3^+) with the system of magnetic separation (Fig. 1, and item 2) was used.

A Duoplasmatron is a gas-fed source of light ions capable of producing positive or negative ion beams. The working principle is based on a two-stage discharge.

The target made of stainless steel and mounted in UHV chamber (Fig.1, item 3) and bombarded with the mass separated ion beam along the surface normal.

A background pressure in the target chamber was 2×10^{-6} Pa, while the density of the ion beam current was 0.2–0.3 mA/cm^2. The monochromaticity of a beam was about $\Delta E/E \approx 10^{-4}$.

A large aperture neutron detector was placed behind glass window of the vacuum chamber (Fig. 1, item 3).

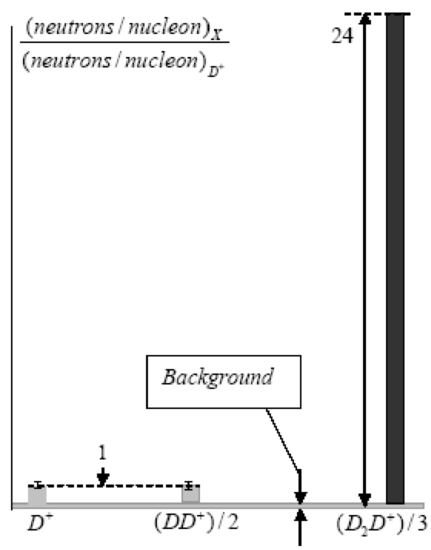

Figure 2. Effectiveness of dd-fusion with neutron generation for different accelerated nano-clusters $D^+ \equiv d$, D_2^+ or D_3^+ with the same specific energy 3.3 keV/nucleon.

In preliminary experiments to investigate the reaction

$$\mathrm{d}+\mathrm{d} \to \mathrm{He}^3 + \mathrm{n} + \Delta E_{\mathrm{d+d}},$$
$$\sigma_{\mathrm{d+d}} \approx 0.09\,\mathrm{bn} \approx 10^{-25}\,\mathrm{cm}^{-3} \quad \text{at } E \approx 100\,\mathrm{keV}, \quad \Delta E_{\mathrm{d+d}} \approx 4\,\mathrm{MeV},$$

it was found that the neutron yield (neutron/nucleon) increased more than an order (typically by 20–25 times) under transition from bombardment by D_2^+ (and $D_1^+ \equiv d$) ions to D_3^+ ions (see Fig.2). All these additional fast neutrons were connected with dd-reaction. and are essentially the result of an increase the fusion efficiency.

It was shown during preliminary analysis that the yield increase of nano-cluster dd-fusion can be connected with:

(1) cumulative effects at cluster component collisions in a target;
(2) satisfaction of the conditions of coherent correlated states formation [3–9] in nano-cluster volume (in potential well formed for atom 2 by atoms 1 and 3 (see Fig. 3).

Our analysis shows that the formation of coherent correlated particle states is a very efficient method of significantly suppressing the action of the Coulomb potential barrier during pair interactions of charged particles (including the nuclear dd-fusion problem and other nuclear reactions). This method provides a great increase of sub-barrier transparency (by $10^{40} - 10^{100}$ and more times). The formation of coherent correlated states in charged moving oriented $(\mathrm{D\text{-}D\text{-}D})^+$ clusters may be connected with periodical or monotonous modulation of interatomic distance during acceleration in duoplasmatron or deceleration on the target surface. The detailed description of such processes at different types of modulation of potential wells is presented in [3–9].

On the other hand in the $(\mathrm{D\text{-}D})^+$ molecular ion this effect is absent.

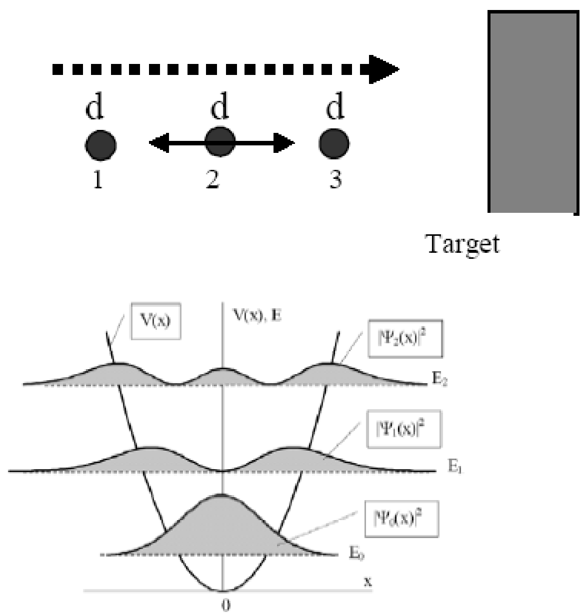

Figure 3. Principle of formation of correlated states of interacting deuterons in moving D3+ nano-cluster.

3. Summary

Our method of optimization of medium-scale energy ("warm" energy) accelerating synthesis at rather small nano-cluster energy can be used to optimize neutron generators to increase the neutron release from dd-reactions. The typical efficiency of a neutron source on the basis of dd-reaction with a fixed target (e.g. LiD crystal) and accelerated nucleus does not exceed $\eta \approx 10^{-7} - 10^{-10}$ (created neutrons/one accelerated nucleus) for fast and medium energy particles. The increase in this efficiency leads to an increase in the neutron flux.

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