CONSTRUCTION OF THE S1-GLOBAL CRYOMODULES FOR ILC

N. Ohuchi#, E. Kako, Y. Kondou, H. Hayano, N. Higashi, H. Nakai, S. Noguchi, T. Saeki, M. Satoh, M. Sawabe, T. Shidara, T. Shishido, A. Terashima, K. Tsuchiya, K. Watanabe, A. Yamamoto, Y. Yamamoto, K. Yokoya, KEK, Tsukuba, Japan
C. Pagani, P. Pierini, A. Bosotti, R. Pararella, INFN, Milano, Italy
T. Arkan, S. Barbanotti, H. Carter, M. Champion, R. Kephart, J. Kerby, D. Mitchell, Y. Orlov, M. Ross, T. J. Peterson, FNAL, Chicago, U.S.A
D. Kostin, L. Lilje, A. Matheisen, W. -D. Moeller, H. Weise, DESY, Hamburg ,Germany

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] is a cryomodule being constructed 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 started in January 2010, and was just completed in May. In this paper, construction experience of the S1-Global cryomodule is presented.

INTRODUCTION

The S1-Global cryomodule was proposed and approved as an international collaborative effort at the SCRF meeting of the ILC Global Design Effort in April 2008. The goals of the S1 Global program are to attempt to achieve an average accelerating gradient of 31.5MV/m across 8 cavities. To accomplish this, eight cavities and couplers are contributed from FNAL, DESY and KEK, and installed in two 'half cryomodules' each 6 m long: Module-C, a new cryomodule designed and constructed by INFN; and Module-A, a modified STF cryomodule by KEK. The S1-G cryomodule design work was completed in January 2009, and the assembly started in January 2010.

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 [2], 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: 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 [3], power distribution for Module-A, and infrastructure for tests.

DESIGN OF S1-GLOBAL CRYOMODULE

The S1-Global assembly is shown in Fig. 1. Two cavities from FNAL and two form DESY are installed in the Module-C, and four cavities of two types by KEK are installed in Module-A. The total length of the S1-Global assembly is 14.9 m. The parameters of the two cryomodules are listed in Table 1.

The cross section of Module-C has the same design as the TTF-type III cryomodule [4]. The cold mass is supported to the vacuum vessel by two composite cylindrical posts spaced 3200 mm apart. All four input couplers are separated by a distance of 1384.15 mm at room temperature. The designs of FNAL and DESY cavity packages differ because of the tuner types, the Blade tuner and the Saclay-type tuner. The difference in length is made up in the bellows between packages.

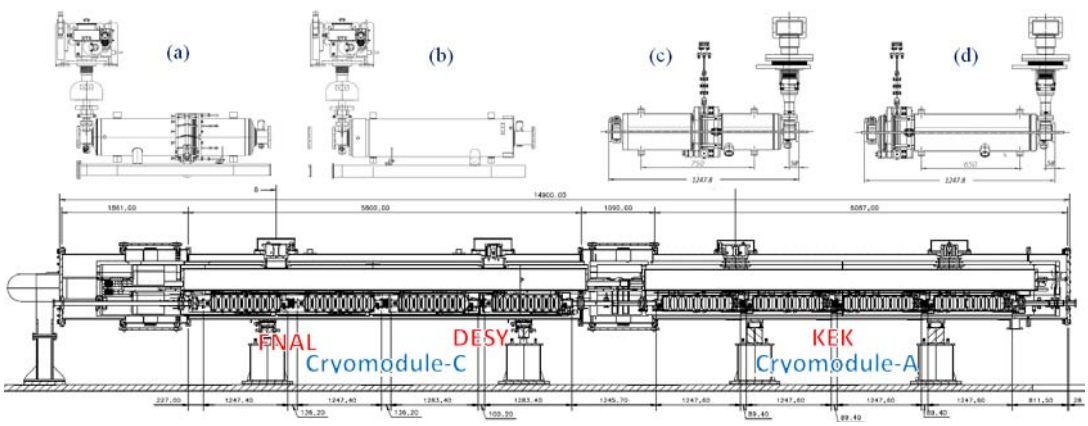

Fig.1: S1-G cryomodule and cavity package of each laboratory. (a): FNAL cavity with Blade tuner, (b): DESY cavity with Saclay-type tuner, (c): KEK-a cavity with slide jack tuner and (d) KEK-b cavity.

Table 1: S1-Global Cryomodule Parameters

	Module-A	Module-C
Vacuum vessel length	6087 mm	5800 mm
Vacuum vessel O.D.	ϕ 965.2 mm	ϕ 965.2 mm
Gas return pipe O.D.	ϕ 318.5 mm	ϕ 312.0 mm
2K LHe supply pipe O.D.	ϕ 76.3 mm	ϕ 76.1 mm
5K shield pipe O.D. [F/R]	ϕ 30/ ϕ 30 mm	ϕ 60/ ϕ 60.3 mm
80K shield pipe O.D. [F/R]	ϕ 30/ ϕ 30 mm	ϕ 60/ ϕ 60.3 mm
Cool-down pipe O.D.	ϕ 27.2 mm	ϕ 42.2 mm
Distance between couplers	1337.0 mm	1384.15 mm
Cavity package	KEK-a/KEK-b	FNAL/DESY
Cavity type	TESLA-like	TESLA-type
Tuner type	Slide jack	Blade/Saclay
Input coupler type	Disk window	Coaxial window
Magnetic shield	Inside jacket	Outside jacket
Package length	1247.6	1247.4/1283.4

The thermal and mechanical designs of Module-A are also similar to the TTF-type III cryomodule. The cold mass is supported from the vacuum vessel with two posts with a distance of 3153 mm. The KEK cavities in Module-A also have two designs of frequency tuner as shown in Fig. 1. The cavity-package of type-A has the tuner located at the center of the helium jacket, while the B-type cavity package has the tuner placed at the opposite end of the jacket with respect to the input coupler.

Connections of cooling pipes between the modules are welded and when needed reducers are used to match the pipe size. The beam tube is not connected as no beam will be accelerated through S1-Global system.

ASSEMBLY OF S1-G CRYOMODULE

Assembly of both Module-C and Module-A is mainly divided into two processes: the cavity string assembly in the class-10 clean room (CR), and the cold mass assembly outside of the CR. For the cavity assembly in the CR, two weeks was scheduled for each module. For the cold mass assembly, two months for Module-C and one month for Module-A were scheduled. Module-C was scheduled for assembly first to ease final assembly of the two modules in the STF tunnel. The durations planned were at times modified not only to ensure the work would be done but also to accommodate the schedule of collaborators who travelled to KEK to participate.

Cavity string assembly for Module-C

Two DESY cavities, Z108 and Z109, arrived at KEK on Dec. 4, while the two FNAL cavities, ACC011 and AES004 arrived at KEK on Dec. 25 and Jan. 8, respectively. The cavity string assembly started on Jan. 15 by a team of three FNAL and two DESY personnel, and was successfully completed Jan. 20. The following tasks were completed in these 5 days:

1. Mounting the four cavities on the assembly fixtures and rough alignment of cavities in the class-1000 CR by KEK in assembly preparation.
2. Leak check of the gate valve sub-assembly and the transition piece.
3. Assembling the flange and valve components to Z109.
4. Interconnecting Z108 to Z109 with standard bellows.
5. Interconnecting ACC011 to Z108 with long bellows.
6. Interconnecting AES004 to ACC011 with standard bellows.
7. Assembling the gate valve sub-assembly to AES004 with the transition piece.
8. Checking the coupler to coupler position. The distances between couplers were confirmed to be 1384 mm.
9. Leak check of the cavity string.
10. Backfilling the string with Argon gas. The Argon gas was 99.9999% purity and supplied through filter from a cylinder. The flow rate was controlled at 0.5 L/m.

Fig. 2: Completion of the interconnection between AES004 and ACC011 with bellows by FNAL and DESY colleagues.

Fig. 3: String of four FNAL/DESY cavities in clean room

Cold mass assembly of Module-C

After moving the cavity-string out of the CR, the cold mass was assembled from January 25 to March 19. The main tasks completed were:

1. Welding the liquid helium (LHe) supply pipes of Ti manually. Ti-SUS junctions were welded at both ends of the assembled pipe for later connection to SUS pipes.
2. INFN and FNAL colleagues mounted the Blade and Saclay tuners and magnetic shields between 9 -12 Feb. The frequencies of cavities were tuned at atmospheric pressure to 1297.400 MHz ± 10 kHz for AES004 and ACC011, 1297.346 MHz ± 10 kHz for Z108 and 1297.349 MHz ± 10 kHz for Z109.
3. Attaching the cavity string to the gas return pipe with C-clamps as shown in Fig. 4. The springs in the C-clamps were torqued to 6 N·m plus 1/4 turn back in the vertical screws, and to 6 N·m plus 3/4 turn back in the horizontal screws.

4. Installing the cool-down pipe, connecting the branch pipes to the cavity jackets, and locking the jackets to the Invar rod.

5. Assembling and welding the sections of the 5K thermal radiation shield, including 10 layers of superinsulation.

6. Assembling 80K thermal radiation shield, including 30 layers of superinsulation.

7. Inserting the cold mass into the cryostat as shown in Fig. 5. The support posts were then assembled on the gas return pipe, and the cold mass aligned to the cryostat.

8. After moving Module-C down to the STF tunnel, four TTF-III warm couplers were assembled by a DESY colleague from March 16 to 19 in a local clean room.

9. Finally 106 thermal sensors, 5 wire position monitors, 24 strain gauges and 24 pin diodes were set in Module-C.

Fig. 4: Attaching the cavity-string to the GRP.

Fig. 5: Inserting the Module-C cold mass into the cryostat.

Cavity string assembly for Module-A

The string of four KEK cavities, MHI-05, 06, 07 and 09, was assembled in the clean room from Feb. 22 to March 8 in parallel with the cold mass assembly of Module-C. The string assembly in the clean room is shown in Fig. 6. Since the KEK cavities were assembled without a horizontal test, the LHe supply pipes were not welded to the cavity jackets. The Ti-SUS junctions were welded in the cross connect to the LHe pipe of SUS. The tasks in the clean room are essentially identical as for Module-C.

Cold mass assembly of Module-A

In the cold mass assembly of Module-A, the followings are different from Module-C.

1. The magnetic shields of the KEK cavities are inside of the cavity jackets, so this step was not needed.

2. Cavity jackets were welded to the LHe supply pipe and the cool-down pipe with Ti-SUS junctions.

3. The upper and lower Al plates of thermal radiation shield were linked with bolts and nuts.

4. 103 thermal sensors, 13 wire position monitors, 24 strain gauges and 24 pin diodes were set in Module-A.

The two cryomodules were lowered to the KEK-STF tunnel on April 28 as shown in Fig. 7. At present, the cooling pipes between modules are being connected.

Fig. 6: String assembly of KEK cavities for Module-A.

Fig. 7: Placing Module-C/A in the KEK-STF tunnel.

TEST PLAN OF S1-G CRYOMODULE

The construction of S1-G cryomodule will be completed in May 2010. The first cool-down is scheduled on June 7, and the cold test will continue until July 23. The second cold test is scheduled from Sept. 6 to Dec. 22.

ACKNOWLEDGEMENTS

The authors would like to thank B. Smith and M. Battistoni (FNAL), and M. Schmoekel and P. Schilling (DESY) for the excellent work in the clean room, and K. Jensch (DESY) for supporting the cold mass assembly of Module-C.

REFERENCES

[1] N. Ohuchi, et al, PAC09, Vancouver, May 2009, WE6RFP005; http://www.JACoW.org.
[2] B. Aune et al., *Phys. Rev. ST-AB*, 3(9), Sept. 2000.
[3] E. Kako, et al, IPAC10, Kyoto, May 2010, WEPEC016; http://www.JACoW.org.
[4] C. Pagani, et al., TESLA Report 2001-36.