Status of the new Source of Polarized Ions for the JINR accelerator complex
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The NICA program consists of several subprojects. Physics with polarized light ion beams is considered as an important part of the NICA collider program also. The expected luminosity of polarized beams is planned at the level of $10^{32} \text{ cm}^{-2} \cdot \text{s}^{-1}$. 
• Development of the polarization program at NUCLOTRON/NICA facility supposes the substantial increasing of pulsed intensity of source of the polarized light nuclei
• **The new project: Source of Polarized Ions project (SPI-project)** assumes the design and production of the **universal high-intensity source of polarized deuterons & protons**
• As the first step the increase of intensity of the accelerated polarized D\(^+\) beam is supposed
• The important fact is depolarization resonances are absent in the total energy range of the NUCLOTRON-M but only for the deuteron beam

The main purpose of the **SPI-project** is to increase the intensity of the accelerated polarized beams at the JINR Accelerator Complex up to **10\(^{10}\) d/pulse**
The SPI-project assumes the development of the source using charge-exchange ionizer

Nearly resonant charge-exchange reactions for production of polarized protons & deuterons are:

\[
\begin{align*}
H^0 & \uparrow + D^+ \rightarrow H^+ \uparrow + D^0 \\
D^0 & \uparrow + H^+ \rightarrow D^+ \uparrow + H^0
\end{align*}
\]

\[\sigma \sim 5 \cdot 10^{-15} \text{ cm}^2\]

- The design output current of the SPI is up to 10 mA for $\uparrow D^+ (\uparrow H^+)$
- The $D^+$ polarization will be up to 90% of the maximal vector ($\pm 1$) & tensor (+1,-2) polarization
- The SPI is based in substantial part on the equipment from IUCF(Bloomington, USA)

*The project is realized in close cooperation with INR of RAS (Moscow, Russia)*
The SPI-project includes the following stages:

- development of the high-intensity Source of Polarized Ions

- complete tests of the SPI

- modification of the linac pre-accelerator platform & power station

- remote control system (console of linac) of the SPI under the high voltage

- SPI & Linac runs with polarized beam and polarization measurements at the linac output
NEW SOURCE OF POLARIZED IONS (DEUTERONS)

$D_2 \rightarrow D \rightarrow D$

$D^0 + H^+ \rightarrow D^+ + H^0$

Spin2014 October 20-24, 2014, Beijing
The **NUCLOTRON** feature is that the injection is possible only for positive ions.

Therefore it is expedient to use the **source of positive polarized deuterium ions**.

**Note:** The highest intensity of the beam is **reached for positive polarized ion sources with charge-exchange plasma ionizer and the storage cell**.

- **SPI-source** assumes to use the storage of polarized deuterium atoms and production of **positive polarized deuterons** by resonance charge-exchange in the hydrogen plasma.
The ionizer with storage of polarized atoms for the SPI allows

- increase intensity of the polarized $\text{D}^+$ beam
- reduce emittance of the polarized beam
- considerably reduce $\text{H}_2^+$ ion current which is difficult to be separated from polarized $\text{D}^+$ due to similar mass of the ions
INR RAS polarized ion source

- atomic beam-type source with resonant charge-exchange plasma ionizer and with a storage cell in the charge-exchange region

(Belov et. al. INR RAS, 1986, 1999)

\[ \text{H}_0^+ + \text{D}^+ \rightarrow \text{H}^+ + \text{D}_0 \]

11 mA of $\text{H}^+ \uparrow$ 80 % polarization has been obtained from the INR source
ABS development

Atomic Beam Source (ABS) of the SPI has been produced and tested at INR RAS

- The pulse density of atomic D beam at the distance of 150 cm from the cooling nozzle outlet is $2.5 \cdot 10^{+10} \text{ at/cm}^3$ at the most probable velocity of $1.5 \cdot 10^{+5} \text{ cm/s}$

- Functional tests of WFT&MFT of the RF cells of the nuclear polarization of deuterium (hydrogen) atoms were performed
ABS tests results

- Atomic D & H beam intensities were measured
  The averaged beam intensities are
  \[ I_D = 8 \cdot 10^{16} \text{ at/s} \quad I_H = 5 \cdot 10^{16} \text{ at/s} \]

- Nozzle temperature was scanned over a range of 16…80 K
  The optimum nozzle temperature is about 27 K
  The optimum feed rate is about 0.045 mbar \cdot l / pulse
RFT scheme and deuteron polarization

<table>
<thead>
<tr>
<th>HFT between 6poles</th>
<th>HFT after 6poles</th>
<th>Final D hfs</th>
<th>P&lt;sub&gt;Z&lt;/sub&gt;</th>
<th>P&lt;sub&gt;ZZ&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>MFT 3 → 4</td>
<td>WFT 1 → 4, 2 → 3</td>
<td>3,4</td>
<td>-1</td>
<td>+1</td>
</tr>
<tr>
<td>MFT 3 → 4</td>
<td>SFT 2 → 6</td>
<td>1,6</td>
<td>+1</td>
<td>+1</td>
</tr>
<tr>
<td>MFT 1 → 4</td>
<td>SFT 3 → 5</td>
<td>2,5</td>
<td>0</td>
<td>-2</td>
</tr>
<tr>
<td>MFT 1 → 4</td>
<td>SFT 2 → 6</td>
<td>3,6</td>
<td>0</td>
<td>+1</td>
</tr>
</tbody>
</table>
Tests of the WFT

Deuterium atoms

- D atoms WFT efficiency – 0.95

Hydrogen atoms

- H atoms WFT efficiency – 0.90
Tests of the MFT

Deuterium atoms

3 → 4 mode

1 → 4 mode
The work which is carried out at JINR includes

- assembly and tests of the charge-exchange plasma ionizer, including the storage cell in the ionization volume

- optimization of the ion-optical system up to \(25 \text{ keV}\) and transport of the high-current deuteron beam

- long-term tests of the SPI with the storage cell in the ionizer

- polarimetry of the accelerated beam at the output of linac

It is necessary to develop control system components for primary analysis & data acquisition and for fiber optic system of data transmission
General view of SPI (September 2012)

ABS

Charge-exchange plasma ionizer
SPI view from the dissociator chamber
General view of SPI (June 2013)
General view of SPI (June 2013)

- HV screen
- Arc plasma source rack (10 kV)
- Electronic rack #2
- HV power supplies rack
General view of SPI (October 2014)
SPI layout at the linac HV - terminal

100 kV high voltage terminal
Tests bench program of the SPI in 2014

- operating with deuterium plasma arc source, running with the charge exchange ionizer
to date, the first phase of work was completed at the energy of the accelerated ions up to 10 keV
- start-up and testing of SPI mode of polarized protons obtaining
at present this work is in progress

- operating with hydrogen plasma arc source, running with the charge exchange ionizer
  including the storage cell in the ionization volume
- start-up and testing of SPI mode of polarized deuterons obtaining

- development of control system components for primary analysis & data acquisition
  and for fiber optic system of data transmission is in progress now
JINR & INR of PAS Contract for 2014-2015 year

- Development and prototyping of the atomic beam mass spectrometer to adjust the RF-units of the SPI and power supplies pulsed plasma generator to operate the charge-ionizer for a polarized ion source of hydrogen and deuterium at energies up to 25 keV

- Accelerating voltage up to 25 kV will significantly increase the polarized beam current at the output of the SPI
Summary

• Active development of the SPI at JINR began in mid-2011

• In August 2012, the ABS was transported from the INR of RAS (Moscow) and assembled at JINR

• All-inclusive SPI-testing will be carried out at JINR in 2014-2015

• SPI assembling and commission run at the linac is planned by the end of 2015
Thank you