Design, Fabrication and Testing of Compact Diagnostic System at IUAC

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Outline..

- IUAC
- High Current Injector
- Compact Diagnostic System
IUAC Overview
Accelerators & Research Facilities at IUAC

Major Accelerators
- 15UD Pelletron
- SC-LINAC
- Positive LEIBF
- Negative LEIBF
- PARAS
- XCAMS
- High Current Injector
- FEL (Upcoming)

Major Research Facilities
- Nuclear Physics
- Material Science
- Radiation Biology
- Atomic Physics
- RBS-AMS
- High Performance Computing System

www.iuac.res.in

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High Current Injector
IUAC Pelletron + SC-LINAC Layout

- Injector Magnet
- MC SNICS
- Multiharmonic Buncher (~1 ns)
- 15 UD Pelletron
- Superbuncher
- Pelletron
- Linac crystals
- SC-LINAC
- Linac 3 Modules
- SC-REBUNCHER (350-400 ps)
- Switching Magnet
- Analyser Magnet
- Switching Magnet
- SC Buncher (150-200 ps)

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IUAC Pelletron, High Current Injector and SC-LINAC Layout

15 UD PELLETRON

Beam Hall 2

Beam Hall 1

Beam Hall 3

High Current Injector

IH-DTL

RFQ

97 MHz SC-LBC

MC SNICS

1

2

3

SB

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High Current Injector

- Novel HTSC-ECR Ion Source
- State of the Art Accelerator Development
- High Current ~A Few Hundreds of microAmperes
- Accelerate Ions of Mass <120 A.M.U.
- More Species-Nobel Gases
- Pelletron as a Stand-Alone Operation
- HCl as an Injector for Existing SC-LINAC
- Accelerate Ions with $A/q \leq 6$ and Output Energy ~1.8 MeV/ A.M.U.
High Current Injector +LINAC
Design Value $A/q \leq 6$

ECR ➔ RT RFQ ➔ RT IH-DTL ➔ SC LBC ➔ SC-LINAC

- (β<0.02)
- (0.02<β<0.06)
- (β ~ 0.06)
- (β ~0.08)

18 GHz PKDELIS
High Tc Axial coils
Injection 1.8 T
Extraction 1.5 T
Operating at 230 K
RF Power 1.7 kW
TE ~50 μm mrad
First HTSCECR-GR

48.5 MHz
8-180 keV/u
Power ~80 kW
4 Rod Structure
2.5 Meter

97.0 MHz
Input 180 keV/u
Output 1.80 MeV/u
Power ~25 kW (Max)
RT IH-DTL
Integrated Bunching
6 Tanks ~7 Meters

97.0 MHz
SC-QWR
8 Cavities
Optimum β ~0.06

97.0 MHz
SC-QWR
3 Modules
24 Cavities
Optimum β ~0.08
Avg. Electric Field per Cavity ~3MV/m

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Compact Diagnostic System
Major Beam Parameters

- Current
- Profile
- Position
- Energy
- T. Emittance
- L. Emittance
- Bunch Length
- Energy Spread
- Phase/Time Spread

Tank-DTL cavity, DB- Compact Diagnostic Box, QT-Quadruples Triplets
## Present Status

<table>
<thead>
<tr>
<th>Work</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prototype Compact Diagnostic Box</strong></td>
<td></td>
</tr>
<tr>
<td>Alignment in LEIBF</td>
<td>Complete</td>
</tr>
<tr>
<td>Beam Centre Calibration</td>
<td>Complete</td>
</tr>
<tr>
<td>Online Beam Test and Validation</td>
<td>Complete</td>
</tr>
<tr>
<td><strong>First Compact Diagnostic Box</strong></td>
<td></td>
</tr>
<tr>
<td>Modification</td>
<td>Complete</td>
</tr>
<tr>
<td>Design and Fabrication FC and SSC</td>
<td>Complete</td>
</tr>
<tr>
<td>First DTL Assembly &amp; Compatibility</td>
<td>Checked and Done</td>
</tr>
<tr>
<td>Stepper Motor Controller and Electronics</td>
<td>Complete</td>
</tr>
<tr>
<td>Fabrication of First Diagnostic Box</td>
<td>Under Process</td>
</tr>
</tbody>
</table>
Prototype
Compact Diagnostic Box
Faraday Cup (FC) and Slit Scanner (SSC)

Diameter – 25 mm
Depth – 20 mm
Length – 25 mm

Slit width – ~ 500 μm
Stroke Length – ~ 80 mm
Compact Diagnostic Box

Diagnostic Box installed in LEIBF Material Science Beam line

- Diagnostic Box
- Faraday Cup
- Slit Scanner
- SS Chamber
- 75 mm
- The vacuum ~10^{-9} torr
CDB Installation & Alignment in LEIBF
Suppressor Voltage
0 to -400 V

IUAC Microhope
Stepper Motor Controller

Current in
Kethley Electrometer
6517B

Beamline Control
Panel Display

Beam Current,
Profile, Spot Size
and Position
Measurement Set-up

Online Beam Profile

LabVIEW Program
& Display

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Beam Centre Calibration

Beam X-Profile

Beam Y-Profile

Beam Centre \([X(0), Y(0)]\) \((L=36 \text{ mm and } L=56 \text{ mm})\) on 0 mm to 70 mm Scale

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## Ion Beam Test

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>ION BEAM</th>
<th>Energy (keV)</th>
<th>Current (µA)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Argon</td>
<td>Ar $^+$</td>
<td>14</td>
<td>2.14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ar $^+$</td>
<td>300</td>
<td>43.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ar $^+$</td>
<td>1200</td>
<td>9.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ar $^+$</td>
<td>2400</td>
<td>0.5</td>
</tr>
<tr>
<td>2</td>
<td>Carbon</td>
<td>C $^+$</td>
<td>250</td>
<td>0.025</td>
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<tr>
<td></td>
<td></td>
<td>C $^+$</td>
<td>300</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td></td>
<td>C $^+$</td>
<td>1200</td>
<td>0.35</td>
</tr>
<tr>
<td>3</td>
<td>Nitrogen</td>
<td>N $^+$</td>
<td>250</td>
<td>74</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N $^+$</td>
<td>1250</td>
<td>1.3</td>
</tr>
<tr>
<td>4</td>
<td>Oxygen</td>
<td>O $^+$</td>
<td>250</td>
<td>2.77</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O $^+$</td>
<td>1250</td>
<td>0.421</td>
</tr>
</tbody>
</table>

_L-Low, H-High, C-current, E-Energy_
## Currents in FC Vs NEC-FC

<table>
<thead>
<tr>
<th>Beam Specification</th>
<th>Energy</th>
<th>Current Measured by NEC Faraday Cup</th>
<th>Current Measured by Faraday Cup</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>C⁺¹</td>
<td>300 keV</td>
<td>30 µA</td>
<td>30 µA</td>
<td>Match</td>
</tr>
<tr>
<td>N⁺¹</td>
<td>250 keV</td>
<td>74 µA</td>
<td>72.5 µA</td>
<td>2 %</td>
</tr>
<tr>
<td>Ar⁺¹</td>
<td>14 keV</td>
<td>2.15 µA</td>
<td>2.15 µA</td>
<td>Match</td>
</tr>
<tr>
<td>O⁺⁵</td>
<td>1.25 MeV</td>
<td>440 nA</td>
<td>440 nA</td>
<td>Match</td>
</tr>
</tbody>
</table>
Beam Profiles and Beam Positions Measured online with LabVIEW for Ar
Online Beam Test for C, O and N

Beam YX Profiles and Beam Positions of Carbon, Oxygen, and Nitrogen Ion Beam
YX Beam Profiling by BPM

Beam spot & Position

Horizontal

Vertical

Beam Profile

Microcontroller

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Beam Digitization and Matching from NEC BPM to Compact BPM

2.5 Times Scale

Ar (+2) 600 keV 31μA

Ar (+8) 2.4 MeV 500nA

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First Compact Diagnostic Box Development
First Diagnostic Box Development
SSC and FC Development
Diagnostic Box Development

Prototype CDB

Faraday Cup

~1kW

First CDB

Slit Scanner

Compact Diagnostic Box

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Salient Features of First CDB

- Compact Size (LL)~70 mm
- Approx. 10 pA to 100 µA
- Approx. 1kW Beam Power
- Ease of Machining
- Mechanical Robustness
- Electrical/ Electronics Operation
- Compatible with DTL Tank
- Low Cost and Reliable
- Beam Current, Position, Profile & Spot Size
Compact Diagnostic Box with First DTL Resonator
Capacitive Pickup
Capacitive Pickup
Capacitive Pickup

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CDB with Capacitive Pickup
Beam Current, Profile & Bunch Length Measurement

Slit Scanner
Faraday Cup
Capacitive Pick-up

\[ i(t) = \frac{YN_\zeta e[T_1-T_2+T_3-T_4]}{2\Delta t} \]
Beam Current, Profile & Bunch Length Measurement

Faraday Cup

Slit Scanner

Capacitive Pick-up

\[ i(t) = \frac{YN_\zeta e^{[T_1-T_2+T_3-T_4]}}{2\Delta t} \]

\( \beta \sim 0.05, R = 15 \text{ mm} \)

\( L = 15 \text{ mm} \)

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## Capacitive Probe Length Calculation

<table>
<thead>
<tr>
<th>Position</th>
<th>Relative Velocity ($\beta$)</th>
<th>Capacitive Pick Up Probe Length L (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expected Bunch Length</td>
<td>0.5 ns</td>
<td>1 ns</td>
</tr>
<tr>
<td>Before 1st DTL</td>
<td>0.02</td>
<td>3</td>
</tr>
<tr>
<td>After 6th DTL</td>
<td>0.05</td>
<td>7.5</td>
</tr>
<tr>
<td></td>
<td>0.06</td>
<td>9</td>
</tr>
</tbody>
</table>

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Capacitive Pick-up Parameters

Simulation Results

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HEBT (IH-DTL+CDB) Commissioning

Ion Beam

387 mm  693 mm  896 mm  936 mm  917 mm  820 mm
Summary

- Developed Compact Diagnostic Box and its Components
- Tested and validated operational aspects
- Measure beam current, profile, position, spot size and bunch length
- Accurate and Reliable
THANK YOU HIAT 2015
どうもありがとうございます
Rajesh V Hariwal

Thanks Team Members

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IUAC Delhi, India

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Rajeev Mehta
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