INSTALLATION OF TRIPS AT INFN-LNS

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Abstract

The design of the TRASCO intense proton source (TRIPS) has been completed in 1999 and it has been installed at LNS in May 2000. Its task consists of the production of 35 mA dc proton beam with a normalized emittance below 0.2 π mm.mrad for an operating voltage of 80 kV. The source is based on the principle of microwave discharge, off-resonance, and it is a modified version of the source SILHI operating at CEA, Saclay since four years. With respect to that source the extraction system have been changed with the goal to increase further the reliability of that source, yet eccellent. The paper will describe the design of the source and its status.

1 INTRODUCTION

The TRASCO (TRAsmutazione SCOrie) Project aims to develop the technologies needed to design an Accelerator Driven System (ADS) for nuclear waste transmutation. The large flux of spallation neutrons from a high current CW proton linear accelerator will drive a subcritical system to transmutate nuclear wastes [1].

The programme has been approved by INFN and ENEA at the end of 1997 and consists of two main parts, regarding, respectively, the accelerator and the sub-critical system.

The accelerator has been designed exploiting the know-how developed in the different INFN laboratories [2]. The ion source has been designed by the Laboratori Nazionali del Sud (LNS), in agreement with the Laboratori Nazionali di Legnaro (LNL), where the RFQ has been designed.

The main features of the source have been defined by taking in considerations the needs of a reliability as high as possible.

The choice of an off-resonance microwave discharge ion source has been done because of the intrinsic advantage of this source in terms of high yield, high proton fraction and stability.

Emittance can be improved by means of gas injection inside the beamline [3] which minimizes the space charge effects, while reliability at high voltage remains a major problem, which we have addressed by means of a conservative electrode design.

The results obtained with SILHI [4,5] confirmed that currents and voltage can be easily achieved and that the emittance can be minimized to the requested value.

Therefore the major developments to be done at LNS will concern stability, reliability and reproducibility.

The main goals which TRIPS shall fulfil are the following [6]: proton current higher than 35 mA at the extraction voltage of 80 kV, RMS normalised emittance below 0.2·π·mm mrad and reliability close to 100% (few failures per year).

2 THE TRIPS ION SOURCE

The design of TRIPS is shown in figure 1. The microwave power obtained with a 2.45 GHz - 2 kW magnetron is coupled to the cylindrical water cooled OHFC copper plasma chamber (100 mm long and 90 mm in diameter) through a circulator, a four stub automatic tuning unit and a binomial matching transformer. The microwave pressure window is placed behind a water-cooled bend in order to avoid any damage due to the back-streaming electrons.

The magnetic field is produced by two on-line movable coils independently energised. In fig.2 the drawing of the source is shown. It can be observed that the two motors permit to move the coils parallel to the source axis. The last four electrodes of the extraction system are divided in two parts: this feature will permit to change easily the extraction optics without changing the electrodes' mechanical support.

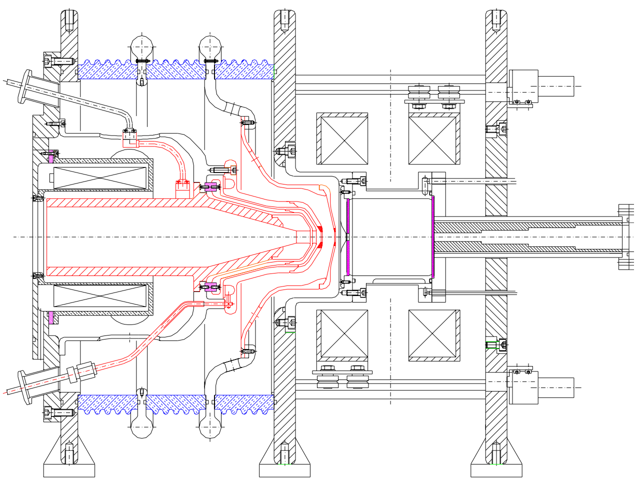

Figure 1: A drawing of TRIPS.

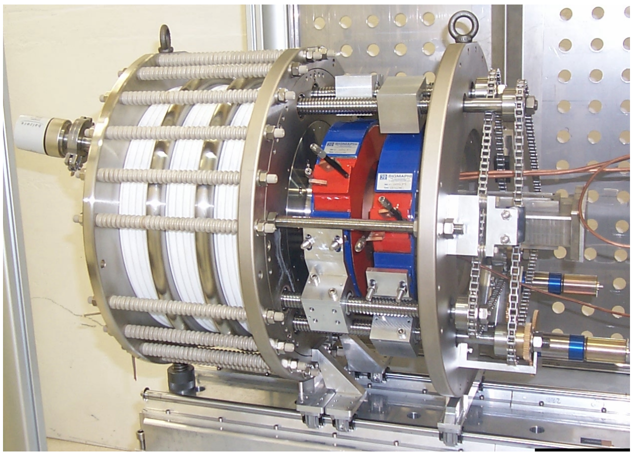

Figure 2: The TRIPS ion source installed over the 100 kV platform.

Moreover, the design have been aimed to simplify the operations of maintenance especially in the extraction zone.

2.1 *The matching transformer*

In order to optimize the coupling between the microwave generator and the plasma chamber a multisection quarter-wave transformer is used (figs.3,4).

In our application the impedance of a WR284 waveguide working in the dominant mode (TE_{10} mode) is to be matched to the equivalent impedance of plasma.

For our purposes we have chosen to use a four step binomial matching transformer [7] that will be inserted immediately ahead of the microwave window.

The transformer realizes a progressive match between the two impedances Z_0 and Z_5 (fig.3) and concentrates the electric field at the center of the plasma chamber (in our design the field enhancement ratio is around 2). The overall result is a significant increase of the extracted current density as we have observed during the commissioning of the source MIDAS2 [8] which uses the same type of matching unit.

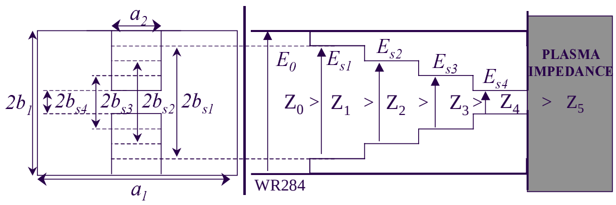

Figure 3: The double ridged binomial transformer.

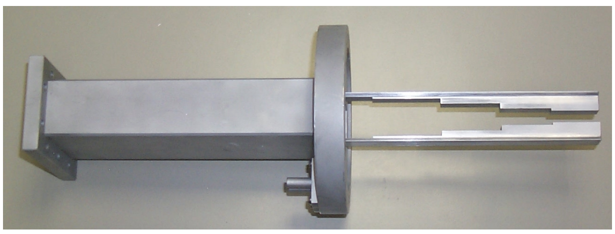

Figure 4: A photo of the binomial transformer

2.1 *The extraction geometry design*

The five-electrode extraction system (fig. 5) has been computed with the Axcel code and the results have been cross-checked with the IGUN code [9].

The main goal is to achieve a rms normalized emittance below 0.2π mm mrad in order to have the optimal matching with the RFQ.

The emittance values calculated by the AXCEL code (including the beam halo) are below this stringent request.

The design has been done with the following guidelines [10]:

- reduction of the length in the extraction zone where the beam is uncompensated,
- use of the intermediate electrode between the plasma electrode and the ground electrode that allows the on-line beam extracted optimisation.

The trajectory plot of the extraction system of TRIPS is shown in fig. 6.

With respect to the SILHI extraction we varied the gaps, the voltage of the intermediate electrode and the extraction holes in order to reduce the aperture-lens effect. The AXCEL simulations have shown that very low divergences can be obtained for lower holes without any beam losses.

Figure 5: The extraction electrodes.

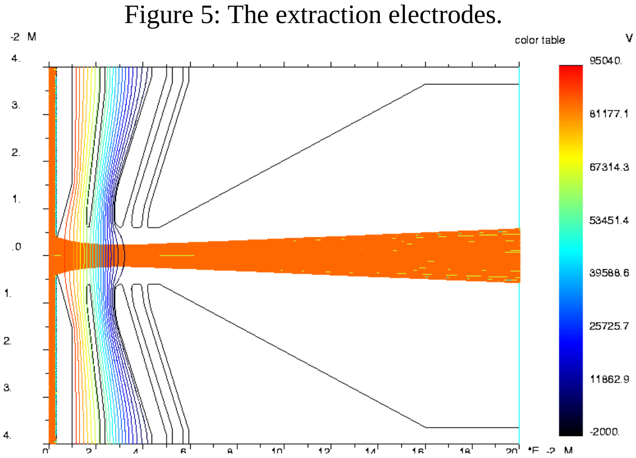

Fig.6- Trajectory plot of the TRIPS extraction system. The extraction voltage is 80 kV and the puller voltage is 45 kV. The plasma density is supposed equal to 1500 A/m^2 and space charge compensation is 98% after the second grounded electrode.

Figure 7: The 100 kV high voltage platform.

3 THE SOURCE STATUS

The 100 kV platform is now operational, the LEBT was assembled and is ready for test (figs. 7,8).

The vacuum is not better than 10^{-6} range because of a leak in the extraction column which will be repaired in July.

Because of this leak it has not been possible to start the test for beam optimization, which were scheduled from June until October, so that emittance measurements and reliability tests could begin before the end of the year 2000.

We have already found the origin of the leak in a bad mechanical contact between a flange and an insulator and we expect to solve this problem within the first half of July.

The microwave injection system is complete except for the bending waveguide which will be delivered in the coming weeks (this element is useful for safety reasons because of backstreaming electrons which can affect the injection line, but it is not essential to operate the source). The ancillary equipment (power supplies, generator, etc) have been tested and they are now remotely controlled.

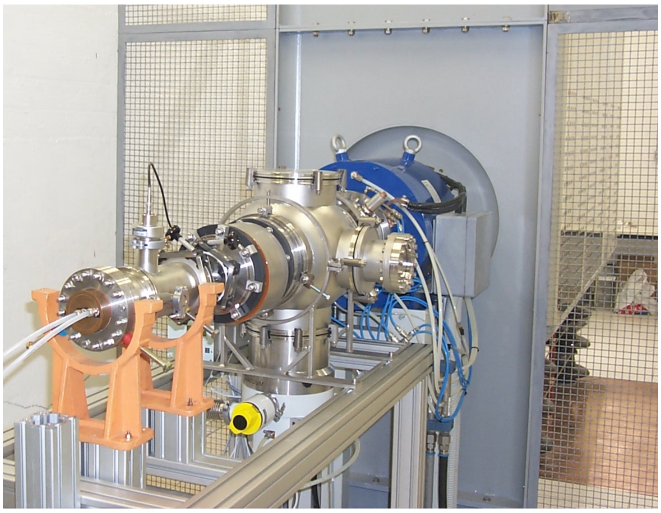

Figure 8: The LEBT line.

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REFERENCES

[1] F. Carminati et al., “An Energy Amplifier for cleaner and inexhaustible nuclear energy production driven by a particle beam accelerator”, CERN/AT/93-47.

[2] A. Pisent et al., “TRASCO 100 MeV high intensity proton linac”, these proceedings.

[3] R. Gobin et al., “Improvement of beam emittance of the CEA high intensity proton source SILHI”, Rev. Sci. Instrum. **70**, 2652, (1999).

[4] P-Y. Beauvais et al., “ Emittance improvement of the electron cyclotron resonance high intensity light ion source proton beam by gas injection in the low energy beam transport”, Rev. Sci. Instrum. **71**, 1413, (2000).

[5] J.M. Lagniel et al., ”Status and new developments of the high intensity electron cyclotron resonance source light ion continuous wave and pulsed mode”, Rev. Sci. Instrum. **71**, 830, (2000).

[6] G. Ciavola, S. Gammino, “A microwave source for high current of protons”, Report LNS October 21, 1996.

[7] L. Celona et al., “Study of microwave coupling in electron cyclotron resonance ion sources and microwave ion sources”, Rev. Sci. Instrum. **69**, 1113, (1998).

[8] L.Celona et al., these proceedings

[9] L. Celona et al., “TRIPS: the high intensity proton source for the TRASCO project”, Rev. Sci. Instrum. **71**, 771, (2000).

[10] R. Keller, “Ion extraction systems: optics and design”, Nucl. Instr. and Meth. **A298**, 247 (1990).