STATUS OF SUPERCONDUCTING RF TEST FACILITY (STF)

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Abstract

The superconducting RF test facility (STF) in KEK is aiming to promote R&D of superconducting linear accelerator to be used in the International Linear Collider (ILC). The phase-1 STF construction was completed in 2008. They are high power RF operation of 1.3GHz SC cavities in the short-cryostat and infrastructure construction and operation for supporting the superconducting accelerator module. The new phase, STF phase-2 construction began to start. The phase-2 plan is aiming to realize ILC RF unit construction and demonstration its performance together with preparation and study of industrial production. This paper summarized the STF phase-1 results and conclusion and start-up of the phase-2 construction.

1 INTRODUCTION

The reference design report (RDR) of the ILC was completed and published in 2007[1]. The baseline ILC configuration was determined as one polarised electron injector, central 6km damping rings, two 11km main linacs with 31.5MV/m gradient, positron line helical undulator at 150GeV, and 14mrad crossing final focus with single IR. The main linac RF unit consists of the following components. The bouncer modulator and the pulse transformer for the 10MW multi-beam klystron are the baseline design of RF power source. Beam is injected after filling time of 500µs from the start of RF fill into the cavities. The klystron has two RF outputs connected to the 4 branch of the linear distribution system of the cryomodule. The circulator of each cavity input ensures the matching condition of waveguide system. There are 9 cavities in the two cryomodules of both side, and 8 cavities and SC quadrupole magnet are in the central cryomodule. Total 26 cavities are in one RF unit. Average operation gradient for these cavities are 31.5MV/m, and loaded beam current is 9mA during about 1ms beam pulse train with 5Hz repetition. This RDR unit configuration is illustrated in Figure 1. The demonstration of this RF unit is the milestone of the STF phase-2 construction. In phase-2 plan, we will construct 12m-long RDR cryomodules including total 26 superconducting cavities and 1 SC quadrupole magnet. It has ILC structure electron beam generated by the photo-cathode RF gun and conditioned by the following two SC capture cavities. Phase-2 plan also includes the compact bright X-ray source development referred as 'quantum beam project' which is founded by the MEXT as an intermediate milestone. The industrialization of cavity fabrication and cost reduction is also one of the targets of this phase-2 construction.

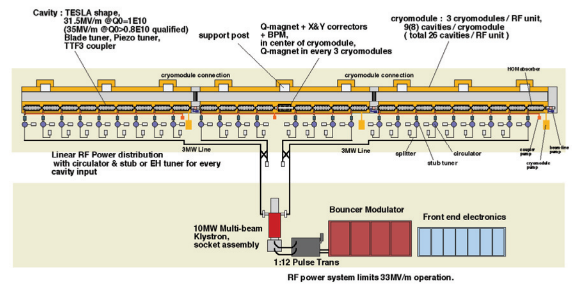

Figure 1 RF unit configuration of ILC main linac.

2 CRYOMODULE TEST OF STF PHASE1

The STF phase-1 test cryomodule consist from the two units of 5m horizontal cryostats which are the half length of ILC design, and each of them can accommodate 4 cavities. The type A 5m cryomodule is designed to accommodate TESLA-style cavities, and the type B 5m cryomodule is for low-loss (LL) cavity. The cool-down test was carried for the one TESLA-style cavity in the cryomodule A, then one LL cavity in the cryomodule B in the next. During high power test and heat load measurement of LL cavity, four TESLA-like cavities were assembled into the cryomodule A. The installation of this cyomodule-A was done in May 2008 and cool-down test was performed from June to December 2008. In the meantime, the cavity development was changed its priority to TESLA-style cavity which is to be used for Phase-2 cavity. LL-cavity development is kept for a candidate of high gradient cavity as a possible option.

3 STF PHASE1 EXPERIMENT RESULTS

The cool-down experiment of one TESLA-like cavity module and one LL cavity module were described in the previous proceedings [2]. The cryomodule of 4 TESLA-like cavities was cooled down twice, in the term June to July 2008 and September to December 2008. The first cool-down is for cryomodule heat load measurement without connection of warm-side input coupler. In parallel, low-level performance measurement of the cavity, such as tuner performance and HOM performance were done. The second cool-down is for the high power RF test of the cavities, Low-Level RF vector-sum control and various power distribution test together with cryomodule heat load measurement.

One of the cavities out of four reached to 31.5MV/m, ILC operation gradient. Other three were stayed around 20MV/m, as shown in Fig.2. First, the study was performed using this high gradient cavity for the gradient demonstration and LD (Lorentz Detuning) measurement and compensation by feeding RF power into the specified cavity only. The field amplitude and phase were feedback controlled using piezo actuator LD compensation. The waveform of this demonstration is shown in Fig.3 (top). The other important demonstration is to show the small LD design of tuner and helium vessel. The LD measurement results shown in Fig.3 (bottom) demonstrated 300Hz detuning during pulse flat-top at 30.2MV/m. It is half detuning amount compared with TESLA cavity, and indicates that only a half stroke of piezo compensation is required.

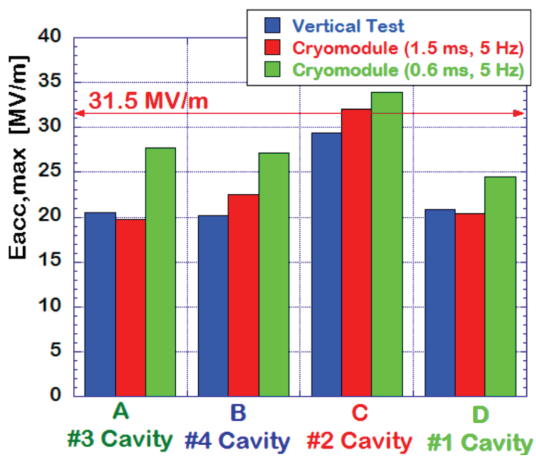

Figure 2 Reached gradient performance of 4 TESLA-style cavities in the cryomodule.

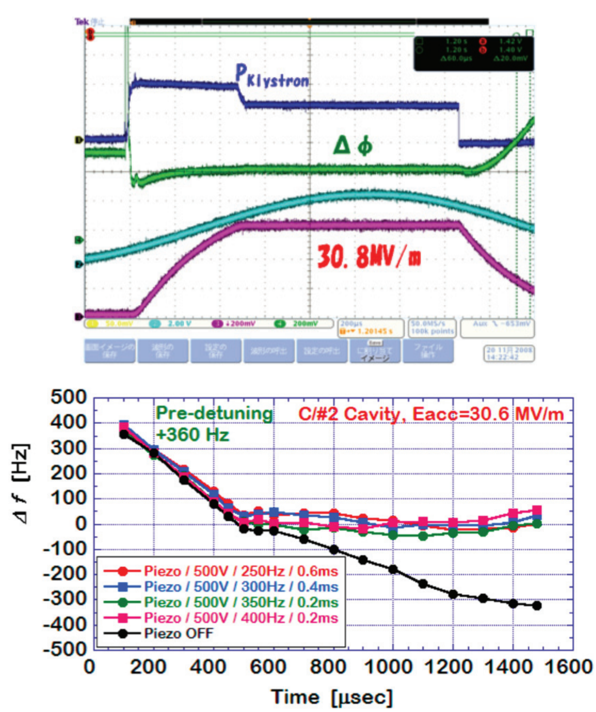

Figure 3 The waveform of the best performed TESLA-shape cavity with Piezo control on and feedback control on (top). The measured Lorentz detuning without piezo(black) and with piezo using various parameters (bottom).

After power test of each cavity, the waveguide was connected to feed RF power to four cavities together. Vector-sum control of Low-Level RF (LLRF) was demonstrated. As shown in Fig.4, stability of amplitude was performed as 0.04%rms and phase 0.02degree.rms. Since these four cavities have different QL, each cavity phase behaved differently during pulsed operation, in the mean time summed signal was controlled in flat. These stability performances are well below the specification ILC. Several trials for LLRF and power distribution were performed, such as simulated beam loading signal mixture, special filtering technique and IF-mixture ADC detection, QL control by waveguide short and phase shifter, etc. [3]

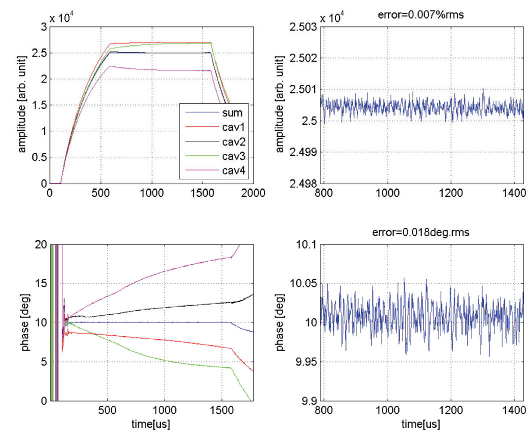

Figure 4 Waveforms of amplitude (top raw) and phase (bottom raw) during vector-sum feedback control for four TESLA-style cavities.

4 INFRASTRUCTURE DEVELOPMENTS

The new electro-polishing (EP) facility and vertical test stand (VT) became in operation after commissioning using FNAL cavity AES001. The EP and VT are now routinely operated once in two week alternately. So far MHI-05 to MHI-08 (4 cavities) were processed and vertical tested. The EP system still in upgrading, such as rinse system for H2O2, Ethanol and degreaser, pre-EP function, TOC and particle monitoring during HPR.

The temperature mapping system is under developing for the vertical test cavities. The 176 temperature sensors are installed around each cell and end group HOMs. The temperature rise is summarized as a map plot as shown in Fig.5. We can identify the heat spot easily, and easy to think the connection with followed surface inspection.

The development and upgrading of cavity surface inspection camera is being done by the collaboration with Kyoto University. Newly developed high performance C-MOS camera and LED illumination combination is under study. The current illumination of EL panel was found to have short life and not so bright. The introduction of LED strip illumination has 10 times brighter and much more long life. Also, in order to inspect various style of cavity like EP-jig installed or helium jacket installed, the camera cylinder rotation is required instead of cavity rotation. It is under development.

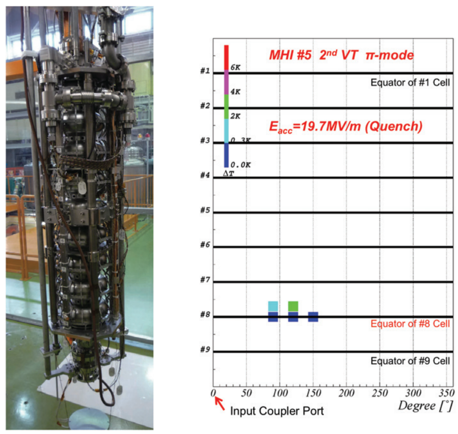

Figure 5: Temperature mapping inspection in the cavity vertical test. Picture of sensor installation (left) and temperature rise mapping result (right) are shown.

5 PHASE-2 DEVELOPMENTS

During the cavity fabrication and design preparation for the cryostat and refrigerator, the S1-Global experiment was planned. The idea of the S1-Global is to realize ILC operational gradient 31.5MV/m in the one cryomodule (8 cavities) by collaboration of world top-level performance cavities, as shown in Fig.6. It will be operating in 2010 at STF.

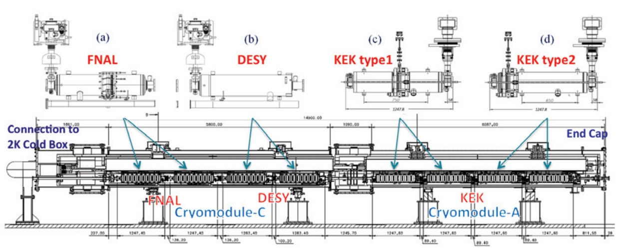

Figure 6 : S1-Global cryomodule experiment.

The planned phase-2 accelerator is illustrated in Fig. 7. They consist of three ILC cryomodules driven by the 10MW multi-beam-klystron, photocathode RF gun, and two 9-cell cavities capture module. On a way of phase-2 construction, the compact X-ray source development is included in the commissioning of the beam source of phase-2 accelerator as shown in Fig. 8. The beam operation of X-ray source is scheduled in fall of 2011 to summer 2012.

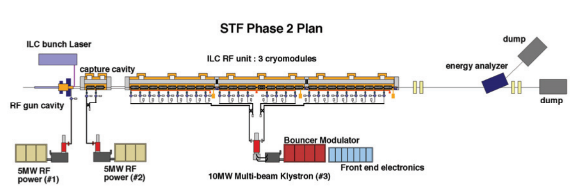

Figure 7: STF phase-2 accelerator diagram.

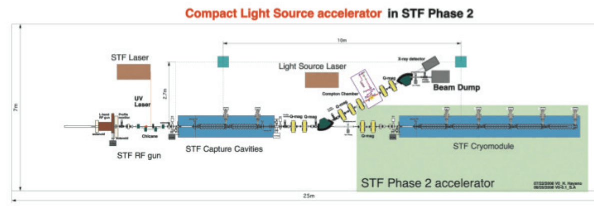

Figure 8: Compact X-ray source development on a way of the STF phase-2 construction.

After finished the X-ray generation experiment, the first ILC cryomodule will be installed in STF tunnel by the end of 2012. The second run of the phase-2 accelerator is scheduled from January 2013 to July 2013. In the meantime, the rest of cryomodules will be in preparation. Also the rest 17 cavities will be fabricated and processed in parallel way, in order to catch up the second and third cryomodule installation. The current concerns are to build carry-in hatch in STF tunnel, expansion of clean-room to accommodate 9 cavities chain, expansion of cryomodule assembly tool, and to clear high-pressure vessel regulation for cavity and cryomodule. Overall schedule is shown in Fig. 9 below.

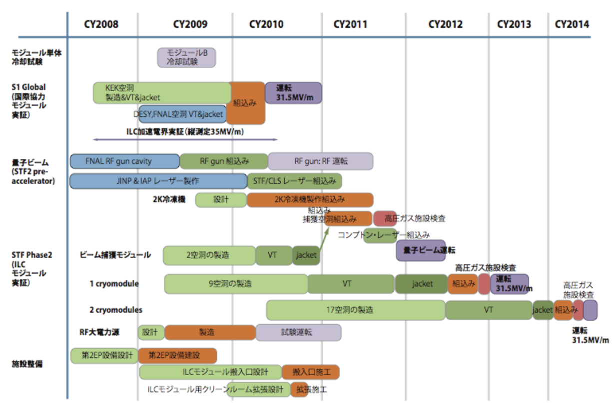

Figure 9: Plan and schedules for the overall STF phase-2 in coming several years.

6 ACKNOWLEDGEMENT

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7 REFERENCE

[1] ILC Reference Design Report, ILC-Report-2007-001 (2007);
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[2] Hitoshi Hayano, "KEK-STF status," Proc. of the 5th Japanese Accelerator Society meeting, 2008.
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