Beam Test Possibilities in Japan

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Radiation Effects in Superconducting Magnet Materials (RESMM'12)

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Mean energies of the particles are rather higher.

Effect of pions, kaons, muons. fragments?

→ NO (a few?) facilities to simulate the radiation parameters perfectly.

Evaluation using by available facilities. >> Scaling is essentially necessary.
Facilities for Materials Irradiation

- Sources of irradiation for SC magnet materials
  - Neutrons: Nuclear reactors (> 0.1 MeV), 14 MeV n by DT
  - Protons: Accelerators
  - Electrons: Accelerators
  - Gamma rays: $^{60}\text{Co}$, etc
  - Pions: ???
  - Ions (high energy): ???

- Some Requirements
  - Sample size (irradiation area): > 10 mm*10 mm, t > 1 mm
    ➔ Criteria(?): $E_p > 10$ MeV, $E_e > \sim$MeV
  - Spatial uniformity: function of scanning in accelerators.
  - Fucence or absorbed dose in acceptable machine time: $10^{22} \text{ p/m}^2$, > 10 MGy
  - Sample environment: temperature, ambient gas or vacuum
    ➔ Trade-off: irradiation temperature or fluence
  - Allowable limit of radioactivity
  - Evaluation apparatuses
Overview of Facilities in Japan

Facilities in East Japan were damaged by the earthquake at March 11, 2012. But most of them have been recovered.
JAEEA Tokai: Tandem Accelerator

- **Proton:** 1 μA at 33 MeV, 1.5 μA at 15 MeV.
- Other ions acceleration by booster is possible.
- Scanning by electro static deflectors (x-y) at R2 beam line: 10 x 10 mm²
- Allowable unsealed radioactivity: 1 MBq for usual nulclides.
- Usage Fee: 50 kJYen/d
JAEA Tokai: Tandem Accelerator(2)

- Degas must be suppressed. Pumping near samples could be needed.
- Cooling of samples: water, gas flow...

R2 beam line

Electrostatic deflectors: 10mm x 10mm

Drafter.
Target chamber inside.
JAEA Tokai: FNS (Fusion Nutronics Source)

- **14 MeV neutron** from DT reaction.
- **Production rate:** $10^{12}$ n/sec at 10 mA, $10^{15}$ n/m²s at 1 cm from target.
- **1 cycle:** 7 hrs x 4 days. 4 cycles per year. >112 hrs only!!
- **Repair work is being carried out. Operation for users will be started in 2012.**
- **New tritium target was successfully developed by JAEA. D beam intensities will be doubled.**
- **Former irradiation test for SC wires at 4 K by Nishimura (NIFS): $10^{20}$ n/m²**

JAEA Tokai: JRR-3

- **Fission neutrons** by research nuclear reactor.
- 1 cycle: 26 days. 6-7 cycles per year.
- Fuel region: VT-1, RG, BR
  - Capsule: φ55 × L900, φ34 × L150. Water cooling (30 °C). $T_{\text{sample}}: \sim 100 ^{\circ} \text{C}.$
  - Nonstop irradiation during a whole cycle. $10^{18} \text{ n/m}^2\text{s} \gg 2\times10^{24} \text{ n/m}^2$ at 1 cycle.
- Heavy water reflector region: HR, PN, SI
  - Capsule: typ. φ30 × L150. Water cooling (30 °C). $T_{\text{sample}}: \sim 100 ^{\circ} \text{C}.$
  - Irradiation time: 1min. – 1 cycle. $10^{15} – 10^{16} \text{ n/m}^2\text{s} \gg 10^{21} - 10^{22} \text{ n/m}^2$ at 1 cycle.
- Collaborative research contract with JAEA is necessary. (Or, usage fee will be charged.)
- Concern: Soundness report is being checked by the government. Resume in 2012 ??
Overview of Facilities in Japan

- J-PARC & JAEA Tokai
- JAEA Oarai (JMTR) & IMR
- KEK
- RIKEN
- Narita Airport
- Fukushima Daiichi Nuclear Power Plant
- IFMIF R&D
- KURRI

Feb. 15, 2012 Radiation Effects in Superconducting Magnet Materials (RESMM'12)
JMTR (JAEA) & IMR (Tohoku Univ.) at Oarai

- **Fission neutrons** by Research nuclear reactor & hot laboratory for material study
- **JMTR**
  - 4 cycles per year
  - 2012 Plan: $1 \times 10^{17} \text{ n/m}^2\text{s} \gg 3 \times 10^{23} \text{ n/m}^2$ at 1 cycle. $T_{\text{sample}}: <100 ^\circ \text{ C.}$
- **IMR Hot Labo.**
  - A number of apparatuses for material study are available.
    - TEM, NMR, X-ray diffractometer, mechanical testing machine, etc.
  - 15.5 T SC magnets w/ VTI: 4 K to RT, rating 500 A
  - Allowed radioactivity: $\sim$GBq to $\sim$100 GBq for 291 nuclides.
- **Concern about JMTR**: Aiming to resume at Oct. 2012. Soundness is being checked.
Overview of Facilities in Japan

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Radiation Effects in Superconducting Magnet Materials (RESMM'12)
JAEA Takasaki: TIARA

- AVF cyclotron + 3MV Tandem + 400 kV ion injector
- **Protons**: 10 - 75 MeV (max. 90 MeV), max. 2 μA
  * Replacement of beam shutter beyond $E_p$ of 70 MeV.
- 3 operational cycles per year. Typical user time: 10 - 20 hrs in a cycle.
- Sample environment at LD1 beam line
  - Vacuum chamber + multiple samples holder (up to 4)
    * Degas must be suppressed.
  - RT by conduction cooling w/ water.
  - Sample chamber w/ LN2 conduction cooling is available. (But, not in use for > 10 years.)
- Irradiation area: max. 100 mm x 100 mm (uniformity: within 10 %)
- Collaborative research contract with JAEA is necessary. (Or, usage fee will be charged.)
- **Concern**: Allowable radioactivity is rather lower. Check in advance.
JAEA Takasaki: $^{60}\text{Co}$ gamma ray source

- **Gamma-rays**: 6 irradiation rooms
  - Idesaki's group: 1 room for RT, 1 room for LT.
- **Irradiation rate**: 10 - 20 kGy/hr, 24 hrs.
- **LN2 irradiation cryostat**
  - Samples immersed in LN2 bath.
  - dose uniformity: < 30%
  - LN2 consumption: 1300 L for 14 days (5 – 6 MGy). >> 150 kJYen
- **In the meantime, priority of irradiation given to the decontamination study related to the Fukushima nuclear plant accident.**

See talks by Ogitsu and Idesaki.
JAEA Takasaki: Electron Accelerator

- **Electron**: $E_e = 0.5 - 2$ MeV, 0.1 - 30 mA.
  - The sample should be thin enough.
- 8 - 13 hrs/day >> ~40 MGy for typical resins
- Exposed in air or inert gas. Scanning: 50 x 1200 mm².
- $T_{\text{sample}}$: RT
  - Conduction cooling with water.
- Casual use??

Sample chamber

Irradiation on HTS tape
Overview of Facilities in Japan

- KURRI
- JAEA Takasaki
- KEK
- RIKEN
- J-PARC & JAEA Tokai
- JAEA Oarai (JMTR) & IMR
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Radiation Effects in Superconducting Magnet Materials (RESMM'12)
RIKEN: RIBF

- Materials irradiation beam line: E5A
  - Protons from RRC: 70, 135, 210 MeV.
  - $I_p = 10 \text{ nA}$
  - $10 \times 10 \text{ mm}^2$ by Wobbler magnet
  - Uniformity within 10 %
- Sample Environment:
  - Vacuum, $10^4 \text{ K}^* - 373 \text{ K}$
  
  * Renovation of cryogenic facility is necessary.
- Machine time proposal for PAC is very competitive.
  - Another beam line with 14 MeV protons (10 μA) from AVF cyclotron is available.
Overview of Facilities in Japan
KURRI: Kyoto Univ. Research Reactor

- **Fission neutrons.** Operated as planned in 2011.
- 1 cycle: 1 MW x 46 hrs + 5 MW x 6 hrs. ~25 cycles per year.
- Usual irradiation
  - Hydraulic Conveyer at reactor core
    - Aluminum capsule, $\Phi_{th}: 8.2 \times 10^{17} \text{ n/m}^2/\text{s}$, 70 hrs at 1 MW$_{eq}$
  - Pneumatic Tubes (Pn-1, 2, 3) at graphite reflector
    - PE capsule, $\Phi_{th}: 2.8 \times 10^{17} \text{ n/m}^2/\text{s}$, 1 hr at 1 MW$_{eq}$
  - Slant Exposure Tube: graphite reflector
    - Large-size samples, $\Phi_{th}: 3.9 \times 10^{16} \text{ n/m}^2/\text{s}$, 70 hrs at 1 MW$_{eq}$.
- Low Temperature Line: irradiation cryostat close to reactor core
  - Cooling by He gas loop: < 20K
  - $\Phi_{fast}$ ($E_n > 0.1 \text{ MeV}$): $1.4 \times 10^{15} \text{ n/m}^2/\text{s}$ at 1 MW
    $\gg 10^{20} \text{ n/m}^2$ at 1 cycle

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See Yoshida's talk.

M. Okada et al., NIM A463 (2001) pp213-219
KURRI: Electron Linear Accelerator

- $6 \text{ MeV} < E_e < 32 \text{ (max. 46 MeV)}, \text{ max. 200 } \mu\text{A}$.
  - Very high absorbed dose rate: $\sim 100 \text{ kGy/s}$
  - Sample activation beyond $E_e$ of 10 MeV
  - Beam size: $\phi 10 \text{ mm}$, NOT uniform.
- Operation: 11 weeks per year
- Sample environment
  - Water cooling chamber (immersed)
  - LN2 sample cryostat

LN2 sample cryostat

Water cooling sample holder (inside)
Overview of Facilities in Japan

- Fukushima Daiichi Nuclear Power Plant
- J-PARC & JAEA Tokai
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- KURRI
- JAEA Takasaki
- Fukushima Daiichi Nuclear Power Plant
- IFMIF R&D ??
J-PARC

- **Proton Linac**
  - Currently, providing the beam to the RCS only: 180 MeV, 30 kW.
  - To be upgraded to 400 MeV soon.
  - Future project: Accelerator Driven Transmutation Experimental Facility. (600 MeV, 200 kW using SC RF cavities)
    - Potential Irradiation Test at primary beam line (TEF-T).
    - Construction budget has not been authorized yet... When???
J-PARC (2)

- RCS: 3 GeV, 200 kW, 25 Hz
  - Providing the beam to MLF and MR.
  - To be upgraded to 1 MW.
- MR: 30 GeV, 150 kW
  - For T2K neutrino exp. (FX) and Hadron exp. (SX)
  - To be upgraded to 750 kW.

Sample space around target system would not be allowed...
Access is very restricted.
Interference for the operation and the main experiment would be concerned, even though T2K neutrino target is appropriate for pion irradiation source...

At present, materials irradiation test at J-PARC is quite difficult.
Summary

- Irradiation facilities in east Japan were damaged by the earthquake, but they were mostly recovered.
  - 2 research reactors are still in process of approval to resume.
- Material irradiation facilities
  - Protons
    - 3 accelerators: 10 MeV - 75 MeV (∼μA), 210 MeV (10 nA)
  - Electrons:
    - 2 accelerators: 2 - 32 MeV (> 200 μA)
  - Neutrons:
    - 3 research reactors
    - 1 DT neutron sources (14 MeV)
    - Cryogenic irradiation at KURR and FNS
  - Gamma rays:
    - 2 facilities w/ $^{60}$Co (JAEE-Takasaki, KURRI)
    - Samples in LN2
- Sample environment
  - Difficulty of cryogenic irradiation at accelerator
  - Trade-off: temperature and fluence