PRODUCTION AND ACCELERATION OF TRITIUM ION BEAM AT THE U-400M CYCLOTRON

Yu.Ts.Oganessian, G.G.Gulbekian, S.L.Bogomolov, A.A.Efremov, V.N.Loginov, Yu.I.Smirnov, N.Yu.Yazvitsky, V.V.Bekhterev, A.Zelenak, M.Leporis, M.V.Khabarov, I.A.Ivanenko, O.N.Borisov, S.V.Pashchenko, A.M.Rodin, G.M.Ter-Akopian, A.S.Fomichev
FLNR (JINR), Dubna, Russia
A.A.Yukhimchuk, Yu.I.Vinogradov, RFNC - VNIIEPh, Sarov, Russia

Abstract

The tritium ion beam was required for study of ^{4}H and ^{5}H resonance states in neutron transfer reactions $t+t \rightarrow {}^{5}H+p$ and $t+t \rightarrow {}^{4}H+d$. Experiments were performed at the separator ACCULINNA [1].

In the report the main aspects of the tritium ion beam production and the result of the cyclotron operation are presented.

1 ION SOURCE AND INJECTION SYSTEM

At the U400M cyclotron the tritium ions should be accelerated as molecular ions $(DT)^{+}$ from the point of view beam extraction by stripping. The required beam intensity on the liquid tritium target was about 10^{8} pps. Taking into account the beam losses on transport and monochromatisation the intensity of the accelerated beam should be about 10 nA (6 10^{10} pps).

The main requirements to the ion source were:

- minimal consumption of radioactive tritium;
- high output of molecular ions;
- long life time.

For production of molecular ions the RF ion source was chosen. During the operation at the test bench the ion source was optimized for production of H_2^{+} ions.

The injection line of the cyclotron [2] was modified to allow the installation of the RF source with the electrostatic optics. The extracted beam was focused by the Einzel lens to the object point of the bending magnet. The schematic view of the RF ion source with electrostatic optics is shown in Figure1.

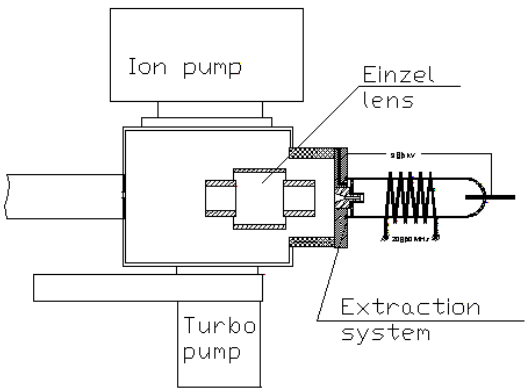

Figure1: The schematic view of the RF ion source.

For feeding of the tritium atoms into the ion source the special gas feed system was developed in RFNC – VNIIEPh (Sarov, Russia) which provides fine regulation of gas flow and safety handling with tritium. The system has two channels for the gas feed – one was used for feeding of deuterium-tritium mixture with the tritium content of 1%, and the second – for the main gas - deuterium.

The hydrogen isotopes, including deuterium-tritium mixture, are chemically kept on ^{238}U. After heating of uranium the hydrogen isotopes flow into the buffer volumes. From the buffer volumes gases are fed into the ion source due to diffusion through the walls of heated nickel capillary. The nickel capillary was heated by direct current. Figure 2 shows the gas flow rate through the capillary used for deuterium – tritium mixture as a function of heating current at different pressures in the buffer volume. It is seen that the gas flow rate is practically independent of the pressure in the buffer volume.

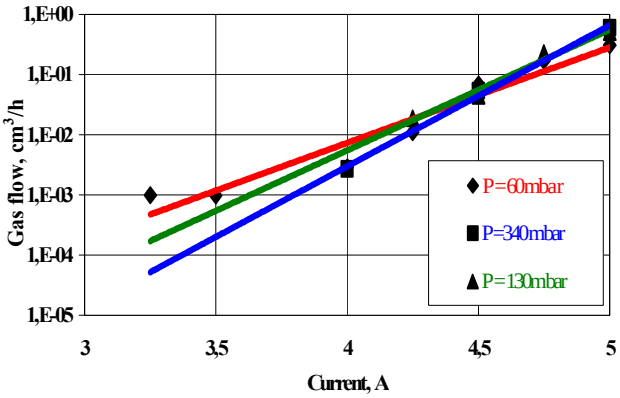

Figure 2: Gas flow rate through nickel capillary as a function of heating current.

Special attention was paid to design of the vacuum system to provide environmentally safe operation.

Preliminary pumping of the injection line was performed by turbopumps. During the operation with tritium the injection line was pumped by titanium ion sputter pumps and by cryopump that allows one to avoid the exhaust of tritium in atmosphere.

CP600, *Cyclotrons and Their Applications 2001, Sixteenth International Conference*, edited by F. Marti

The regeneration of cryopump was performed by special vacuum system with the titanium and intermetallic $Zr(V_{0.8}C_{0.2})_2$ traps of hydrogen isotopes.

2 RESULTS OF THE CYCLOTRON OPERATION

The whole system was tested with the beam of $(D_2H)^+$ ions. The ions were produced when the source was fed with hydrogen and deuterium through two independent nickel capillary. The ions were injected into the cyclotron and internal accelerated beam was produced. The spectra of ions produced from the deuterium - hydrogen mixture is shown on Figure 3.

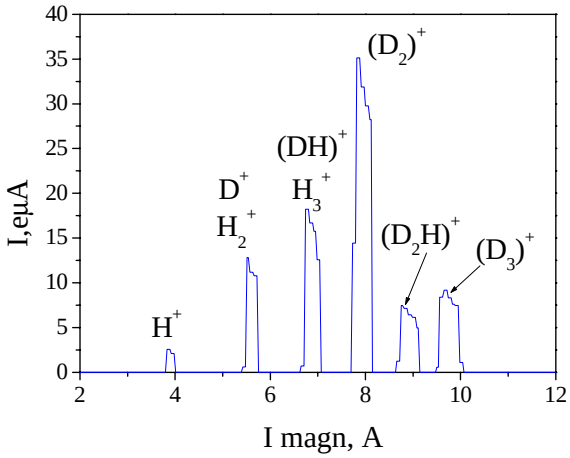

Figure 3: The spectra of ions produced from deuterium - hydrogen mixture.

After tests hydrogen was replaced by deuterium - tritium mixture.

The ion source and gas feed system have shown stable and reliable operation during experiment since the end of November 2000 till the end of January 2001.

The ion source operated at the following typical parameters: RF power – (40 – 50) W (frequency about of 50 MHz); extraction voltage – 0.5 kV; injection voltage – 15.9 kV; the potential of the Einzel lens – 10 kV.

The ion spectra obtained during the tuning of the injection system and cyclotron for acceleration of $(DT)^+$ ions is shown in Figure 4. In routine operation the intensity of accelerated beam was about of 10nA.

The consumption of main gas deuterium constitutes about of 1.7 cc^3/h. The consumption of deuterium – tritium mixture constitutes about of 0.06 – 0.1 cc^3/h which corresponds to tritium consumption less than 10^8 Bq/h.

A beam of 58-MeV tritons was obtained from the U-400M cyclotron and delivered to the tritium target. The ACCULINNA separator ion optics was used to select the beam having an energy spread smaller than 0.5%, angular dispersion of $\Delta\theta<0.5^o$ and a 4-mm beam spot in the final focus plane. The average intensity of the delivered beam was around 2×10^7 s^{-1}.

All together, the beam quality, target parameters and performance of detector telescopes, allow one to have an experimental resolution of ~500 keV for the widths of ^{5}H resonance states which could result from the $t+t$ reaction.

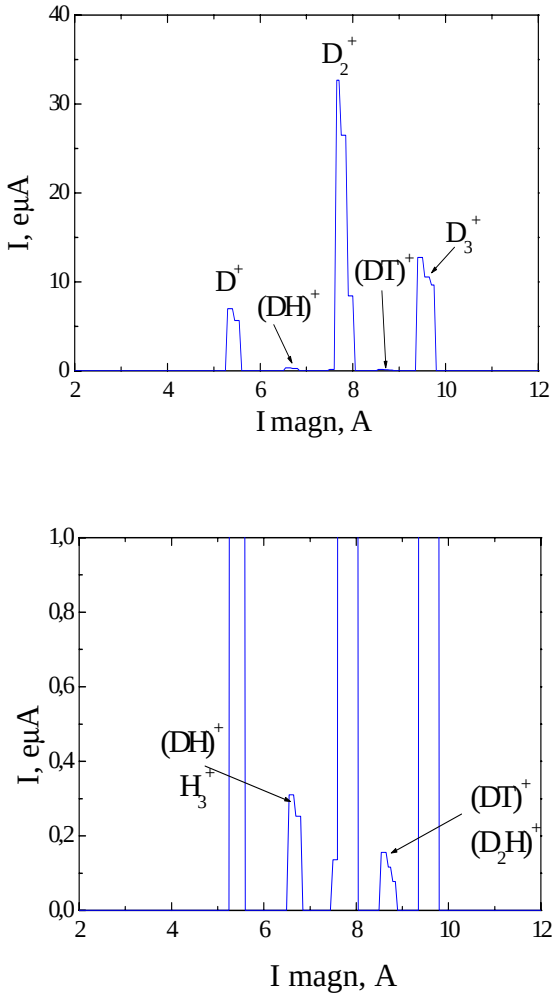

Figure 4: The spectra of deuterium-tritium ions: top – full scale; bottom – magnified scale.

REFERENCES

[1] Rodin A.M. et al., NIM **B126** (1997) 236

[2] Gulbekian et al. Proceedings of the 14th International Conference on Cyclotrons and their Applications, Cape Town, South Africa, 1995, Edited by J.C.Cornell (World Scientific, Singapore, 1995) p.95.