THE CTF3 TWO-BEAM TEST-STAND INSTALLATION AND EXPERIMENTAL PROGRAM

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Abstract

The CTF3 Two-beam Test-stand will be used to investigate the power-generation and accelerating structures for the Compact Linear Collider CLIC. It is a unique facility to test CLIC structures with beam and in the two-beam acceleration scheme. We report on design and construction which was recently completed and discuss the experimental program that initially will be devoted to the test of power generation structures in the drive beam part.

INTRODUCTION

The Two-beam Test-stand (TBTS) is devised to test key components of the two-beam acceleration concept that is the basis of the CLIC project [1]. The scheme of the TBTS has been described earlier [2]. It is part of the CTF3 complex at CERN [3] that consists of a linac, delay loop and combiner ring creating a high power drive beam that is delivered to the experimental hall (CLEX) containing the TBTS. The drive beam is decellerated in order to generate the RF power needed to accelerate a second beam, the probe beam. The probe beam required for this two-beam acceleration scheme is created by a second linac installed in the CLEX hall [4]. Both beams are delivered to the TBTS as shown in Fig. 1. A separate test beam line (TBL) is devoted to beam dynamics studies of beam decelleration by a row of RF power production structures.

The CTF3 drive beam has a time structure suitable for power generation at all harmonics of 1.5 GHz but is optimized for the nominal CLIC frequency of 12 GHz. It can reach beam intensities from 5 to 32 A at pulse lengths between 140 and 1500 ns at a beam energy of 150 MeV maximum, see Table 1. The CALIFES probe beam can reach beam intensities up to 0.9 A at pulse lengths between 21 and 150 ns at a beam energy of up to 170 MeV.

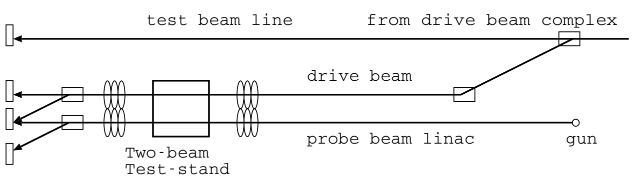

Figure 1: Layout of the CLEX hall.

Table 1: Main parameters of the TBTS

Incoming beam	Drive beam	Probe beam
Energy	150 MeV	170 MeV
Bunch frequency	1.5–15 GHz	1.5 GHz
Pulse length		
- nominal	140 ns	21 ns
- long pulse	1.5 μs	150 ns
Intensity		
- nominal	32 A	0.9 A
- long pulse	5 A	0.09 A
Repitition rate	5 Hz	5 Hz
Test area		
Available length	1.8 m	2 m
Beam height to floor	1.35 m	1.36 m
Distance between beams	0.75 m	

The TBTS is the only facility where CLIC type structures can be tested with a beam. It will be used for an extensive program to test power production (PETS) and accelerating structures, as well as a complete 2 m long CLIC module consisting of two focusing quadrupole magnets and four PETS in the drive beam connected to eight accelerating structures in the probe beam.

DESIGN

The design layout of the TBTS with the parallel drive and probe beams and the central test area is shown in Fig. 2. The optics of the two beam lines is similar with differences in the drift spaces to adjust for the physical constraints in the CLEX hall so as to have the test areas for drive and

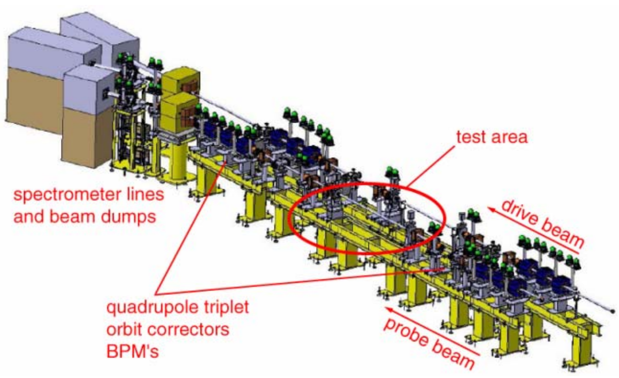

Figure 2: Layout of the Two-beam Test-stand (TBTS).

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probe beam next to each other while allowing sufficient space for beam instrumentation and other diagnostics including spectrometer lines at the end of both beam lines.

The drive and probe beams are at a height of 1.35 and 1.36 m from the inclined floor and at a distance of 0.75 m from each other. The test areas of 1.8 m length in the drive beam and 2 m in the probe beam are bordered by vacuum sector valves to allow for changing equipment without affecting the accelerator vacuum. The beam line vacuum tubes are made of 40 mm diameter aluminium pipes. Detailed parameters of the beam line optics are listed in Table 1.

To meet the requirement of small beam sizes with a β value of 1 m in the test area, a quadrupole triplet is located just upstream of the test area. The drift space between triplet and test area contains two horizontal/vertical steerer dipoles and two beam position monitors (BPM) to control incident angle and beam position. The probe beam includes an extra steerer dipole to be used as a small chicane to separate electrons emitted from an accelerating structure under test from the accelerator beam electrons. An ion pump and vacuum gauges are included to control the vacuum pressure. The same set-up of quadrupole triplet, steerer dipoles, BPM's and ion pumps is copied downstream from the test area.

The downstream triplet provides a small beam size for energy measurements for which a dipole is included to create a spectrometer line before the beam dump. This line includes a BPM and a beam screen. The quadrupole triplet is tuned as to make an elliptical spot on the beam screen to maximize the energy resolution.

CONSTRUCTION

The mechanical design of the TBTS, including girders and alignment supports, has been streamlined with designs used in the CTF3 complex. Each piece of equipment has its individual alignment support which allows them to be moved individually and to reconfigure the beam lines as needed especially around the test areas. It simplifies additional installation of diagnostics equipment as needed. Alignment accuracy is ±0.15 mm with respect to a best-fit polynomial passing through the real positions of the equipment. A photo of the TBTS installation is shown in Fig. 3.

The quadrupole triplets, spectrometer dipoles and vacuum components are all similar to equipment already used in CTF3. The twelve quadrupoles have a maximum field gradient of 11.2 T/m with an integrated value of 2.53 T. The two spectrometer dipoles have a maximum field strength of 1.64 T with a field integral of 2.53 Tm. The ten steerer dipoles for small horizontal and vertical beam orbit corrections have a maximum of 0.017 T and 0.0045 Tm.

The BPM is an 8 electrode inductive pick-up that can be used for both beam position and current measurements [5]. The measurement accuracy for a relative beam position change is ±10 μm. The signal bandwidth for horizontal and vertical position measurement is 0.8 kHZ – 150 MHz and for intensity measurement 0.3 kHz – 250 MHz. The BPM signals will be recorded by 512 MS/s analogue memory with a 500 ns buffer before being transfered to a 14 bit ADC at 800 kS/s. Both analogue memory and ADC are located in the experiment hall close to the BPM's and therefore made of radiation hard components [6].

The beam screens, located behind the spectrometer dipoles and observed by CCD cameras, are used for measurements of beam energy spread and to optimize the beam conditions. The drive beam screen is based on optical transition radiation (OTR) and is made of aluminium in a parabolic shape to reduce the vignetting effect in the optical system [7]. The probe beam with its lower beam intensity has a high sensitivity fluorescent ceramic screen (St.Gobain type AF995R).

The beam dumps are made of a graphite core surrounded by either iron or lead and concrete. It is being discussed to replace the core with a segmented dump for measurement of time resolved beam energy resolution.

EXPERIMENTAL PROGRAM

The TBTS is designed as a versatile facility focused on research and test of RF structures for both beam acceleration and power production. The aim is to demonstrate

- two-beam acceleration with prototype CLIC structures

This includes power production in a prototype PETS and acceleration with high gradient and low RF breakdown rates in a prototype accelerating structure. It furthermore requires a good timing between the two beams. Therefore the experimental program will concentrate on

- beam dynamics
- beam kick due to RF breakdown or dipole modes
- beam loading compensation

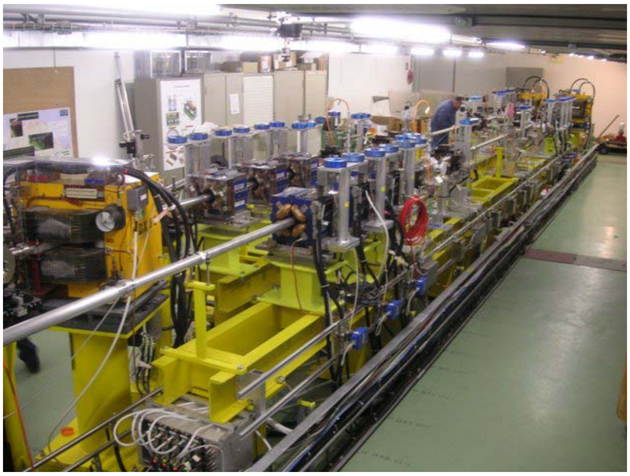

Figure 3: Photo of the TBTS installation.

- RF breakdown rates
- RF breakdown currents.

Construction will finish by the end of June. The phase 0 test program of the beam line commissioning without any structures in the test areas will start end July. In October phase 1 will start with the installation of the first CLIC prototype PETS structure in the drive beam test area. As the power of the available drive beam is lower than foreseen for CLIC, the prototype PETS will be longer and equiped with an RF power recirculation option [8]. An extensive test program is foreseen to condition the structure, verify its power production and beam dynamics effects.

The phase 2 tests starting around March 2009 will add an accelerating structure in the probe beam test area, receiving its RF power from the PETS in the drive beam line. It is foreseen that a second accelerating structure can be added and powered by the same PETS. The test program will include conditioning of the structure, verification of the accelerating gradient and studies of breakdown rates and beam dynamics effects. Tests with several accelerating structures installed simultaneously, but not necessarily powered, are foreseen within the coming years to study beam based alignment on full CLIC modules containing up to eight accelerating structures.

An important element of the experimental program will be the study of beam kicks upon breakdown of the RF field in the structures. The position measurements with the BPM's in each beam line are used to determine the parameters related to incoming beam position, transverse kick angle and relative energy change that the beam experiences during the breakdown, see Fig. 4. With a BPM resolution of 10 μm we expect to resolve the kick angle with a resolution of 10 μrad and a relative energy deviation of $4{\times}10^{-5}$ [9, 10]. The steerer magnets just before and after the test areas are used as a small chicane to remove the breakdown current from the main beam to minimize disturbance of the kick measurements.

Energy loss and gain in the drive and probe beams are measured with the BPM's in the respective spectrometer lines while energy spread is observed with the beam screens. It is planned to enhance the beam diagnostics with sensors, located between the steeres used as a chicane, to look at breakdown currents emitted from the structures as shown in Fig. 4. Of special interest is the investigation of the dark currents during the breakdowns where they have been accompanied by ions [10].

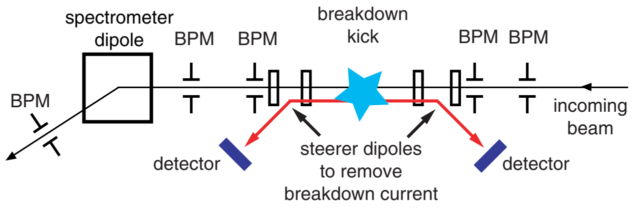

Figure 4: Scheme of the transverse kick measurement.

Breakdowns can be identified by RF power measurements and comparing incoming, reflected and transmitted power levels. The RF power signals will be extracted from the wave-guides by directional couplers, detected with diodes where only amplitude is required, and where phase information is also required IQ demodulators are used. The signals are sampled on a 8 bit ADC with a 250 MHz bandwidth at 1 GS/s. The acquisition and control software is based on CERN standards.

CONCLUSIONS

The Two-beam Test-stand is a unique and versatile facility with excellent beam diagnostics and easy access for changing components and the layout of the test areas. It is the only facilty available to demonstrate two-beam acceleration and the ability to test CLIC type structures and study RF breakdown with a beam. Construction has finished and the experimental program will start this Summer.

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