FIRST BEAM FROM THE TRASCO INTENSE PROTON SOURCE (TRIPS) AT INFN-LNS

G. Ciavola, L.Celona, S. Gammino, F. Chines
Istituto Nazionale di Fisica Nucleare – Laboratori Nazionali del Sud
Via S. Sofia 44, 95123 Catania, Italy

C. Campisano
HITEC 2000 srl
Via G. Arcoleo 2, Gravina di Catania, 95040 Catania, Italy

Abstract

The TRASCO intense proton source (TRIPS) has been installed at INFN-LNS in May 2000 and the commissioning is in progress. The paper describes the design of the source along with the first results and the next developments. The source has been able to deliver more than 20 mA of protons with high reliability from a 4.5 mm extraction aperture at 65 kV, largely above the minimum requested current density. The goals in terms of beam energy (80 keV) and current (60 mA from 8 mm extraction aperture) have been achieved. Further optimisation of the source is under way, with special care to the reliability needed for ADS purpose.

1 THE SOURCE DESIGN

The TRASCO Project is a R&D program which goal is the design of an Accelerator Driving System (ADS) for nuclear waste transmutation. The high current cw proton linear accelerator will drive a subcritical system to transmutate nuclear wastes.[1] The accelerator design is shared between different INFN laboratories and the LNS is in charge of the source design and construction.

The proton source TRIPS is a high intensity microwave source, which goal is the injection of a minimum proton current of 35 mA in the following RFQ [2], with a rms normalized emittance lower than $0.2\pi\cdot$mm$\cdot$mrad for an operating voltage of 80 kV.

With respect to other sources for high intensity applications, some new features have been added, according to our experience with the high-intensity source SILHI [3] and with the high-efficiency MIDAS source [4]:

- the microwave matching system has been improved;
- a system to move the coils on-line has been realized;
- the extraction system has been optimised with the aim to increase the source availability and reliability, in order to meet the requirement of a driver for an ADS system.

The final 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 OFHC copper plasma chamber (100 mm long and 90 mm in diameter) through a circulator, a four stub automatic tuning unit and a maximally flat matching transformer [5]. The microwave pressure window is placed behind a water-cooled bend in order to avoid any damage due to the back-streaming electrons.

Two coils, independently on-line movable and energized with separate supplies, allow to vary the position of the electron cyclotron resonance (ECR) zones in the chamber and to produce the desired magnetic field configuration. The design have been aimed to simplify the maintenance especially in the extraction zone.

The maximally flat matching transformer optimizes the coupling between the microwave generator and the plasma chamber. It realizes a progressive match between the waveguide impedance and the plasma impedance, thus concentrating the electric field at the center of the plasma chamber (in our design the field enhancement ratio is around 2).

The extraction geometry was studied with the AXCEL code and the results were cross checked with the IGUN code and with the PBGUN code [6].

The gaps, the voltage and the extraction holes have been designed in order to reduce the length of the extraction zone (where the beam is uncompensated) and to reduce the aperture-lens effect. Rms normalized emittance below 0.2π mm mrad (including the beam halo) have been calculated [7].

2 EXPERIMENTAL RESULTS

Fig. 2 shows the experimental set-up and fig. 3 shows the source on the 100 kV high voltage platform. The first section of the low energy beam transfer line (LEBT) devoted to the beam analysis consists of a current transformer (DCCT1), of a focusing solenoid, of a four sector ring to measure beam misalignments and inhomogeneities, of a second current transformer (DCCT2) and of an insulated 10 kW beam stop (BS) which measures the beam current.

The first operations of TRIPS have been performed at an extraction voltage of 65 kV and with an extraction aperture of 4.5 mm (instead of the design value of 8 mm), in order to work at relatively low currents so that the functionality of all the ancillary equipment is verified. In this configuration a proton beam of 20 mA can be routinely generated (the Child-Langmuir limit for such configuration is about 23 mA) and then transported through the LEBT line with high transmission. Typically more than 90% of the HV drain current is detected by the DCCT2 and about the same current value is measured by the beam stop. We estimated that the beamline transmission is close to 100% and that the proton fraction is anyhow above 90% as soon as the discharge power exceeds 300 W. Such results are obtained by means of an accurate rf matching: the microwave coupling with the matching transformer and the automatic tuning unit permits to operate with low values of reflected power (below 5%) and a high electric field on the axis, thus increasing either the proton fraction and the current density, above 200 mA/cm^2. The best results have been obtained through the optimisation of the coils parameters (positions and currents); the movable solenoids permitted to optimise the plasma generation by easily changing the magnetic field profile. The best profile, according to systematic measurements with different coils positions and currents, is the one with two ECR zones at both ends of the plasma chamber and with a value of magnetic field greater than the resonance value inside the plasma chamber (fig. 4).

Recently the 8 mm hole plasma electrode replaced the 4.5 mm one. Preliminary measurements have given results largely exceeding the TRASCO design current: up to 61 mA were extracted at 80 kV and about 90% of this current was transported to the beam stop, 285 cm far. The RF power was 1 kW and the puller voltage was 42.5 kV during this test

Two different types of electron donors were used to enrich the plasma density: the BN disk at injection and extraction sides of the plasma chamber, as used elsewhere [3] and Al_2O_3 coating (40 μm) which recently replaced the extraction BN disk. This coating increased the plasma density and finally the current density during a 50 hours test (fig. 5). Further investigations will be carried out using coated electrodes for weeks.

Finally we have investigated the more stringent request concerning the reliability with a 24 hours test, at 65 kV extraction voltage, with the puller at 32.5 kV and the repeller at –2 kV. Rf power was 480 W (reflected power was less than 20 W) and the proton current exceeded 15 mA at a source pressure of $8.5*10^{-6}$ mbar. A quiet plasma with two ECR zones inside the plasma chamber was obtained. After the conditioning (a couple of hours), the source have been operating without discharge for 24 hours (fig.6).

The source have not required any particular tuning during 24 hours, except for a few variations of the inlet hydrogen pressure in the plasma chamber. This is really an important parameter that has a strong influence on the beam current stability; for this reason a feedback system on the mass flow of the inlet gas is under study. It must be remarked that the source can produce a very high current with quite low rf power.

3 CONCLUSION AND FUTURE DEVELOPMENTS

In table 1 the status of the source is compared with the requirements of the TRASCO project. The requested reliability at 80 kV is not yet achieved, but the source performance are already good in terms of beam intensity, reproducibility and stability. The innovative solutions presented above have confirmed their validity. We are confident that in a few months a more significant reliability test at 80 kV (over two weeks) can be done. As this goal will be accomplished, the emittance measurements can be done with a similar emittance measuring device as the one described in [3].

ACKNOWLEDGEMENTS

The authors would like to acknowledge the relevant technical support of S. Marletta, E. Messina, S. Passarello and C. Percolla (INFN-LNS). The continuous exchange of information and suggestions of R. Gobin and of the people of SILHI team (CEA, Saclay) have been appreciated, as well as the participation of Jiang Yong Liang and Baoqin Cui (CIAE, Bejing) to the summer 2001 session of tests.

REFERENCES

[1] F. Carminati, R. Klapish, J. P. Revol, Ch. Roche, J. A. Rubio, and C. Rubbia, Report No. CERN/AT/93-47.
[2] The TRASCO_AC Group, Status of the high current proton accelerator for the TRASCO program. Report INFN/TC-00/23.
[3] J.M. Lagniel et al, Rev. Sci. Instrum. 71 (2), 830.
[4] L. Celona, S. Gammino, G. Ciavola, F. Chines, S. Marletta, E. Messina, Proc. EPAC 2000, Wien, 1601
[5]L. Celona, G. Ciavola, S. Gammino, Rev. Sci. Instrum 69 (2), 1113.
[6] L. Celona, S. Gammino, R. Gobin, O. Delferierre, R. Ferdinand, D. De Menezes, N. Pichoff, J. Sherman, Third activity report on SILHI ion source. Report CEA DAPNIA/SEA/IPHI 99-52.
[7] L. Celona, G. Ciavola, S. Gammino, R. Gobin, R. Ferdinand, Rev. Sci. Instrum. 71 (2), 771.

Table 1: TRIPS status

	Requirement	**Status**
Beam energy	80 keV	80 keV
Proton current	35 mA	55 mA
Proton fraction	>70%	≈90% (estimated)
RF power, Frequency	2 kW (max) @2.45 GHz	Up to 1 kW @ 2.45 GHz
Axial magnetic field	875-1000 G	875-1000 G
Duty factor	100% (dc)	100% (dc)
Extraction aperture	8 mm	8 mm
Reliability (24h)	≈100%	100% @ 15mA (65 keV, 4.5 mm extraction hole and over 24 hours)
Beam emittance at RFQ entrance	≤0.2 πmmmrad	To be done

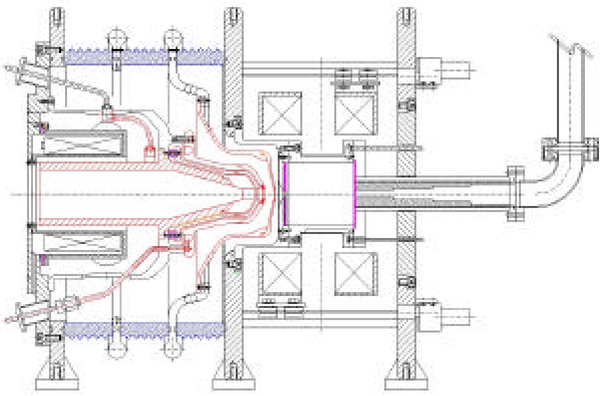

Figure 1: The TRIPS ion source

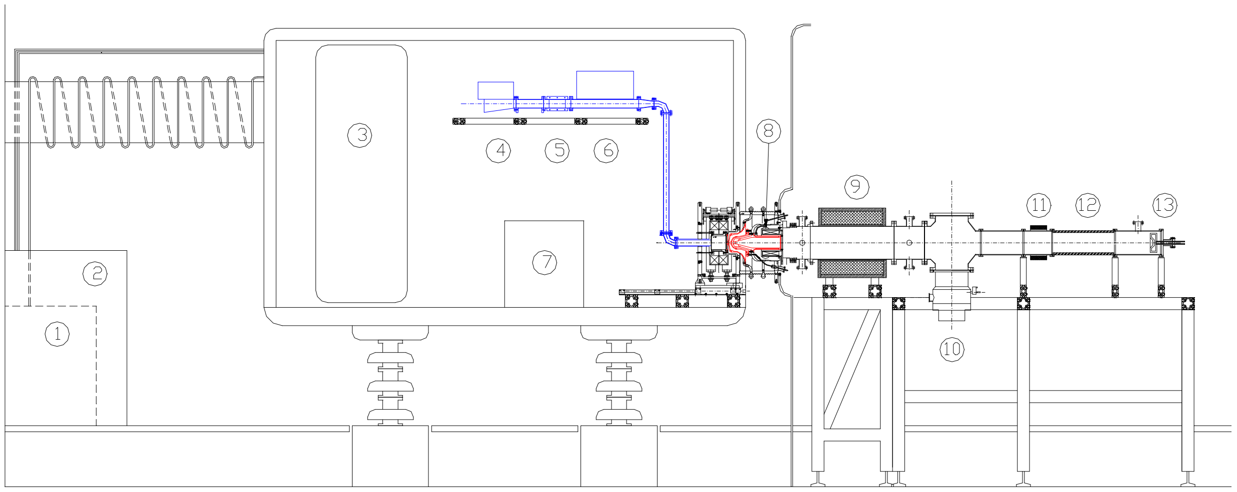

Figure 2: The experimental set-up (1- Demineralizer; 2- 120 kV insulating transformer; 3- 19” Rack for the power supplies and for the remote control system; 4- Magnetron and circulator; 5- Directional coupler; 6 – Automatic Tuning Unit; 7- Gas Box; 8- DCCT 1; 9- Solenoid; 10- Turbomolecular pump; 11- DCCT 2; 12- Quartz tube; 13- 10 kW Beam stop)

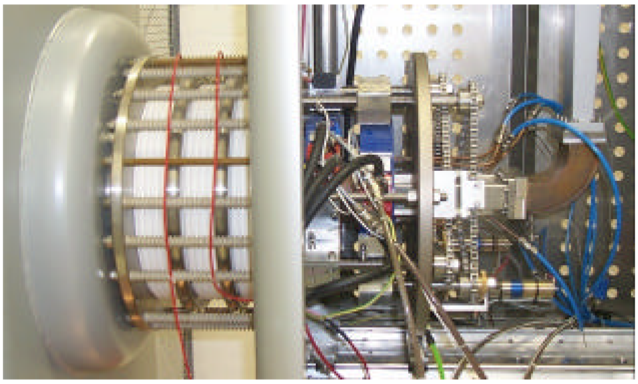

Figure 3: The TRIPS ion source on the 100 kV platform

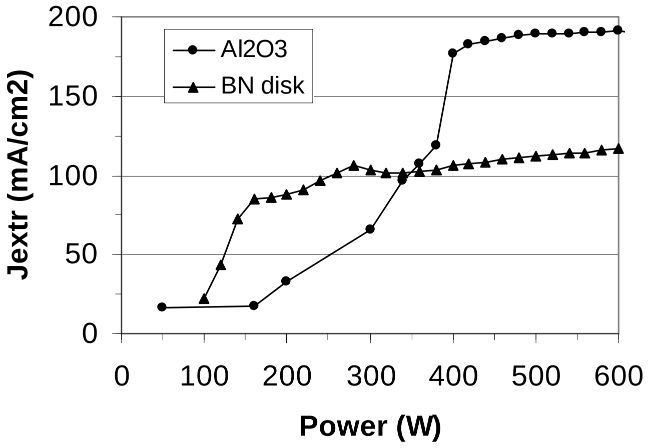

Fig. 5 - RF power vs. current density for different electron donors.

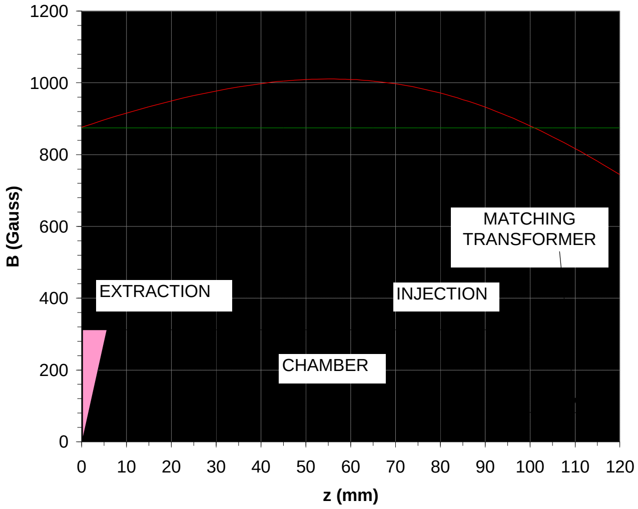

Figure 4: The optimum magnetic profile.

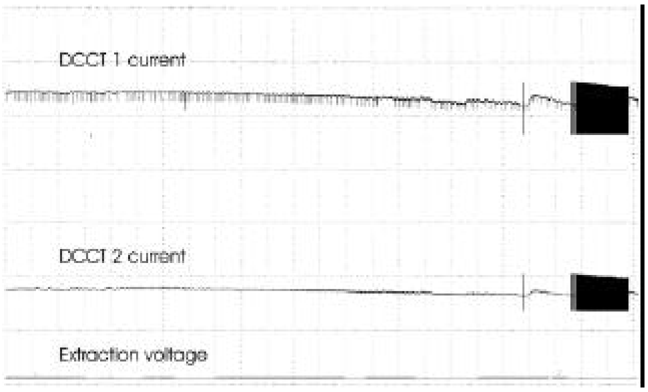

Fig. 6 – The 24 hours reliability test (the different tracks are plotted in different scales).