A Proposal of cryogenics system for the SC FD quad at ATF2

N. KIMURA, A. Yamamoto, T. Tomaru, K. Tsuchiya, and T. Tauchi (KEK)

Outline

• Infrastructures at ATF2
• Proposal for cryogenics system by KEK
  (Additional components)
• Summary
# Infrastructures at ATF2

## Infrastructures at ATF2

<table>
<thead>
<tr>
<th>Infrastructure</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>LHe supply</td>
<td>Very limited</td>
</tr>
<tr>
<td>(supplied only by dewar, from Cryogenics Science Center)</td>
<td></td>
</tr>
<tr>
<td>Cryogenics facility</td>
<td>None</td>
</tr>
<tr>
<td>Space for Liquefier around ATF</td>
<td>??</td>
</tr>
<tr>
<td>GHe recovery line</td>
<td>Yes</td>
</tr>
<tr>
<td>Human resource for cryogenics operation</td>
<td>None</td>
</tr>
<tr>
<td>Power supplies for SC magnets</td>
<td>None</td>
</tr>
</tbody>
</table>

We would like to propose our plan which can be operated under **limited infrastructures at ATF!!** and can be consistent with BNL’s magnet cooling design.
Environment for SC-FF @ ATF2

Replace for SC-FF magnets
Proposal for cryogenics system at KEK

- Solution of cooling scheme @ ATF2
  - Re-condensation cooling type with low vibration Cryo-coolers.
  - It may be better than conducting cooling type for respecting BNL design.
- However, design of heat load should be reduced, hopefully, lower than 1 W (Max 2W)!
- Total heat load in the current design/plan by BNL ~15 W may not be handled/accepted at the current ATF2 environment.
Proposal for cryogenics system (cont.)

• In addition, we propose/suggest to install a laser interferometer or equivalent system into the cryostat for vibration measurement of SC coil.

• The relation between rigidity of support and vibration is not clarified yet. We would like to discuss the relation with BNL.

• It is important to reduce total heat load lower than 1 W (except for the current leads)!
Example of Ultra-low Vibration Pulse tube cryo-cooler system at KEK

This system was originally developed for gravitational wave detector.

Vibration level of the system was almost the same as that in Kamiokamine. Vibration level is \(~1\text{nm}@1\text{Hz} \) (Bin width \(~0.01\) )

When the cryo-cooler uses as a re-condensation cooler, do not need vibration reduction stage in above figure.

Point is separated Rotary valve from cold-head.

By courtesy of Dr. T. Tomaru (KEK)

This system was presented at ICC13.
Re-condensation type

HTC Current leads
300A x 4 pairs (1.6 W)
100A x 10 pairs (1 W)

0.5W/4.2K Plus tube type cryocooler as 20K cooler with low vibration mounting

Low heat load support posts <0.2 W at 4.2 K

1W/4.2K Plus tube cryocooler with low vibration mounting

heat load of cryostat w/o HTC CL must be less than 1.0 W @ 4.2 K
Example of Pulse tube cryo-cooler

Model: SRP-052A
Commercialized by SHI Ltd.
Specification: 0.5W@4.2K / 20W@45K with a 7kW compressor
Standard System Configuration of SRP-052A, without connecting tube
Advantage: • Valve Unit Separated from Cold Head
          • Easy for Maintenance, Short Down Time
          • Flexibility for Vibration Reduction
Presented

Ultra-low Vibration Pulse tube cryo-cooler was developed with collaboration of KEK and SHI.
Re-condensation type

HTC Current leads
300A x 4 pairs (1.6 W)
100A x 10 pairs (1 W)

0.5W/4.2K Plus tube type cryocooler as 20K cooler with low vibration mounting

Low heat load support posts <0.2 W at 4.2 K

1W/4.2K Plus tube cryocooler with low vibration mounting

heat load of cryostat w/o HTC CL must be less than **1.0 W @ 4.2 K**
Proposal of Re-condensation type by KEK

Full FF-SC system is constructed at BNL. KEK contributes Plus tube cryocooler with low vibration mounting for BNL. But, it need some discussion of starting point with KEK and BNL. Also need some discussion of power supply with quench protection circuit and scheme.
Summary

• Re condensation cooling system @ ATF2 are proposed by KEK. It requires revising design (of support posts) for SC magnet thermal design to reduce total heat load lower than 1 W, with a possible balance with the low vibration requirement.

• For better understanding of vibration level on surface of SC magnet, we hope to extend discussion with BNL magnet group to find an optimum solution to reduce total heat load and to satisfy the low vibration requirement.

• For reducing vibration level lower than 50 nm, we may contribute to the low vibration cryocooler system design to be adaptable to the BNL magnet design in cooperation to the design study for the magnet support system and the thermal load.

• We would like to extend discussion with BNL to find possibility of testing FF-SC magnet @ ATF2.

• We also would like to discuss quality of Power supply for the magnet, and quench protection design.
Theme of Discussion

• Revising design (of support posts) for SC magnet thermal design
• Optimum solution to reduce total heat load and to satisfy the low vibration requirement
• The BNL magnet design in cooperation to the design study for the magnet support system and the thermal load
• Find possibility of testing FF-SC magnet @ ATF2
• Quality of Power supply and quench protection design
Appendex
Cryogen-Free Superconducting Magnet by using Cryo-Cooler

• Cryo-cooler Technology has been progressed,
• A medium-scale superconducting magnet with a heat load of ~ a few W may be cooled by using Cryo-coolers.
• It may help the magnet operation in fully automatic mode with “operational shift-free”.
Superconducting Magnet for Solar Axion Search @ ICEPP U-Tokyo

- Dipole field of 10 T•m
- Cooled by using cryo-coolers (2 W at 4.2 K).

Cryo-cooler

Race Track Coils (5 T x 2m)

Compressor

Valve

Regenerator

Displacer
Example of Conduction cooling type magnet at KEK

HTC Current leads
300A x 1 pair

GM-type
4.2K Cryo-coolers

Total heat load of cryostat with HTC CL was less than $2 \text{ W @ 4.2 K}$

The magnet were made for Axion search project.

Coil type: Race truck type
Coil number: 2
Coil length: ~2.1m
Coil mass: ~135kg/coil
Center field: 5 T
Nominal current: 336 A
Superconducting Magnet
For the MUEGAMMA (MEG) @ PSI

COBRA S.C. Magnet

Cryo-Cooler

Compensation coil

2.5 m

0.7-0.8 mD

1.2 T

Liquid xenon calorimeter

Timing counter

Drift chamber
Simulation of cooling power at 20K using 0.5W@4K Pulse tube

25W@59K(1st)/5W@18K(2nd)
**Cryo-coolers for radiation shields**

- 60W at 80K
- 6W at 20K

**An example of semi cryogen free system**

**SKS Cryogenics system at KEK**

- **Re-condensation Cryo-coolers**
  - (GM-JT type, 5W at 4.2K x3)

**Liquid He Vessel**

- **Cryo-coolers for radiation shields**
  - 60W at 80K
  - 6W at 20K

- **SC-Coil Vessel**
- **Vacuum Vessel**

- **20K shield**
- **80K shield**

- **GHe recovery line**
- **LHe supply line**

- **Cold mass:** ~ 2 Ton
- **Pre cooling time:** ~ 4 weeks
- **Cryogen:** LN2 (for pre-cooling) & LHe
- **Current feeds by HTC current leads**

**IMURA –30/Sep./2009**
## Comparison table

<table>
<thead>
<tr>
<th></th>
<th>Re-condensation Cooling</th>
<th>Conduction Cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent of BNL’s magnet design</td>
<td><strong>Very near</strong>&lt;br&gt;<strong>But need some of modifications</strong></td>
<td>Far way</td>
</tr>
<tr>
<td>Operation</td>
<td>easy</td>
<td>Very easy</td>
</tr>
<tr>
<td>Needs LHe for pre-cooling?</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Needs GHe recovery line?</td>
<td>Yes</td>
<td>None</td>
</tr>
<tr>
<td>Needs permission of operation by local government?</td>
<td>Yes, but not difficult</td>
<td>None</td>
</tr>
<tr>
<td>How many coolers?</td>
<td>2 (1 for HTC CL)</td>
<td>2 (1 for HTC CL)</td>
</tr>
<tr>
<td>Human resources for operation</td>
<td>Few</td>
<td>Very few</td>
</tr>
</tbody>
</table>