MULTIPURPOSE RESEARCH COMPLEX BASED ON THE INR HIGH INTENSITY PROTON LINAC

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I will talk about:

1. General description and recent status of the Complex (Accelerator and Experimental Area).
2. Main current goals.
3. Some experience of accelerator operation.
MULTIPURPOSE RESEARCH COMPLEX

Moscow

41 km

Troitsk

2 km
MULTIPURPOSE RESEARCH COMPLEX

What do we mean?

1. Linear Accelerator
2. Experimental Area
   • RADEX facility
   • Spallation neutron source IN-06
   • LNS-100 spectrometer
   • Beam Therapy Complex
3. Isotope Production Facility
Linear Accelerator

Proton Injector

Injection Lines
Low Energy Part (Drift Tube Linac)

750 keV  20 MeV  49 MeV  74 MeV  94 MeV  100 MeV

RFQ → Tank 1 → Tank 2 → Tank 3 → Tank 4 → Tank 5

Booster RFQ

Inside Drift Tube Tank

5 Drift Tube Tanks
Frequency – 198.2 MHz
Output energy- 100 MeV
High Energy Part (Coupled Cavity Linac, 100-600 MeV)

27 four-section Disk and Washer cavities

Frequency 991 MHz

Accelerating cavities in the tunnel

Klystron Gallery
Main accelerator parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Design</th>
<th>Obtained</th>
<th>September 2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particles</td>
<td>p, H-minus</td>
<td>p, H-minus</td>
<td>p</td>
</tr>
<tr>
<td>Energy, MeV</td>
<td>600</td>
<td>502</td>
<td>209</td>
</tr>
<tr>
<td>Pulse current, mA</td>
<td>50</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Repetition rate, Hz</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Pulse duration, µs</td>
<td>100</td>
<td>200</td>
<td>0.3–200</td>
</tr>
<tr>
<td>Average current, µA</td>
<td>500</td>
<td>150</td>
<td>130</td>
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</tbody>
</table>
**Accelerator operation**

1993 - Beginning of regular accelerator runs

From 1993 till September 2012 - 102 accelerator runs

with total duration of 38102 hours

Including:

- 2002 – 1400 hours (6 runs);
- 2003 – 2400 hours (7 runs);
- 2004 – 2200 hours (7 runs);
- 2005 – 1900 hours (6 runs);
- 2006 – 2250 hours (7 runs);
- 2007 – 2040 hours (7 runs);
- 2008 – 1300 hours (5 runs);
- 2009 – 1208 hours (6 runs);
- 2010 – 1700 hours (7 runs);
- 2011 – 1652 hours (5 runs);
- 2012 – 1050 hours (3 runs);
1 - RADEX facility
2 - Spallation neutron source IN-06
3 - LNS-100 spectrometer
4 - Beam Therapy Complex
Experimental Area. Recent results.

1. Proton and H-minus beams separation system.

2. Energy Adjustment system in Proton Therapy beam line.

With wedge-shape degrader. Fine energy adjustment within the range of 209÷70 MeV.

M.I. Grachev et al. Proton Channel that Provides Simultaneous Independent Operation of a Treatment Room of Proton Therapy and Neutron Sources of the Experimental Complex INR RAS, WEPPC051
The main goal for the nearest future for the accelerator is improvement of accelerator efficiency.

**Improvement of Accelerator Efficiency**

**Increasing the beam pulse repetition rate from the current 50 Hz to 100 Hz**

**Distribution of the beam between IPF and Experimental Facility**

**Injector**

- a) 100 Hz Protons
- b) 50Hz protons + 50Hz H-

**RF System**

- H+ 0.75 MeV
- 100 MeV
- 160 MeV
- 247 MeV
- 423 MeV
- 602 MeV

**Isotope Production Facility**

**Experimental Area**
RF System.
The main problems in DTL RF system

*Doubling of average RF power,* dissipating in vacuum grid tubes, anode-grid and cathode-grid resonators of RF power amplifiers, coaxial feeder, drift tubes cavities, numerous RF junctions etc.

*Increasing the cavity warm-up time* after switching off the RF power due to breakdowns or other reasons.

*Increasing of high voltage in the pulse-forming lines of the modulators.*

*50 Hz modulation of a 100 Hz RF pulse sequence.*
A.N.Drugakov et al. Investigation of INR Linac DTL RF System Operation at 100 Hz Repetition Rate, MOPPA023
50 Hz modulation of 100 Hz RF pulse sequence.

Envelopes of RF field in accelerating cavities (upper beam) and stages K3-K4 anode pulses (lower beam)

Block diagram of DTL RF channel. Red colour – tubes with directly heated filaments by AC current

After proper phasing of filament heating currents
Some other problems with RF system

**DTL RF system:**
Stopping of production of grid tubes for
M1 - GMI-44A
K3 - GI-51A
K4 - GI-54A

Solution:
Replacement of GI-51A by GI-57A
GI-54A by GI-71A
Restoration of GMI-44A (S.E.D.-Spb)

**CCL RF system:** Deficiency in klystrons. The capabilities of industry to produce the klystrons enable to balance at the level of 209 MeV.

Status of INR DTL RF System, MOPPA022
Distribution of the beam between IPF and Experimental Facility

**Development, fabrication, installation and commissioning of the Beam Pulse Separation System for intermediate beam extraction area (160 MeV)**

Frequency – 50 Hz  
Up to 50 Hz to IPF  
Full beam to IPF in DC mode

B.O. Bolshakov et al. Power Supply System of the Pulse Bending Magnet for the Linear Accelerator Operated at the Moscow Meson Factory, WEPPC034

N.I. Brusova et al. Beam Pulse Separation System of INR Linac, WEPPC003
Glass vacuum chamber for Pulse Magnet

Pulse and DC Magnets in Intermediate Extraction Area

Top of the current pulse

The first pulse magnet test with beam
PECULIARITIES OF ACCELERATOR TUNING

• Longitudinal tuning
• Transverse tuning
• Beam loss minimizing
Longitudinal tuning

Phase scan of DTL Tank with degrader-absorber

Beam degrader-absorber at the exit of DTL Linac

Phase scan of DTL Tank 5 with two current harmonic monitors

ΔT procedure in CCL cavity
Transverse tuning (5 matching-correction areas)

Matching

Correction
Beam loss minimizing

Neutron Detectors

Beam Loss PMT Signal

Beam Current Signals

Beam Loss Along Sector #4

Beam loss information in Sector #4 of accelerator (247-423 MeV)
Continuous observations of beam cross section

Emittance Measurements at the Exit of INR Linac, WEPPD055

Conclusion

1. Multi-purpose Scientific Complex based on high intensity Proton Linac is in operation at the Institute for Nuclear Research.
2. Permanent modernization of the accelerator and the Experimental Area enables not to only to maintain the complex in operational state but also to improve beam parameters and complex capabilities.
3. The existing experimental facilities are the basis for variety of both basic and applied researches.