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ScienceDirect

Physics Procedia 74 (2015) 97 – 103

Physics Procedia

Conference of Fundamental Research and Particle Physics, 18-20 February 2015, Moscow, Russian Federation

Computer simulation of gas-filled neutron tube ion-optic system

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Abstract

Computer simulation of gas-filled neutron tube has been fulfilled. Fully relativistic electromagnetic particle-in-cell finite difference, time-domain cod SUMA [1-2] has been used to investigate ion-optic system, the ionization and knock on processes and their influence on the deuteron beam and the output neutron flow parameters. When deuteron and ionized particles space charge self-field forces become the same order of magnitude as external one, virtual cathode may occurs. It happens because the injected from ion source deuterons cannot overcome their own space charge potential wall and move in transverse direction. However, electrons, produced by ionization, are trapped within the deuteron beam space charge potential wall and decrease it significantly. Thus, space charge neutralization of deuteron beams by electrons, may considerably increase target current and, as a result, output neutron flow. Moreover, own longitudinal electric field rise near the target leads to reduction of accelerating electrode target potential wall, which was made to prevent knock on emission from the target. As a result, additional knocked on electrons may appear in the region and should be taken into account. The data obtained were compared with experimental results.

Keywords: Computer simulation, ion-optic system, ionization,neutron tubes

1. Introduction

To design neutron tube with assigned parameters such as: flow value, sizes, service life and so forth, a preliminary computer simulation should be fulfilled. PIC code SUMA was used for ion-optic system modeling and investigation of ionization processes influence on deuteron beam dynamics and output data of gas filled neutron tubes.

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doi:10.1016/j.phpro.2015.09.228

2. Code SUMA

For numerical simulation relativistic PIC code, solving complete system of Maxwell equation is used. The code is a 2.5 dimensional time dependent model that makes it possible to describe self-consistently the dynamics of charged particles in rectangular, cylindrical and polar systems of coordinates. The system of equations used in mathematical model consists of the Maxwell equations, the equation of the medium and the equation of motion. The charge and current densities appearing in the Maxwell equations are calculated first at each step of the solution at time t. The charges and current are distributed among the nodes of the spatial mesh and smoothed by weighing the areas of a particle (cloud) and a mesh. The arrival of new particles at a simulation step Δt to the region under investigation is simulated by the mechanism of injection, emission or secondary emission with corresponding laws of distribution. Then the Maxwell equations are solved numerically, and the resultant solution is corrected for matching to the Poisson equation.

The Poisson equation is solved using the algorithm of fast Fourier transformation in one coordinate and marching (Thomas algorithm) in the other coordinate. For domains with a complex geometry as well as in the presence of electrodes in the domain, the capacity matrix method is used, which relates the potential and charge at the required nodes. Since the solutions of the Maxwell equations give the field at the nodes of 2D mesh, the field at the intermediate points at which particles are located must be calculated for numerical integration of the equations of motion. For this purpose, interpolation and smoothing of mesh functions is used. Integrating the equations of motion, we determine the distribution of particles in the phase space at the next instant $t + \Delta t$, and so on. For integration, the relativistic version of the method is employed with overstep using a time shift of the spatial coordinate and momentum.

3. Computer simulation

A typical gas-filled pulse neutron tube has been studied as a sample (see Fig. 1). Accelerated electrode and target are under negative potentials -85 kV and -83 kV accordingly, focusing electrode is grounded. Preliminary ion source deuteron beam parameters has been obtained experimentally. For this purpose alone Langmuir probes,

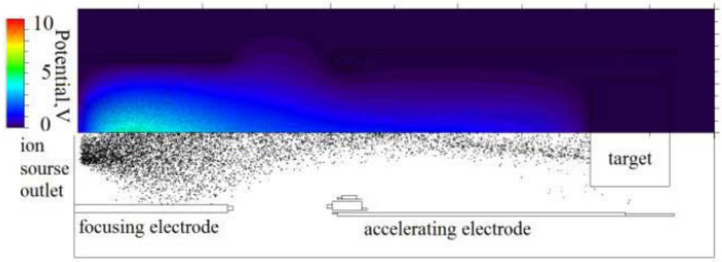

Fig. 1. Deuterons distribution (lower) and their self field potential (upper) in neutron tube.

multi-electrode energy analyzer and Faraday cup were used. We obtain following deuteron beamparameters: longitudinal energy 1.7±0.4keV, current150 μA for initial gas pressure $0.5 \cdot 10^{-3}$ Torr. Moreover, some beam density distribution measurement were fulfilled. Nevertheless, it was not enough data for computer simulation. Therefore, the attempt to solve inverse problem was made. As the result to be obtained the experimental deuteron current density distribution on target shown on Fig. 2*a* was used.