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

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Abstract

After ITRP's technical choice, KEK tried to seek contributions for the international linear collider and made a plan for the super-conducting test facility (STF) at KEK. STF comprised phase-I and phase-II; the former is a plan for two years from FY2005, and is aimed at the quick construction of a test facility to evaluate 4-35MV/m cavity structures and 4-45 MV/m cavity structures with a beam. Phase-II is the next plan of the test facility to extend two 16m cryomodules. In this paper, a general description of the STF is made, and the rf source plan is described.

INTRODUCTION

Since ITRP chose the ILC accelerator technology over cold technology, KEK determined to explore the superconducting accelerator. Fortunately KEK has been involved in many superconducting structures, including the KEKB rf cavities and the JPARC high-beta proton accelerator structures. KEK made an action plan to build the superconducting test facility (STF) at KEK; this plan was reported at the ILC WS held at KEK in the fall of 2004[1]. This plan includes Phase-I and Phase-II, as shown schematically in Fig. 1. In the Phase-I project, two 5-m long cryomodules, comprising a 4-cavity structure having a 35MV/m gradient and a 4-cavity structure having a 45MV/m gradient, and an rf (or dc) gun will be constructed from FY2005 to FY2006. In phase-II, two full-size (16m) cryomodules with 10 cavities will be constructed from FY2007 to FY2009. Both phases include beam acceleration to evaluate the total linac system. This STF will be constructed in a vacant area of the Proton Linac Building of JPARC with the cryogenic system, a cavity processing area having a clean room for EP, HPR, anneal, and tuning cold mass assembly, and a cryomodule assembling area. This building has a 94-m long tunnel, which is long enough to install the structures shown in Fig.1.

Two rf sources are to be installed in phase-I. One will be manufactured in FY 2005 and used for a coupler evaluation using the 5-MW klystron, and then planed to be used in the RF-gun. Another is aimed for the rf source of the two 5-m long cryomodules using the 5-MW klystron. In phase-II, a full version of the rf source using the 10-MW multi-beam klystron for two 16-m long cryomodules is intended. Beam tests will be scheduled in December of 2005 and 2007, and then LLRF will be the key technology to achieve stable operation utilizing digital feedback. The rf group staff members of the KEKB injector linac are in charge of constructing the STF rf source of phase-I. International collaboration, especially Asian collaboration, will be strongly desired for the development of phase-II.

RF SOURCE OF PHASE-I

The first rf source of Phase-I, including the klystron, modulator, power distribution system (PDS) and low-level rf system (LLRF), are required to be operated until the fall of 2005 to evaluate couplers being used in the superconducting cavities. The quick preparation obliged us to "recycle" the existing rf properties of KEK as much as possible with a proper reform. One resource is the

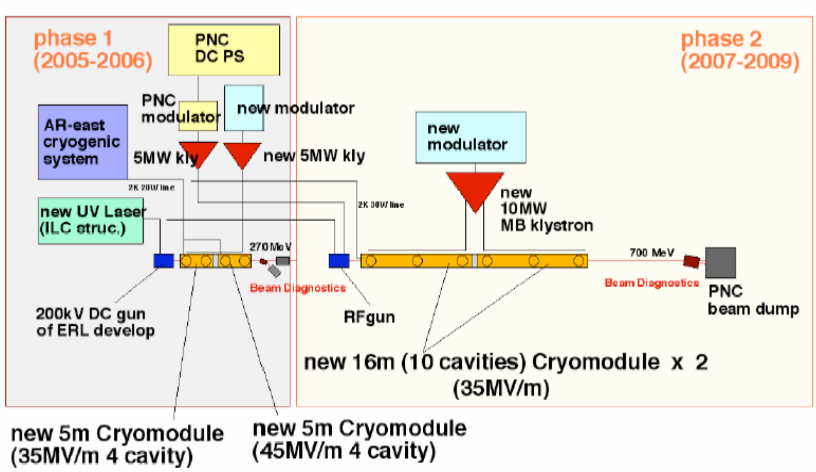

Figure 1: Phase-I and phase-II plans of KEK-STF.

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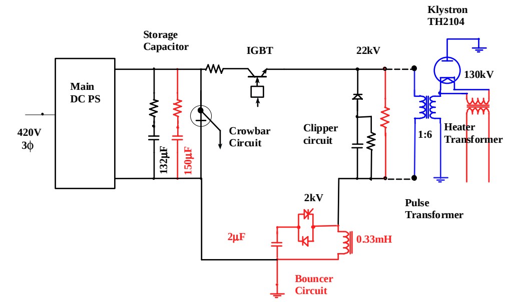

Figure 2: Block diagram of modified modulator. Red shows new parts, blue shows revised parts.

properties of the Japanese Hadron Project (JHP), developed more than 10 years ago, including a 5-MW klystron, a pulse transformer and a driving amplifier [2]. Another resource is the properties transferred from Power Nuclear-reactor Corporation (PNC), including modulator and various waveguide components [3]. The second rf source of Phase-I will be newly manufactured to mate with the specifications of a 10-MW multi-beam klystron. The scheme of the second rf source may have similar specifications and design as that of the present TESLA module [4]. A more optimised and individually designed rf system will be expected for the rf source of Phase-II, which is competent for the ILC project. Table 1 lists three modulators and the will-be used klystrons.

Modulator

As described before, two modulators will be made for STF phase-I. In FY2005, we will modify the PNC modulator to start quickly and reduce the budget. The PNC modulator has three modes (60kV cw mode, 90kV 4ms pulse mode and 140kV 100 μs mode) for the klystron with a modulation anode, and it is necessary to change many parts of the circuits. A block diagram is shown in Fig. 2. A DC power supply, a crowbar and IGBTs are kept using in this revised modulator. Storage capacitors are reinforced and a bouncer circuit is added. Pulse transformer has been revised from the one used in JHP, since its pulse width was 600μs. The old one is shown in Fig. 3. Cores are added to mate with the pulse

Table 1: Specifications of Modulator

Item	Unit			
Modulator No		Phase-I-1	Phase-I-2	Phase-II
Klystron		TH2104A	TH2104C	MBK
Klystron applied voltage	kV	140	130	115
Klystron beam current	A	107	96	132
Pulse width(70%-70%)	ms	1700	1700	1700
Rise time	ms	200	200	200
Pulse flat top(90%-90%)	ms	1370	1370	1370
Flatness within pulse duratio	%	0.5	0.5	0.5
Repititiom	Hz	5	5	5
duty		0.0085	0.0085	0.0085
Step-up Ratio of PT		1 : 6	1:12	1:12
Pimary Voltage	kV	23.3	10.8	9.58
Primary Current	A	642	1152	1584
Primary Impedance	Ω	36	9.4	6.05
Peak Power of Modulator	MW	15	12.5	15.2
Average Power of Modulator	kW	128	106	129

Figure 3: Pulse-transformer of JHP is modified for STF. waveform shows the forward travelling wave.

width of 1.7ms. Recycling of the old pulse transformer results in the bigger size than the one which is optimally designed. A step-up ratio is 1 to 6, since the primary voltage is 22kV in the PNC circuit. In FY2006, a new modulator will be made; this specification corresponds to the 10-MW MBK klystron. This design was also started in FY2005.

Klystron

Two Klystrons will be used as the RF source of STF phase-1. One is the TH2104A, which was once used at the test station of JHP (shown in Fig. 4) [2]. It was purchased more than 10 years ago, and a short pulse test will soon performed as an acceptance test, since it was operated at a frequency of 1.296 GHz. Another is the TH2104C, which will be delivered in the autumn in 2005. The output powers of both tubes are 5MW.

Figure 4: Existing klystron TH2104A (left) and high power water load in test stand (right).

Power Distribution System

The power distribution system of Phase-I uses 2 different schemes, as shown in Fig. 5. A serial power-dividing scheme using identical 3-dB hybrids is employed to cryomodule-1, since we have many existing 3-dB hybrids. It is interesting to investigate the possibility to use identical hybrids in the system. Investigating the crosstalk among the 2 output ports of the hybrid is another item to be studied when the small circulators are eliminated. The linear distribution system used in the TESLA is used in cryomodule-2. In this case, we have a plan to use a hybrid design similar to that of Kazakov's proposal in the X-band SLED from a manufacturing advantage. In order to protect the klystron from any large reflected rf power, a 5-MW circulator of the Ferrite Corp. will be installed. At first, a 5-MW line is filled with SF6 gas, but the possibility to use air is an important testing item. At phase-I, although the existing waveguide components will be utilized, including the water load, more suitable waveguide components will be considered and designed for the next phase-II and ILC.

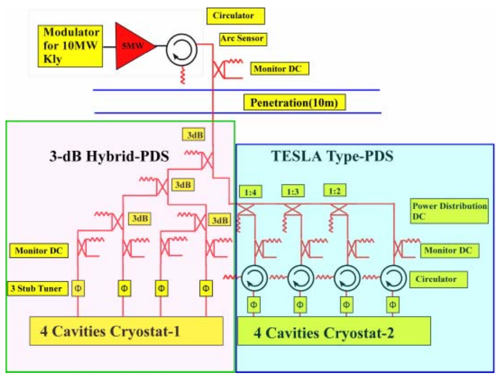

Figure 5: Plan of power distribution system for STF.

LLRF

For the coupler test scheduled for fall of 2005, LLRF composes the minimum system with a master oscillator and a 300W amplifier, which was used in JHP. A protection system for the VSWR and an arc sensor are equipped. At the same time, a digital LLRF system will be developed with cavity simulators. Four cavity simulators are utilized for software development. Since a beam test is scheduled for December, 2006, LLRF employing a digital feedback system is required for the commissioning. Figure 6 shows a block diagram of the LLRF. KEK has been developing the digital feedback LLRF in the J-PARC linac, of which the frequency is 324 MHz. Making use of this experience is efficient and useful to develop it in a short period. As shown in Fig. 7, the technical flow of developing the LLRF digital feedback system is in three steps. For a compact PCI system, an RF clock, a mixer and an IQ-modulator are modified from J-PARC LLRF. Control IO and DSP are based on J-PARC LLRF. Since the numbers of cavities controlled are deferent, FFGA boards have been newly manufactured. The preliminary achieving goal of the amplitude and phase stability are +-0.1% or +-0.1 deg., respectively [5].

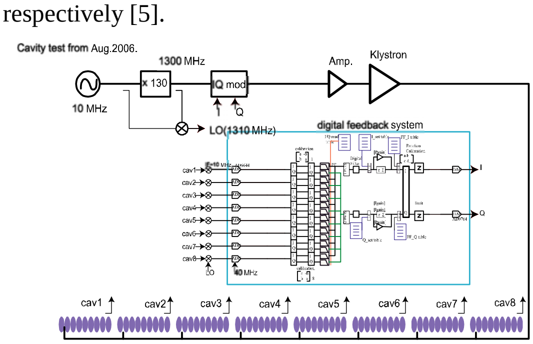

Figure 6: Block diagram of LLRF.

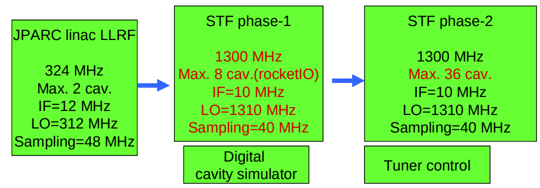

Figure 7: Technical flow of LLRF from J-PARC to STF.

RF SOURCE OF PHASE-II

After commissioning of the phase-I project, though there is an ambiguity in the budget, we expect to proceed to the phase-II project, which comprises two 16-m cryomodules that have 10 cavities each. The main purposes for phase–II are full evaluations of the construction and operation of super conducting structures. For an rf source of phase-II, a new 10-MW multi-beam klystron will be employed. Furthermore, it will be necessary to re-consider the TESLA-type rf source. For example, the cost of a pulse transformer in the modulator is about 25% and the amount of insulation oil is not favourable to be used in the long ILC tunnel. Modulator and klystron schemes may have a room to re-consider. These are important issues to be considered during phase-I construction.

SUMMARY

The STF plan in KEK started from FY2005, and two cryomodules with a 4-cavities 35MV/m and a 4-cavities 45MV/m will be developed for 2 years. For this phase-I project, two rf sources are to be fabricated. One is being manufactured utilizing the existing properties, such as the modulator, the pulse transformer, the klystron and waveguide components, to start the couplers test quickly. Another is being designed. Since a beam test is scheduled for December, 2006, a high performance including the digital feed-back in LLRF is required. After phase-I commissioning, we expect to start the next phase-II project.

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