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Laser-Driven High Energy Alpha Beam Interaction with Solid p11B to Achieve Fusion Ignition by Alpha Heating

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ABSTRACT

We present for the first time numerical results on fusion ignition process produced by laser-driven high energy alpha beam interaction with compressed solid p11B fuel. Relevant results on alpha measurements from nuclear reactions, induced by laser-driven proton beam interaction with 11B plasma [1, 2], justify extensive numerical investigations on fusion burning feasibility of pB11 fuel using a multi-fluid code [3, 4, 5, 6]. The consideration of a new physical process, termed as alpha avalanche effect [7, 8] contribute to enhance the alpha heating effect and consequently the reaction rate of the fusion process. The p11B nuclear fusion reaction is attractive not only because is an aneutronic reaction but because have the advantages to produce three alphas with total energy 8.9 MeV. But the main difficulty for fusion ignition in solid density p11B targets is that the cross section for nuclear fusion reactions is efficient for energies higher than 250 keV. The proposed concept, to overcome this difficulty, is to inject an energetic alpha beam in the compressed target and simulate the temporal evolution of the temperature and the reaction rate of the p11B fuel due to alpha heating effect. The initial high energy alpha beam could be produced by ultra-short and high intensity laser beam interaction with thin DT solid targets (see fig.3 of ref.9). The high energy alpha beam interact with a p11B plasma compressed 4-10 times the initial solid density and with low initial temperaturature. The numerical results show that the maximum of the reaction rate is achieved tens of nsec after the injection of the alpha beam. After this time interval the reaction rate decreases due to the depletion of the plasma ion density. The temperature corresponding to the maximum of the reaction rate is about 200 keV. The time corresponding to the maximum reaction rate depend strongly on the density of the injected alpha beam, the initial plasma temperature and the compression factor of the p11B fuel. In the near future Petawatt or Exawatt –Zetawatt laser systems [10, 11] and especially the IZEST project and the fiber based laser system investigate for the ICAN project, will be able to attain intensities up to 1025 W/cm2 and 1029 W/cm2 with pulse duration of the order of attoseconds or zettaseconds. These projects will enable unique applications on laser-driven ion beam acceleration with high current [12, 13, 14]. The numerical results of this work promote the development of new high efficiency and high power fibre laser systems like ICAN in order to generate high density alpha beams.

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