GENEPI: A HIGH INTENSITY DEUTERON ACCELERATOR FOR PULSED NEUTRON PRODUCTION

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Abstract

A neutron pulsed generator using a duoplasmatron and a high intensity electrostatic accelerator is presented. The aim, the design and the first experimental results are presented.

1 INTRODUCTION

GENEPI (Generateur de Neutrons Pulsés Intenses) is a high intensity pulsed neutron generator under construction at Grenoble, for studying the physics relative to sub-critical reactors, which would be driven by accelerators. It will generate short neutron isotropical pulses in the center of the experimental reactor MASURCA, in Cadarache (France) by sending a 240 keV deuteron beam on a tritium target.The specificity of GENEPI is the high intensity (>50 mA peak) for short (1 µs) and sharp edged pulses. The machine is shown figure 1 and its characteristics are summarized table 1.

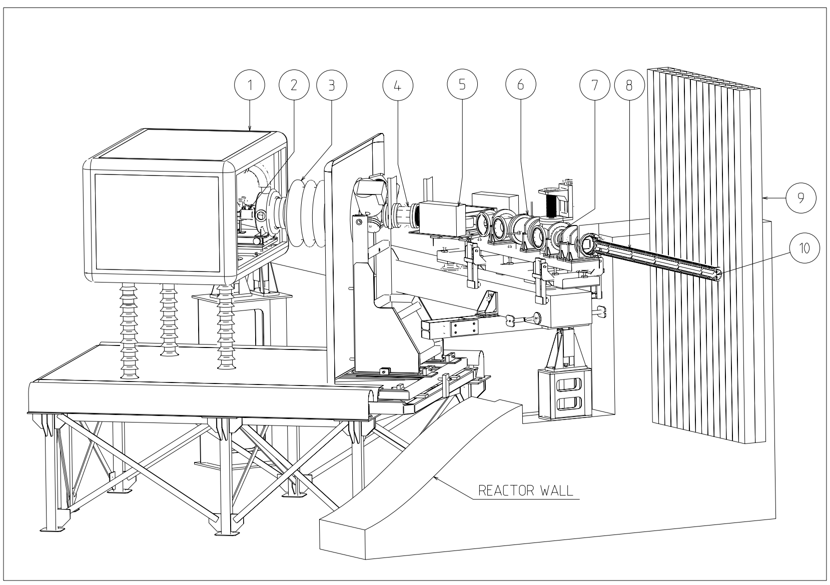

Figure 1: View of GENEPI with the HV terminal (1), the duoplasmatron (2), the accelerating tube (3), three electrostatic quadrupoles (4,6,7), the dipole (5), the beam line (8) inside the reactor (9) towards the target (10)

peak current	>50 mA
repetition rate	0-3 kHz
mean beam current	<200 µA
beam energy	240 keV
pulse length	1µs
neutron energy	14 MeV
spot size	∅ 30 mm
target (inside Titanium)	tritium
neutron production (peak)	$\approx 5\ 10^6$ n/pulse
neutron production (mean)	$5\text{-}10\ 10^9$ n/s

Table 1: GENEPI characteristics

2 BEAM DYNAMICS

Beam dynamics has been studied for the whole machine. The pulsation duration is too short and the duty cycle is too low to take advantage of beam neutralisation by the residual gas (0.1-1 ms typical neutralization time) and space charge is high. Four kind of calculations have been done:

• A map describing the potential inside the focusing electrodes for the extracted beam has been obtained by the finite element code SYSTUS. Five maps have been made. For each map, an electrode is a the 1 volt potential while the others are grounded. The global potential is obtained by linear combination of the maps. This avoids a finite element calculation for each choice of the voltages during the simulations. Each large map is then reduced to a small one by fitting the potential with harmonic polynomials and the field is derived analytically.

• A tracking code has been written, including space charge. Beam is supposed to be with a gaussian profile. So, the RMS size only is needed to calculate the space charge field anywhere. This code has been used mainly to study the focusing at exit of the source and the the acceleration tube.

• In parallel, a code integrating Sacherer-Lapostolle enveloppes equations has been written and compared to the previous one, leading to the same conclusion. The enveloppe equations have been particularly useful to design the beam line after the accelerator, when a very short computation time is needed.

• The magnetic field in the dipole has been obtained by the three dimension version of SYSTUS. Particle have been tracked, also with space charge, to calculate precisely the separation of the molecular ions.

3 THE SOURCE

A duoplasmatron is well suited to provide short pulses [1]. It works like an hydrogen thyratron. The ionization is made by an electron beam obtained by using a cathode, a hole acting like a grid and an anode. A positive pulse (2-3 µsec) is put on the grid to start the discharge. The anode is polarized via an L-C line, designed in a way to give a calibrated electron discharge (1 µs, sharp edges). The ions are extracted at about 40 keV. After extraction, the beam is matched to the acceleration tube by electrostatic lenses as in [2]. This optics is a four electrode accel-accel-decel-decel type. The total power needed for the source is less than 2 kW.

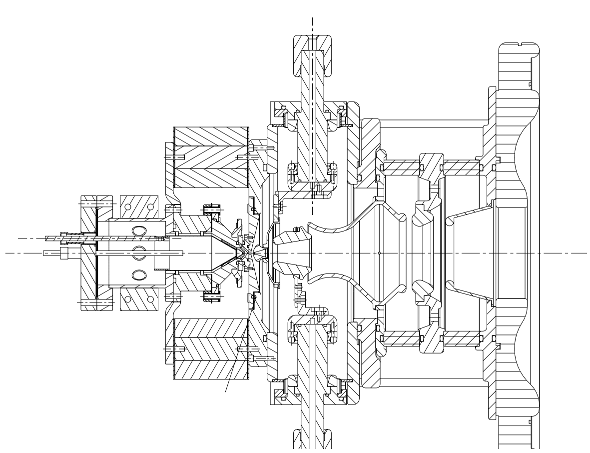

Figure 2: The source and the focusing electrodes

4 THE ELECTROSTATIC ACCELERATOR

The acceleration tube has been bought to the french company IRELEC. The accelerating voltage of the tube is 200 kV, leading to a final energy of 240 keV. The field is about 1.4 MV/m to take advantage of the focusing effect of the entrance in the accelerating field and to contain the strong diverging force due to space charge.

5 BEAM HANDLING

According to the structure given figure 1, the 240 keV beam is transported towards the target by the following system:

• A first electrostatic quadrupole is set at the exit of the accelerating tube.

• A 45 degree magnetic dipole (magnetic radius 0.5m, field 0.2 T) is used to purify the beam, which is composed of about 70% of deuterons and 30 % of other ions like molecular D_2^+ ions. This analysis is compulsory to keep the sharp egdes of the beam pulse. The dipole has oriented faces in order to get focusing both in the vertical and the horizontal plane, for containing space charge. As the beam is very large in the dipole, a window-frame magnet is required to preserve the homogeneity of the field over a large domain.

• The separation is done by a slit put 600 mm downstreams, where the beam width is 100 mm and the separation 150 mm (between centers of mass).

• Two electrostatic quadrupoles are used to match the beam to the line handling the beam inside the reactor ("glove finger").

• Downstreams, the beam has to be transported along 2.5 m towards the target, at the center of the reactor. The beam tube cannot exceed 90 mm in width and focusing is needed inside for space charge. It is done by an electrostatic FODO line, made of 4 quadrupoles (length 356 mm) and 2 half-length quadrupoles. The electrodes are planar in order to give a large enough aperture to the beam (∅ 70 mm) and are connected in series inside the vacuum chamber in order to use two power supplies only. The linearity of these quadrupoles ig good enough and has been maximized by a proper choice of the electrodes size.

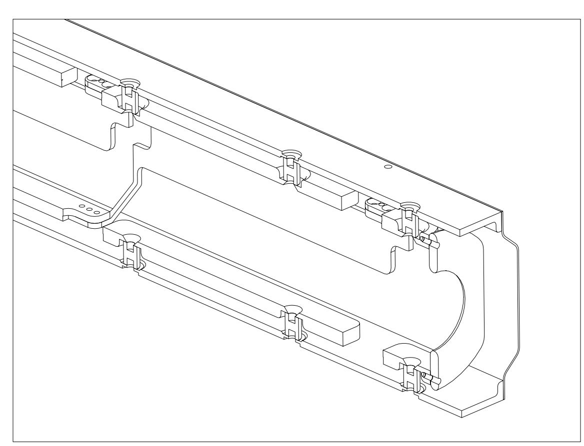

Figure 3 : The extremity of the "glove finger", showing the planar electrodes connected in series in an helical way.

Figure 4 shows the theoretical beam enveloppes from the exit of the tube to the target (Sacherer equations)

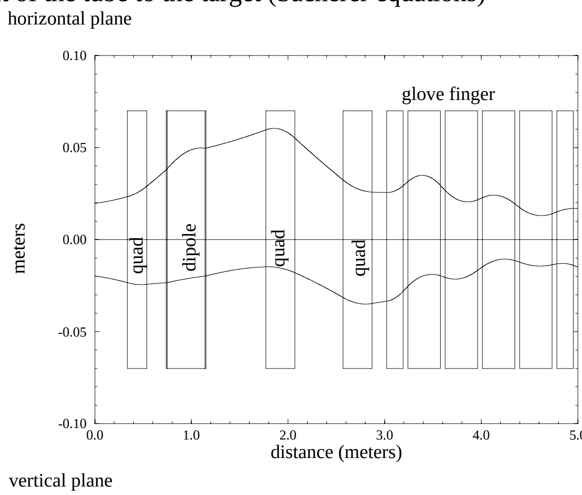

Figure 4: Theoretical beam enveloppes (85% of the beam, vertical and horizontal planes) from the accelerating tube exit towards the target.

6 VACUUM

An organic-free (tubomolecular pumps, UHV technology) vacuum system is used in order to preserve the life time of the filament (several months), the quality of the ion extraction and the good behaviour of the focusing electrodes under high electric fields. The pressure is close to 10^{-5} mbar inside the accelerating tube, including the gas delivered by the source. We have checked that there was no sparks within theses conditions.

7 EXPERIMENTS

Experiments at 45 keV have been made both for protons and deuterons. A filament life time of several months has been demonstrated. A good beam pulse shape has been obtained. Figure 5 shows the intensity of the electron arc and the corresponding beam pulse.

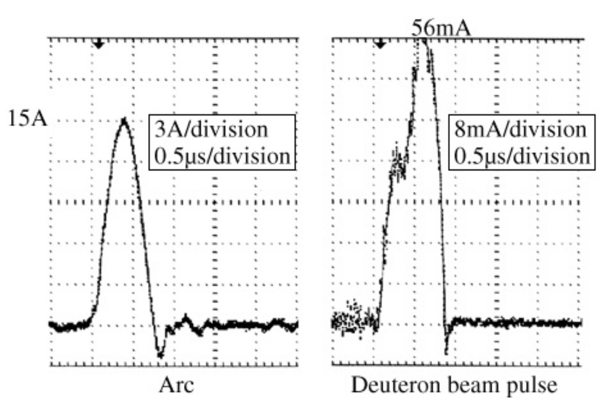

Figure 5: electron arc and beam pulse at 45 keV

The beam has been mass analyzed in order to be pure and a very sharp beam tail has been obtained. This point is crucial for reactor studies. The transverse emittance has been measured in order to determine the appropriate focussing voltages and has been used by simulation to check the tunability of the whole machine. The glove finger is also a critical issue (small apertures, non-linearities, new technology) and has been tested at 40 keV and 10 mA, which is equivalent to about 240 keV 100 mA deuterons. A good transmission has been obtained (figure 6) with, in addition, a good agreement with simulation, which gives a good confidence for the whole design.

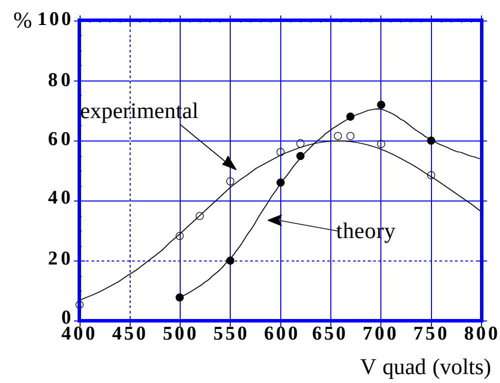

Figure 6: Transmission of the "glove finger". The beam is 10 mA, 40 keV protons, showing the good agreement between theory and experiment.

The accelerating tube has been mounted on the terminal and tested successfully up to 230 kV without beam (nominal value: 200 kV).

8 CONCLUSION

Many crucial parts of GENEPI have been tested successfully, giving a good confidence level on the whole design, the reliability and the performances within the foreseen bugdet. The machine has now to be built and tested at 240 keV, before the final installation a Cadarache in 1999.

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