ILC 1.3 GHz SUPERCONDUCTING RF TECHNOLOGY DEVELOPMENT PROGRAM AT IHEP*

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Abstract

With the aim to develop 1.3 GHz superconducting radio-frequency (SCRF) technology in the frame of ILC collaboration, IHEP has started a program to build an SCRF Accelerating Unit. This unit contains a 9-cell 1.3 GHz superconducting cavity, a short cryomodule, a high power input coupler, a tuner, a low level RF system and a high power RF source, etc. This program also includes the SCRF laboratory upgrade, which will permit the unit to be built and tested at IHEP. We will use this unit as a horizontal test stand for 9-cell cavities and other components (e.g. input couplers, tuners), as in Europe and North America. In this paper, we report the recent R&D status and the future plan of this program.

INTRODUCTION

Developing the superconducting radio-frequency (SCRF) technology is at the heart of the current ILC global R&D activities. To master the SCRF key technologies before the end of the ILC TDP, IHEP has launched a 3-year (2009-2011) program "1.3 GHz SCRF Accelerating Unit and Horizontal Test Stand Project".

The "SCRF Accelerating Unit" is a 2-meter-long short cryomodule containing one 9-cell cavity, one high power coupler, one tuner, and the corresponding low level RF (LLRF), high level RF (HLRF) and cryogenic systems (Fig. 1). The components will be designed, fabricated and commissioned with reference to the existing designs worldwide which meet the ILC RDR specifications.

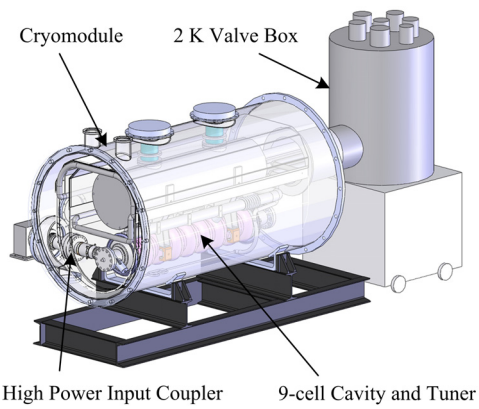

Figure 1: Layout of the IHEP 1.3 GHz SCRF Accelerating Unit

This unit will also serve as a Horizontal Test Stand (HTS) for new components R&D (e.g. cavity packages, input couplers, tuners, LLRF systems, cryomodule cold mass structures, etc.). Similar horizontal test stands are available in many labs such as CHECHIA in DESY, CRYOLAB in Sacley, HOBICAT in BESSY FEL, HTS in Fermilab and HTC in Cornell ERL.

Constructing and commissioning SCRF infrastructures and facilities is an important part of this program, which will allow sustainable SCRF technology development in IHEP and China.

R&D STATUS AND PLAN

High Gradient Cavity

The combination of the low-loss shape and large grain niobium material is expected to be the possible way to achieve higher gradient and lower cost for ILC 9-cell cavities. The cost reduction of the large grain niobium cavities lies in eliminating the expensive and complicated electro-polishing process, and the newly developed multi-wire slicing technique on large grain niobium ingots [1].

IHEP has started R&D on the 1.3 GHz large grain cavity since 2006 in collaboration with KEK. Three electro-polished ICHIRO single-cell cavities were fabricated and processed in KEK with Ningxia large grain niobium. The maximum gradient achieved was 47.9 MV/m [2]. Then two low-loss shape single-cell cavities using Ningxia large grain niobium were fabricated and surface treated by IHEP and tested at KEK in early 2008. One of the chemical polished cavities (without electro-polishing) reached the high gradient of 40 MV/m without Q-slope [3]. These results have shown apparent advantages of large grain over fine grain material [4].

Now a 1.3 GHz low-loss shape bare-tube 9-cell cavity using Ningxia large grain niobium is being fabricated by IHEP, and will be surface treated and tested in the next few months. Again, only chemical polishing will be performed on this cavity for the first test loop.

The low-loss 9-cell cavity with full end groups is also under development. The end cell shape, the HOM couplers and the end plate will be optimized to damp higher order modes and reduce high field Lorentz force detuning according to ILC requirements. Two low-loss shape large grain 9-cell cavities with full end groups will start fabrication before the end of 2009. One of them will be installed into the cryomodule for the horizontal test.

*Work supported by NSFC 10525525
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Cryomodule and Cryogenic System

The cryomodule structure design, cryogenic flow diagram, thermal and mechanical simulations and heat load estimation have been performed since 2006 [5, 6]. Together with the experience obtained in fabricating the 12-meter-long Euro-XFEL prototype cryomodule by IHEP and the thermal analysis of STF cryomodule in collaboration of KEK [7], further optimization and engineering design of the short cryomodule is expected to be done by the end of 2009.

One of the most important issues during the components design is to agree with the ILC plug compatibility specifications. In this way, it will be possible to install and test IHEP components in the ILC main linac test facilities worldwide, and vice versa, easier for the components from abroad to be tested in the IHEP horizontal test stand.

The cryogenic system for the cryomodule is described in [6].

High Power Input Coupler

IHEP has started the 1.3 GHz high power input coupler R&D since 2006. 3D modelling and RF characteristics simulation for variable coupling and static thermal simulation of the KEK capacitive coupler were performed.

Based on the successful performance of the KEKB input coupler, one 500 MHz input coupler for BEPCII was fabricated by IHEP and 270 kW CW RF power transmitted through the coupler during conditioning test at KEK [8].

We will apply the similar chock structures to the 1.3 GHz high power input coupler design. In collaboration with KEK, IHEP has made the static and dynamic thermal analysis of the STF baseline input coupler [7], the RF simulation of the fixed coupler (Fig. 2) and the optimization of the variable coupler for STF phase 2.

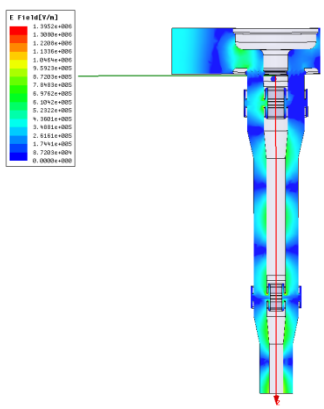

Figure 2: E-filed of the KEK STF baseline high power input coupler with two choke structures.

At first stage, the fixed coupling will be adopted. The tuning mechanism will be used for the variable coupling design for the next stage.

LLRF & Tuner

In order to test the 9-cell superconducting cavity, two kinds of 1.3 GHz LLRF systems are under construction. One is an analog LLRF based on PLL for the vertical test, and the other is a digital LLRF based on FPGA for the high power horizontal test.

In the digital LLRF for the horizontal test (Fig. 3), a local signal of 1299 MHz is locked with the 1.3 GHz master oscillator, that is used to down the frequency of RF signals from cavity and klystron to the IF signals of 1MHz. The tuning loop and tuner device will be designed and tested next year.

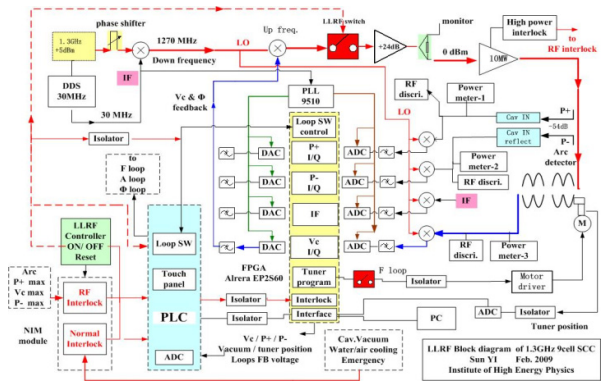

Figure 3: LLRF system layout of the 1.3 GHz SCRF Accelerating Unit.

The type of the tuner has not been decided yet. The two candidates are the slide-jack tuner of KEK-STF and the blade tuner of INFN.

HLRF Marx Modulator

The solid-state Marx modulator is under development at IHEP with ILC baseline specifications, supported by innovation funds of the Chinese Academy of Sciences. The key component 12 kV solid switch has been developed and one 12 kV cell module was demonstrated successfully as shown in Fig. 4.

We are also developing the new EPICS based control system and 150 kW charging power supply for the Marx modulator.

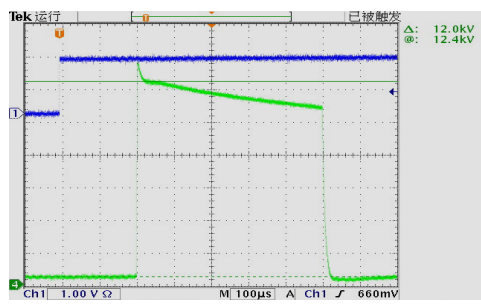

Figure 4: Pulse of the 12 kV solid switch cell module.

Facilities Upgrade

IHEP SCRF Lab, built in 2004, is one of the most advanced superconducting RF labs in China. We have treated and tested several low beta single-cell SCRF cavities in this lab since 2005.

The 1.3 GHz SCRF program will significantly improve the IHEP SCRF infrastructures and facilities to meet the 9-cell cavity requirement for surface preparation and vertical tests, especially the new helium recycling system which will allow the routine vertical tests possible. The upgrade items include:

- CBP (tumbling) machine for 9-cell cavities
- Clean rooms upgrade
- HPR facility for 9-cell cavities
- CP facility for 9-cell cavities
- Pretuning machine
- New dewar and related devices for vertical tests
- Helium recycling system for vertical tests based on the BEPCII cryogenic plant, or a brand new vertical test stand near the horizontal test stand
- T-mapping and cavity inner surface inspection tools

Most of the above facilities are being manufactured now, and will be ready to use within one year.

The horizontal test stand will be located out of the current SCRF lab with helium recycling system connected.

SUMMARY

The 1.3 GHz superconducting RF technology development program "IHEP 1.3 GHz SCRF Accelerating Unit and Horizontal Test Stand Project" has been started. International collaboration is of great importance for the success of this project. The R&D goals are:

- Cavity gradient of 25-35 MV/m for the vertical test;
- Cavity gradient of 25-31.5 MV/m for the horizontal test;
- 1 MW (5 Hz, 1.5 ms pulse, TW) power through the high power input coupler in conditioning tests; 300 kW (5 Hz, 1.5 ms pulse, SW) power during the horizontal test;
- LLRF phase stability 0.1 degree, amplitude stability 0.1 %;
- Labs and facilities capable for the 9-cell cavity processing, pretuning, vertical tests and horizontal tests.

ACKNOWLEDGEMENT

We would like to thank the KEK LC office headed by K. Yokoya, and KEK colleagues H. Hayano, S. Noguchi, E. Kako, N. Ohuchi, K. Saito, F. Furuta, H. Matsumoto, T. Saeki for their help and discussion.

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