Cryogenics, Cryomodule & Superconductivity for Accelerator Programme in Asia

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(On behalf of Core Committee)
AFAD Participation from this group (WG 7)
2013 (Russia) : Nil
2014 (Australia) : 2
2015 (Taiwan) : 9 (Good Participation)

Significant activity on Cryogenics/ Cryomodule in year 2014

A Core Team is formed (Members Nominated from Respective Country)

1. Kenji Hosoyama / Hirota Nakai: KEK. Japan
2. Shaopeng Li: IHEP. China
3. Yong Sub Cho: KAERI. Korea
4. Feng – Zone Hsia. NSRRC. Taiwan
5. N. N. Agapov. JINP. Russia
7. T S Datta. IUAC. India

Compiled activity report is presented here based on the feedback from core members/ invitees
Major on-going Accelerator Programme with Cryogenics & Superconductivity

- **Japan**: C- ERL, ILC STF, JPARC
- **Korea**: RAON project, PLS-II, KOMAC
- **China**: ADS PROGRAMME, ILC – China
- **Taiwan**: TPS
- **India**: ADS by DAE, RIB Linac
- **No report from Australia/ Russia. Turkey**

All these programmes are based on Superconducting cavity rather than SC magnet (Except JPARC & Russian Programme)
Chinese ADS proton linear has two 0~10MeV injectors and one 10~1500MeV SC linac.

- Both Institutes finished installation of Helium Refrigerator (~ 1 kW @4.2 K)
- Test cryomodule at IMP is in beam line (2.5 Mev) and expected commissioning of first cryomodule by Mid 2015 (5 MeV) and with two at the end of 2015 (10 MeV)
- Test Cryomodule at 2 K for Spoke cavity (IHEP) & 2K system are ready

Courtesy: Prof. Shaopeng Li
Commissioning: Jul. 2014
Achieved Refrigeration Capacity: 1020 W

Valve Box Commissioned in 2014

Five 20MPa helium tank
One 20m³, 1.7MPa liquid nitrogen tank
Three 100m³, 1.6MPa helium tank

Under Commissioning

Courtesy: Prof. Shaopeng Li

IHEP Cryogenic System for ADS
2K valve box and Cryomodule (IHEP)

First Cryomodule (7 Cavities + 7 Solenoid) Under Construction

TCM with 2 Cavities

2 K Pumping system

Courtesy: Prof. Shaopeng Li

CHINA
Status of IMP-ADS injector II

- ECRIS + LEBT + RFQ + MEBT + TCM1
- Beam energy: 2.5MeV
- finished in 2014

Beam energy: 5MeV
- Middle of 2015

162.5 MHz HWR010
- ECRIS+LEBT+RFQ+MEBT+CM6,
- Beam energy: 5MeV
- Middle of 2015
- 10 MeV (2016)

IMP Injector Cryomodule: 2 Nos
(8 HWR+9 Solenoid+BPM)

TCM with 2 Solenoid and one HWR

Cryogenic: 850 W (960 W) by Linde
- Oct. 2013 First Commissioning
- Dec. 2013 Second Commissioning
- 4000 Operating Hours
- 12000 M3 Helium Storage Tank

Courtesy: Prof. Shaopeng Li

ACFA 22, Dongguan (T S Datta)
Japan: Three Major Running Projects

1. 3 GeV ERL (R&D)
2. STF (KEK) for ILC

(ILC needs: 16000 9-cell cavities and more than 1000 Cryomodules with each length of approx 12 meter)

Test: > 35 MV/m, Q = 0.8 \times 10^{10}
With Beam > 31.5 MV/m

3. Japan Proton Accelerator:

4 Helium refrigerator installed & Special Combined SC magnet for Neutrino beam line, Muon beam line installed. Torroidal SC Spectrometer Installed

The J-PARC complex consists of 3 accelerators, a linear accelerator, a rapid cycle synchrotron (RCS, 3GeV) and a 50 GeV (Max) synchrotron.
Superconducting RF Test Facility (STF) at KEK

Helium Refrigerator:
250 L/h or 600 W at 4.4 K

Tested on October 2014

Capture cryomodule:
9-cell cavity x 2

STF CM-1: 9-cell cavity x 8 + SC Quad.
STF CM-2a: 9-cell cavity x 4

Cortsey: Prof. Hirota Nakai
First Cool-down Curve of STF CM-1+2a

- 5K Shield
- 80K Shield
- GRP Top
- GRP Bottom
- Cavity 1-1 Side
- Cavity 1-1 Bottom
- Magnet Top
- Magnet Bottom

Weekends and holiday

Date in 2014

Temperature [K]

Liquid Level [%]
Full C – ERL Completed in 2014 (30 MeV)

Injector Cryomodule (2-cell x 3 cavity)

Main Linac Module
2 x 9-Cell cavity

Cryogenics: 80 W at 2 K (500 W @4.2 K)

Achieved: 14.5 & 13.5 MV each cavity

Courtesy: Prof. Hirota Nakai
KOREA : PLS -II

A. 3 SRF Cavity and Cryomodule at Pohang Light source. Total 3.5 MV, Current = 300 mA

Cryogenic System : 700W @4.2 K (Encountered many problems with RF cavity and Cryogenic system in 2012-13, 39 % of Failure)

Second cavity installed in Feb 2013.

Third Cavity was installed in 2014

May 2014. Operating Current improved to 300

Max Current achieved : 400

Courtesy : Dr Yong Sub Cho
RAON (Delightful) Superconducting Linac

- RAON SCL is designed to accelerate high intensity heavy ion beams
- Optimized geometric beta of SC cavities (0.047, 0.12, 0.30, 0.51).
- Prototyping of SC cavities and cryomodules is under way at present.

Required Refrigeration Capacity: 18 kW; (May be the largest in Asia)

Courtesy: Dr Dong-o Jean, IBS
RAON Accelerator Prototyping

ECR ion source

ECR cryostat fabricated (2014.09)
SC cavity prototypes delivered for test (2014)
Cryomodule prototypes to be delivered (2014.12)

With 7 Cryo cooler)

High Tc SC magnet

QWR Cavity & Cryomodule

HWR Cavity & Cryomodule

SSR Cavity & Cryomodule

Courtsey: Dr Dong-o Jean, IBS
TPS (3 GeV) Helium Plant

Capacity: 890W @4.5K
Commissioned in 2014

TPS Storage / Booster Ring

Cryomodule: KEK B
Ready to Install

Courtesy: Dr Feng – Zone Hsia

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Cryomodule and Cryogen Distribution

Installation and Test Period: 2014.10~2015.02

Cavities tested (1.5 – 2 MV)

CVB1: Control Valve Box
CVB2: Control Valve Box
CVB3: Control Valve Box
CVB4: Control Valve Box
TL1: 26.9-m
TL2: 30.3-m
TL3: 27.1-m
TL4: 25.4-m
TL5: 26.9-m
TL6: 7.4-m
TL7: 6.9-m

SRF cavity 1
SRF cavity 2

DVB: Distribution Valve Box
New Helium Cryogenic System
7000-L main Dewar

Installation and Test Period: 2014.10~2015.02

ACFA 22, Dongguan (T.S. Datta)

Courtesy: Dr. Feng – Zone Hsieh
TARLA project aims to produce FEL in oscillator mode between 2-250 microns range using 15-40 MeV electron beam.

First Cryomodule with 2 nine cell cavities (ELBE) are being developed in collaboration with Stanford University. Expected by March 2015.

Cryogenic plant is expected Commissioning by End 2014

FEL BEAM is Expected in 2018

Courtsey: Dr. O. Yavas, Ankara
Except the Helium refrigerator, all the Components (Cavities, Cryomodule, LHe Transfer line, Cryogenics control were developed at IUAC with the support from Indian Industry.

Superconducting Linac at IUAC. Delhi: **Completed**

Beam Acceleration were performed with full Linac in 2013 & 2014
SUPERCONDUCTING CAVITY PROGRAMME IN INDIA

1990-2000:
Quarter Wave Cavity at TIFR & IUAC
Developed in India, $E_{\text{acc}} = 2.5$ to $6 \text{ MV/m}$
$f = 150 \text{ MHz, } 97 \text{ MHz}$

2005-2014:
Elliptical Cavity for Proton LINAC at RRCAT, BARC, VECC
(Developed in India, Surface preparation and Testing at USA: > $30 \text{ MV/m}$, $f = 1.3 \text{ GHz}$)

Spoke Cavity and Low $\beta$ cavity at IUAC
For Project X at Fermi Lab and HCI at IU
(Under Development $f = 352 \text{ MHz}$)
High Energy Proton LINAC Based Spallation Neutron Source (RRCAT)

Collaboration between Fermi Lab & Indian Institutes
5 Cell 1.3 GHz SCRF cavity developed at RRCAT/IUAC

Surface Preparation Lab With all System are Commissioned

New Helium Refrigerator Is Expected in March 2015

\[ E_{\text{acc}} = 20.3 \text{ MV/m at 2 K} = 42 \text{ MV/m at 1.6 K} \]

Testing of Cavity at 1.6 K

ACFA 22, Dongguan (T S Datta)
World’s FIRST 1.3GHz Laser Welded SCRF Cavity (RRCAT)

Advantage: No Vacuum, less capital cost. Low HAZ, Low Shrinkage & Distortion

Japan office grants patent for Laser Welding Technique developed at RRCAT

Quenched at 31.6 MV/m
Q > 1.0E+10

Courtesy: S C Joshi & P K Kush
1. Superconducting Cyclotron: Tested; Difficulty on Beam Extraction
2. Electron Linac for RIB: Under Development
3. Magnet Programme for FARE Project

INJECTOR CRYOMODULE
( TRIUMF + VECC) Tested

Both Injector & Capture Cryomodule will be ready in 2015-16 at VECC
A Separate Helium Refrigerator for RIB Linac is Ordered

INJECTOR CRYOMODULE
( TRIUMF + VECC) Tested

One 9-cell cavity

Capture Cryomodule Required
At VECC Injector

Courtesy: Dr. A. K. Chakrobarty
1. Shortage of Helium Gas supply: Price rise (doubled from 2011)

Federal Helium Programme, USA; Supplies Crude Helium 50%
(They can stop any time: Deadline Oct, 2013 Extended by Senate)
Total requirement: 200 MM3

Helium Recovery from Users has to be improved: Loss to be minimized

2. COP (plug power for 1 W refrigeration) of Helium Refrigerator

During 1980 it was 400-500 (Tevatron), 1998 (LHC) improved; 225 (30% of Carnot): No further improvement. (Hope for ITER System): 170 (40%)

Refrigeration capacity for ILC: 210 kW. Power Saving: 10 MW

3. Limited Niobium Supplier: Demand growth in current five years will be high

4. Limited Man Power in ASIA
Cryogenics, Superconductivity will play a key role on Future Accelerator programme in ASIA Considering: Power Saving, Compact Size

1. Significant Growth of activity in Asia for last 5-7 Years
2. Superconducting Cavity rather than SC magnet (Earlier) dominates
3. Cryocooler with HTS Magnet / Cavity for ECR or Injector will be a viable alternative option (RAON Project)
6. In November 2014, IUAC-KEK-RRCAT had a meeting in the presence of Prof. Atsuto Suzuki, Dr D Kanjilal & Dr P D Gupta.
7. Asian School on Superconductivity & Cryogenics: Prof. Gao Jie
Welcome to ICEC 26 - ICMC 2016
At Delhi, March 7 - 11, 2016

THANK YOU