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

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Abstract

Super-conducting rf test facility (STF) has been progressed in KEK since 2005. In this paper, we describe the current status of rf sources in STF. STF rf sources comprise a long pulse modulator with a bouncer circuit , a pulse transformer, an L-band 5-MW klystron, a power distribution system and a low level rf system. We have completed the construction of the first rf test system for coupler tests. We have operated the rf source for the system evaluation and for the coupler tests of the super conducting cavities. We obtained a good result of the bouncer circuit performance. The sag of the voltage pulse for a pulse width of 1.7 ms was improved from 12% to +-0.8%, and the sag for an rf pulse of 1.5 ms from 70% to +-4% by using the bouncer circuit. It is scheduled to feed a power to the cryomodule with 4-35MV/m cavity structures and 4-45MV/m cavity structures in the spring of 2007.

INTRODUCTION

In KEK, super-conducting rf test facility (STF) has been developed since 2005[1]. This includes Phase-I and Phase-II, as shown schematically in Fig. 1. In Phase-I, a cryomodule, with a four-cavities structure having a 35 MV/m gradient and a four cavities structure having a 45 MV/m, and an rf (or dc) gun will be constructed from FY2005 to FY2006. In Phase-II, three full-size (12m) cryomodules with 8 cavities will be constructed from FY2007 to FY2009. This plan employs the same unit as the ILC BCD (basic configuration design) cryomodule. Both phases include beam acceleration to evaluate the total linac system. In FY 2005, we made a plan to construct the first rf source quickly to make use of the old resources such as the modulator come from the PNC (Power Nuclear-reactor Corporation), the klystron used in KEK-JHP (Japan Hadron Project: the former project of J-PARC), and waveguide components of both projects[2]. In the spring of 2006, we completed the rf system to perform the high-power test of couplers which were to be used in cryomodule. We tested the modulator with a bouncer circuit and obtained a good result to improve the pulse sag characteristics. Some couplers were tested up to 2 MW rf peak power with a pulse width of 1.5 ms, and the first tests wee successfully finished.

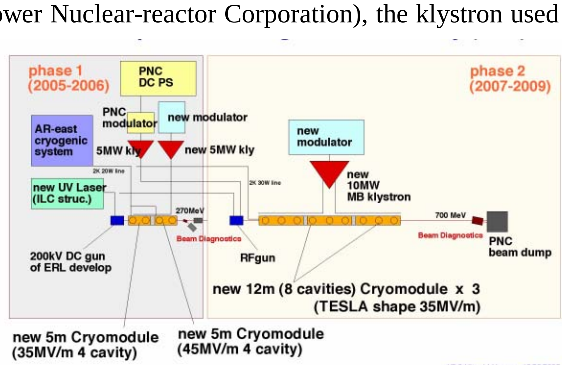

Figure 1: STF layout.

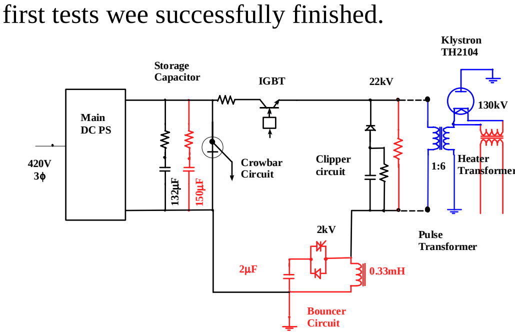

Figure 2: Block diagram of the revised modulator. Red parts are newly added and blue parts are modified.

MODULATOR

As described in previous section, the first modulator was reformed from the PNC modulator, to start quickly and reduce the budget. Since it was originally designed for the modulated anode type klystron, we changed to the modulator to drive a diode type klystron, and increased the storage capacitor from 132μF to 282μF in accordance with the increase of the pulse width. Increment of the capacity was not enough for the pulse flatness specification, and we added a bouncer circuit to improve the pulse sag. A pulse transformer was also revised from JHP one, which was originally designed for a 0.6 ms pulse width, to the STF one with a 1.7ms pulse width, by increasing the amount of cores from 24 to 39. Block

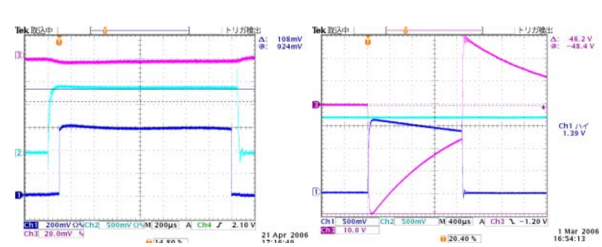

Figure 3: Current pulse waveforms with the bouncer circuit on (left blue) and off (right blue). Flatness was improved from 12% to +-0.4% in this case.

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diagram of the modulator is shown in Fig. 2.

For the bouncer circuit, the technology of the bouncer circuit was established well at DESY-TTF, while we have a first time to employ it in Japan. After the first operating test, we added a bouncer circuit and investigated the performance of the bouncer circuit. Sags of the voltage and current pulse for a pulse width of 1.7ms were improved from 12% to +-0.8% by changing the trigger timing of the bouncer circuit[3]. Figure 3 shows the waveforms of the bouncer circuit and the relation between the flatness and the bouncer trigger timing. The sag of the rf pulse was greatly improved from 70% to +-4% at the operation point of 2MW output power from the Thales 2104A klystron. It may be expected smaller rf sag at the higher voltage operation point. So the bouncer modulator was operated successfully for the first proto-type.

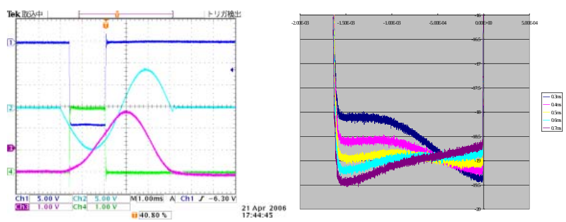

Figure 4: Left figure shows the pulse waveform (blue), bouncer voltage waveform (light blue) and bouncer current waveform(red). Right figure shows the variation of the flatness with the change of the timing of a bouncer trigger.

For this modulator, double protection circuits were employed to prevent from the failure of the klystron when the load was shorted. Though the original PNC modulator had a crowbar circuit, we didn't want to operate the crowbar circuit frequently when the klystron needed the processing to increase the pulse width. We introduced the fast switch-off circuit of the IGBT when the over-current was detected. There were two threshold levels to sense the over-current of the load. Lower threshold was for the IGBT switch-off and the next one, slightly higher than the first, was for the crowbar circuit. Active trigger time was set from the requirement that the power dissipation in the tube should be less than 30J. This trial forced us to decrease the maximum applied voltage to the klystron. For the original 36 stages of IGBT, the maximum available voltage was 120kV and the output power from the klystron was less than 3.5MW. Now we are planning to increase 4 IGBT stages to raise the voltage.

In FY2006, we started to construct the second modulator. Though the first modulator comprised separate cabinets of devices, a new one was a similar type built by FNAL and PPT in DESY-TTF. This modulator has a capability to operate both a 5-MW klystron and a 10-MW MBK. The step-up ratio of a pulse transformer is slightly different from the BCD of ILC. We chose 1:15 instead of 1:12 for using the lower voltage IGBT. A bid was finished and it will be delivered to KEK in the beginning of 2007.

HIGH POWER KLYSTRON

Thales TH2104A, which was once used in JHP, was tested with short pulse in 2005 and confirmed its performance up to a 5-MW output, since the central frequency of the tube is slightly lower such as 1.296 GHz. After the completion of modulator, it was processed up to 120kV with a pulse width of 1.7ms and a 5-pps repetition, since Thales had processed up to a 0.5ms pulse width due to their modulator limitation. RF processing has not yet been completed up to 5 MW with a 1.5ms pulse width due to the shortage of the voltage as described in previous section. In FY 2005, we purchased another Thales klystron TH2104C as the backup tube. For MBK, which was developed in TTF of DESY, one will be purchased by US-Japan collaboration, while the test will be performed in USA.

WAVEGUIDE SYSTEM

We have constructed the waveguide system for the klystron test and the coupler tests in the spring of 2006. Figure 5 shows the photo of the test stand. As shown in Fig. 6, the waveguide system has four distributing lines by changing the u-link waveguide: a line from the klystron to a high power water load, two individual lines to have coupler tests performed by two groups, and a line from the klystron to the cryomodule, which will be set in the basement tunnel of the STF building. At the beginning of the rf test, we suffered the frequent arcing and the leakage of rf due to the poor contact between the flanges, since the specifications of the PNC waveguide flange were to use the combination of CPR650F and CPR650G. Some cases we used the flat contactors between the flat flanges, which Thales recommended. SF6 gas was filled in the waveguide from the klystron to the window after a 5-MW circulator to protect the klystron window.

Coupler tests of two independent groups were performed in the middle of 2006. One had the power transmission test of 300 kW and another had the power transmission test of 2 MW and the full reflection of 500-

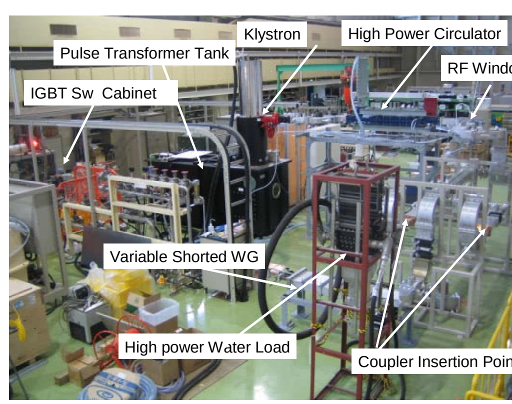

Figure 5: Picture of the STF rf test stand.

kW power. During these tests, klystron vacuum trip and the output adjustment due to the poor gain were encountered, since the operational voltage level is not the optimum position for TH2104A. Power drift was also observed since an LLRF digital feedback system was not completed at that time.

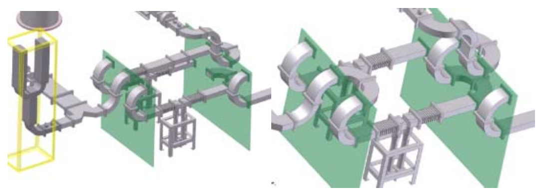

Figure 6: Examples of the waveguide system. Left shows the power distribution from the klystron to the water load. Right shows the power distribution for the coupler test.

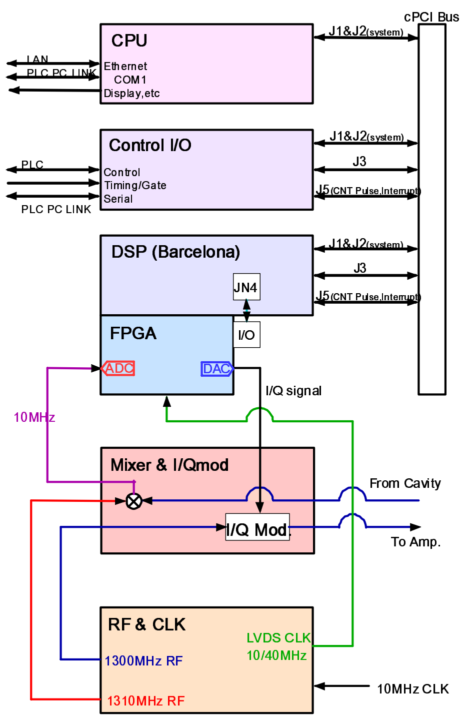

Figure 7: Block diagram of the digital LLRF control system for STF.

Power distribution system will be constructed from klystron gallery to the cryomodule in the basement tunnel in the end of this year. We are planning to have two kinds of power distribution: TTF like linear power distribution and tree like distribution using 3dB hybrids [2]. We use circulators for all cavities at first, however, the performance test without the circulator are also planed. In this Phase-I plan, the beam acceleration is also included and this is a good chance for rf source to evaluate alternative power distribution proposed in ILC-GDE.

LLRF

LLRF analogue system including an oscillator, a klystron drive amplifier, a high power protection and an rf monitor were completed and used for the high power testing of the klystron and couplers. Since the accelerating electric field of 0.3 % (rms) in amplitude and 0.3 degree (rms) in phase are required in STF Phase-I, the digital LLRLF control system using FPGA was adopted to satisfy these requirements. The components required for the digital LLRF system have been developed and their performances have been evaluated using the cavity simulator [4]. Figure 7 shows the block diagram of the digital LLRF control system of STF. This hardware has been completed. Total performance test of the digital LLRF system will be carried out in the autumn of 2006.

R&D

We have been preceding some R&D works for STF and ILC. One is to develop a 10-MW multi-beam klystron, which is used in lower voltage such as 50kV, to eliminate a pulse transformer, which is expensive and a big volume. This MBK has 36 beams. It comprises six guns which have six beam-lets. This was developed under the collaboration of KEK and Russian scientists in BINP. In FY 2006, 1/6 of this tube will be manufactured and to be evaluated.

Another R&D is to develop the waveguide components such as the phase shifter and hybrid, to seek the cheaper power distribution.

SUMMARY

The STF plan in KEK has been developed from 2005 to 2006. First rf source was completed and started to operate the klystron and have coupler tests. We obtained a good result of the modulator with a bouncer circuit, and successfully decreased the sag of the pulse flat top. Coupler tests have been successfully under going. LLRF are progressed and the total performance test will be carried out soon. Operation of the STF rf test and beam acceleration will be scheduled in the spring of 2007 and rf source are under preparing for this schedule.

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