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Abstract

Cluster ion acceleration is a method particularly well suited to produce neutral beams of high particle current density at energies of the order of 1 keV/atom. Since this is the energy required for converting hydrogen atoms or molecules into negative ions in a cesium vapour cell, it is proposed to use cluster ions for the production of negative ion beams of high current density. The system is envisaged as a tandem accelerator with a terminal voltage of 1 MV.

Erzeugung negativer Wasserstoffionen aus beschleunigten Clusterionen

Zusammenfassung

Clusterionenbeschleunigung ist besonders für die Erzeugung von Neutralstrahlen hoher Teilchenstromdichte bei Energien in der Größenordnung von 1 keV/Atom geeignet. Dieses ist die Energie, die benötigt wird, um Wasserstoffatome oder -moleküle in einer Caesiumzelle in negative Ionen umzuwandeln. Daher wird vorgeschlagen, Clusterionen zur Erzeugung negativer Ionenstrahlen hoher Stromdichte zu verwenden. Das vorgeschlagene System sieht einen Tandem-Beschleuniger mit einer Spannung von 1 MV vor.

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For heating of plasmas in fusion reactors by neutral injection an energy of the order of 1 MeV/atom is envisaged in order to enable the injected particles to penetrate sufficiently far into the plasma core. To produce these particles it has been proposed to accelerate D^- ions that may be converted into neutrals with high efficiency compared to other methods, e. g. dissociation of D_2^+ or D_3^+ ions[1]. A favoured method to produce D^- ions is that of charge exchange of D^+ on a target of alcali vapour[2]. The best efficiency of conversion - about 20 % - is obtained by passing D^+ ions of an energy of 1 keV or lower through Cs vapour. At higher energy the yield drops off sharply, e. g. to 5 % at 5 keV. The current density of conventional ion sources, however, ist quite low at these low energies. Therefore, it has been considered to use a Na target that allows the use of higher energy at the expense of a lower conversion efficiency[3] (12 % at the optimum energy of 5 keV).

To overcome the problem of low current density one may think of using cluster acceleration as a method to produce particle beams of high intensity in the energy range of interest, that is 0.1 - 1 keV/atom[4]. Because of the low specific charge cluster ion beams have less space charge problems so that high particle current densities are possible[5]. To obtain negative atomic ions, clusters obviously must be disintegrated into their constituents. An investigation of the neutralization of accelerated cluster ions on gas targets has shown that they disintegrate into neutral fragments with high efficiency[6,7]. The target density required was found to be less than 10^{14} H_2 or H_2O molecules per cm^2 [7,8]. Experimental evidence indicates that the fragments are predominantly molecules. The target thickness is one order of magnitude less than that required for conversion of D^+ or D^o into D^-. Thus disintegration of clusters and conversion into negative ions may be executed in one step in the Cs target.

The use of cluster ions accelerated to about 10 keV/atom for injection into experimental plasmas has been proposed previously[5,9]. A cluster ion accelerator intended to be used for heating and refuelling experiments at a toroidal device is presently under construction at our laboratory[10]. Its design values are 100 kW power at 1 MV and an atom current equivalent of 10 A_o. It could be used to accelerate a particle current equivalent of 100 A_o to 1 keV/atom. In contrast to this machine a cluster ion accelerator for production of negative ions can be envisaged as a tandem accelerator. Positive cluster ions will be accelerated into the high voltage terminal where they will be converted in part into negative ions which in turn will be accelerated through a second acceleration tube to ground potential. Except for the necessity of a second acceleration tube this system actually will be simpler than our present one, since the cluster ion source with all its auxiliary equipment will be operated on ground potential and does not have to be housed in tanks filled with pressurized insulating gas.

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