

CLIC Note 350

Active Alignment System for CLIC 30 GHz Modules in CTF2

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1. INTRODUCTION

CERN is studying a linear collider (CLIC) to obtain electron-positron collisions with center-of-mass energies in the TeV range. The CLIC scheme is based on beam acceleration at high gradient (100 MV/m) and high frequency (30 GHz) with RF power generation by the Two Beam Acceleration (TBA) method. Pulsed microwave power is extracted from the drive linac by means of power generating transfer structures and fed into the main linac through waveguide feeders.

To demonstrate the feasibility of CLIC a test facility (CTF 2) is being constructed with the 30 GHz two-beam section consisting of four identical modules resembling as closely as possible the real CLIC design .

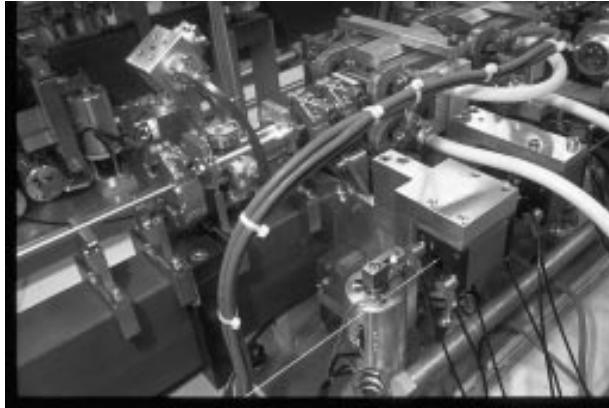
The accelerating, correction and beam detection components for the 30 GHz modules must be aligned to an accuracy of $\leq 10 \mu\text{m}$. The alignment system used, consisting of supports, position sensors and actuators, was developed in the CLIC alignment test facility.

A 30 GHz module for CTF2 consists of two girders, one per linac, supporting accelerating or power generating transfer structures, and beam position monitors. The quadrupoles sit above each girder on independent supports. For phase 1 of CTF2 two modules are installed.

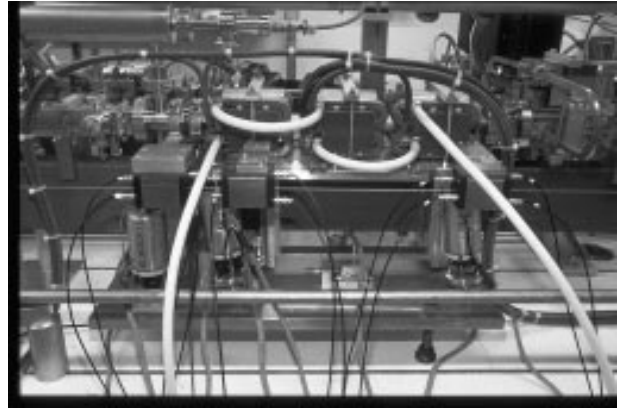
2. SUPPORT AND DISPLACEMENT SYSTEM

The accelerating and transfer cavities, and the beam position monitors sit on girders on pre-aligned vees (Fig. 1a). The girders are supported by inter-girder articulated supports. These supports fixed at the end of a girder have two micromovers with link rods for the vertical movement, one micromover with one link rod and a screw stop for the horizontal movement, and two link rods to support and adjust the front of the next girder. The distance between two articulation points is 1.41 m. The quadrupoles sit on a ground metal plate supported by three micromovers with link rods for the vertical movement and two micromovers with link rods and a screw stop for the horizontal movement (Fig. 1b and 1c)

The micromovers of an inter-girder articulation and the micromovers of the nearest quadrupoles sit precisely on a metal plate. This plate is aligned and fixed on a concrete block integrated into the concrete floor. There is one concrete block for two modules (Fig. 1b).



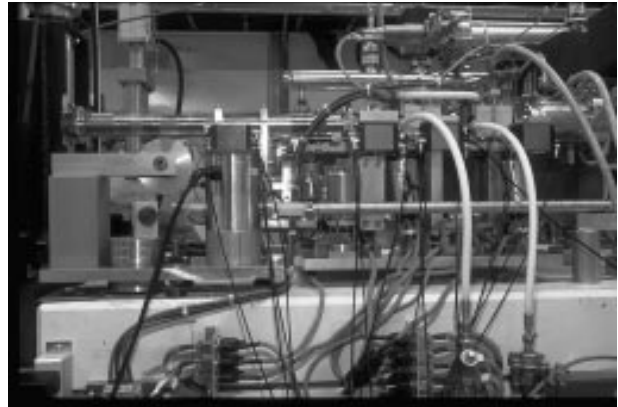
1a



1b



1c



1d

Fig. 1 Different views of CTF2

3. ALIGNMENT : METHOD AND SENSORS

The alignment system has two main functions. The first is to pre-align the elements to make sure that the beam can pass through the aperture and produce signals in beam position monitors. These signals are then used to make the final alignment. The second function is, once aligned, to maintain the elements in this position.

The Wire Positioning System (WPS) is used to position the girders and the quadrupole supports. The reference for each linac is a wire under tension. The spatial position of the wires is fixed by four reference systems, one at each end of the two modules. Each reference system consists of a Hydrostatic Leveling System (HLS) and a WPS put in the theoretical position by geometrical measurement from the local geodetic network (Fig. 1d). The inter-girder articulations and the extremities of the quadrupole supports are each fitted with a WPS which is

itself precisely located with respect to the axes of the accelerator components (Fig. 1b). The WPS sensors measure the distance between the axis of the sensor and the wire in vertical and horizontal directions perpendicular to the accelerator axis. An accelerometer/tiltmeter (TMS) is used on each girder and each quadrupole support to measure transverse tilt and vibrations.

4. MAIN CHARACTERISTICS OF THE INSTRUMENTS

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|---|---|
| <p><u>Girder</u></p> <ul style="list-style-type: none"> • Silicon-carbide • Length including extremity plates : 1.40 m • Cross section : 0.6 x 0.12 m • Wall thickness : 7.5 mm • Module of elasticity : 2100 daN/mm² • Density : 2.65 g/cm³ • Thermal expansion : 4.8×10^{-6} • Very good thermal conductivity • Weight : ~ 12 kg • Tolerance for adjustment of the vees and the end support plates $< 5 \mu\text{m}$ | <p><u>Micromover</u></p> <ul style="list-style-type: none"> • Stepwise motorisation • Length at mid course : 155 mm • Diameter : 60 mm • Travel : ± 4 mm • Resolution : 0.2 μm • Repeatability : 1 μm • Maximum load along thrust axis : 400 N |
| <p><u>Wire Positioning System (WPS)</u></p> <ul style="list-style-type: none"> • Two axes • Measurement range : ± 5 mm • Resolution : 0.1 μm • Repeatability : 1 μm • Bandwidth : 0-10 Hz | <p><u>Wire</u></p> <ul style="list-style-type: none"> • Carbon + aramid fiber (Kevlar) • Apparent diameter : 0.50 mm • Weight of 100 m : 20 g + 16 g • Elastic limit : ~ 300 N • Mass of counterweight used : 6 kg |
| <p><u>Tilt Meter System (TMS)</u></p> <ul style="list-style-type: none"> • The instrument measures the inclination and the acceleration in two axes • Resolution : 10^{-7} rad • Repeatability : 10^{-6} rad • Bandwidth : 0 to 100 Hz • Measurement range : $\pm 3 \times 10^{-3}$ rad | <p><u>Hydrostatic Leveling System (HLS)</u></p> <ul style="list-style-type: none"> • Measurement range : 5 mm • Resolution : 0.2 μm • Repeatability : 1.2 μm • Separate external electronics |

5. ELECTRONICS

Two distinct versions of the electronic processing and command system have been developed, the first using standard components and the second using specially developed higher performance hardware.

5.1 System installed in the CTF2

The system now installed in the CTF2 consists of :

- 38 stepping motor driven linear actuators and 10 double Europe 4 axis motor driver cards. The cards provide complete motor control and are connected to the control system using an RS232 bus.
- 78 measurement axes including four HLS, ten TMS (three axes), eighteen WPS (two axes) and eight thermometers. Analogue signal processing units are installed near each of the sensors in crates located in niches in the concrete support block. The concrete support block also provides radiation protection. The processed analogue signals are brought together in the patch panel and are connected to the control systems.

5.2 New Development

This system, which is now being produced, will provide increased alignment precision, higher processing speed, simultaneous and synchronised displacements, decreased equipment volume, decreased cost, and easier and more flexible use. Processing, in the version 1 system, made by the CPU of the VME controller, is made by local units in the version 2 system. These local units consist of VME Main Control Card (MCC) modules operating in slave mode. The MCC modules contain two Digital Signal Processors (DSP), one dedicated to motor movement control and the other to numerical signal processing, local RAM, control and communication with the VME bus. Logical circuits and volatile memory are contained in two Logic Cell Arrays (LCA). The DSP clock rate is 40 MHz.

The motor driver circuits are arranged in-groups of six, with five circuits on each three unit high Europe crates. Three cascaded fibre optic cables connect the crates to the MCC. Asynchronous communication is used in order to avoid problems caused by delays in fibre optics transmission.

Analogue signals are captured using 14 and 16 bit (resolution and precision respectively) A/D converters that are capable respectively of 20 and 14 channel differential multiplexing. Extra care has been taken to ensure that the 16 bit A/D's precision is not degraded by cross-talk with the multiplexing (MPX). The A/D converters communicate with the MCC via two fibre optics cables.

Each MCC can control 80 actuators and 160 sensors with an average response time of 1 ms. the decentralised processing of this system allows the number of elements to be increased even further without degrading the response time. Communication by fibre optics cables ensures high precision and immunity to electronic noise.

6. CONTROL SYSTEM

The active alignment of the 30 GHz modules of the CLIC Test Facility is done in Real Time (RT) through the standard Control System which is used for the operation of all the accelerators in the CERN-PS complex.

6.1 Hardware Architecture

- UNIX Workstations (IBM RS6000) or X-terminals running under AIX
- UNIX IBM systems used as files servers, database servers, development and backup servers
- VME Crates, 68000 processor running LYNX OS
- Ethernet Network and FDDI

6.2 Software Architecture

The PS Control System is strongly based on an object oriented approach with the “Control Modules”, equipment classes with the same functionality, distributed over the Control Network, to the VME crates. Class and instance variables are encapsulated in the VME “data tables” and are handled by RT tasks and the class functions only. Configurations are maintained by means of an Oracle database. C and C++ languages are used to write Drivers, RT tasks and application programs where MOTIF is used for the graphic applications. Communications are based on a CERN UDP Remote Procedure Call.

6.3 Front End Level

Two main classes of equipment are connected to the VME crate :

- for the sensors, three analogue input boards with 32 differential analogue input channels and 12 bit resolution are used for acquisition of temperature, HLS, TMS values and 4 height-differential-channel digitisers with 16 bit resolution for acquisition of the TMS values.
- A VME card providing 8 RS232 communication channels per sub-slot to the motor interfaces drives the micromovers.

The CPU board has 32 Mbytes memory. Two home made modules are required for diagnostics, remote reboot, timing reception and generation of interrupts.

The analogue value levels provided by the captors and the motor parameters are scanned and treated by means of two specific RT tasks that finally store the resulting values in the “Control

Module” data-table. The alignment process itself (in reality one per beam) only requires access to data-table values and position correction algorithms.

Its function can be quickly described as follows :

- obtain wire reference position values
- obtain quadrupole, girder position and tilt values
- correct captor values according to wire displacement, wire sag and operator interaction
- check positions and tilts against tolerances
- process data and calculate correction values for actuators
- check complete motor system status: power on, not moving
- send corrections to quadrupole and girder actuators
- record all sensor values and micromovers positions in backup files for later historic analysis.

These different tasks are synchronized with the normal PS accelerator timing system providing a basic period time of 1.2 s and different sub-timings in this period. Sensor scanning is performed every basic period and alignment is active only every 2.4 s. It allows the processing of stable acquisition values, not perturbed by the actuator movements.

6.4 Interface Level

The application program, which is available in the console manager of any operation workstation, is built around a full screen graphic representation of the two 30 GHz modules and their components (Fig. 2).

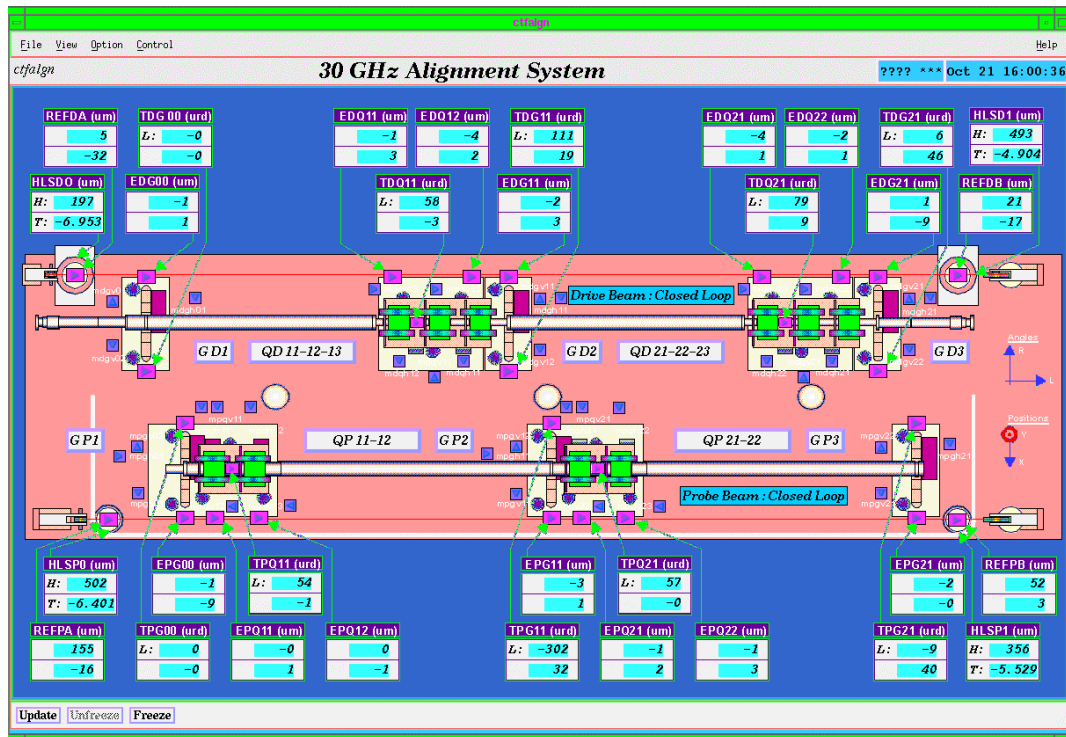


Fig. 2 Copy of the active control screen

Direct interaction on this picture allows individual control of active equipment by knob widgets. This is completed by normal operation facilities like starting or stopping the alignment process for a beam, or introducing manual offset position corrections for each girder or quadrupole.

7. CONCLUSION

The system is now successfully running with a particle beam. In closed loop, the elements are continuously maintained, with respect to the wire, in a window less than 5μ and steering adjustments are carried out by controlling quadrupole displacements.

Next year the experiments will be upgraded by installation of two new modules with the new electronic and control system described above. With the characteristics of this new system, in combination with the performances of the mechanical supports and the sensors, we will be very close to a good solution for an alignment system for the CLIC machine.

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