PLAN OF THE S1-GLOBAL CRYOMODULES FOR ILC

N. Ohuchi[#], H. Hayano, N. Higashi, H. Nakai, K. Tsuchiya, A. Yamamoto, KEK, Tsukuba, Japan
S. Barbanotti, C. Pagani, P. Pierini, INFN, Milano, Italy
T. Arkan, H. Carter, M. Champion, C. Grimm, J. Kerby, D. Mitchell, T. J. Peterson, M. Ross, FNAL, Batavia, Illinois, U.S.A
L. Lilje, DESY, Hamburg, Germany

Abstract

In an attempt to demonstrate an average field gradient of 31.5 MV/m in a cryomodule as per the design of the ILC, a program called S1-Global is in progress as an international research collaboration among KEK, INFN, FNAL, DESY and SLAC. The S1-Global cryomodule will contain eight superconducting cavities from FNAL, DESY and KEK installed in two half-size cryomodules, each approximately 6 m in length. The module containing four cavities from FNAL and DESY will be constructed by INFN with KEK supplying the remaining four cavities and the associated module. The designs of the cryomodules are ongoing, and the operation of the system is scheduled at the KEK-STF from June 2010. This paper presents the S1-Global cryomodule plan and the module design.

INTRODUCTION

In order to realize the average operating gradient of the ILC of 31.5 MV/m, construction of a 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. For this assembly, eight cavities will be 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 S1-G cryomodule design work started in May 2008, and the general design of this cryomodule has been completed. Assembly will start in October 2009, and the cold tests are scheduled from June to December 2010.

The international collaborative framework of the S1-G is shown in the followings:

- INFN: Design and construction of the 6 m Module-C for DESY and FNAL cavities, and production of the blade tuners [1] for the FNAL cavities.
- FNAL: Two TESLA type cavities [2] and integration of the INFN blade tuners in the cavity packages.
- DESY: Two TESLA type cavities, Saclay-type tuners.
- KEK: Four TESLA-like cavities, 6m Module-A for KEK cavities [3], and infrastructure for tests.
- SLAC: Power distribution system for Module-C.
- IHEP and RRCAT: Participating in discussion of the design and tests.

The main target of the S1-Global cryomodule is the 'Realization of an average accelerating gradient of 31.5 MV/m with 8 cavities'. The following detailed research subjects are planned:

- Attempt to attain an average accelerating gradient of 31.5 MV/m in a pulsed RF operation at 5Hz with 1ms flat-top length, 0.07% rms amplitude variation and 0.35 degree rms phase variation.
- Experience with the design, assembly and the alignment procedures for different types of cavity packages from participating parties.
- Measurement and comparison of the heat loads for each cavity package and cryomodule in the static and 31.5 MV/m dynamic conditions.
- Comparative studies of cavity package performances from the participating institutes.
- Advance implementation of the 'plug-compatible concept' for the ILC concept.

S1-GLOBAL CRYOMODULE DESIGN

The S1-Global cryomodule consists of two 6-m cryomodules, Module-A and Module-C, shown in Fig. 1. 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 Table 1.

The design of the module-C cross section is almost the same as the TTF-type III cryomodule [4], as shown in Fig. 2. The cold mass is supported by the two composite cylindrical posts to the vacuum vessel, and the distance of 3200 mm between the posts was designed so that the cold mass sag would not exceed 50 microns. The distance of 1383.6 mm between the input couplers, same as the TTF-type III and XFEL design, was used for four cavities although the cavity-packages of FNAL and DESY have different lengths, 1247.4 mm and 1283.4 mm, respectively. The designs are different because of the different type of frequency tuner, the blade tuner and the Saclay-type tuner, as shown in Fig. 1. However, the cavity support lugs have a fixed distance from the input coupler axis, independent of the type of cavity package design and as a result, the cavity package supports to the gas return pipe, GRP, are identical, i.e. 'plug compatible'.

The Module-A was used for the cold tests in STF phase-1 [5]. The thermal and mechanical designs of Module-A were based on the TTF-type III cryomodule, as shown in Fig. 3. However the components in the Module-A have different dimensions from those in the Module-C as shown in Table 1. The cold mass is supported from the vacuum vessel with two composite cylindrical posts with

[#]norihito.ohuchi@kek.jp

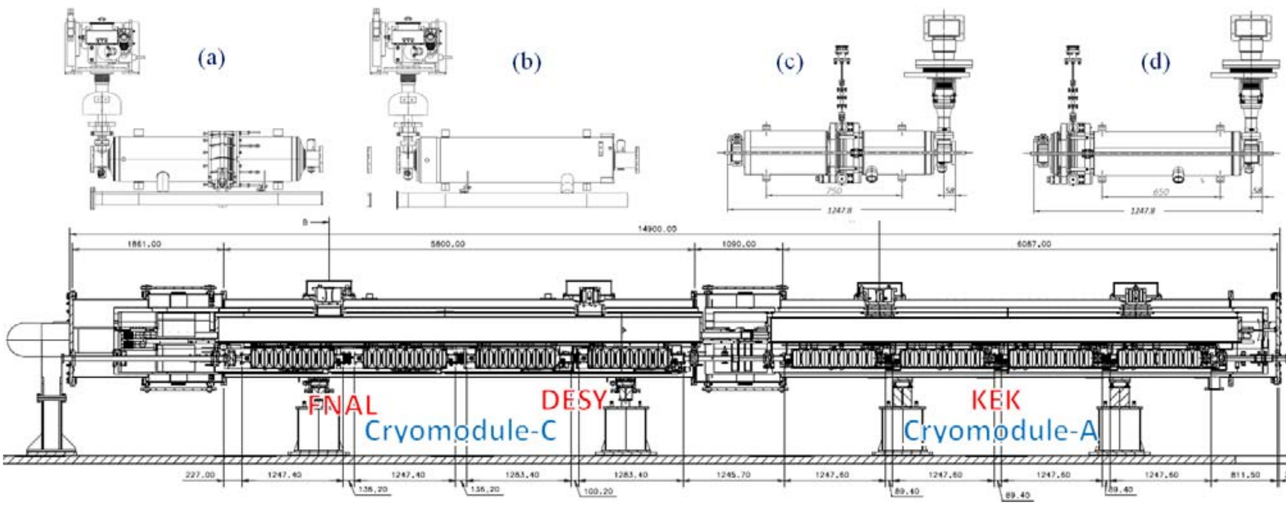

Figure 1: Cross section view of S1-G cryomodule, and the cavity package of each laboratory. (a): FNAL cavity with blade tuner, (b): DESY cavity with Saclay-type tuner, (c): KEK-a cavity with slide jack tuner and (d) KEK-b cavity.

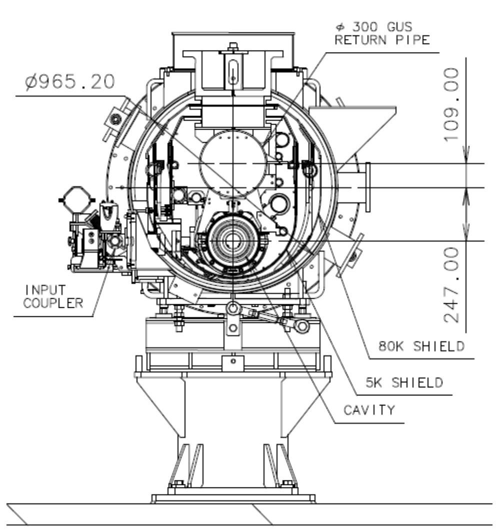

Figure 2: Cross section of Module-C for FNAL cavity.

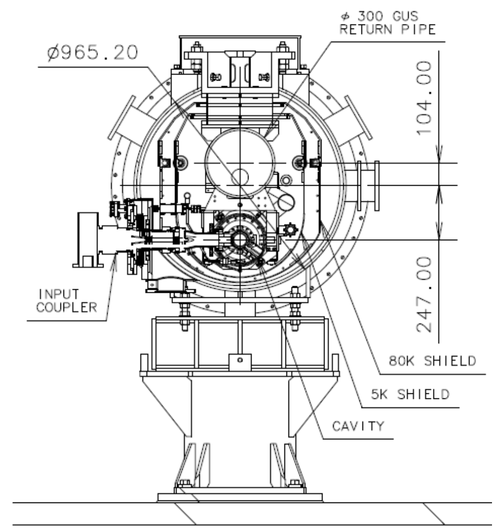

Figure 3: Cross section of Module-A for KEK cavity.

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 length	5830 mm	6000 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	1383.6 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

a distance of 3153 mm. The cold mass sag is within 50 microns. The KEK cavities for Module-A have two designs with different locations of the frequency tuner. The cavity-package of type-A has the tuner located at the center of the helium jacket. The distance between the support lugs along the cavity axis is designed to be 750mm, i.e. the same distance as the FNAL and DESY cavities. The B-type cavity package has the tuner placed at the opposite end of the jacket with respect to the input coupler. With this configuration, the distance of the support lugs is changed to 650 mm and the tuning action does not require sliding of cavity at the support pads. Since the KEK tuners have the driving motor outside the vacuum vessel, the ports for the shafts are welded on the vacuum vessel.

Connection of cooling pipes between the modules will be done with reduced pipe components by welding. At both ends of the GRPs, a closing flange with an extension pipe of ϕ76mm is welded to allow the interconnection of the 2-module string.

CRYOMODULE ASSEMBLY

The two 6-m cryomodules will be assembled in the KEK-STF, then lowered and connected together operation for test. The assembly effort will allow comparison of the components, process and tooling of different laboratories and provide input leading toward optimization for future mass production. The main assembly works inside and outside of the clean room are listed:

- Inside the class 10 clean room
  - Assembly of the cold coupler parts to the cavities.
  - Preparation of the string of four cavities, including rotational alignment of the cavities.
- Outside the clean room
  - Assembly of the different tuner and magnetic shield types on each cavity jacket.
  - Alignment of cavities to the standard fiducial.
  - Suspension of the cavity string to the GRP.
  - Assembly of the thermal radiation shields, thermal intercepts and superinsulation on the shields.
  - Insertion of cold mass into the vacuum vessel.
  - Pressure and vacuum leak tests of cooling pipes.
  - Assembly of the warm coupler parts.

COLD TESTS

The S1-G cryomodule will be cooled with the STF cryogenic system, which can produce cooling power of 35 W at 2K [6]. The specific heat load at 2K and 31.5 MV/m for one ILC module is estimated to be 11.4 W [7], and the STF cryogenic system has sufficient cooling power for the S1-G cryomodule operation.

The research subjects are already described in the introduction. In order to measure the heat loads of the cryomodule and the components, the following measurements will be performed:

- Measurement of the cryomodule system in static and dynamic (at 31.5 MV/m) conditions.
  - Heat load at 2K; evaporation rate of 2K saturated liquid helium by measuring the mass flow of helium gas at room temperature.
  - Heat load at 5K; enthalpy change of 5K thermal radiation shield by measuring the shield temperature rise after stopping the cooling flow.
  - Heat load at 80K; enthalpy change of 80K thermal radiation shield by measuring the temperature rise of the shield after stopping the LN_2 cooling flow.
- Thermal performance of components
  - Thermal calculation from the measured temperature profile of the components in static and dynamic (31.5 MV/m) conditions.
- Cool-down/warm-up effects on the cavity alignment
  - Changes of the KEK cavity-jacket positions and deformations of the GRPs will be measured with wire position monitors and strain gauges.

The sensors for S1-G cryomodule are listed in Table 2.

THERMAL ANALYSIS

Thermal analysis of the cryomodule is being performed with ANSYS by the INFN group. A thermal model has been implemented and a static analysis of the Module-C temperature distribution during module static operation and cool-down/warm-up transients has been performed. As an example, the static temperature profile of 5K shield after cool-down is shown in Fig. 4.

Table 2: Sensors for S1-Global Cryomodule

	Range	No. of sensors
CERNOX temperature sensor	1.4K~100 K	78
PtCo temperature sensor	4K~300 K	56
Cu-Constantan thermocouple	70K~300K	74
Strain gauge	-	24
Wire position monitor	-	18
Absolute pressure sensor	0 ~ 27 kPa	4
Pressure sensor	-0.1~ 0.5 MPa	5
Mass flow meter	0 ~ 64 m^3/h	3

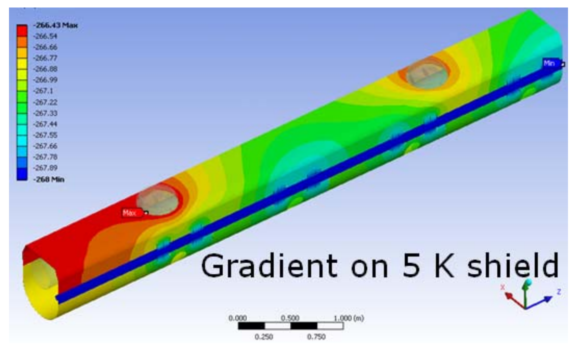

Figure 4: Temperature profile in the 5K shield.

CONCLUSION

In order to realize the average operating gradient of 31.5 MV/m for the ILC, the S1-Global cryomodule was proposed as an international collaborative research effort.

The general design of the S1-Global cryomodule has been completed, and manufacturing of the components started. Cold tests of this cryomodule are scheduled to start in June 2010.

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