STATUS OF RF SOURCES IN SUPER-CONDUCTING RF TEST FACILITY(STF) AT KEK

S. Fukuda#, M. Akemoto, H. Hayano, H. Honma, H. Katagiri, S. Kazakov, S. Matsumoto, T. Matsumoto, S. Michizono, H. Nakajima, K. Nakao, T. Shidara, T. Takenaka, Y. Yano, M. Yoshida, KEK, Ibaraki, 305-0801, Japan.

Abstract

The super-conducting RF test facility (STF) at KEK has been functional since 2005, and the STF phase-I, which involves the testing of a cryomodule with four superconducting cavities, is now under way. Furthermore, KEK will conduct the S1-global test and the STF-II project in the future. The S1-global test aims at evaluating the performance of the superconducting cavities provided by Japan and the international collaborators, USA and Europe. The phase-II project aims at testing RF unit of the proposed ILC. In this paper, we describe the current status of the RF sources in the STF phase-I and the development of RF source for future projects.

INTRODUCTION

The superconducting RF test facility (STF) at KEK comprises two phases, as shown in figure 1, and has been operational since 2005 [1]. The STF Phase-I consists of a cryomodule with a four-cavity structure having a gradient of 35 MV/m and is being tested. In Phase-I, the high level RF (HLRF) team is planning to install two types of power distribution systems (PDSs) and conduct the associated R&D. The low level RF (LLRF) team is planning to test the digital feedback with vector sum control. The STF Phase-II employs one RF unit, which is similar to the ILC baseline configuration design (BCD) layout. Phase-II employs beam acceleration to evaluate the entire linac system. The construction of STF-II is delaying and it is scheduled from 2012 to 2015. Recently, an S1-global phase was proposed; this phase will be completed before Phase-II of the STF. The S1-global phase will include two cryomodules with eight super-conducting cavities provided by Japan and international collaborators, USA and Europe. A different RF PDS scheme is tried to be used for evaluating the performance of the cavities, and currently, our efforts are focused on meeting the requirement to optimized operation of the cavities. In this paper, we describe the current status of the RF sources in the STF-I phase and the preparation of RF sources for future projects.

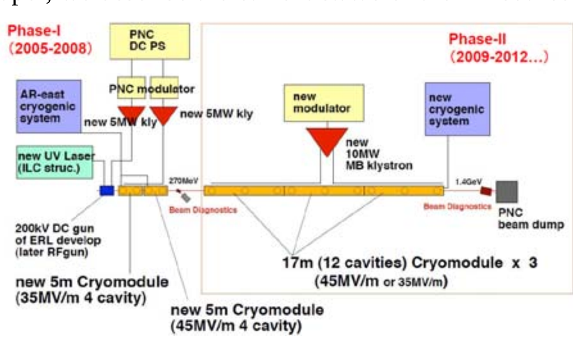

Figure 1: STF layout.

#Shigeki.fukuda@kek.jp

HLRF

Modulator and Klystron

The current STF RF sources comprise two stations. In the first station, a bouncer-type insulated gate bipolar transistor (IGBT) modulator is used along with a pulse transformer with a step-up ratio of 1:6. A 5-MW Thomson klystron, TH2104C, is used in this station; this klystron was previously used in the JAPAN HADRON PROJECT (JHP). The maximum available power of this station is 3.0 MW [1]. The power limitation is come from fast over-voltage protection for the IGBT switch which comprises 36 IGBT devices connected in series. The maximum voltage applied to a IGBT in the switch comes when the switch is turned off for a klystron gun spark, and must not exceed the maximum rating of 1200 V. The maximum IGBT switch operating voltage is 21.5 kV at the primary of the pulse transformer, which corresponds to a klystron voltage of 120 kV[2]. The RF source used in station no. 1 is utilized for conducting coupler processing tests and the STF-I experiment. Station no. 2 uses another bouncer-type IGBT modulator with a pulse transformer having a step-up ratio of 1:15 [3]. A 5-MW Thales klystron, TH2104A, is used in this station. The performance of the bouncer circuit in both modulators was excellent and a flat-top of less than ±0.8% was achieved in both modulators. A breakdown failure of the IGBT modulator in station no. 2 occurred due to a water leak in the pulse transformer; therefore, we have been checking the protection system for the shorting the undesired load ever since. The layout of the STF is shown in figure 1. We will introduce a third modulator and a 10-MW multi-beam klystron in the STF phase-II. We will select this modulator from two candidate modulators—the bouncer-type modulator and a Marx modulator.

PDS for STF-I

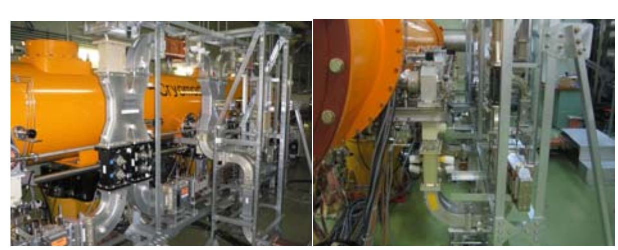

Figure 2: Tree type PDS connected to cryomodule.

As described in ref [1], we prepared two types of PDSs: a tree-like PDS using 3 dB hybrids and a TESLA test facility (TTF)-like linear power distribution network. Although a 5-MW circulator is installed at the output waveguide of the klystron, both PDSs utilize circulators at the upstream of the cavity couplers; four circulators were developed by SPA Ltd., Russia and four were developed by Nihon Kosyuha, Japan, as described later in this paper. Two systems will be tested in the STF Phase-I this year. Figure 2 shows the tree-type PDS connected to the STF cryomodule. PDS is evaluated by investigating several themes. The tree-like PDS employs 3-dB hybrids with a variable tap-off (VTO), which the power dividing ratio is adjusted by the depth of the button of the hybrid divider. This enables us to vary the power dividing ratio from 2.5 to 3.5 dB. If the cavities accept different allowable powers, it is possible to vary the power of each cavity within this range. STF Phase-I tests are performed using circulators for all cavities; in the same testing period, performance tests without circulators are also planned. The 3-dB hybrid with a VTO also changes the isolation between the two splitting waveguides, from 25 to 40 dB. We expect to study the effects of crosstalk between the reflections from the adjacent cavity with the function of the isolation when we eliminate the isolator. The total performance is evaluated under the condition of the vector sum control of LLRF. The cost impact of eliminating the circulator in the ILC design is large, and the circulator issues are important for investigating the HLRF performance in the STF. These tests will be conducted in November 2008.

Developed Waveguide Components

In order to perform the planned tests for S1-global, STF-I, and STF-II, we developed the key waveguide components such as the phase shifter and reflector that allow us to change either the power level or the loaded Q

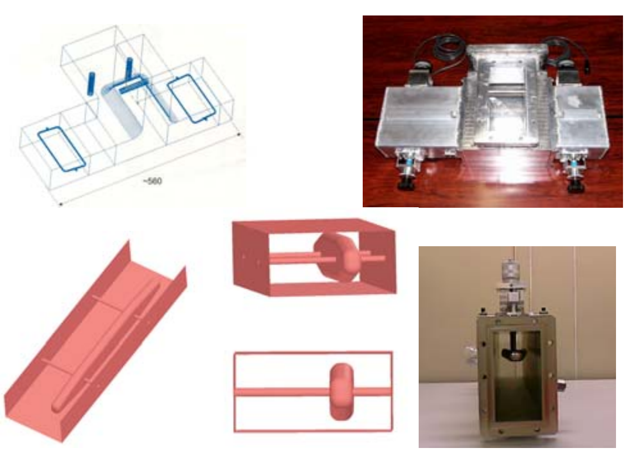

Figure 3:Top shows phase-shifter with two reflectors: top left, schematic drawing and top right, outer view. Bottom shows phase shifter with a plate; bottom left and middle shows schematic draw and bottom right shows outer view.

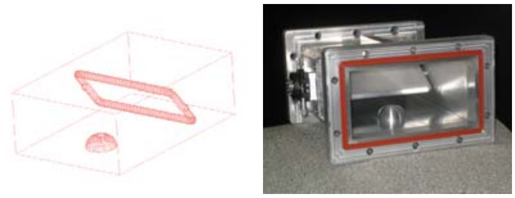

Figure 4: Left shows the schematic draw and right shows the outer view of reflector.

value of the cavity. The 3-dB hybrid with a VTO is an example of a simple power-varying component and is used in the tree-like PDS. We purchased four circulators from Russia, which are used in DESY and also developed the equivalent circulators at the Nihon Kosyuha Corp. in Japan. The circulators would be operated successfully up to 500 kW with a pulse width of 1.5 ms and a pulse repetition rate of 50 pps. The Japanese circulator has an insertion loss of 0.15 dB, which is slightly larger than that in the Russian circulator. Apart from the phase shifter used in DESY, KEK developed several different types of phase shifters, as shown in figure 3. We manufactured three phase shifters with a moving plate, as shown in figure 3, and used them in the liner PDS. Another important component is a reflector, which varies the power and the loaded Q value. Figure 4 shows a schematic representation of a reflector. A reflector can be used in combination with a phase shifter as shown in figure 5. All components described here are successfully tested up to 2 MW with a pulse width of 1.5 ms and a pulse repetition rate of 50 pps.

PDS Layout for S1-global Plan

If the cavities under test show a large variation in their parameters, an adjustment is required to ensure that all

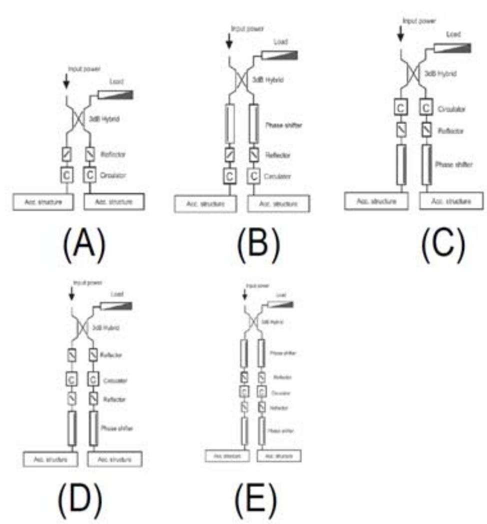

Figure 5: Schematic concept for changing a power, a phase and a loaded Q (Q_L) for the cavity in the PDS. (A) Power control, (B) power and phase control,(C) Q_L control, (D)power and Q_L control, and (E) power, phase and Q_L control.

cavities have matched parameters. Figure 5 presents the techniques for changing the parameters such as the loaded Q, phase, and the power in the linear PDS. In the case of the proposed S1-global plan—in which superconducting cavities manufactured in three regions in the world will be evaluated—a large variation in the cavity parameters may exist. We plan to add a phase shifter and a reflector between the circulator and the cavity in the linear PDS to change the loaded Q value of the four cavities in the cryomodule. It is possible to vary the available power of the four cavities in another cryomodule by using a 3-dB hybrid with a VTO in the tree-like PDS. The schematic layout of the PDS for the S1-global plan is shown in figure 6. Figure 6 shows the two different PDS connected to the different cryomodules.

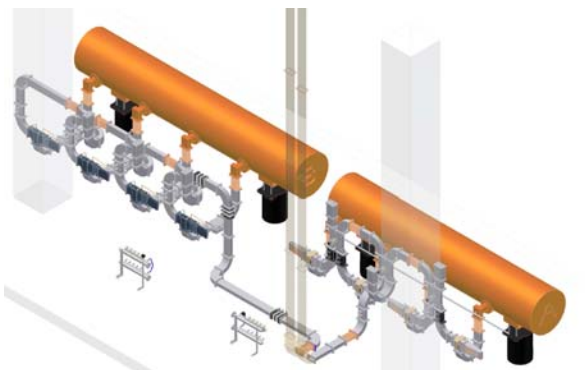

Figure 6: PDS planned in the S1-global. The right cryomodule is connected to the tree-like PDS with 3dB hybrid with a VTO. The left cryomodule is connected to the linear PDS having phase-shifters and reflectors in the down stream of the circulators.

PDS Layout for Phase-II

Since phase-II aims at the construction and evaluation of one RF unit of the ILC BCD, a basic layout is the same as the layout shown in the RDR [4]. On the other hand, the GDE of the ILC is discussing more efficient and cheap layout. Though recently an RF cluster scheme is proposed, in which 35 to 37 RF stations in the surface combined the power up to 350 MW and this power is delivered to the linac, PDS in the tunnel seems to be basically the same. Circulator elimination and VTO components are R&D items. We are tentatively preparing for PDS based on the BCD.

LLRF

After the LLRF evaluation using cavity simulator, several studies are conducted using super conducting cavity in STF-0.5. Feed forward control to vary the RF power with the step function in the 1.5ms pulse width were also done for cavity processing. For digital feedback control, the measured RF stabilities of the digital LLRF system at the STF were 0.04% in amplitude and 0.02°. in phase, respectively [4] and performance is shown in figure 7. The RF waveforms obtained using the digital LLRF system are utilized for the evaluation of cavity parameters such as microphonics and for determining Lorentz force detuning. Several studies related LLRF were performed. A digital LLRF control system with four intermediate frequencies was successfully operated [5]. Measurements of the feedback-instability by 8/9π and 7/9π modes were conducted to check the mode-mixing other than π mode [6]. Direct sampling test to input 1300 GHz signal to ADC by connecting fast-speed FPGA board was performed [7].

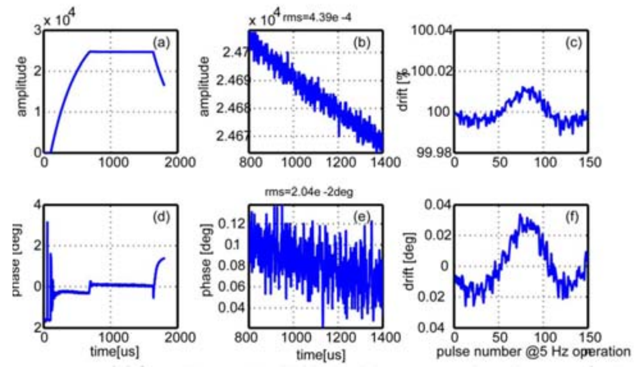

Figure 7: Performance of the llrf field regulation. Amplitude (a) and (b), drift of the amplitude during 30 seconds (150 pulses) (c), phase stability (d) and (e), drift of the phase during successive 150 pulses.

SUMMARY

The STF at KEK has been operational since 2005; currently, the STF-I phase is being carries out. The operations of HLRF and LLRF for a single cavity have been successfully performed. The operation of four superconducting cavities is scheduled for November 2008, and further studies on HLRF and LLRF will be conducted: these studies will include the possibility of circulator elimination. Several waveguide components have been designed and tested up to two MW to achieve the requirements of phase-I and the S1-global cavity testing. The layout and the scheme of PDS for the achievement of requirements are described in this report.

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