FABRICATION AND VALIDATION OF THE PROTOTYPE SUPPORTING SYSTEM FOR THE CLIC TWO-BEAM MODULES

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Abstract

The micron-precision RF structures are mounted and aligned on specially developed supporting girders, which provide stability and re-positioning. The supporting girders have stiffness and damping specifications imposed by stringent beam physics and RF requirements. In addition, several constraints, such as allocated space and weight limitation have to be taken into consideration. This paper describes different support concepts following various fabrication techniques and materials. Extensive qualification measurements have been performed on the first prototype units, and the main results are also reported.

INTRODUCTION

The Compact LInear Collider (CLIC), currently under study at CERN, aims at the development of a Multi-TeV e+ e- collider and relies upon a novel two-beam acceleration concept. In the two-beam acceleration, the Radio Frequency (RF) power is extracted from a low energy but high-intensity particle beam called Drive Beam (DB) and it is transferred to a parallel high energy Main Beam (MB). The two-beam modules are the smallest repetitive units which compose the two linacs.

The RF components of the two-beam modules are periodically repeated for both MB and DB with demanding alignment requirements to succeed the particle beams collision at the interaction point. To achieve it, their supporting girders must have deformation lower than 10 μm [1, 2]. Due to the optics requirements for the MB, a few two-beam module types were defined in which the focusing MB quadrupoles (MB Q) are replacing RF components. All MB Q have their own independent support due to their high stability requirements (1.5 nm integrated rms displacement at 1 Hz). For this reason the MB girder length depends on the module type and varies from 446 to 1946 mm. The length of the DB girder is always fixed to 1946 mm.

The fabrication and assembly precision of the CLIC supporting system is on the edge of available technologies. Consequently, prototypes of the supporting system were fabricated for extensive validation. For the girders, fundamental part of the CLIC supporting system, baseline and alternative configurations were considered. The chosen solutions for the prototype girders are based on different materials. The corresponding fabrication methods are in accordance to the technical specification [2, 3]. FEA simulations and qualification tests have been performed to compare and qualify the first prototypes.

The RF structure supports are also part of the supporting system together with the actuators and related sensors. The RF structures are stabilized and supported on the girders via V-shaped supports. The girder itself is supported on its extremities by so-called cradles, which are mechanically connected to the actuators and sensors.

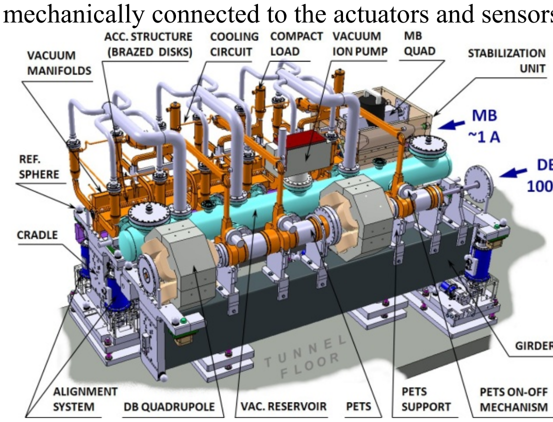

Figure 1: Typical CLIC Two-Beam Module (type 1).

The main results of the experimental program are presented along with the ongoing and planned work.

TECHNICAL REQUIREMENTS

The girders must form a mechanically articulated chain all along the linac. The extremity cradles provide a link between two adjacent girders via a common articulation point. The girder rectangular cross-section of 320 mm × 150 mm is a result of an overall design optimization, which takes into account several parameters, such as tunnel constraints. To fulfil the beam physics requirements, vibrations induced by environment and operation conditions need to be damped. The corresponding eigen-frequencies should be greater than 50 Hz to guarantee the proper module behaviour. Lateral and vertical deformations lower than 10 μm are acceptable.

To achieve such requirements the girder material must be stiff, and as a consequence the modulus of elasticity higher than 320 GPa. In addition, each girder must weigh less than 250 kg, to be compatible with the available actuators performing the active pre-alignment. The load induced by RF components is about 400 kg/m for each girder. The different material choices impose fabrication techniques compatible with the above-mentioned requirements. Due to proximity to the beam, an additional parameter to be taken into consideration is the expected high radiation background.

Precision reference surfaces are necessary on the supporting system components and RF structures to insure their proper positioning. A flatness varying from 10 μm up to 25 μm was achieved for all the reference surfaces.

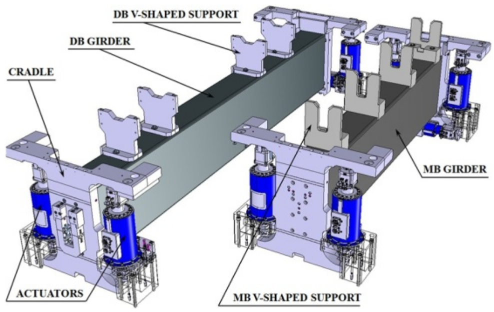

Figure 2: Typical CLIC Two-Beam Module supporting system (type 1).

On both beams, MB or DB, the V-shaped supports are carrying the RF structures providing them with a micrometric interface to the girders (Fig. 2). The shape accuracy of the V-shaped supports as well as their positioning with respect to each other (for each girder) is of prime importance. The V-shaped support axis for each girder has a tolerance defined by a cylinder with a diameter lower than 10 µm. The longitudinal positioning of the V-shaped supports has larger positioning tolerance, up to 0.5 mm. The V-shaped supports are always firmly fixed on the girders, so the possibility of direct implementation was investigated. Alternative girder configurations including non-integrated V-shaped supports have higher positioning flexibility, while keeping the same precision specifications.

Each master cradle is equipped with two vertical and one lateral linear actuators, allowing for 3 degrees of freedom movements.

With such configuration the girder required movement can be achieved. The cradles also house the pre-alignment sensors to compute the beam axis position. To achieve the precise assembly between girder and cradles, the girder extremities are machined with a flatness tolerance below 10 µm. All reference surfaces of the girder are positioned with respect to each other within 50 µm accuracy.

MATERIALS AND FABRICATION TECHNIQUES

The girder material was a driving choice of this study. After a thorough investigation, several materials such as aluminium and stainless steel were excluded as not fulfilling the technical specification. Alternative materials, such as carbon fibres and metal foams, proved that the required length combined with the deformation constraints could not be met. As a result, silicon carbide (SiC) was chosen as the girder baseline material. In addition the newly developed Epument mineral cast was selected as an alternative solution. Both materials meet the technical requirements, in spite of different fabrication processes.

For the baseline configuration, to improve stability, it has been decided to integrate V-shaped supports made of SiC. For the alternative configuration, the V-shaped supports, made of stainless steel and firmly fixed to the girder, were considered.

For the prototype girders, fabrication techniques and strategies were specially developed in accordance with the corresponding material. Baseline girders were produced by two different suppliers (A and B). Their calculated eigen-frequencies were approximately 70 Hz and 50 Hz and their masses 100 kg and 70 kg respectively. Alternative girders were fabricated by one supplier (C) and their eigen-frequencies were about 90 Hz and their mass 130 kg.

For the SiC girder production, the first step is the sintering of SiC grains to form the first monolithic parts. The V-shaped supports are produced in parallel. The next step is the machining of the reference surfaces needed for the final assembly. To obtain one girder with integrated V-shaped supports, the different SiC parts are brazed or glued together. Finally, precise machining of the reference surfaces takes place.

For the Epument mineral cast solution the first step is the girder mould production, which is made of stainless steel for better precision. Fixation inserts (with threaded holes) and anchored rails are introduced into the mould so as to be cast in the girder. The Epument 145B epoxy based raisin mixed with additives and rocks is poured and stirred in the mould until solidification at room temperature and atmospheric pressure. After solidification the girder is taken out of the mould and its external surfaces are polished and varnished. The final step is the precise machining of the reference surfaces, which will be in contact with the other supporting system components. Fixation interfaces to the V-shaped supports are threaded inserts and stainless steel rails. The cradles are screwed directly on the girder extremity threaded holes via dedicated inserts.

MEASUREMENTS AND TESTING

All prototype supporting systems were controlled before and upon delivery to verify their conformity. The SiC girders with integrated V-shaped supports were measured at factory with a laser tracker (± 10 µm accuracy of 1σ) and confirmed with a Coordinate Measuring Machine (CMM with ± 6 µm accuracy of 3σ) at CERN after delivery. Table 1 shows the highest measured values. Flatness corresponds to the reference surfaces linked to the V-shaped support assembly.

Table 1: Prototype Supporting Systems Measurements (*)

Supplier	V-shaped Support Co-axiality	Reference Surface Flatness
A	± 8 µm (*)	10 µm (*)
B	± 6 µm (*)	-
C	(non-integrated V-shaped supports)	10 µm (+)

*: CMM, +: laser tracker

The Epument prototypes were measured at factory by similar measurements and their CMM measurements is scheduled at CERN by the end of 2011.

The experimental program also includes the validation of the material behaviour under radiation. The first pilot tests took place in February 2011 with the aim of investigating radio-activation properties. The Tandem accelerator at the facilities of the National Centre for Scientific Research "Demokritos" irradiated the material samples with neutron beams, reaching an energy range from 4 MeV up to 11.2 MeV. According to the simulated CLIC dose, the dose rate of the irradiation experiments is reflecting about 60% of the neutron flux for CLIC.

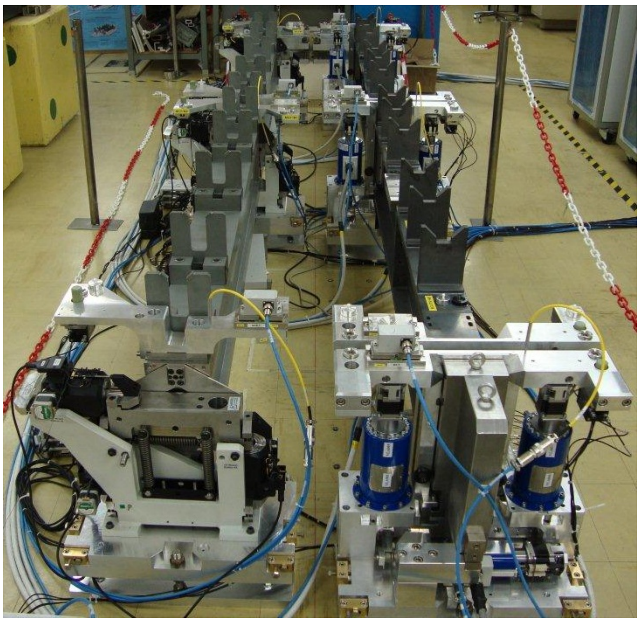

Figure 3: Prototype CLIC Two-Beam Module supporting system (2 test modules type 0).

The mechanical tests of both, irradiated and reference samples at the National Technical University of Athens were carried on in June 2011.

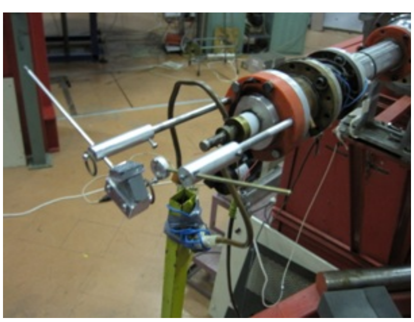

Figure 4: NCSR Demokritos irradiation facility test stand.

Future steps for the prototype supporting systems will concern the assembly and precise positioning of the RF structures on the V-shaped supports. Several tests simulating the different CLIC operating conditions, including transport, will follow.

CONCLUSIONS

The prototype supporting system for the two beam modules has been specially developed and currently is under validation. The delivered prototypes met the specified parameters with respect to reference surfaces and mechanical deformation.

The irradiation measurements showed that the measured activation properties are in agreement with the expected values. Future irradiation sessions, at higher total flux, are planned.

In parallel, data analysis on mechanical tests of irradiated specimens is currently ongoing. The very first results revealed that no significant changes occur to the mechanical properties.

The supporting system qualification will continue following the assembly of the different components on the girders. Based on the lesson learned, the next iteration of supporting system will be launched in the first quarter of 2012 and experimentally qualified.

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