STATUS OF THE CTF3 FREQUENCY MULTIPLICATION RINGS

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Abstract

The CLIC Test Facility (CTF3) is in construction at CERN by an international collaboration to demonstrate the feasibility of the two beam acceleration scheme at the CLIC parameters. The drive beam of CTF3 is accelerated by a fully loaded Linac that generates a long bunch train and two rings that provide the high current and bunch frequency multiplication by interleaving bunch trains. The status of the commissioning of the first ring (Delay Loop) and of the transfer lines are reported together with the installation of the second ring (Combiner Ring).

INTRODUCTION

The Compact LInear Collider (CLIC) Test Facility project [1,2] has the aim to demonstrate the feasibility of a 3 TeV electron-positron linear collider with reasonable length and cost using the dual beam accelerator scheme [3,4,5]. The layout is shown in Figure 1.

The two main characteristics of the CLIC accelerators are:

- the high accelerating gradient (>100MV/m) in high frequency RF accelerating cavities
- the production of high RF power by extracting power from a low energy high intensity electron beam, the Drive Beam, manipulated in order to create the appropriate time structure.

An international collaboration has been set to develop the CTF3 project with the following participating Institutes: Ankara Un. (Turkey); BINP, JNR, IAP (Russia); CCLRC-RAL (UK); CERN; CIEMAT, UPC, IFC (Spain); DAPNIA, LAL, LAPP, LURE (France); HIP (Finland); INFN-LNF (Italy); KEK (Japan); LLBL, LBL, NW Un., SLAC (USA); PSI (Switzerland); RRCAT (India); Uppsala Un.(Sweden) Incoming partners are Pakistan, Iran, Cockroft Inst., J.Adams Inst., JLAB, EPFL, INFN-Mi.

CTF3 is based at CERN in the building that hosted the LEP pre-injector complex, whose hardware and infrastructure are largely reused. Drive Beam is generated by a fully loaded Linac, 70 m long, followed by two rings in which the beam manipulation is performed: the Delay Loop (DL) 42 m long and the Combiner Ring (CR) 84 m long.

The drive Linac operates at 3 GHz and produces electron beam pulse trains at the energy of 150 MeV with a 1.4 μsec pulselength and 3.5A current at 1.5 GHz bunch frequency. The Linac RF power is transferred to the electron beam and an efficiency of 94% has been measured.

A RF power production station has been also installed, halfway along the linac, to test the RF power extraction structures (PETS). The electron beam is alternatively extracted in a dog-leg line and is sent to the PETS: the 30 GHz power extracted is transferred through 30 GHz waveguide to an external laboratory where the accelerating structures are conditioned and tested.

In the frequency multiplication system successive trains of bunches coming from the Linac are interleaved in the two rings by injecting with RF deflectors.

The time structure necessary for the recombination process is produced in the injector: a high current thermoionic electron gun is followed by three sub-harmonic buncher cavities at 1.5 GHz and 3 GHz bunching system. The sub-harmonic cavities and their sources are wide-band system and allow fast phase shift along the bunch train. The 1.5 GHz electron pulse, 1.4 μsec long, is composed by up to 10 sub trains in which the phase is shifted by 180.

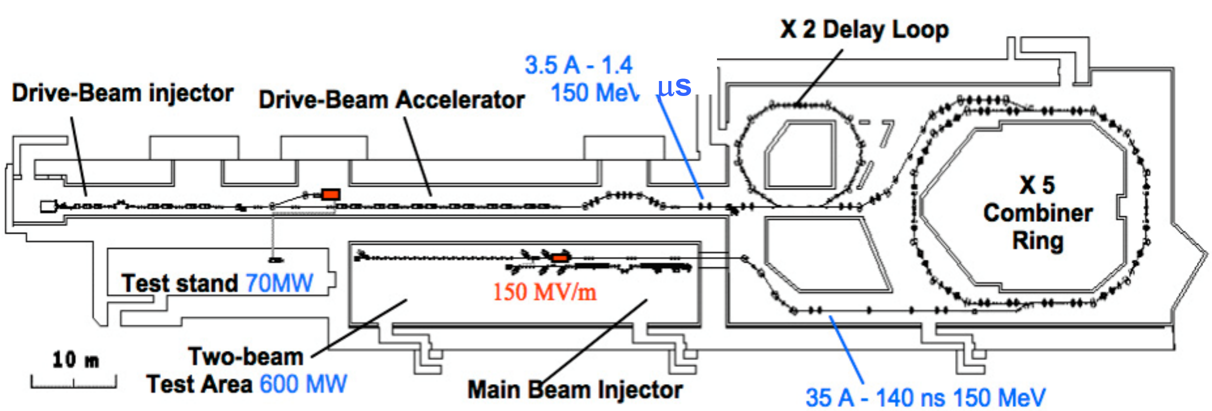

Figure1: CLIC Test Facility accelerator and building layout.

At the entrance of the Delay Loop a 1.5 GHz RF deflector kicks bunches of the train that have the right phase (even) to be injected in the ring and kicks off the bunches with opposite phase (odd) [6].

The length of the ring is exactly a multiple of the RF period in order to receive the exit kick at the deflector and to interleave even and odd bunches of the successive trains.

At DL exit a series of electron pulses, with doubled current, 140 nsec long with frequency of 3 GHz and empty space of 140 ns duration are created (see Figure 1) ready for multiple combination in the second ring.

In the Combiner Ring, the successive trains of bunches are injected with funnelling technique up to a number of five. Twin 3 GHz RF deflectors are used to correct the injection angle of the incoming beam and to kick on a closed bump the previous injected trains. The length of the Combiner Ring can be fine adjusted to permit bunches to pass in the RF deflectors with the right phase.

Fine tuning of the path length is assured by local deformation of the beam trajectory performed using a compensate three pole wiggler: this idea has been successfully tested in the Delay Loop.

DELAY LOOP

The installation of the Delay Loop started early 2005 and before the 2005 CERN winter shut-down the first beam passed in the ring with 90 % of transport efficiency.

Between March and May 2006 the commissioning continued sharing the operation time with the 30 GHz RF power production and accelerating cavities tests. The injection with the 1.5 GHz RF deflector has been proved at the energy of 100 MeV and the bunch recombination process demonstrated up to the nominal current and pulselength values

Horizontal and vertical emittances have been measured in different location along the linac and at the chicane exit to match the optical function. Quadrupole scan methods has been used observing the beam transverse dimensions on carbon OTR screen via large aperture optics CCD camera.

Pulselength and longitudinal structure of the trains have been measured with a streak camera collecting the synchrotron radiation produced in the DL bending magnet through glass windows and the OTR radiation.

A measurement at the RF deflector location has been also performed passing the electron bunches in the RF deflector zero crossing phase: the head and the tail of the bunch are deflected in opposite direction and observing the transverse dimension on a OTR screen the pulselength has been measured with one picosecond resolution.

After the orbit correction the dispersion function has been measured by scaling the quadrupoles currents and measuring the beam trajectory.

In Figure 2 the beam currents, measured at Linac end, in the DL and after the recombination at the DL output are reported

Detailed description of the commissioning phase has been reported in the EPAC06 conference [7].

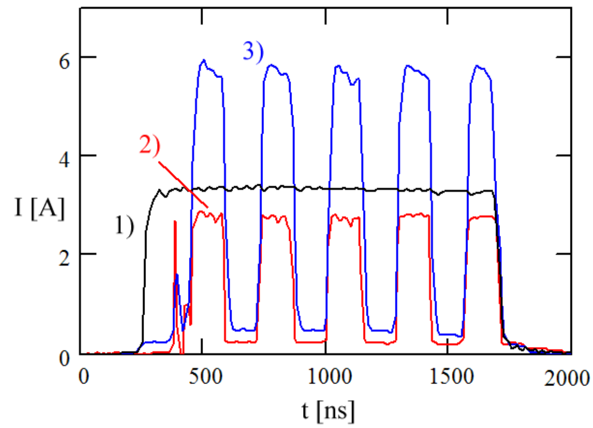

Figure 2: Beam current as a function of time, measured: 1) before the delay loop 2) in the loop 3) after the loop, showing the final recombination in five 140 ns pulses.

COMBINER RING

The design of the Combiner Ring must fulfil the Drive Beam requirements of producing short bunches equally spaced at the RF power production frequency after the recombination process in order to have the maximum power extraction efficiency in the PETS. The beam energy spread must be as small as possible and the machine lattice has to be isochronous in order to avoid lengthening of bunches. The energy loss must be small to avoid different bunch spacing for the trains that perform different number of turns in the ring.

To reduce the contribution of the Coherent Synchrotron Radiation (CSR), due to the short bunch, a magnetic chicane that can vary the bunch length on a wide range has been placed at the Linac end

Vacuum chambers

All the vacuum components of the DL and CR are designed to have very low coupling impedance to minimize the energy loss and energy spread in the beam. The bending magnet vacuum chambers have racetrack inner shape and are realized with aluminium alloy.

Each chamber is manufactured from two plates of aluminium machined under controlled environment condition and then welded together along the equatorial plane. Also the straight chambers have the same shape with exception of part of the injection and extraction region.

The bellows are RF shielded with copper sliding contacts and the pump ports are RF shielded using screen with hidden slots directly machined on the chamber wall and surrounded by an antechamber where the vacuum pump is connected.

The construction of transfer line and CR vacuum chamber components have started in summer 2006 and largest part has been produced by Italian firms.

Beam Position Monitor

The DL and CR Beam Position Monitors with racetrack shape (BPI) have a stay clear aperture of 90x37mm^2. This monitor works in principle as a transformer excited by the beam, representing a single turn primary loop, whose four secondary windings surround toroidal ferrite cores placed in correspondence of a vacuum chamber ceramic gap. The beam current acts as a winding that drives magnetic flux in the core, inducing a voltage signal in the secondary windings.The beam image current, diverted to the four strip placed outside a ceramic gap and short circuited to the two ends of the metallic vacuum chamber, is picked up through the small ferrite core transformers (FerroxCube 4C65) placed at the end of each strip and providing signals whose amplitude is beam position dependent. The striplines are surrounded by ferrite (Ferroperm Magnetics *PERMAX* n°56) to improve the low frequency response. Such ferrites are lossy at high frequencies and damp unwanted resonances of the external metallic shield.

In the combiner ring BPIs the ratio of the small transformers and the signal load impedance has been reduced, to increase the low frequency response of the device providing a lower cut-off frequency below 50 KHz.

TL1-Transfer line commissioning

The transfer line between the DL and CR (TL1), including the injection straight of the CR, has been installed and commissioned in autumn 2006.

The beam trajectory and transport efficiency in the transfer line and Combiner Ring injection section has been measured by means of 11 BPI as shown in Figure 3.

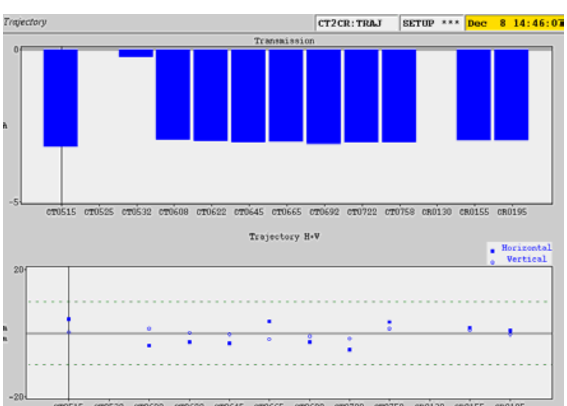

Figure 3: electron beam trajectory and transport efficiency in TL1 and CR injection.

A diagnostic station has been placed in front of the auxiliary port of the first CR dipole vacuum chamber to measure with an OTR monitor the beam profile and emittance. The beam transverse distribution is shown in Figure 4.

In February this year the Combiner Ring vacuum chamber will be installed; all the components are ready except the BPI that are in preparation at the Frascati Labs. The installation of the missing BPI is foreseen for March this year in order be ready for the commissioning at the end of CERN winter shut down.

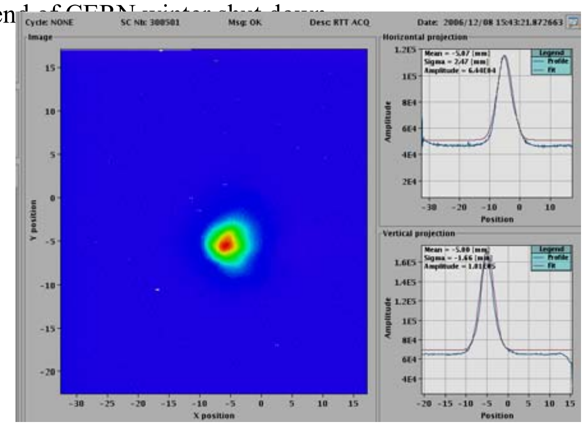

Figure 4: electron beam tranverse shape observed after CR injection.

CONCLUSIONS

The CLIC Test Facility CTF3 is a developing project in which the commissioning phases follow the installation of the different machine that compose the project.

The CTF3 international collaboration aims to demonstrate the CLIC feasibility before 2010. The construction of the Drive Beam has been advanced in stages and the Linac, the transfer lines and the Delay Loop have been successfully commissioned. The final commissioning of the frequency multiplication rings is foreseen in 2007.

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