STATUS OF THE RF SUPERCONDUCTIVITY ACTIVITIES AT DESY

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Abstract

At DESY one major activity in the field of RF superconductivity is the Tesla Test Facility (TTF) which has been designed, built, installed and operated by the international TESLA collaboration [1]. For phase 1 of TTF a linear test linac of about 120 m length was built and operated for several years. Since February 2000 the linac it is operational with the SASE FEL [2] . Activities have started to improve various components of the accelerator module. Elements like tuners, couplers and lay out of superconducting (s.c.) cavities are redesigned. The treatment and production sequences are improved. The goal of these activities is to improve the performance, the reliability and to achieve a further cost-reduction for the TESLA accelerator. An approved project at DESY is the conversion of TTF 1 to an FEL user facility (TTF2) with a total length of 300 m which will be realised in 2003.

1 INTRODUCTION

Within the international TESLA (TeV Energy Superconducting Linear Accelerator) collaboration the TESLA TEST FACILITY (TTF) was built and is in operation at DESY. The aim is to show the feasibility of a 500 GeV e^+e^- Linear Collider with an integrated X-Ray-Free Electron Laser (FEL). The acceleration of the electron beam is based on 9-cell superconducting accelerating L-band structures [3]. Presently two cryogenic modules, equipped with eight superconducting cavities each, are in operation. Two sections are equipped with instrumentation [2] for beam dynamic studies. To study the Self-Amplified Spontaneous Emission (SASE) FEL radiation in the range of 80–180 nm three undulator modules are installed within the beam-line. The SASE FEL experiment is operational since Feb. 2000 [4]. To upgrade TTF to a TTF FEL user facility (TTF 2) a total of 6 modules will be installed to reach the energy of 1GeV.

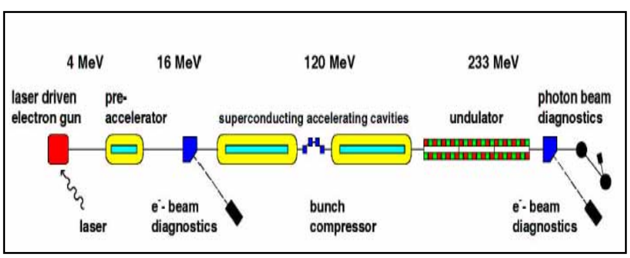

Figure 1: Schematics of the TTF linac (run 2000-2001)

One module for TTF2 will be equipped with cavities electro-polished (EP) by Nomura plating in co-operation with KEK. The technology for EP developed at KEK yields in acceleration gradients above 40 MV/m for single cell cavities. To demonstrate the benefit of EP for 9 cell cavities as well an EP infrastructure is under construction at DESY. Single cell and Multi-cell structures as well as the proposed double 9 cell superstructure [1] for TESLA will be polished here. For further cost reduction of the TESLA s.c. accelerators the so-called superstructures has been developed. A prototype superstructure consisting of two pairs of coupled 7 cell structures is under fabrication and will be tested with beam-load in 2002

2 STATUS

2.1 Linac

The TTF linac, set up with strong contributions of the members of the TELA collaboration, is operational for machine studies since 1997. Two cryogenic modules with a length of 12.2 m each, a bunch compressor, a pre-accelerator s.c cavity and a three-stage undulator are installed (Figure 1) [2]. With the actually installed laser driven injector a pulse train of 800 µs and the bunch charge of a TESLA pulse was generated and accelerated in the TTF linac. The linac with all its systems has been operated for approximately 9000 h [5].

2.2 SASE FEL at TTF

Since February 2000 the FEL section is operational and shows the spontaneous self-amplification effect [2].
With beam energies of 181-272 MeV laser wavelength of 80 - 181 nm are established [6] (Figure 2+3) and since September 2001 saturation of the SASE FEL has been shown [7].

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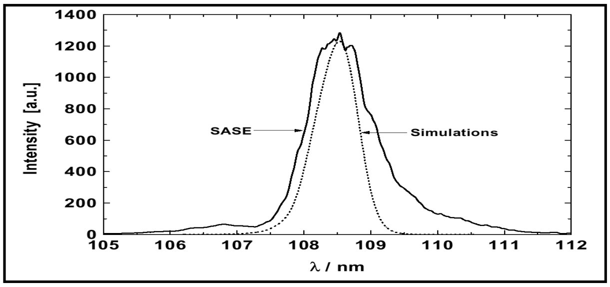

Figure 2: Distribution of the Sase FEL radiation Feb2000

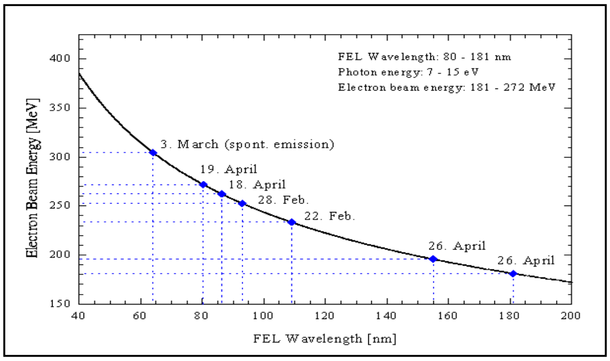

Figure 3: Spectrum of the SASE FEL measured in run 2000-2001

2.3 Cavities and Modules

Until 1998 a Niobium lip served as cavity sealing area (Type I). The flange assembly consisted of a Helicoflex (trademark) gasket, a sophisticated stainless steal split rings flange on the cavity side and the counter flanges. This system was the origin of particle contamination [8] and more than 40 % of the seals leaked during assembly and cold test. In the actual design (Type II) an Nb Ti flange is welded to the cavity. The vacuum gasket is made from solid rings of AlMgSi05 with diamond shape.

Figure 4: TTF standard cavity of Type II

In 105 final chemical treatment sequences, a total of 46 cavities were prepared for vertical and horizontal test's as well as for module assembly. Thirty one cavities were delivered since 1999. Six cavities fabricated under production lot 2 were made from Nb of different suppliers for qualification. They showed acceleration gradients of 22.8 MV/ m in average. No clear limitation, related to supplier, could be found.

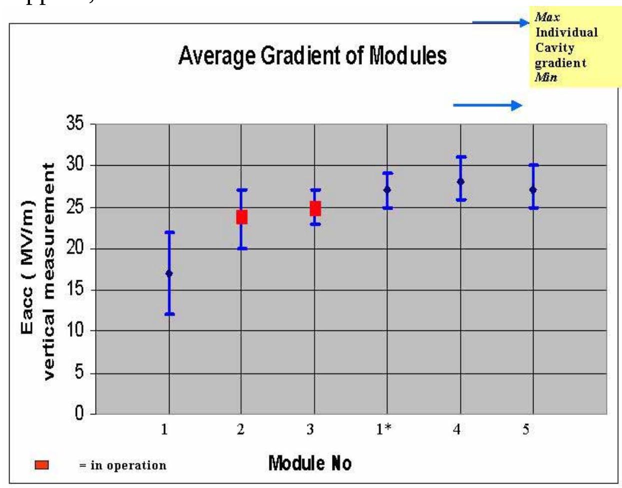

Figure 5: Acceleration gradient in TTF modules

The 24 cavities of lot 3 production are made from Niobium material of one supplier and fabricated with improved fabrication and treatment methods. An average gradient of 28.3 MV/m was measured on the 16 cavities tested up to now. Eighty percent of these cavities reached this gradient right after the first preparation. Four cavities were processed after a break down of the HPR stand and were limited by strong field emission .

No	Cavity Type	Module Type	Coupler Type	Status
1	I	1	FNAL/ DESY	Dismounted / leak on flanges
1*	II	1	FNAL	Read for installation
2	I	1	FNAL	In operation
3	II	1	TTF2	In operation
4	II	2	TTF2	Ready for installation
5	II	2	TTF3	Under preparation
6	II EP	2	To be decided	Parts Delivered
7	Super structure	1	To be decided	Parts Delivered

Table 1: Equipment and status of TTF modules

A new type of module was designed to reduce costs and to improve the filling factor. The outer diameter of the vacuum vessel is reduced from 1073 mm (module type 1) to 946 mm (module type 2) [9]. The 2 K Helium filling tube of Cavities in module type 2 is tilted by 33° with respect to the vertical orientation of filling lines in the original design. The cavities are connected to the 300mm He-return pipe by ball bearings at the connecting holder brackets in type 2 modules. An INVAR rod serves as fixed point for every cavity in these modules.

3 INFRASTRUCTURE OF TTF

3.1 Multibeam - Klystron

A prototype 10 MW TTF Klystron was developed in co-operation with the Thomson company. The tube with seven beams and two output windows, having a microperveance of 0.5 each, was commissioned in May 2000. Pulses of 1.5 ms, an output power of 10 MW as well as a gain factor of 48.2 dB and an efficiency of 65% were shown on that prototype tube. Up to now the tube has been used for about 1000 h of routine operation [10].

3.2 Cavity test facility

To study alternative fabrication and test methods, independent from the continuously running 9 cell cavity preparation, a test facility is being set up at DESY in Petra Hall NO. The infrastructure of the former 500 MHz cavity test area is modified and can handle cavities up to 3 cells of 1.3 GHz resonance frequency. A vertical cryostat for 1.8 K operation, a test insert designed for temperature mapping studies on cavities and a 200 W cw-operation RF-equipment are being installed. A class 100 cleanroom for assembly and a High Pressure Rinsing set up is operational. First successful cavity preparations have been made and qualified the cleanroom equipment for cavity studies.

3.3 Electro- polishing

In collaboration with KEK and Nomura plating in Japan the first 9 cell resonators for TTF were treated by electro-polishing (EP) successfully. They showed acceleration gradient of 30 and 32 MV/m in the first attempt. At DESY an electro-polishing facility is under construction. The application of EP in large-scale production and an optimum process for EP combined with cleanroom handling procedures of TTF will be studied. The polishing stand with a total length of 3.5 m [11,12] is of modular design and can handle mono-cell cavities as well as double 9 cell superstructures as proposed in the TDR [1]. The facility is located in an annex to the TTF cleanroom and will be operational in spring of 2002 .

3.4 Electron beam welding machine

Experiments showed that a vacuum of at least 10^{-5} mbar is necessary to retain the RRR of 250 in the weld region [13]. To study the influence of improved vacuum a new electron beam (EB) welding machine is set up at DESY. A welding chamber of 7 m^3 volume is designed for a total pressure in the 10^{-9} mbar range. All motors and gearboxes are located outside of the chamber. Via vacuum feed through the cavity can be positioned properly for welding. Two cryogenic pumps with 10 000 l/sec pumping speed each, intermediate pumping between O-ring seals on the large charging ports as well as metal gaskets on fixed vacuum connections are installed. A separate turbo-molecular pumping unit is installed on the gun. A standard 150 kV gun was modified. Vacuum connections and materials of solenoids are redesigned to minimize leakage and outgasing.

Figure 6: View on the EB welding machine at DESY

The chamber walls are made from electro-polished stainless steal. The vacuum chamber is housed in a heater jacket allowing heating of the chamber to 100 C before welding.

3.5 Database

All process data, assembly and test data are stored in an ORACLE-based database. To handle the data in- and output standardized window frames are programmed. Input windows show technical drawings with all necessary information on design values. Standardized forms have to be filled by operators. Measurements and data files like Q versus Eacc plots are automatically transferred to the database. A selection of output windows allow easy access to the data and provide overview information and analysis of data. In the future access to the database will be provided via Internet [14].

4 DEVELOPMENTS

4.1 Superstructure

Two pairs of double 7 cell superstructures will be tested and installed in the TTF linac in 2002 [15].

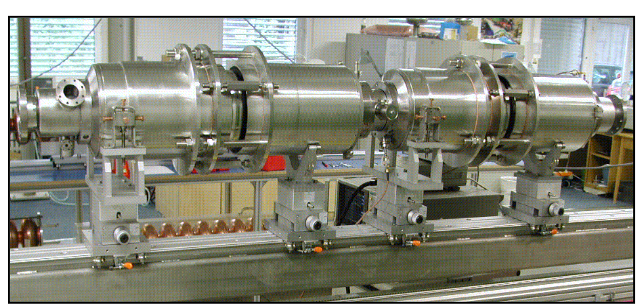

Figure 7: Two times 7 cell Superstructure on test bench

Due to the limited space of the TTF infrastructure the seven cell cavities have to be tested vertically in an RF test at 2 K separately before welding them to the superstructure. Six 7 cell resonators of 1.3 GHz resonance frequency have been delivered. Test assemblies and low level RF tests were successfully done on an assembly bench. For high power RF tests at 2 K a hat, made from Niobium, has to be adapted to the substructure cavity via a superconducting gasket. In the first system tests the resonators were limited at 16 MV/m an showed a strong Q switch. From mode measurements it can be concluded that the gasket area seems to be the origin of Q drop.

4.2 Tuners

One goal of TTF was to show gradients of 25 MV/m in s.c. resonators. The mechanics of tuners, designed and fabricated at SACLAY, is suitable to stabilize the cavities

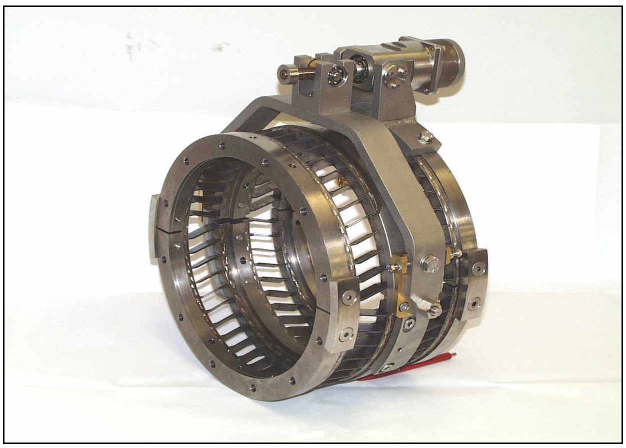

Figure 8: New Type of tuner for TTF (dog bone design)

against static Lorenz forces on that field level. For acceleration gradients of 35 MV/m, like foreseen for TESLA 800 [1] and for improved filling factor in modules a new tuner (dog bone tuner design) was manufactured. The tuner made from Titanium is located on the Helium tank. A rotation of a ring element results in changing of cavity length via elastic deformation of titanium blades. The first prototype was tested successfully at 2 K. [15].

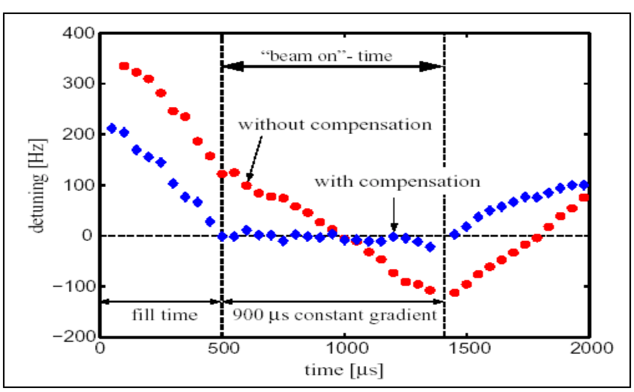

Figure 9: Compensation of Lorenz force detuning at 23 MV/m gradient by Piezo elements

During the 900 µsec flat top pulse of TTF, dynamic Lorenz force detuning of 400 Hz was measured at 23.5 MV/m (TESLA 500) [16]. First investigation showed that low voltage piezo elements like in use for Diesel fuel injection systems in automobiles, are able to compensate the forces down to some Hz detuning (see Figure 9). Presently these elements are exposed to X rays to study the applicability in accelerator environment.

4.3 HOM damping

The HOM couplers of the cavities will not significantly damp higher order modes above 6 GHz. For the TESLA 500 Linac cryogenic losses of 20 Watt per module at the 2 K Helium level origin from these modes were calculated. A new broad band absorber, to be installed in the beam-line and connected to the 70 K shield cooling, is under construction [17]. In collaboration with the Thomas Jefferson National Lab(TJNL), USA, different absorber materials like CERADYNE (Trademark) are under investigation. A prototype will be tested in spring of 2002 in the TTF beam-line.

4.4 Hydroforming

The first single cell cavities shaped by hydroforming have been fabricated and tested. The cavities made from pure Niobium and from explosion bonded Nb Cu sandwiches as well have been tested in the TJNL laboratories and DESY and showed gradients from 30 MV/m up to 42 MV/m [18]. After modification of tools 3 cell resonators will be shaped from a Nb tubes by hydroforming.

4.5 Power coupler and multipacting simulation

A total of 32 power couplers are installed in the TTF modules 1-4 (see table 1). Twenty new couplers are under conditioning and will be installed in module 5 and 6. Twenty more couplers, to be installed in two spare modules, will be fabricated at ORSAY. For the TESLA Superstructure a new power coupler is under design at ORSAY as well. The infrastructure for this test program is being installed at the ORSAY laboratories.

To optimise power couplers with respect to multipacting a software code was developed in collaboration with the Institute of Helsinki (Finland). The code for two-dimensional computation of multipacting phenomena is available now [19].

5 ACKNOWLEDGEMENTS

Stimulating discussions and exchange of information and data with many members of the TESLA collaboration and the colleges from DESY are gratefully acknowledged

6 REFERENCES

[1]TESLA Technical Design Report DESY 2001-011 ECFA 2001-209 ISBN 3-935702-00-0

[2]ICFA BEAM DYNAMIC NEWSLETTER No24 K.Hirata and J.M.Jowett DESY M01-01 April 2001
[3] TESLA Collaboration, D.A.Edwards (ed.); "TESLA Test Facility Linac - Design Report", DESY-TESLA-95-01 (1995)
[4] J.Rossbach, et al.; "Observation of Self-Amplified Spontaneous Emission in the Wavelength Range from 80nm to 180 nm at the TESLA Test Facility at DESY " to be published in Nucl. Inst. Meth. A (2001)
[5] W.D.Moeller (DESY); this conference SA005.
[6] H.Weise (DESY); Snowmass Conference July 2001, to be published.
[7] J.Rossbach (DESY); priv. Communication.
[8] A.Matheisen,D.Reschke; "Control of Particle Contamination with Liquid and Air Particle Counters during Prepartion of the TTF 1.3 GHz Resonators", Proceedings of the 8th Workshop on RF Superconductivity Abano Terme Oct. 1998; P 640
[9] C.Pagani (Milano); this Conference TL015.
[10]Alexander Gamp for the TESLA Collaboration; "Recent Progress at the TESLA Test Facility", invited talk given at the XXVII National Accelerator Conference in Protvino, Russia.
[11] E.Schulz (DESY); this conference PT010.
[12] K.Escherich (DESY); this conference PT015.
[13] W.Singer (DESY) ; priv. communication
[14]P.D.Gall (DESY); this conference PR003.
[15] J.Secutowicz (DESY); this conference FA010.
[16] M.Liepe, S.Simrock (DESY); this conference SA011.
[17] M.Dohlus (DESY); Snow Mass Conference July 2001, to be published.
[18] W.Singer (DESY) ; this conference FA009
[19] P.Yla-Oijala (Helsimki),D.Proch (DESY); this conference FA001