S1-GLOBAL COLLABORATIVE EFFORTS

8-CAVITY-CRYOMODULE: 2 FNAL, 2 DESY AND 4 KEK

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Abstract

In an attempt to demonstrate an average accelerating gradient of 31.5 MV/m as in the design of the ILC, the S1-Global project [1,2] is a cryomodule being constructed and tested by an international collaboration hosted by KEK and including INFN, FNAL, DESY and SLAC. The S1-Global system joins two half-length cryomodules, each 6 m in length and containing 4 cavities, Module-C contains cavities from FNAL and DESY and was constructed by INFN. Module-A contains four KEK cavities and was constructed by KEK. The assembly of the cryomodules was completed in May 2010, and the cold test started from June 2010. In this paper, the international collaboration efforts of the S1-Global cryomodule are presented with the preliminary cold test results and the following test plans.

INTRODUCTION

The ILC main linac consists of 1815 cryomodules [3] which have two designs, one has 9 cavities in the 11.83 m cryomodule and the other has 8 cavities and one quadrupole package in the module center. For developing the main linac, the ILC General Design Effort has the R&D programs of S0, S1 and S2 [4]. S0 is for production yield of 9-cell cavity over 35 MV/m, S1 is for operation of the cavity-string at 31.5 MV/m as the design of the ILC, and S2 is for the beam test by an accelerator unit of the cryomodule string. The S1-Global is the project to make the R&D of S1 reality with the international research collaboration and the main target of the S1-Global cryomodule is aimed to be the ‘Realization of an average accelerating gradient of 31.5 MV/m with 8 cavities’.

The construction of the S1-Global cryomodule was proposed and approved as an international collaborative effort at the SC-RF technical meeting of the ILC General Design Effort in April 2008. The eight cavities were contributed from FNAL, DESY and KEK, and installed in two ‘half’ cryomodules’ each 6 m long: a new one designed and constructed by INFN and a modification of the existing 6-m STF cryomodule by KEK.

The collaborative framework of S1-G is demonstrated in the contributions of the participating laboratories:

- INFN: Design and construction Module-C and production of the blade tuners for the FNAL cavities.
- FNAL: Two TESLA type cavities [5], power couplers and integration of the INFN blade tuners in the cavity packages.
- DESY: Two TESLA type cavities, including Saclay-type tuners, and power couplers.
- SLAC: Two set of VTO power distribution for Module-C, and aging of FNAL couplers.
- KEK: Four TESLA-like cavities, with two types of tuner design, Module-A for KEK cavities [6], power distribution for Module-A, and infrastructure for tests.

SCHEDULE OF THE PROJECT

Figure 1 shows the general schedule of the S1-Global project. The cryomodule design work started in May 2008 with the joint team of INFN, FNAL and KEK, and the design of this cryomodule was completed at the end of 2008. In 2009, the construction of Module-C components by INFN and the modification of Module-A by KEK were performed. The productions and the tests of 8 cavities were carried out by DESY, FNAL and KEK in 2009. Assembly of the S1-G cryomodule and the installation of this cryomodule in the KEK-STF tunnel were scheduled from January to May 2010. At present, the cold tests are scheduled from June to December 2010.

![Figure 1: General schedule of S1-Global project.](image-url)
CRYOMODULE DESIGN

The S1-Global cryomodule consists of two 6-m cryomodules, Module-A and Module-C, shown in Fig. 2. Four cavities from FNAL and DESY are installed in the Module-C, and four cavities of two type cavity-jackets by KEK are installed in Module-A. The total length of the S1-Global cryomodule is 14.9 m. The parameters of the two 6-m cryomodules are listed in Tab. 1.

Table 1: S1-Global Cryomodule Parameters

<table>
<thead>
<tr>
<th></th>
<th>Module-A</th>
<th>Module-C</th>
</tr>
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<tbody>
<tr>
<td>Vacuum vessel length</td>
<td>6087 mm</td>
<td>5800 mm</td>
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<tr>
<td>Vacuum vessel O.D.</td>
<td>φ 965.2 mm</td>
<td>φ 965.2 mm</td>
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<td>Gas return pipe length</td>
<td>5830 mm</td>
<td>6000 mm</td>
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<tr>
<td>Gas return pipe O.D.</td>
<td>φ 318.5 mm</td>
<td>φ 312.0 mm</td>
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<td>2K LHe supply pipe O.D.</td>
<td>φ 76.3 mm</td>
<td>φ 76.1 mm</td>
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<tr>
<td>5K shield pipe O.D. [F/R]</td>
<td>φ 30/φ 30 mm</td>
<td>φ 60/φ 60.3 mm</td>
</tr>
<tr>
<td>80K shield pipe O.D. [F/R]</td>
<td>φ 30/φ 30 mm</td>
<td>φ 60/φ 60.3 mm</td>
</tr>
<tr>
<td>Cool-down pipe O.D.</td>
<td>φ 27.2 mm</td>
<td>φ 42.2 mm</td>
</tr>
<tr>
<td>Distance between couplers</td>
<td>1337.0 mm</td>
<td>1383.6 mm</td>
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<tr>
<td>Cavity type</td>
<td>TESLA-like</td>
<td>TESLA-like</td>
</tr>
<tr>
<td>Tuner type</td>
<td>Slide jack</td>
<td>Blade/Saclay</td>
</tr>
<tr>
<td>Input coupler type</td>
<td>Disk window</td>
<td>Cylindrical window</td>
</tr>
<tr>
<td>Magnetic shield</td>
<td>Inside jacket</td>
<td>Outside jacket</td>
</tr>
<tr>
<td>Package length</td>
<td>1247.6</td>
<td>1247.4/1283.4</td>
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</tbody>
</table>

CONSTRUCTION OF THE CRYOMODULE

Production of Cryomodule Components and Cavities

Production of the Module-C components started from January 2009, and the process of manufacturing was kept...
on time under the supervision of INFN. Production of all components was completed in the middle of October, and they arrived at KEK by ship on December 25, 2009. Figure 4 shows the completed gas return pipe with two support posts. The DESY and FNAL cavities are held from this pipe. As an example of international collaborative work, 24 strain gauges, 8 thermal sensors and 5 wire position monitors were assembled on this gas return pipe in order to measure the thermal and mechanical behaviors of this gas return pipe, by working together with KEK, INFN and the technicians of the company in Italy.

The productions and tests of cavities for S1-G started from 2009. Eight cavities were tested in the vertical test stand in each responsible laboratory. Two DESY cavities, Z108 and Z109, and two FNAL cavities, AES004 and ACC011, reached at the field gradients from 29 MV/m to 33 MV/m. Four KEK cavities reached the field gradients from 27 MV/m to 33 MV/m. The results are shown in Fig. 5. The average field gradient of 8 cavities was 30.0 MV/m.

Assembly of S1-Global Cryomodule

Two DESY cavities, Z108 and Z109, arrived at KEK on December 4, and the two FNAL cavities, ACC011 and AES004 arrived at KEK on December 25 and January 8, respectively. The cavity string assembly started on January 15 by the joint team of three FNAL, two DESY and two KEK personnel, and the assembly was successfully completed on January 20 as shown in Fig. 6 (a). This team is shown in Fig. 7.

After moving the FNAL/DESY cavity-string out of the clean room, INFN and FNAL colleagues mounted the
Blade and Saclay tuners and magnetic shields on the four cavities from February 9 to 12, shown in Fig. 8.

The string of four KEK cavities, MHI-05, 06, 07 and 09 was assembled in the clean room from February 22 to March 8 by the KEK team. This work is shown in Fig. 6 (b). Figure 9 shows the KEK S1-G team after completing four KEK cavity string.

The Module-C cold mass was assembled from January 25 to March 19. The main assembly processes were:

- Assembly and connection of cooling pipes.
- Supporting the cavity string from the gas return pipe with C-clamp with being instructed by the INFN colleague.
- Attaching thermal sensors and wiring.
- Assembling and welding 5 K and 80 K thermal radiation shields with the multi-layer insulation.
- Inserting the cold mass assembly into the vacuum vessel, shown in Fig. 10.

The completed Module-C was moved down to the KEK-STF tunnel on March 12.

The Module-A assembly was proceeded in the same way as the Module-C in April. Figure 11 shows the four KEK cavity string supported from the gas return pipe. The Module-A was moved down to the tunnel on April 30. Connection of the Module-C and the Module-A were completed in May as shown in Fig. 12. The helium leak test of the 8 cavities with the liquid helium pipe was executed, and the system was confirmed to be able to cool down to 2 K.

COLD TEST OF THE CRYOMODULE

The cold test schedule of the S1-G cryomodule is shown in Fig. 13. The test period is scheduled from June to December 2010, and it is divided into two terms including the summer shut-down.

In the first test term from June to July, the measurements of the thermal and mechanical performances of the cryomodule and the RF tests of 8 cavities at the low power [9] were scheduled.

The first cool-down of 8 cavities is shown in Fig. 14. It took 5 days to cool the 8 cavities down from 300 K to 4 K. At 4 K, the heat load to cavities was measured and it turned out to be 9 W. The main heat sources are signal wires of more than 330 sensors and RF cables connected to cavities from room temperature. The heat load by these wires is calculated to be about 5 W. After confirming thermal performance of the cryomodule, the 8 cavities were cooled down to 2 K. While cooling down from 200 K to 4 K, the stretched wires of the wire position monitors had damages by the thermal deformation of the gas return pipe. The thermal deformation of the gas return pipe between the center and the ends reached about 9 mm in the vertical direction. The 18 wire position monitors were installed for measuring the positions of the gas return pipes of Module-C and Module-A and the four KEK cavities.
As the leading project of ILC, the S1-Global cryomodule was successfully constructed on schedule under the international research collaboration of INFN, DESY, FNAL, SLAC and KEK.

In the first cold test, the S1-G cryomodule was cooled down to 2 K, and all functions were confirmed. The S1-G cryomodule has started to be cooled down again, and the cold tests will be continued until the end of 2010.

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REFERENCES