SCRF TEST FACILITIES TOWARD THE ILC*

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Abstract

Since the ICFA selection of the superconducting linear collider technology in August 2004, many intensive ILC R&D programs are in the planning stage, or already underway; North America (ILCTA), Asia (STF), and Europe(TTF). In this paper, the global activities represented by the superconducting RF test facility will be reviewed. Their goals, schedules and possible complementarities will be presented. The performance expected from the different R&D efforts by 2009, or the corresponding contribution to the ILC Technical Design Report, will be especially emphasized.

INTRODUCTION

A technology based on superconducting RF (SRF) was selected at the ICFA meeting for the linear collider on August 2004, which was recommended from ITRP (International Technology Recommendation Panel). In this meeting, ICFA named the proposed linear collider the ILC (International Linear Collider). The GDE (global design effort) was formed as the ILC international design team on May 2005. ILC global R&D programs have been started in three regions. In this paper, the global activities represented by the superconducting RF test facilities will be reviewed.

ILC BASE DESIGN

ILC baseline design parameters were discussed at the ILC 2nd workshop in Snowmass in August 2005. The parameter package is called the ILC BCD (Baseline configuration design). It was finally completed at the last GDE meeting in Bangalore on March 2006. The result is listed in Table 1, which emphasizes cryomodule parameters.

SRF TEST FACILITIES TOWARDS ILC

To date, there are three SRF test facilities for the ILC R&D underway or in planning stage. DESY originally completed the TTF (TESLA Test Facility) for TESLA R&D during 1995 - 2005. They are upgrading it now for the XFEL pilot facility. FNAL is constructing an ILC test accelerator (ILCTA). KEK also has started an ILC R&D program and is building a superconducting test facility (STF).

Table 1: ILC Baseline Parameters

ILC parameters related to cryomodule		BCD: Baseline	ACD: Alternative
Cavity shape		TESLA	Low loss Reentrant
Cavity Acceptance Performance	Gradient [MV/m]	35	40
	Qo	0.8E10	0.8E10
Cavity operation performance	Gradient [MV/m]	31.5	36
	Qo	1.0E10	1.0E10
Cryomodule CM	Type	Type-IV	
	Number of cavity in one CM	8	8

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TTF

DESY has long term R&D experience with SRF linac in the TESLA collaboration since 1990. They built the TTF (later upgraded TTF-II) at the DESY site. This facility includes both BCP (buffered chemical polishing) and EP(electropolishing) cavity surface preparation (Fig.1 left), cavity clean-room assembly, vertical test, horizontal high power test with single 9-cell cavity, cavity string assembly (Fig1 right), cryomodule assembly (Fig.2), and the test linac (Fig.3). In addition, they recently built a cryomodule test facility. They have accumulated experience on the SRF cryomodule technology, tested cavity performance, and investigated beam quality for TESLA and XFEL. TTF demonstrated not only cavity performance but also the machine performance. However, after the ICFA decision DESY changed direction from the ILC to the EURO XFEL project, due to German policy. The finance of the EURO XFEL is almost ready. The construction phase wilt start in 2007 and the beam commissioning will be from the middle of 2011[1].

Figure 1: EP facility in TTF (left), Cavity String Assembly (right)

Figure 2: Cryomodule assembly facility in TTF

TTF contributions to ILC R&D

DESY must now concentrate on EURO XFEL project. Most of DESY activities will be directed to this. Even in this situation, where the TTF will be kept and operated as a unique pilot VUV-FEL facility, the TTF may offer up to ~30% of the machine time for ILC studies. For ILC R&D, this unique beam facility is very important for studies such as HOM beam position monitor, long term linac operation, and so on [2].

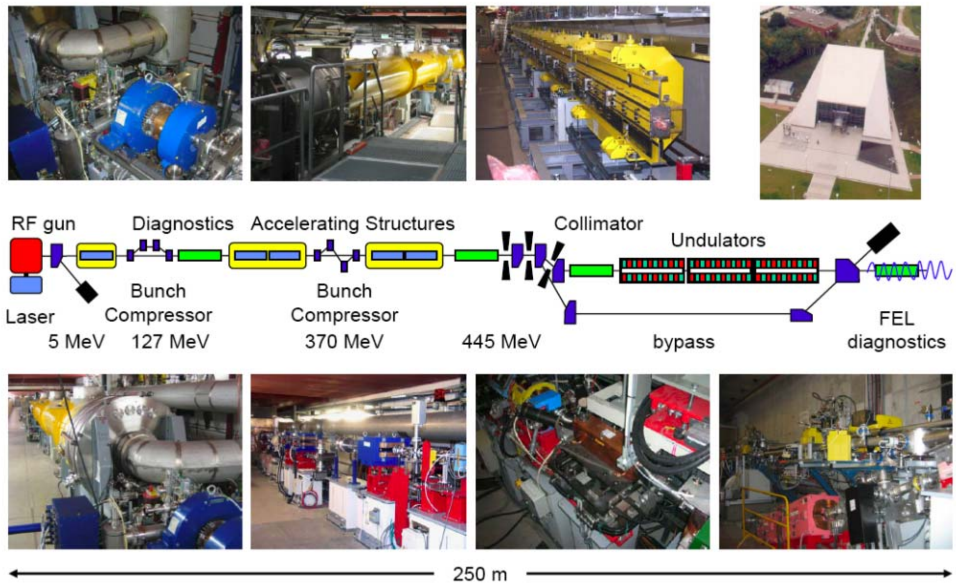

Figure 3: TTF superconducting linac in DESY (Courtesy DESY)

The cryostat design is different in the EURO XFEL(Type-III+) and ILC(Type-IV). However, so far TTF is only the place with ongoing cryomodule fabrication, assembly and testing. In May-June 2006, they assembled the TTF module M#6, which is intended to demonstrate 35MV/m operation in the linac (Fig.4); the TPR R1 issue. At this, they invited company people and many foreign colleagues to see the real module assemble process. The TTF is very important for cryomodule studies. The demonstration of 35MV/m operation itself is the highest priority R&D issue for the ILC. The Piezo fast tuning also will be tested in this program, also a very important issue with the ILC. The BCD of the high power input coupler is the TTF-III type. LAL-Orsay has responsibility for the fabrication and DESY is making its high power test for EURO XFEL. Currently they have succeeded in reducing coupler processing time to ~15 hr, originally it took 100-120 hr.

EURO XFEL cavity performance is not identical to that of ILC. The operation gradient is 23MV/m (max. 28MV/m) in EURO XFEL and 31.5MV/m (max. 35MV/m) in ILC. DESY current state of art with cavity fabrication satisfies the EURO XFEL specification. Their next first priority is to transfer the technology to industries.

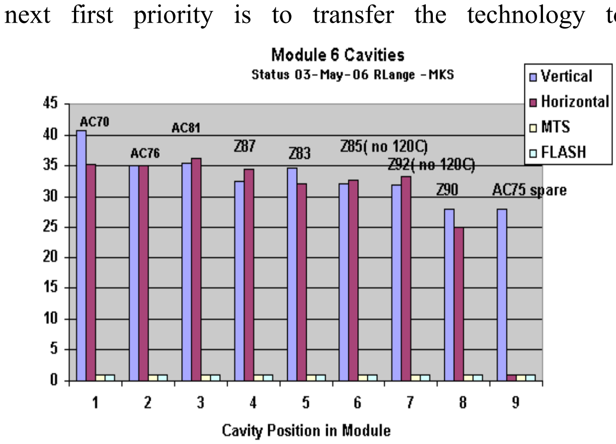

Figure 4: 35MV/m cryomodule

The RF distribution systems are also different. One 5MW klystron drives 32 cavities in EURO XFEL, and one 10MW klystron supplies RF power to 24 cavities in ILC. TTF has a long term R&D experience of 10MW klystron development for TESLA with companies: Thales, CPI and Toshiba. Recently Toshiba has successfully developed a vertical 10MW klystron with KEK help. ILC and EURO XFEL both need horizontal klystrons. Its R&D will be continued by DESY.

ILCTA (SMTF)

As mentioned above, TTF will now primarily be a VUV-FEL facility. ILC has to build a test facility with sufficient scale to demonstrate the specified machine performance before the real construction can begin. FNAL is forming a central Lab for ILC R&D in USA. They are building a superconducting module test facility on the site: SMTF (later the name changed to ILCTA :ILC test accelerator), refurbishin their old facilities like FNAL New Muon Lab (ILCTA NM), Industrial Building 1 (IB1), and Meson Detector Building (MDB), and so on [3].

Goals and schedule of the ILCTA: The goals of ILCTA include three items[4];

1) Vertical and horizontal test of cavities,
2) Test of cryomodules,
3) Beam based measurement.

The first goal is to determine the maximum operation gradient of each cavity, evaluate gradient spread, Qo and their operation implications, and measure dark currents, cryogenic load, and radiation level. A vertical test stand will be built in ILCTA IB1 in FY2007, which is equipped with a large refrigerator capable of 60W at 1.8K for superconducting magnet originally. Horizontal test system (HTS) is also under design for both ILCTA IB1 and ILCTA MDB. MDB has an existing 1800W @ 4K refrigerator, and it will be upgraded to supply 60W of

Figure 5: ILCTA building in FNAL (left), The Emptied MDB (right top), Cryomodule assembly tools from INFN (right bottom)

1.8K refrigeration for the HTS. Both HTSs will be constructed by FY2007.

In the second goal, they will measure gradient of cavity in cryomodule and investigate vibration of components, system trip rates & recovery time. By FY2009, an ILC cryomodule test facility will be completed in ILCTA NM, where will be installed one ILC RF unit (3 cryomodules, modulator, one 10MW klystron, LLRF, etc) as seen Fig.6. A clean-room has been constructed in MDB for the cavity string assembly.

FNAL expects to get the first cryomodule end of 2006 from DESY[5]. Eight dressed cavities will be provided from DESY with this module. The cold mass (Type-III+) is to be provided from DESY/INFN and delivered to FNAL by October 2006. The cryomodule assemble will be done in FNAL by March 2007. The second cryomodule will include 8 cavities with standard length. The cold mass will be ordered by FNAL from Zanon in Italy. Cavities will be purchased by FNAL, vertical tested first at Cornell with BCP, and secondly at Jlab with EP. The dressing and horizontal test will be done at FNAL. The cryomodule assembly will be done by December 2007 in FNAL CAF. The third one will install ILC length cavities. The cold mass (Type-VI) will be ordered from a US company. FNAL will purchase the cavities from an US company: Advanced Energy Systems. Surface treatment will be done using the joint ANL/FNAL superconducting surface processing facility (SCSPF) with both BCP and EP, which is now under construction in ANL site. Dressing and horizontal test will be done in

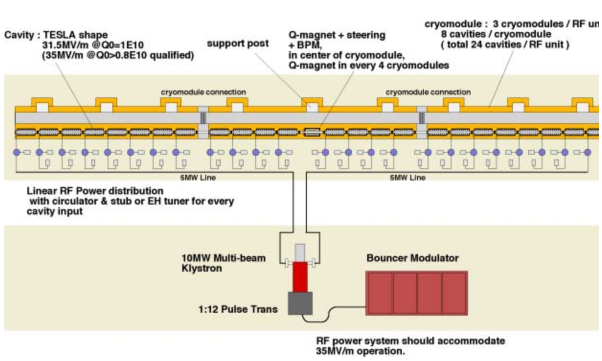

Figure 6: ILC one RF unit installed in the ILCTA

FNAL. The module assemble will be completed in ILCTA-CAF by Middle of 2008. The ILC cryostat design Type-VI will modify the Type-III+ due to the different superconducting-Quad location in the module (moved from the end to the centre) and the changed cavity separation (from 344mm to 283mm). ILC international cryo-design team is re-designing it.

Cornell University

Cornell has responsibility for BCP and its vertical test with the second module cavities. They have already set up new BCP facility and HPR systems in their Lab. Cornell is ready to start the program[5].

Jlab

The ILC gradient (35MV/m as accepted) is too high for BCP cavity made from polycrystalline niobium material (ILC BCD). EP technology is needed for such a high gradient performance. Jlab has responsibility for EP development. Originally they bought a KEK type EP system (Fig.7) from Nomura Plating in Japan for the SNS project, but it was not used because BCP satisfied the SNS specification (Eacc ~10MV/m). They have re-started EP using this system. Jlab has the best vertical test facility in the world, it was initially built for CEBAF cavities development.

Large grain or single crystal niobium material is an alternative issue in ILC. Such material is produced by direct cutting from a niobium ingot, like silicon wafer production. This can simplify the current niobium sheet production; it eliminates forging, rolling etc. This could blead to a cost reduction for niobium material. It has another merit, namely, to increase reliability for cavity performance. In addition, BCP could achieve the high gradient Eacc > 35MV/m using such the material. Jlab has responsibility for the large grain /single crystal cavity R&D. Promising results have been reported by P.Kneisel with single cell cavities[5].

Figure 7: EP system in Jlab

ANLFNAL has a plan for a surface facility with both BCP and EP. This program is a collaboration between ANL and FNAL. They are constructing the joint FNAL/ANL superconducting surface processing facility (SCSP) in ANL site, located 50km from FNAL. FNAL will bring cavities from ANL for assembly after surface treatment.

STF

After the ILC 1st workshop, KEK started superconducting ILC R&D [6]. KEK also saw a need for a superconducting RF test facility; the STF. They decided to build it in the existing J-PARC Linac R&D Building, which was emptied in summer of 2005. This building has a 90m tunnel in its underground basement.

Goals of STF and the schedule

Two groups are working in parallel on ILC cavity package R&D in KEK; 35MV/m STF baseline and 45MV/m high gradient. The baseline group has responsibility to develop the 35MV/m TESLA-like cavity mechanically stiffer at the Helium base plates, 350kW high power input coupler, and ~500kHz range tuner system (slow and fast). High gradient team is similar but the gradient is 45MV/m with LL shape, coupler 500kW @ 45MV/m, and wide range (3kHz @ 45MV/m) tuner. The goals of STF are;

1) to establish the industrial design of the ILC linac unit for the accelerating gradient, both for the baseline value of 35MV/m and the higher value of 45MV/m,
2) to advance the Asia/Japanese industrial level for IL component production,
3) to form an Asian base for international collaboration,
4) to enlist and educate newcomers to the field.

STF project consists of two phases, Phase I (2005-2007) and Phase II (2007-2009). The layout plan is shown schematically in Fig.8. The STF entrance hatch into the tunnel is too small to pass an ILC type 12m long cryomodule. In the Phase I, two modules 5m long will be assembled on the ground floor in the STF building. Then, they will be connected together to form one long module in the tunnel. One short module will include four 35MV/m TESLA-like baseline cavities. The other will include two or four 45MV/m LL shape 9-cell cavities; so called ICHIRO cavity. These module assemblies will be done on October 2006. These two cryostats have already been delivered to KEK.

On the ground level, the RF source and cryogenics system (mostly recycled) have been installed. The RF source has started operation at 2MW from middle of May 2006 for high power processing of both input couplers for 35MV/m and 45MV/m cavities. High gradient group is developing coaxial capacitive coupler for ICHIRO cavities, which has succeeded to handle a 1-2MW power @ 1.5 msec on middle of June 2006 after 15 hr processing. The operation of the STF-I linac is scheduled to start on December 2006.

On the ground level of the STF building, a new EP facility, HPR system, clean-room for cavity string assembly, and cryomodule assembly are to be constructed. The clean-room was already completed on end of March 2006 (Fig.9). Ultra-pure water system will be equipped by the end of July 2006. HPR system will be connected to the clean-room in August 2006. EP facility will be build by the end of March 2007.

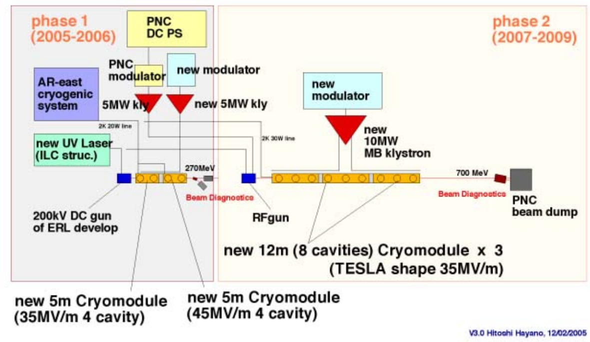

Figure 8: Superconducting Test Facility (STS) Plan in KEK

STF Phase-II

STF-II is planed tobe in operation from 2007 to 2009. In this program an RF unit will be installed in the STF tunnel. The cavity shape will be decided in 2006. This is for full demonstration of 35(31.5)MV/m cavity operation in the linac with beam. This program is an opportunity for the industrialization in Japan/Asia.

ARE2ndEX @ KEK

AR East 2nd experimental hall (ARE2ndEX) is another central facility in KEK/Asia for ILC activity. This building is equipping with a centrifugal barrel polishing machine (CBP), pure water production system, HPR system, class 10 clean-room, and vertical test facility. In this facility components for SRF technology (e.g. high gradient single cell cavity) have been developed since 1992. Both the STF baseline and high gradient teams are using this facility for 9-cell cavity vertical tests. So far, the performance is limited to around 20MV/m by multipacting (MP) with the baseline cavity, and 30MV/m with the ICHIRO 9-cell cavity due to MP at the enlarged beam tube.

The high gradient R&D group is performing many of single cell cavity test also. They have demonstrated the high gradient performance ~50MV/m by new shapes; LL

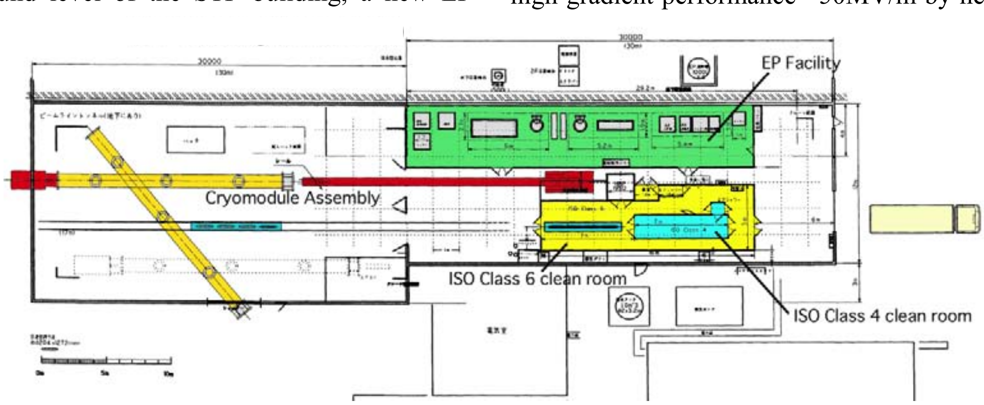

Figure 9: Planed EP, String assembly, and Cryomodule assembly facility on the ground level in the STF building

and Reentrant [7]. They demonstrated that the reproducibility of 45MV/m is 50% in the first tight loop study with their recipe, using 6 virgin single cell cavities. They also performed a study to understand other 50% failure rate. The failure is due to surface contamination, most likely sulphur in the EP acid or unsaturated oxidation on the niobium surface. They proved this in a pilot study for a new surface preparation recipe [8]. They have scheduled another tight loop study with the new recipe to be completed by the next TESLA collaboration meeting at KEK in September 2006. This program could contribute very much to the high priority high gradient issue for the ILC.

The high gradient group is also performing a tuner test in this facility. Note that ILC has no BCD tuner at present. KEK has proposed a coaxial ball tuner for the ICHIRO cavity. At room temperature, they demonstrated the 3kHz wide tuneability with Piezo. They are testing the performance at LN_2 temperature.

EXPECTED OUTCOME TILL ILC TDR

A summary of these representative ILC R&D facilities is given in Table 2. This shows what kind of facilities are ready where and by when. The issues to be resolved by the ILC TDR (Technical Design Report) are listed in connection with SRF technical issues. The urgent issues in EURO XFEL; 10MW horizontal klystron and industrialization of SRF technology could be completed by 2008 by DESY initiative. The 31.5MV/m operation should be demonstrated at TTF in 2006-2007. the tuner and Input coupler should be realized 2006-2008 in TTF and STF. The gradient issue, the highest priority now for ILC, should be settled by STF and ILCTA initiatives in 2008-2009. Large grain niobium cavity will be ready by 2008 in ILCTA and TTF.

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Table 2 Summary of ILC Test Facilities

		TTF (DESY)	ILCTA (FNAL)	STF (KEK)
Acceptance test (Vertical test)	EP Facility	OK	2007 @ ILCTA(ANL)	March 2007 @ STF
			OK @ Jlab	OK @ KEK/NP
	HPR	OK	2007 @ ILCTA (ANL)	August 2006 @ STF
			OK @ Jlab, Cornell	OK @ NP and KEK
	Cavity Assembly	OK	2007 @ ILCTA	2007 @ STF
			OK @ Jlab, Cornell	OK ARE2nd EH (KEK)
	VT System	OK	2007 @ ILCTA	End 2007 @ STF
			OK @ Jlab, Cornell	OK ARE2ndEH (KEK)
Cryomodule Assembly	String Assembly	OK	End 2006 @ ILCTA	August 2006 @ STF (4 cavities) Upgraded, 2007 @ STF (8 cavities)
	Horizontal test	OK	2007 @ ILCAT	Under discussion
	CM Assembly	OK	December 2007 @ ILCTA	September 2006 @ STF (4 cavitie)
Cryomodule Test	OK		2009 @ ILCTA	NO Plan
Test Linac	OK		2009 @ ILCT	December 2006
Beam Test	OK		2009 @ ILCT	March 2007 (STF-I) 2008 (STF-II)
Cryomodule	M6 May 2006 (Type-III) M7 September 2006 (Type-II) M8 January 2007 (Type-III+) M9 early 2007 (Type-III+, for FNAL)		#1 March 2007(TTF-III+) #2 December 2007(TTF-VI) #3 Middle 2008(ILC type)	#1 September 2006 (for STF-I) #2 2009 (ILC type for STF-II)

Table 3: The Performance expected from ILC Test Facilities

	Issue	Needed Facilitey	Where and When
1) Gradient	35MV/m Qo=0.8E10, > 90% Yield(BCD) 40MV/m Qo=0.8E10, > 90%Yield (ACD)	VT	STF(07-08) ILCTA(07-09)
	31.5/35MV/m operation (BCD) 36/40MV/m operation (ACD)	LINAC	TTF(06-07) STF(07-09) ILCTA(08-09)
2) Preparaction Recipe	> 90% Yield	VT	TTF(06-07) STF(06-07)
3) Tuner	Piezo fast tuner,	LINAC	TTF(06-07) STF(07-09) ILCTA(07-09)
4) Input coupler	Processing time, Cost	Test stand / LINAC	TTF(06-07) STF(06-09) ILCTA(08-09)
5) Large grain Nb	Cost , BCP relalibity @ 35MV/m	VT	ILCTA(07-09)
6) 10MW Klystron	Horizontal, 10MW reliability	LINAC	TTF(07-08) STF(08-09) ILCTA(08-09)
7) Industrialization	Transfer SRF tech. to companies		TTF(06-08) STF(07-) ILCTA(07-)