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D–D neutron generator development at LBNL

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Abstract

The plasma and ion source technology group in Lawrence Berkeley National Laboratory is developing advanced, next generation D–D neutron generators. There are three distinctive developments, which are discussed in this presentation, namely, multi-stage, accelerator-based axial neutron generator, high-output co-axial neutron generator and point source neutron generator. These generators employ RF-induction discharge to produce deuterium ions. The distinctive feature of RF-discharge is its capability to generate high atomic hydrogen species, high current densities and stable and long-life operation. The axial neutron generator is designed for applications that require fast pulsing together with medium to high D–D neutron output. The co-axial neutron generator is aimed for high neutron output with cw or pulsed operation, using either the D–D or D–T fusion reaction. The point source neutron generator is a new concept, utilizing a toroidal-shaped plasma generator. The beam is extracted from multiple apertures and focus to the target tube, which is located at the middle of the generator. This will generate a point source of D–D, T–T or D–T neutrons with high output flux. The latest development together with measured data will be discussed in this article.

Keywords: Neutron generator; RF-induction ion source; BNCT

1. Introduction

The RF-driven multicusp ion source developed at Lawrence Berkeley National Laboratory (LBNL) has found numerous applications from semiconductor industry and accelerator injectors to sophisticated neutron generators. The typical feature of these plasma generators is their ability to generator high atomic deuterium or tritium species, high current densities, long lifetime and stable and consistent pulsing characteristics.

The plasma and ion source technology group at LBNL is developing neutron generators (Reijonen et al., 2002, 2003) for various applications. These applications include prompt gamma activation analysis (PGAA), fast neutron activation analysis (FNAA) and pulsed fast neutron transmission spectroscopy (PFNTS) for material characterization and detection techniques and boron neutron capture therapy (BNCT) for the medical applications. In this presentation, several new neutron generator developments will be presented. They are designed to function in different applications; these generators include the sectioned insulator axial neutron generator, high power co-axial neutron generator and a new fast pulsing, point neutron generator. All of these generators are operated with RF-induction discharge to ensure high efficiency and long lifetime.

Most of the neutron-based material identification and interrogation systems require pulsed neutron beams. Various ways of pulsing the primary ion beam, and therefore the neutron beam, can be used, for example, RF-discharge, puller electrode and beam sweeper-based pulsing. RF-discharge pulsing is discussed and results are shown in this presentation.

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2. Axial, sectioned accelerator neutron generator

The axial, sectioned insulator neutron generator utilizes external-antenna-driven RF-plasma generator with 13.56 MHz, see Fig. 1. The alumina (Al_2O_3) discharge chamber of the ion source is actively water-cooled and thus can operate reliably at cw mode with more than 3 kW of discharge power. The main characteristics of this type of ion source is the high current density, $j \sim 100\,mA/cm^2$ at 3 kW of discharge power (see Fig. 2), and high atomic species from molecular gases, the H^+ fraction $>90\%$ at RF power ~ 1 kW (see Fig. 3).

The ion beam current is a function of various parameters, like the RF-power and the source pressure. The external antenna ion source can be operated at a wide range of operating parameters, depending on the needs of the application. The hydrogen current as a function of pressure and RF-power is shown in Fig. 2.

The ion species distribution is an important parameter in determining the overall efficiency of the neutron generator. Some of the widely used neutron generator ion sources produce significant fraction of molecular ion species, thus reducing the energy per nuclei at a given accelerator voltage. The RF-discharge has demonstrated nearly mono-atomic ion species with a wide range of operating parameters. This can be seen in Fig. 3, where the hydrogen species are measured as a function of the discharge power.

For the D–T neutron generator no significant increase in neutron yield can be achieved after about 120 kV, when solid targets and mono-atomic deuterium and tritium ions are used. Thus reliable operation at this voltage regime is needed for future D–T neutron

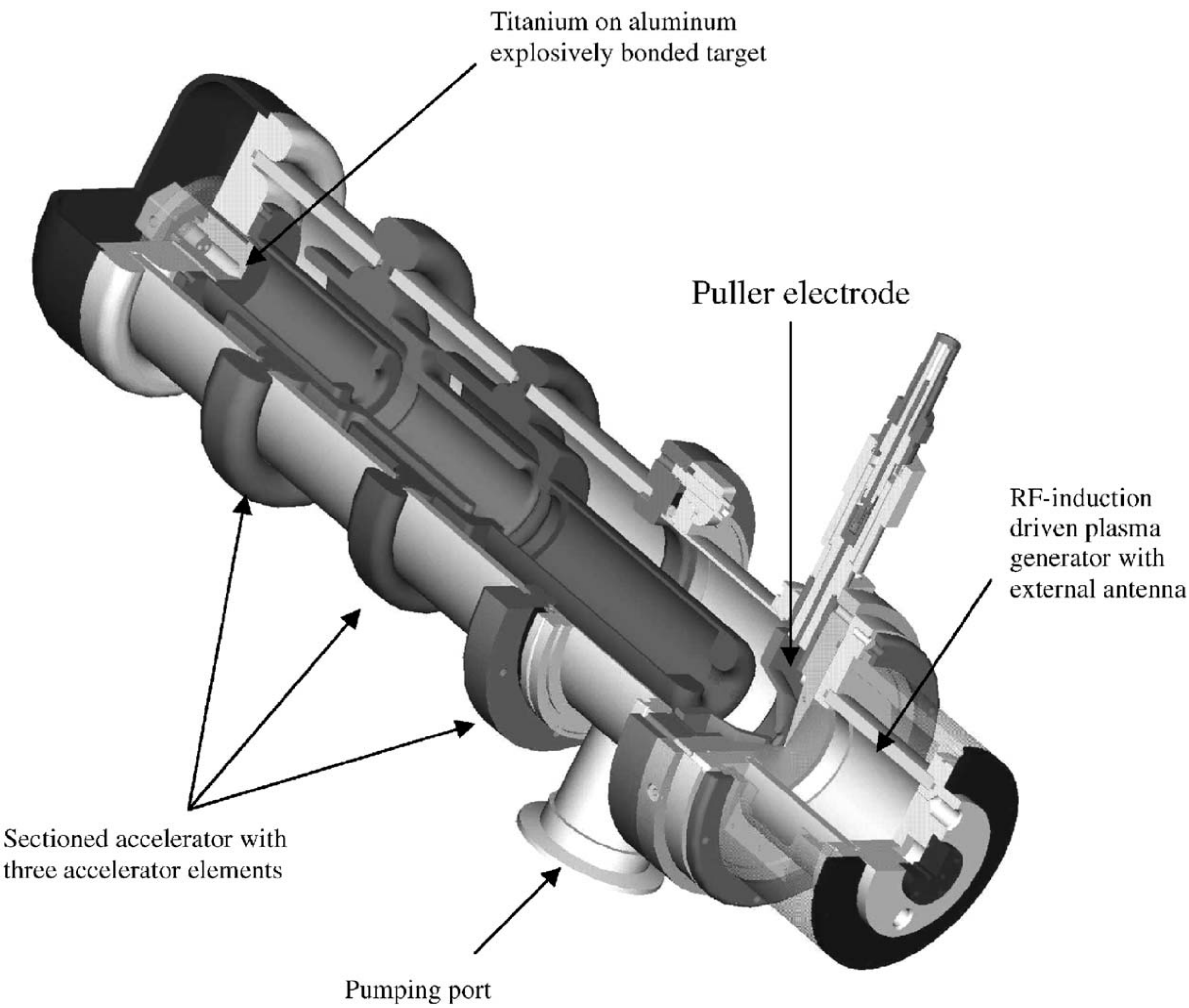

Fig. 1. Sectioned insulator, axial neutron generator with a multi-stage accelerator structure. The alumina plasma generator is water-cooled and driven by a external RF-antenna. Puller electrode can be pulsed.