VITA based Neutron Source
- Status and Prospects


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VITA team
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**Monday**
Igor Sorokin – X-ray Radiation of the High-Voltage Elements of the Tandem-Accelerator With Vacuum Insulation

**Wednesday**
Alexander Kuznetsov – Calibration Testing of the Stripping Target of the Vacuum Insulated Tandem Accelerator
Vladimir Aleynik – The Control System for the Tandem-BNCT Accelerator Facility
Alexander Makarov – Optimization of the Negative Hydrogen Ion Beam Injection into the Tandem Accelerator with Vacuum Insulation
boron neutron capture therapy of cancer

epithermal neutrons: 0.5 eV – 10 keV
$10^9 \text{ cm}^{-2} \text{ c}^{-1}$

accelerators: $> 2\text{MeV}$, $> 10 \text{ mA}$
Introduction

Vacuum Insulation Tandem Accelerator (dc 5 mA 2.5 MeV protons)

Lithium target for $^7\text{Li}(p,n)^7\text{Be}$

dc source of negative hydrogen ions (8 mA 21 keV)

High voltage power supply

Dose rate in tumor ~ 1 RBE Gy per minute
Introduction
Facility for development of BNCT in operation since 2008
Novel accelerator (VITA) has been proposed and created

Bayanov et al. NIM A 413 (1998) 397

Lithium target (solid, thin, metallic) has been developed, manufactured and optimized

Kandiev et al. Applied Radiation and Isotopes 69 (2011) 1632

Neutron generation was realized


First in vitro investigations were carried out

Our main problems were:

1. **Low reliability of feedthrough insulator**
   It required re-assembly every year because of SF$_6$ leakage through vacuum seal (Indium wire). Re-assembly takes 3-4 months.

   We have changed Indium wire by vacuum rubber this summer. Result is still positive.
Our main problems were:

2. Low proton current
   We obtained 3 mA proton beam during several seconds, but average current was only 0.1 – 0.7 mA @ 2008-2010.

We have carried out several experiments to increase current
Dark current:

- The accelerator has a high electric field in the electrode gap – about 25 kV/cm, and a large total area of the electrodes – tens of square meters.

In such a system dark current must inevitably occur, which may have a significant impact on the potential distribution along the accelerating channel.

**Dark current was investigated.**

**Facility was modified to prevent the occurrence of high intensity dark current**
Electrostatic lens:

- The accelerator has strong entry electrostatic lens.

We installed a detector in entry lens area and measured beam profile depending on the focusing magnetic lenses current.

We determined:
1. Full compensation of the space charge takes place in the transport channel.
2. Transverse ion temperature is equal to 1 eV at the plasma boundary of the ion source.

This study resulted in better focusing of the beam required for acceleration of the beam without significant losses.
Stripper:

We installed new gas stripper (400 mm, \( \varnothing \) 16 mm) and measured output current depending on stripping target density. We determined:

1. The dependence of the output current on stripping target density is in good agreement with the calculated one when injected \( \text{H}^- \) current is around hundreds of microamps.
2. When the injected current is around several milliamps, there is some reduction of the output current in the saturation region with increasing gas supply.
Main result of these accelerator investigations:

These investigations allowed us to move to a long stable operation with much higher average current – 1.5 – 2 mA instead of 0.1 – 0.7 mA achieved previously.
Beam Shaping Assembly for therapeutic epithermal neutron beam:

2 – 3 MeV proton beams and Li targets:

- Italy team: Palamara et al. 10 ICNCT (2002)
- Ohio Un. team: Khorsandi and Blue. 11 ICNCT (2004)
- Obninsk team: Kononov et al. 11 ICNCT (2004)
- KURRI team: Kobayashi et al. 12 ICNCT (2006)
- IBA team: Jongen et al. 12 ICNCT (2006)
- Argentina team: Kreiner et al. 14 ICNCT (2010)

Dose rate @ 10 mA = ~ 1 RBE Gy per minute
Advanced depth = ~ 6 – 10 cm
Therapeutic ratio = ~ 4 – 6
Current status

Standard mode
@ 2.5 MeV

Dose rate @ 10 mA = 1.5 RBE Gy / min

AD = 11 cm

TR = 5
Current status

Standard mode
@ 2.5 MeV

Dose rate @ 10 mA = 1.5 RBE Gy / min

AD = 11 cm

TR = 5
Current status

Near threshold mode
@ 1.95 MeV

Dose rate @ 10 mA = 1 RBE Gy / min

AD = 7 cm

TR = 2.5

advantages:
1. low yield of neutrons
2. low activation of the lithium target and the facility
Current status

Orthogonal mode @ 2.5 MeV

Dose rate @ 10 mA = 3 RBE Gy / min

AD = 12 cm

TR = 4

advantage:
1. high dose rate
2. à la gantry possibility
Current status

current design of the facility
Orthogonal mode and rotating BSA allows to use any angle neutron beam.
Prospects

BNCT:

- VITA improving:
  - new H\(^-\) source – 15 mA 150 kV
  - new oil-free vacuum pumping
- Li target and BSA development
- neutron spectra and flux measurements
- blistering and target investigations
- \textit{in vitro} and \textit{in vivo} investigation
- new design of medical facility
other applications:

- generation of 9.17 MeV $\gamma$-rays @ 1.747 MeV protons for development of technique of monochromatic $\gamma$-rays resonance absorption in nitrogen to detect explosives and narcotics

- measuring the cross section and the spectrum of $\alpha$-particles from neutronless thermonuclear reaction $^{11}\text{B}(p,\alpha)\alpha\alpha$

- dating of rock formation (apatite) by inducing the fission of uranium contained in the rock

- forming monochromatic beam of epithermal neutrons for calibration of dark matter detector

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Conclusion:

VITA based facility for development of BNCT is now in use @ 1 - 2 mA
Thank you for your attention!

www.inp.nsk.su/bnct/