KOMAC operation and future plans

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on behalf of KOMAC

KOMAC / KAERI
1. Introduction: KOMAC
2. Accelerators and Applications
3. Summary
KAERI: Korea Atomic Energy Research Institute

- Established for Nuclear R&D (Power & Rad. Applications) in 1959
- Located in 3 sites: Daejeon (HQ), Jungup (ARTI), Gyeongju (KOMAC)
KOMAC: Korea Multi-purpose Accelerator Complex

- Located in Gyeongju

KTX Station
Daejeon ↔: 1:05 hours
Seoul ↔: 2:05 hours

Reserved
(260,000m²)
650m x 400m

User facility to provide proton and ion beams for many applications
Main Facility

- 1. Proton Linac
- 2. Power Station
- 3. Utility
- 4. Cooling Tower
- 5. Sewage Plant
- 6. Ion Beam Facility

- **Main Hall**
- **Main Gate**
- **Guest House**

- **Main Facility Details**:
  - Area: 180,000 m²
  - Building: 27,322 m²
  - Power: 154kV, 20MVA

- **KOMAC Opening Ceremony**: 5th April, 2018
KOMAC 100-MeV Proton Linac

- Linac and beam lines: installed in 1<sup>st</sup> floor
- Tunnel: 100 m
- 100-MeV linac: 75 m
- HPRF and cooling system: installed in 2<sup>nd</sup> floor
- Commissioned & Started user service in July 2013
Operation Statistics (2013~2017)

- Operated in weekly-based schedule through a yearly plan
  - Beam service: Monday 13:00 ~ Friday 12:00
- Operation statistics

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation hours</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>2,290</td>
<td>82.0%</td>
</tr>
<tr>
<td>2014</td>
<td>2,863</td>
<td>86.3%</td>
</tr>
<tr>
<td>2015</td>
<td>2,948</td>
<td>90.5%</td>
</tr>
<tr>
<td>2016</td>
<td>2,961</td>
<td>94.9%</td>
</tr>
<tr>
<td>2017</td>
<td>3,231</td>
<td>94.9%</td>
</tr>
<tr>
<td>Sum</td>
<td>14,293</td>
<td>89.7%</td>
</tr>
</tbody>
</table>

- R&D Fields: Materials(36%), Bio/Medical(26%), Space Rad./Basic Sci.(21%) etc.
Proton Beamline (1)

- **General Purpose Beamline: 20-MeV / 100-MeV Proton**

  **Application:** Proton beam irradiation for general purpose (material / nano-science, semiconductor etc.)

  **Proton beam**
  - Energy: 20 MeV / 33 ~ 100 MeV
  - Beam power: 10 kW @ 100 MeV

  **Status:** Under operation (2013~)

**Beam profile at the target**

- Hot cell for sample manipulation
- Beam irradiation station
- Beam window
- Proton beam
Proton Beamline (2)

RI Production Beamline: 100-MeV Proton

- **Application**
  - RI production: Cu-67, Sr-82, etc.

- **Proton beam**
  - Energy: 33 ~ 100 MeV
  - Beam power: 30 kW @ 100 MeV

- **Status**
  - Completed installation: Dec. 2015
  - Status: under operation (2016~)

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**Target Preparation**

- $^{68}\text{Zn}(p,2p)^{67}\text{Cu}$
- $^{\text{nat}}\text{Rb}(p,x)^{82}\text{Sr}$

- 91, 93.3, 184.6 keV gamma from $^{67}\text{Cu}$ decay
- 511 & 776 keV gamma from $^{82}\text{Sr}$ decay
Proton Beamline (3)

Low-flux Beamline: 100-MeV Proton

Application: Space radiation, Detector R&D, Bio etc.

Proton beam

- Energy: max. 100 MeV
- Avg. Current: max. 10 nA
- Uniformity: < 10%, 100 mm X 100 mm
- Flux: $1 \times 10^5 \sim 1 \times 10^8$/cm$^2$/pulse

Status: Under operation (2017~)
Low-flux Beamline: 100-MeV Proton

Target room: (2D IC, Farmer IC, Degrader, Collimator etc.)

Octupole magnet off: 240mm × 240mm
Octupole magnet on: < 5% @ 100mm X 100mm
Circular beam by collimator

Accumulated dose during irradiation

Linear Response

Beam Off
Beam On

greater than $10^5$ #/cm²-pulse
Li-8 Production Beamline: 100-MeV Proton

**Application:** Beta NMR

**Proton beam**
- Energy: 100 MeV
- Beam Power: 1 kW @ 100 MeV
- Li-8 Ion Production: $1 \times 10^8$ pps
- Target: BeO

**Status:** Under development (2017~)

Li production rate calculated by FLUKA
Pulse Neutron Production Beamline: 100-MeV Proton

- **Application**: Pulse Neutron Production
- **Proton beam**
  - Energy: 100 MeV
  - Beam Power: 1 kW @ 100 MeV (upgrade 160 MeV)
  - Target: Tungsten
- **Status**: Neutron utilization, accelerator upgrade (2017~)

**Pulse neutron spectrum**

**Pulse neutron yield depending on proton energy**

Superconducting accelerator
- Energy: 100 MeV ~ 160 MeV
- Type: HWR (Half-Wave Resonator)
- Cryomodule: Cylindrical
- Operating temperature: 2K
- Focusing: External normal conducting QM
Short pulse (10 ns) proton injector for pulsed neutron generation

Status
- Short pulse extraction test at test stand
- Planed to be installed in 100 MeV linac tunnel

Specification

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Max. electron current</td>
<td>300 mA</td>
</tr>
<tr>
<td>Max. electron energy</td>
<td>20 keV</td>
</tr>
<tr>
<td>Max. ion energy</td>
<td>60 keV (for proton)</td>
</tr>
<tr>
<td>Magnetic field</td>
<td>6 T</td>
</tr>
<tr>
<td>Magnet bore dia.</td>
<td>50 mm</td>
</tr>
<tr>
<td>Drift tube length</td>
<td>200 mm</td>
</tr>
</tbody>
</table>

Charge in single pulse: 250 pC

Single pulse extraction (present: 150 ns)
Ion Beam Facility (1)

Ion Beam Implanters

- Application: Surface Modification
- Beam specification
  - Ion species: N, Ar, O etc. (Gas)/Cr, Fe, Co etc. (Metal)
  - Beam energy: 200 keV (Gas)/150 keV (Metal)
  - Beam current: 4mA (N) / 1 mA (Metal)
- Status: Under beam service (2013~)
ion beam machine based on MEVVA ion source

MEVVA ion source
- Species: all metal
- Pulse width: 1ms
- Rep. rated: 0-20Hz
- Acc. voltage: 30kV - 80kV
- Avg. beam current: 0~5mA

Under construction
Ion Beam Facility [2]

1 MV High Current Accelerator

- **Application**: Silicon On Insulator (SOI)
- **Beam specification**
  - Ion species: H, N
  - Max. voltage: 1 MV
  - Beam current: > 1mA
- **Status**: Under development
  (Beam service 2018~)

High voltage power supply, ion source, accelerating tube

Switching magnet

Irradiation chamber

Accelerating tube

Compact RF ion source

High current, compact, and cheap
Ion Beam Facility [3]

Radio Frequency Quadrupole (RFQ) based accelerator

- **Application**: Irradiation, neutron production
- **Beam specification**
  - Ion species: D, highly charged heavy ion up to Xe
  - Beam energy: 1 MeV/n
  - Beam current: 1 mA
- **Status**: Under development
7 T EBIS

- Ion Source for RFQ based compact ion beam accelerator
  - Multiply charged gas ions, Metal ions (Breeding)

- Status
  - Development of 7T Superconducting solenoid
  - Development of electron gun
  - Development of DT and collector

- Specification

<table>
<thead>
<tr>
<th>EBIS Specifications</th>
<th>BNL</th>
<th>ANL</th>
<th>KOMAC  (Design)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$e^-$ beam current (A)</td>
<td>10</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>$e^-$ beam energy (keV)</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>$e^-$ beam density (A/cm²)</td>
<td>575</td>
<td>385</td>
<td>660</td>
</tr>
<tr>
<td>$e^-$ gun diameter (mm)</td>
<td>9.2</td>
<td>4.2</td>
<td>9.2</td>
</tr>
<tr>
<td>DT length (mm)</td>
<td>1500</td>
<td>500</td>
<td>1500</td>
</tr>
<tr>
<td>DT diameter (mm)</td>
<td>42.2</td>
<td>20</td>
<td>42.2</td>
</tr>
<tr>
<td>Ion trap capacity (charges)</td>
<td>$11 \times 10^{11}$</td>
<td>$1.4 \times 10^{11}$</td>
<td>$11 \times 10^{11}$</td>
</tr>
<tr>
<td>Max. magnetic field at DT (T)</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Solenoid length (mm)</td>
<td>2000</td>
<td>1000</td>
<td>2000</td>
</tr>
</tbody>
</table>
1.7 MV Tandem Accelerator

**Application**: Surface analysis, ion implantation, standard neutron

**Beam specification**
- Ion species: H, He, Cl etc.
- Voltage: max. 1.7 MV
- Beam current: 10 uA (H+)
- Beam line: PIXE, RBS/ERD, Implantation, standard neutron source

**Status**: Under operation (2016~)
3 MV Tandem Accelerator

- **Application**: AMS, Material damage test by ion beam
- **Beam specification**
  - Ion species: C, He, Fe etc.
  - Voltage: max. 3.0 MV
  - Beamline: AMS, irradiation, PIGE
- **Status**: Under installation (Beam service 2018~)

AMS pretreatment facility (Carbon dating)

3 MV Tandem under installation
Neutron Sources: Materials, Bio-life, Energy, Environment, etc.

- **Long Pulse (1.3 ms):** Spatial resolution: μm~nm, Temporal resolution: μs~ns
  - SANS, Holography, Phase shift interferometry, Static & Dynamic tomography, Spin echo, etc.
- **Short Pulse (~μs):** Spatial resolution: 0.01~10 nm, Temporal resolution: ns~fs
  - Elastic scattering, Diffraction, PGAA, Neutron resonance transmission, Neutron resonance capture analysis, Neutron spectroscopy, Neutron stimulated emission CT, etc.

Muon Source: Materials, HEP, Nuclear engineering, etc.

Neutrino Source: HEP
Summary

- **100-MeV linac operation**
  - Commissioned the 100-MeV linac with 1 kW in 2013
  - Availability > 90% since 2015
  - Stable for beam service

- **Proton beam service**
  - Many Users with complicated requirements
  - New beam lines for RI production in 2016 and for low-flux in 2017
  - Preparing beam lines one by one according to user demand
  - Next beam lines will be neutron and beta-NMR.

- **Pulsed neutron**
  - Under user service with 100-MeV linac
  - Accelerator upgrade plan up to 200 MeV and 1GeV for future

- **Ion Beams**
  - Ion beam is a very useful radiation for industrial applications
  - KOMAC is operating & developing several ion beam machines
  - More R&D for ion beam machines is required.
Thank you