New Tandetron Accelerator Laboratory at MTA Atomki, Debrecen: Multi-Purpose and Multi-User Facility

István Rajta
*MTA Atomki, Debrecen, Hungary*

Dirk Mous
*High Voltage Engineering Europa B.V., Amersfoort, The Netherlands*
Accelerators at Atomki

- 100-300 kV neutron generators (1958-1960)
- 800 kV Cockroft-Walton cascade (1961-1992)
- 1 MV Van de Graaff (1970-)
- 5 MV Van de Graaff (1971-)
- MGC-20 Cyclotron (1985-) Russian made
- ECR ion source (1996-)
- Isotope separator (2009-)
- AMS (2011-) ETH-Zürich
- 2 MV Tandetron (2014-) HVEE
Van de Graaff generators

Founders of *High Voltage Engineering Corp.*
History of HVEE

1959
Established as subsidiary of High Voltage Engineering Corp., USA

2005
High Voltage Engineering Europa B.V.

Mission:
Develop and manufacture customized particles accelerator systems for science and industry

Energy range of ion beams:
1 keV … > 50 MeV

6 MV Tandetron HZDR, Germany
Tandem particle accelerators 1 – 6 MV
**Tandetrons™**

Typical applications:
- Accelerator mass spectrometry
- Ion beam analysis
- Ion beam material modification
- ns resolution pulsed beams
- etc.

Single-ended particle accelerators 1 – 6 MV
**Singletrons™**

Typical applications:
- Electron beam processing
- High brightness ion beams
- High current ion beams
- Material modif, “solar wind generator”
- PBW
- etc.
The new accelerator should provide:
• High current proton and alpha beam
• High brightness proton beam
• Heavy ion beams
• High beam brightness
• High stability (small energy spread)
• 24/7 run time, allow unattended operation
• Simple and quick maintenance

Solution the HVEE can provide:
• Tandetron (tandem machine)
• H and He multicusp ionsource, Cs sputter source
• 90-degree analyzing magnet with slits feedback
2.0 MV Medium-Current Plus Tandetron Accelerator System
- Low-ripple kit
- Active stripper gas pressure control

Main specifications
- TV ripple: $< 25 \text{ V}_{\text{RMS}}$
- TV stability GVM: $< 200 \text{ V}$
- TV stability SLITS: $< 30 \text{ V}$
- Beam current capability at 2 MV: $> 200 \mu\text{A}$ proton
  $> 40 \mu\text{A}$ He
- Beam brightness: guaranteed $> 10 \text{Amp}(\text{rad})^{-2}\text{m}^{-2}\text{eV}^{-1}$
  expected $> 20 \text{Amp}(\text{rad})^{-2}\text{m}^{-2}\text{eV}^{-1}$

Parameters
- measured $< 6 \text{ V}_{\text{RMS}}$
- measured $< 50 \text{ V}$
- to be measured
Tandetron (high voltage generator): installed
Duoplasmatron ionsource and injector magnet: installed
Switching magnet: installed
External beam: installed
Nuclear astrophysics beamline: installed ("Best poster prize" @ EuNPC2015 Groningen)
Nuclear physics beamline: installed (Dark photon vs. 5th force)
Nanoprobe: installed, reached 200 nm spot size
Collaboration between Atomki and HVEE:
• Energy calibration using (p,γ) and (p,n) reactions
• Description of the new facility
• 2nd paper a bit of nuclear physics and more E_cal points between 3 – 4 MeV

Submitted to NIMB

Differential cross sections of proton induced reactions on $^{14}$N and $^{28}$Si and recommended resonances for accelerator energy calibration

L. Csedreki, I. Vajda, I. Rajta, Gy. Gyürky, R. Huszánk and Á. Z. Kiss

Institute for Nuclear Research, Hungarian Academy of Sciences, MTA Atomki, P.O. Box 51, H-4001 Debrecen, Hungary
Multi-Purpose, Multi-User Laboratory

- **Basic research**
  - Atomic physics
  - Nuclear physics
  - Nuclear astrophysics

- **Applied research**
  - Ion Beam Analysis (various application areas)

- **Innovation**
  - P-beam Writing (e.g. microfluidics for medical applications)

- **Education**
  - MSc, PhD, outreach
Nanoprobe

- Funded by: Infrastructure grant (Hungarian Academy of Sciences)
- Major components manufactured by Oxford Microbeams Ltd.
- Installation in progress
- Planned parameters
  - < 100 nm beam size
  - ~100 µm scan size
  - ~0.1 – 10 pA intensity

The existing microprobe

- 1 µm beam size
- 2.5 mm scan size
- 10 – 1000 pA intensity

Both are going to be needed because they have different parameters, thus serve different application areas and users.
GINOP: EU funding to continue

Building: Phase 2
Building: Phase 3

Phased 3

Equipment:
- Cs-sputtering ionsource
- Multicusp ionsource (H, He)
- 90-deg analyzing magnet etc.
Permanent magnets provide multicusp shaped trap for the plasma.

SO-120 Multicusp

\[
H^*_2 + e^- \rightarrow H^-_2 \rightarrow H^0 + H^- \]
SO-120 Multicusp

H⁻ current: ~ 10 nA – 3000 µA

Extraction potential pot: 30 kV

Beam Energy spread: ≤ 10 eV

hash: ≤ 5% (10 kHz – 1 MHz)

Gas system: 3 gas bottles (H₂, D, and He); 2 gas systems

Filament lifetime > 500 hours (24/7 ~ 1 mA),

~ 800 hours 24/7 25 µA H⁻

Ion beam current regulation

$$\varepsilon = 7.5\pi \text{ mm mrad for 63\% of Current}$$

**SO-120/130 Multicusp**

**Injector characteristics:**

- 2 multi-cusp type ion sources
- **SO-120** output: from 10 nA up to **3 mA H⁺, D⁻**
- **SO-130 + Na CEC** output: unprecedented
  - ~50 µA He⁺
- Differential pumping system
- 30 keV injection for H⁻ and D⁻
- 20 keV injection for He⁺
- Second order corrected ion optics
- Small footprint (1.4 x 1.8 m²)
Na Charge Exchange

\[ He^+ + Na \rightarrow He^0(1s2s)^3S + Na^+ \]

\[ He^0(1s2s)^3S + Na \rightarrow He^-(1s2s2p)^4P + Na^+ \]

Charge exchange efficiency \( \frac{He^-}{He^+} \)


About 1% charge exchange efficiency for Na!
HE extension
TV stabilization

Schematic representation of the terminal voltage stabilization system
AR (Augmented Reality) software development for Android platform. Aim to show the inside of the accelerator and the ionsources. What is not visible from outside we will show virtually.
Call: H2020-INFRAIA-2018-1
Funding scheme: RIA
Proposal number: 824096
Proposal acronym: RADIATE
Duration (months): 48
Proposal title: Research And Development with Ion Beams – Advancing Technology in Europe
Activity: INFRAIA-01-2018-2019

Consolidation leader: HZDR – Helmholtz-Zentrum Dresden-Rossendorf EV
Members: 18 (13 countries)
Our participation: JRA – Joint Research Activity
  WP19 Ion Sources and Beams
    T19.1: Microbeam Optics
  WP20 Detectors and Electronics
    T20.1: Single Ion Detection
European Network of Small-scale Accelerator Facilities – ENSAF

to be held at the
Institute of Nuclear and Particle Physics of NCSR “Demokritos”, Athens, Greece, October 3-4, 2018.

ENSAF is a networking activity (WP7) of the European Nuclear Structure and Applications Research 2 (ENSRAR 2) Integrating Activity of H2020.
Summary

- Flagship project of Atomki since 2012
- Tandetron, duoplasmatron ionsource, switcher magnet
- In December 2015: official opening ceremony (INARIE workshop)
- Nanoprobe: installation in progress
- Atomki manpower: engineers, technicians, physicists
- New GINOP project funded
  - 3 new ionsources
  - 90-degree analyzing magnet
  - Analytical endstation
- Final configuration to be completed in a couple of weeks
Thank you for your attention!

Acknowledgements:

MTA Infrastructure grants
GINOP grant
OTKA grants

All participating colleagues