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A Tracer-Encapsulated Pellet Injector TECPEL-2

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Abstract

A new technique and a device for producing tracer-encapsulated cryogenic pellets (TECPEL) have been designed for local deposition of the tracer ions in a steady state plasma and for an accurate measurement of the particle transport in magnetic confinement devices. The technique allows manufacturing TECPEL in the form of a solid deuterium (or hydrogen) cylinder of 3 mm diameter containing an impurity core of 0.1–0.2 mm in size as a tracer. To increase the TECPEL injection reliability, the process of core loading into the hydrogen pellet was made visible. A brief injector design and the first experimental results are presented.

Keywords:
plasma diagnostics, particle transport, impurity pellet, injector

1. Introduction

The plasma transport in fusion devices is one of the most important problems to be studied before a big machine such as ITER is designed. The main difficulty in analyzing the plasma transport is the lack of accurate experimental information, because the laser blow-off method [1] and impurity pellet injection [2] give a broad source profile of the impurities. A new diagnostic method is based upon the localized particle source as a tracer within a limited small volume of about 1 cm^3 in the plasma [3]. The tracer particles are deposited by a TECPEL consisting of the small tracer core of a light atom and the major outer layer of a hydrogen isotope, which is the same species as the bulk plasma ions. The first TECPEL-1 injector was designed and successfully tested [4]. To increase the TECPEL injection reliability, to simplify the injector operation and to increase the amount of cores capable of being loaded into the cryogenic pellet in a steady state mode, a new technique and a device named TECPEL-2 were developed. These are discussed below.

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2. Injector Design and Operation

TECPEL-2 is a pellet injector which produces a solid hydrogen (or deuterium) pellet by in-situ condensation [5] with an impurity core inside and accelerates this TECPEL by a single-stage light gas gun. The new technique of producing and accelerating the TECPEL involves the following procedures: 1) loading a core from a storage into the injector barrel and keeping the core on the barrel axis by a special needle, 2) formation of the solid hydrogen inside the barrel around the core, 3) pulling out the needle from the pellet, leaving the core inside, 4) ejection of the formed TECPEL with a propellant gas.

A schematic diagram of the barrel cross section with a core storage is shown in Fig. 1. The barrel inner diameter is 3 mm and the core size varies between 0.1 and 0.2 mm. There are 50 holes of 0.23 mm diameter in the storage where the cores are housed before the injector is cooled down. A special needle of 0.6 mm diameter is placed inside the storage and can move to the barrel center.

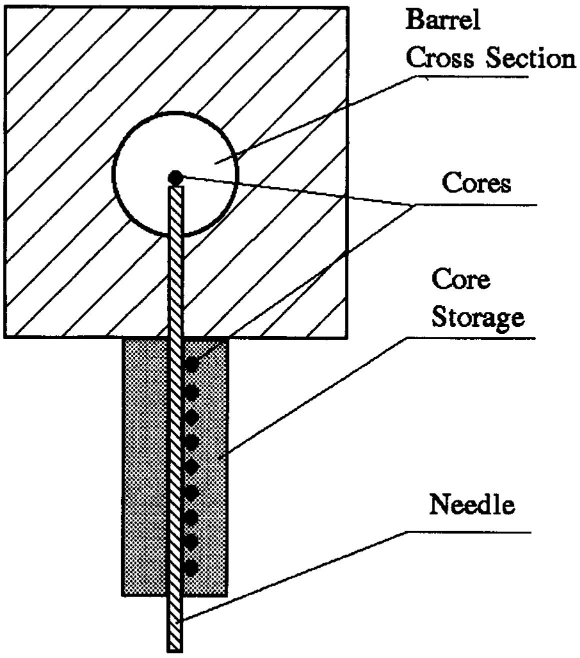


Fig. 1 The barrel cross section with a core in the center.

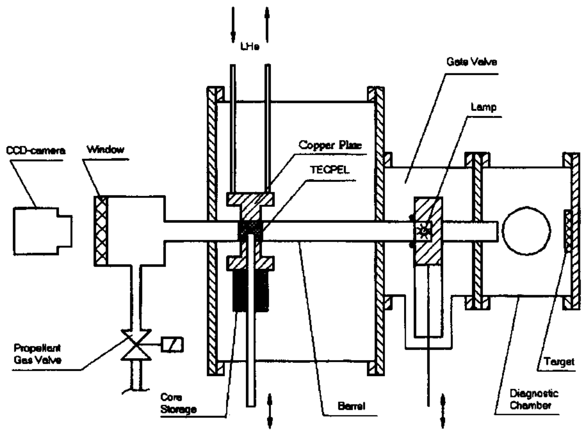
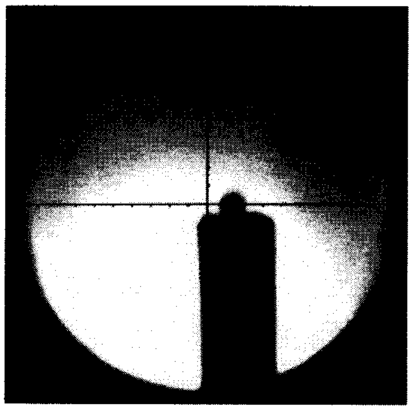
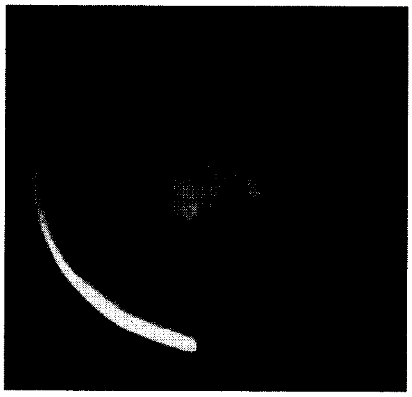


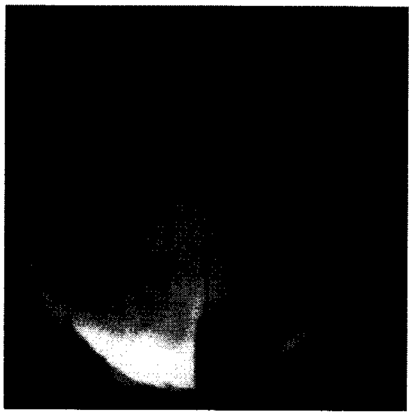
Fig. 2 A schematic diagram of the TECPEL-2 injector.



(a)



(b)



(c)

Fig. 3 Stages of TECPEL formation inside the barrel.

A schematic diagram of the injector is shown in Fig. 2. A copper plate of 3 mm thickness is brazed to the barrel and connected to the core storage. This plate is equipped with a helium heat exchanger. There is a channel of 3 mm diameter inside the plate for hydrogen condensation. A small chamber with a window and a propellant gas valve is attached to one end of the barrel. The second end is inserted into the gate valve with a miniature lamp. The lamp illuminates the inner barrel surface when the gate valve is closed. There is also a diagnostic chamber attached to the gate valve. The injector operation is illustrated in three photos in Fig. 3. The needle captures a core in the storage and moves it into the copper plate channel. The cross section of the plate with the core (small dark circle) on the top of the needle is shown in Fig. 3, (a). A hydrogen gas is admitted into the barrel and condensed on the barrel walls within the copper plate cooled by liquid helium to 10 K. The dark O-ring of the solid hydrogen on the barrel walls is shown in Fig. 3, (b). After the whole barrel cross section is frozen and the formed pellet becomes transparent, the needle is pulled out of the pellet. The core remains inside the pellet, as shown in Fig. 3, (c). A small amount of hydrogen gas is admitted and frozen in the channel which remains after the needle removal. The gate valve is opened and the TECPEL is accelerated by the propellant gas admitted through the valve.

3. Experimental Results

For technical demonstration of the device producing TECPEL, we used spherical stainless steel cores of 0.15–0.22 mm diameter. Here, we present some preliminary results of the injector operation. Three series of 50 cores were loaded into the barrel before the pellet condensation with a reliability of 88–95%. The loading process took less than 100 s for every core and was controlled remotely. Owing to the possibility of visual observation of the loading process and the pellet formation through the window and barrel, the injector operation was recorded by a CCD-camera. The TECPELs produced were accelerated to 0.9–1.2 km/s by a hydrogen propellant gas. We registered steel cores that had penetrated into the surface of an aluminum target installed at the end of the diagnostic chamber. Photos of pellets in flight were made to prove the TECPEL configuration after the acceleration.

4. Conclusion

A new device TECPEL-2 for producing a diagnostic pellet to measure the particle transport both parallel and perpendicular to the magnetic field lines of fusion devices has been constructed and operated. The TECPEL-2 shows some advantages over the TECPEL-1 design and operation; in particular, the posibility of visual observation of core loading and pellet formation. It has been shown that no injection can be performed without a core. Only one driver is used for the core loading, which simplifies the loading process. A large number of cores (50 instead of 24 in the previous injector) can be loaded into the injector before cooling. Cores have no contact one another and can not be hindrance for the next core loading.

References

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