Beam Commissioning of 100-MeV KOMAC Linac

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for KOMAC accelerator team

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KOMAC, KAERI
KOrea
Multi-purpose
Accelerator
Complex

- Facility Introduction
- 100-MeV Linac
- Operation Status
- Beam Service Status
- Plan for Beam Power Increase
- Summary
KOMAC Site: Gyeong-ju

KTX Station
To Seoul ~2 Hour

KOMAC phase 2 Site
650 m(L) X 400 m(W)

KOMAC site
450 m(L) X 400 m(W)

Land & Electricity for Future
Easy Access from Seoul, Busan, and Pohang
Good for sightseeing

Seoul-Busan Expressway
Main Facility

- Beam application building: Construction to be completed in December 2014
- Site: 180,000 m²
- Building: 39,000 m²
- Electricity: 154 kV, 20 MVA

1. Proton Linac
2. Beam Line
3. Power Station
4. Utilities
5. Cooling Tower
6. Sewage Plant
Linac and Beam Lines

Features of KOMAC 100MeV linac
- 50-keV Injector (Ion source + LEBT)
- 3-MeV RFQ (4-vane type)
- 20 & 100-MeV DTL
- RF Frequency : 350 MHz
- Beam Extractions at 20 or 100 MeV
- 5 Beamlines for 20 MeV & 100 MeV

<table>
<thead>
<tr>
<th>Output Energy (MeV)</th>
<th>20</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Peak Beam Current (mA)</td>
<td>1 ~ 20</td>
<td>1 ~ 20</td>
</tr>
<tr>
<td>Max. Beam Duty (%)</td>
<td>24</td>
<td>8</td>
</tr>
<tr>
<td>Avg. Beam Current (mA)</td>
<td>0.1 ~ 4.8</td>
<td>0.1 ~ 1.6</td>
</tr>
<tr>
<td>Pulse Length (ms)</td>
<td>0.1 ~ 2</td>
<td>0.1 ~ 1.33</td>
</tr>
<tr>
<td>Max. Repetition Rate (Hz)</td>
<td>120</td>
<td>60</td>
</tr>
<tr>
<td>Max. Avg. Beam Power (kW)</td>
<td>96</td>
<td>160</td>
</tr>
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- No full beam dump
- Beam power increase goes with target room preparation

1kW dump in tunnel
10kW dump in target room

100MeV Beam lines
20MeV Beam lines

Linac
Ion Source

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**Accelerator Development**

- Developed proton linac technologies over the past 10 years
  - Microwave ion source
  - RFQ
  - DTL
  - Elliptical SC cavity
  - LLRF and EPICS control system

- Built KOMAC 100-MeV proton linac of our own design with the technologies
100-MeV Linac

- Linac and beam lines: installed in 1st floor
- Tunnel: 100 m
- 100-MeV linac: 75 m
- HPRF and cooling system: installed in 2nd floor

Viewed from the ion source

Viewed from the end of 100-MeV DTL
Target Room

- 2 beam lines and 2 target rooms are installed and in services
  - 1 for 20 MeV, 1 for 100 MeV
- Irradiation: in air through 0.5-mm Al-Be alloy window
RF Power Conditioning

- Performed high-power conditioning with installation of the components
RF Power Conditioning

- Number of HPRF systems: 9 sets

- Nominal operation conditions of modulator:
  - 5 MW @ 1 ms, 10 Hz (for 2 klystrons)
  - 7 MW @ 1 ms, 10 Hz (for 3 klystrons)

- Nominal operation conditions of Klystron:
  - RFQ Klystron: 500 kW @ 550 us, 10 Hz
  - DTL Klystron: 1.2 MW @ 700 us, 10 Hz

- RF system is controlled by digital LLRF systems
Commissioning

- RF set point tuning was performed by
  - Monitoring radiation along the linac and in the target room
  - Scanning beam phase by BPM

Radiation monitoring

Beam phase scan
Commissioning in 2013

- Commissioning goal in 2013: 1-kW proton beam into TR103
  - Delivered 1-kW beam into TR103 in July, 2013
  - Checked beam energy change by turning off 7 DTL tanks one-by-one
- Operation license by the Nuclear Safety and Security Commission of Korea
- Started user beam services for 1-kW beam from July 22, 2013
Commissioning in 2014

- Goal: 10-kW beam @ 100 MeV
- Achieved 10-kW beam in August 2014: 550us, 10Hz
- Normal operation with 10-kW is to start with revision of operation license

RFQ output beam
20 MeV output beam
100 MeV output beam (500 us, 10 Hz)
10 Hz beam operation
Beam Profile at Target Room

- User requirement for beam size: max. 300-mm diameter
- Monitoring beam profile
  - Flat panel detector with CsI scintillator
  - Panel size 430 mm × 430 mm, pixel size 139 um

Beam profile inside target room

Flat panel detector

Beam window

Beam rms radius: 25 mm
Control Room & Operator

- EPICS based control system
  - Accelerator / Utilities / PSIS / RMS are controlled in the main control room
- Operators: 2 for accelerator, 2 for beam service in target room
Operation plan: Weekly based
Beam service: Monday ~ Friday
Operation statistics (accumulated)
- Operation: 3,772 hours (FY 2013: 2,290 hours / FY 2014: 1,482 hours)
- Beam service: 798.4 hours (FY 2013: 432.7 hours / FY 2014: 365.7 hours)
- Availability: FY 2013: 82.0%, FY 2014: 91.5%
Downtime Statistics at 2013

Accumulated down time in beam service : 94.7 hours

Downtime in 2013

- Initial RF conditioning problem
- DTL / RF 40%
- Modulator 25%
- Utility 28%
- Ion source 7%
- Moulator IGBT blast
- MPS interlock
- Moulator controller malfunction
- Klystron magnet fault
- Moulator Oil pump failure
- HV fault at ion source
- LLRF controller fault
- RF arcing at Power coupler
- Electrical failure
- Shielding door failure
- PSIS PLC fault

Initial RF conditioning problem: 35 hours
Issue: Utilities

Although completed commissioning of the utility, several troubles

Examples
- Watered electronics in klystron gallery due to unexpected triggering the fire extinguisher (Shut down vacuum, RF and control system)
- Abnormal stopping cooling pump caused by momentary electrical power failure
- Tripped off vacuum system due to improper grounding
**Issue: Modulator**

- **Major issues**
  - IGBT blasting at low duty 500 us, 2 Hz
  - Controller failure
  - SCR firing circuit failure
- **Minor issues**
  - PLC logic
  - IGBT over-current set value
  - SCR control circuit jumper
  - Oil pump hose and so on
- In our case, insufficient spare parts lead to long downtime

M02 A phase IGBT blasting
Beam Service Statistics (2013~2014)

- Total number of charges: 1,641 (2013: 937 charges / 2014: 704 charges)

**Users in R&D fields**
- TR103: 67%
- TR23: 33%
- Basic science/Physics/Space: 22%
- Energy/Environment: 4%
- Nuclear/Radiation/Neutron: 7%
- ETC: 8%
- Bio/Medical science: 21%
- Nano/Material/Semiconductor: 12%

**Users in institutions**
- Research Institute: 46%
- Industry: 7%
- University: 48%

**100MeV/20MeV users**
- Users in institutions
Plan for beam power increase

Plan for RI production at KOMAC
- Major RI: Sr-82, Cu-67, etc.
- Beam requirements
  - Sr-82 : 100 MeV, 60 kW, 4 weeks on Rb target
  - Cu-67 : 100 MeV, 60 kW, 2 days on Zn target
- To start RI production target room construction in 2015

100 kW beam commissioning
- In 2016, using RI target room and dummy target

Operation
- Day-time for user beam experiments
- Night-time for RI production
Summary

Operation in 2013
- Successfully commissioned 100-MeV linac with 1 kW
- Licensed normal operation (Nuclear Safety and Security Commission of Korea)
- Started user beam service in July.

Operation in 2014
- Increased beam power to 10-kW
- Continued user beam service with improved beam conditions

Near-term plan
- Installation of beam line and target room for RI production
- 100-kW beam test

Long-term plan
- Linac upgrade to 1GeV for spallation neutron source
Thank you