THE CLIC 30 GHz TWO-BEAM TEST ACCELERATOR

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Abstract

As part of the experimental effort to demonstrate the feasibility of the CLIC scheme, a 3 m long representative section of the CLIC accelerator has been constructed, installed in the CLIC Test Facility (CTF) and successfully commissioned with beam. Prototype 30 GHz components developed during the course of the CLIC study including accelerating structures, power generating transfer structures, and high power RF loads, have been successfully integrated with the micron-precision active alignment system, the vacuum system, the water cooling system, and the high power RF distribution system to produce a very compact two-beam test accelerator. This paper describes the layout and gives details of the important subsystems.

1 INTRODUCTION

A 3 m long 30 GHz two-beam test accelerator has been constructed and is presently operating with beam in the new CLIC test facility (CTF2). The test accelerator layout follows that currently foreseen for CLIC but has a higher density of quadrupoles - and consequently a lower RF filling factor - due to lower beam energies. The test accelerator is equipped with a prototype active alignment system in order to gain operating experience in a real accelerator environment. The bunched electron beams needed for the drive and main linacs are supplied by two separate 3 GHz linacs.

Since both CLIC and the test accelerator are composed of repeated two-beam 'modules', the construction of two fully equipped modules has enabled many of the technical difficulties of the full length linacs to be solved. All necessary subsystems including water cooling and vacuum have been included. The layout of a test accelerator module is shown in figure 1. Two such modules have been installed and a further two will be installed in 1999.

Prototypes of components developed in the course of the CLIC study have been used wherever possible. These include: accelerating sections, high power RF loads, main linac beam position monitors, main linac quadrupoles, support girders and the active alignment system. The power extracting structures are similar to those of CLIC but have a stronger coupling to the beam to compensate for the lower drive beam charge. Other components including waveguides, phase shifters, vacuum and beam line components were specially developed for the accelerator.

The test accelerator is shown in figure 2. Commissioning with beam started in the autumn of 1997. A maximum accelerating gradient of 50 MV/m [2] has so far been achieved and is currently limited by available drive beam charge.

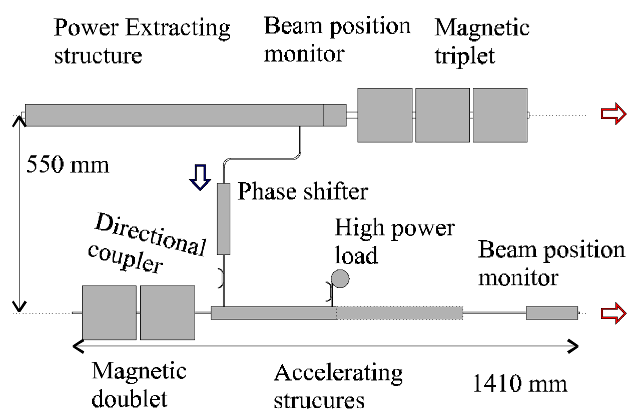

Figure 1: Schematic layout of one module of the main (lower) and drive (upper) linacs.

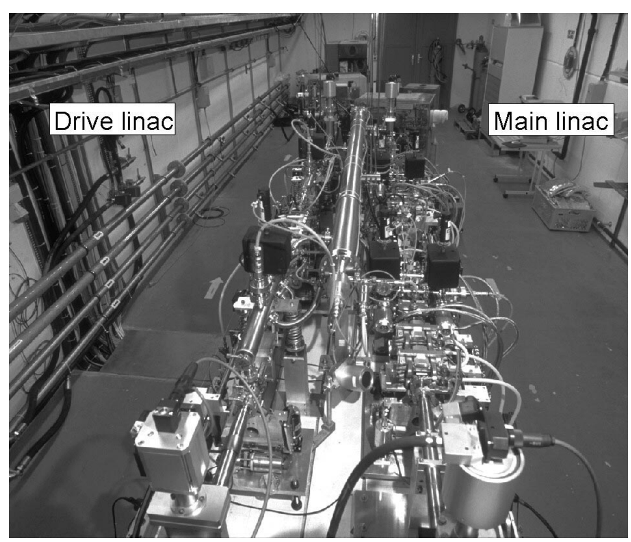

Figure 2: Downstream view of the test accelerator installed in the CTF.

2 RF SYSTEM

Each two-beam accelerator module has one power extracting structure, shown in figure 3, which feeds two accelerating sections. An extracting structure has four output waveguides - opposing pairs are combined to feed the two accelerating sections. For the moment all four output waveguides are combined to produce a higher accelerating gradient for a given drive beam charge (but less total energy gain). RF power is combined in 'Y' junctions that are split in the magnetic field plane. The output of each accelerating section is connected to a high-power stainless-steel load which is vacuum pumped. The area around the accelerating section in the first module is shown in figure 4.

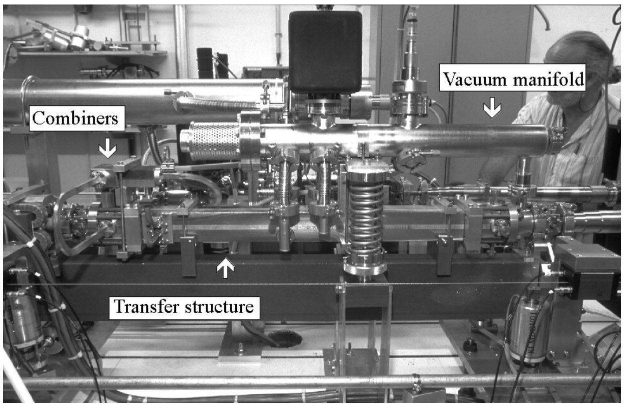

Figure 3: Installation around a power extracting structure.

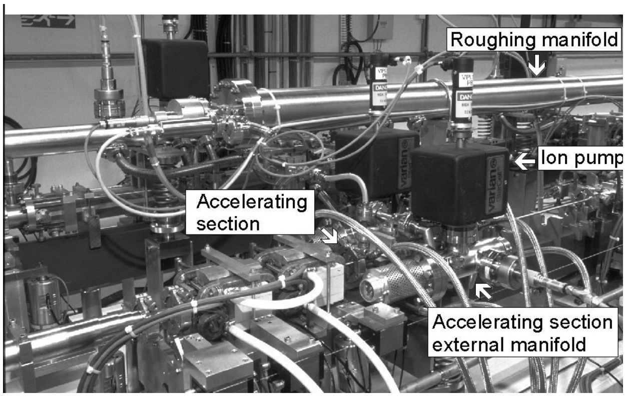

Figure 4: Installation around an accelerating section. The view of the section is obstructed by the vacuum manifolds.

The upstream ends of the power extracting structure waveguides are terminated with vacuum compatible loads containing ceramic absorbing elements. In order to maintain free movement of the support girders, all RF connections between components on the girders and those on the concrete support block contain lengths of flexible waveguide. These are made from copper plated commercially-available hydro-formed waveguide tube. The flexible waveguides also provide vibration isolation. The waveguide between the power extracting and accelerating structures contains a phase shifter.

Vacuum-tight high-power RF connections were made using a flange design with a flat face-to-face contact and a Helicoflex seal. There are no windows anywhere in the high power RF line. Low power signals are extracted from the high power system via vacuum-to-air 56 dB directional couplers before and after each accelerating section, providing calibrated incident, reflected and transmitted power signals. 1 mm diameter ceramic disks brazed into the coupling holes separate vacuum from air in these couplers. 12 m long WR-28 waveguide runs connect the outputs to the signal processing electronics in the klystron gallery.

3 BEAM POSITION MONITORS

A prototype 30 GHz resonant cavity BPM [4] with an integrated phase and charge reference cavity is installed in each main linac module. Common mode rejection is made in vacuum-compatible magic Ts. Position signals pass from vacuum to air-filled waveguide via alumina windows mounted on the difference ports of the magic Ts. Signal processing electronics is mounted in the klystron gallery.

A four-button BPM is mounted in each drive linac module. Each button electrode is connected directly to a coaxial vacuum-to-air feed-through. 20 to 30 cm lengths of standard flexible coaxial cable connect the BPM on the support girder to fixed semi-rigid coax fixed onto the concrete block.

4 ALIGNMENT SYSTEM

The entire accelerator is mounted on a concrete block that is grouted to the floor - a precaution that would only be meaningful in a proper stable linear collider tunnel. The block also contains niches where radiation sensitive alignment control electronics are mounted. All other components of the alignment system have been designed to be radiation hard

The test accelerator is actively aligned and held to within a few microns using a stretched wire system [3]. All beam line components other than quadrupoles are mounted on 1.41 m long (length of one module) silicon carbide support girders. The components are directly supported by ± 1.5 μm precision V blocks. Continuity of the beam axis from girder to girder to a similar precision is provided by a system of link rods that connect the ends of the successive girders. The link rods create articulation points at the beam axis intersections. The articulation points, and thus the linacs, are aligned by moving the ends of the girders with 0.1 μm step linear actuators, which are shown in figure 4.

Actuator movements are calculated from readings of the 0.1 μradian resolution tilt meters and the 0.1 μm resolution capacitive sensors of the stretched wire system. The vertical positions of the ends of the wires are measured by a hydrostatic leveling system.

Quadrupole doublets and triplets are mounted on independent platforms with their own wire sensors, tilt meters and actuators. The quadrupoles are referenced to the same stretched wire as the support girders.

The system operates in a closed feedback loop holding the linacs within an alignment window of ± 2 microns.

The end-station of the stretched wire system is shown in figure 5.

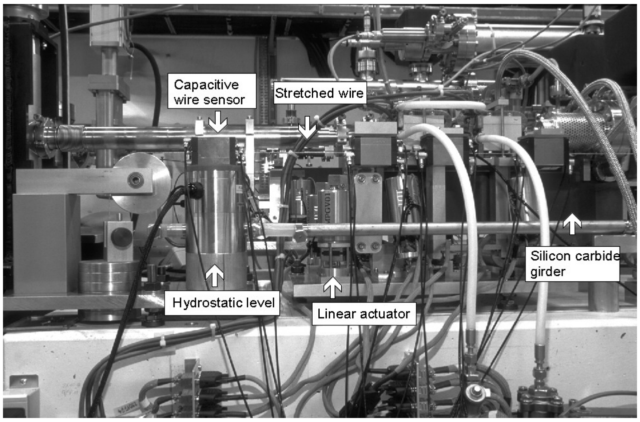

Figure 5: End station of the stretched wire system.

5 BEAM LINE COMPONENTS

The internal diameters of the main and drive linacs are 4 and 22 mm respectively. The main and drive linac beam pipes have been designed to present low transverse impedances. The drive linac beam pipe must also carry high image currents without arcing or heating locally. Maintaining these design objectives has been most difficult for the inter-girder articulations, which must also be flexible and vacuum tight. In the current design, the articulation points have a 1-2 mm beam pipe gap with a 50 mm diameter bellows placed around the gap region to contain the vacuum.

Connections between fixed drive-linac beam-line components are made using a flange design derived from the vacuum RF flange. The requirements for the RF flange, a small impedance mismatch and a high current capability, are identical to those of the drive-linac beam-line flange.

The prototype main and drive linac quadrupoles have internal apertures of 10 and 30 mm respectively. The resulting ± 2 mm clearances between the quadrupoles and the beam pipes allows the beams to be steered using quadrupole offsets. The field gradient in the main linac quadrupoles is 100 T/m.

6 VACUUM SYSTEM

The primary design challenges for the vacuum system are to provide adequate pumping to the very low conductance main linac beam pipe and to allow unconstrained movement of the alignment system. The design level of 10^{-8} torr has been achieved.

This vacuum level in the main linac is obtained by pumping each accelerating section cell with four 1 mm diameter radial holes. It is sufficient to pump only accelerating sections since in CLIC they make up most of the main linac length. Each accelerating section is pumped by a pair of local manifolds each of which contains a getter and an ion pump. The manifolds (weighing some 20 kg) are mounted on spring supports and follow girder movements with little applied force. Power extracting structures are pumped by a single local manifold also with a getter and an ion pump.

All of the local manifolds are connected via flexible tubing to a central roughing manifold, which appears prominently in all photographs of the test accelerator such as figure 1. After an appropriate vacuum has been reached the roughing manifold is isolated from the manifolds by valves. The accelerator can be isolated from the rest of the CTF with valves at the ends of each linac.

7 WATER COOLING SYSTEM

With average RF and beam power levels in the test accelerator a small fraction of those anticipated in CLIC, the water cooling requirement is less demanding. Nonetheless, the water connections must still remain sufficiently flexible when pressurized not to constrain the alignment system. Hydro-formed thin walled stainless steel tubing has been used to connect to the accelerating sections but the solution is unsatisfactory because the tubing is a vibration source. Latex tubing was later chosen for the quadrupoles and appears to function very well.

8 CONCLUSIONS

The successful installation and operation of the test accelerator represents an important step in the demonstration of the feasibility of the CLIC scheme. Difficulties of layout and assembly resulting from the high density of components of the 30 GHz accelerator have been overcome. The active alignment system has been successfully integrated with all the other subsystems, maintains alignment within a ± 5 micron window and operates reliably in a high radiation environment without any evidence of deterioration. A precise agreement between drive beam, generated power and main beam energy gain indicates that the RF system is functioning correctly.

9 REFERENCES

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