STRUCTURE STUDIES FOR THE CERN LINEAR COLLIDER CLIC.

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Abstract.

Each linac proposed for the CERN Linear Collider CLIC is composed of 50'000 25cm long accelerator sections operating at 29 GHz with gradients of 80 MV/m to produce beam energies of 1 TeV. Basic structure parameters have been established and fabrication of these sections by the electro-forming and machine-and-braze techniques is being investigated. Results obtained from various prototype test pieces are given and discussed.

Introduction.

An energy of 1 TeV per beam will be obtained in CLIC by classical RF acceleration using a high gradient disc loaded waveguide (DLWG) operating at 29 GHz. Although most of the sections will have a circular aperture a small fraction will have slots. These slotted sections, when suitably orientated and positioned, produce RF quadrupoles of considerable power whose main role is to create a large spread in the wavelengths of the transverse oscillations of the particles within a bunch in order to stabilize the disruptive transverse wake fields.

The CLIC design luminosity L = 1.1×10^{33} $cm^{-2}s^{-1}$ is based on single bunch operation but could in principle be increased by running in a multi-bunch mode in which case transverse damping slots would have to be worked into the accelerating cells. Although emittance blow-up problems associated with multi-bunch schemes make this option for the moment unlikely, the possibility of incorporating such slots into CLIC structures is being studied.

This paper updates and completes information given previously [1]. The influence of operating mode and slot height on the main structure parameters is given. Results of measurements made on short stacks of precision machined cups are compared with theoretical predictions. Revised estimates of damping slot length and water cooling requirements have enabled the previously presented conceptual design for a fully engineered accelerating section to be greatly simplified.

Structure and main linac parameters.

The basic CLIC accelerating structure is made up of 50'000 short sections of traveling wave disc loaded guides. A rather large aperture to wavelength ratio of 0.2 is however necessary to limit the destructive effects of beam induced transverse wake fields to reasonable limits in single bunch operation.

The main parameters for phase matched structures with straight-sided discs of thickness 0.575mm have been calculated by URMEL [2]. The results have been presented previously as a function of beam hole diameter [1] and are given as a function of operating mode in Fig.1.

One would like to have
(a) a high shunt impedance R' to keep the input power low
(b) a high ratio R'/Q to minimise the stored energy
(c) a high group velocity to minimise the pulse distortion and maximise the length of the sections.

The above requirements are best satisfied by operating in the $2\pi/3$ mode.

The assumed design values for operation in the $2\pi/3$ mode at 29 GHz. are given together with the main linac parameters in Table 1. R' and Q have been reduced by 5% to account for extra losses due to surface roughness.

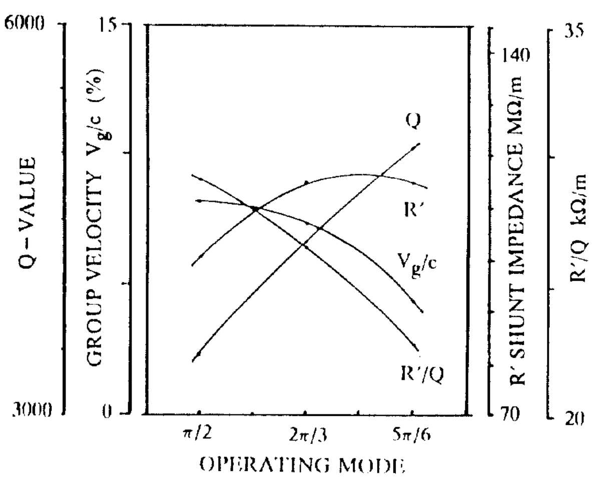

Fig.1 Structure parameters versus operating mode.

Table 1: Main structure and linac parameters

Shunt impedance	109 MΩ/m
Quality factor	4112
R'/Q	26.5 kΩ/m
Group velocity (v_g/c)	7.4%
Field attenuation	0.25 Nepers/section
Gradient	80 MV/m
Section length	24.8 cm
Fill time and pulse length	11.3 ns
Cells per section	72
Sections per linac	50'000
Ratio output/input power	0.61
Total peak input power	1.875 TW/linac 150 MW/m
Repetition rate	1.69 kHZ
Total average input power	35.75 MW/linac 2.86 kW/m
Average dissipated power	1.125 kW/m

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The variation of effective focussing gradient (G) and effective axial electric field (Ez) as a function of transverse position over the aperture has been investigated for a six cell slotted structure using the MAFIA 3D computer code [2]. The results are shown in figure 2 for a structure with a slot height of 3.5 mm. The on axis value of G/Ez=0.85 corresponds to a peak gradient of 68 T/m for an effective accelerating field of 80 MV/m. Although the effective energy gain for off-centre particles travelling parallel and perpendicular to the slots is different, the relative differences for a few microns of transverse displacement (typical CLIC betatron amplitudes) are negligible — values of $\Delta E/E_0$ per micron are in the 10^{-5} range.

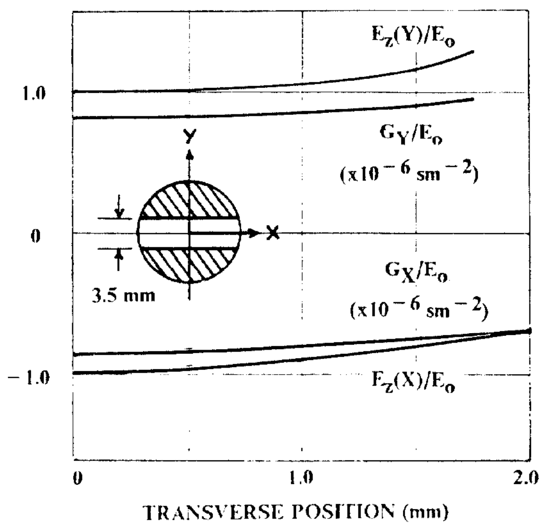

Fig.2 Normalised focussing gradient and effective axial electric field versus aperture position.

Transverse alignment.

The very small beam emittances required in CLIC to achieve the design luminosity must be conserved through the accelerating structure as the beam passes from the damping rings to the final focus. This sets very tight tolerances on the structure position. Recent results from computer simulations of emittance growth indicate that the rms errors in lateral displacement and longitudinal tilt angle must be less than 10 μm and 40 μrad respectively. Since it is uncertain that such tolerances can be obtained by purely static devices, the position of the accelerating sections will have to be continually adjusted within a feedback system by precision movers using a beam derived error signal. The suitability of using a simple circular cavity, coaxial to the beam axis and excited in the E_{11} mode by an off-centre beam, is being studied as a possible position pickup device.

Conceptual design.

A simpler version of a previously presented [1] conceptual design of the CLIC main linac structure is shown in Fig.3. Several high precision accelerating sections are mounted on a common support beam which is equipped with precision movers at each end to enable positioning errors of the structure to be corrected. The error signal is provided by a beam position monitor which is built into the first accelerating section of each multiple section module.

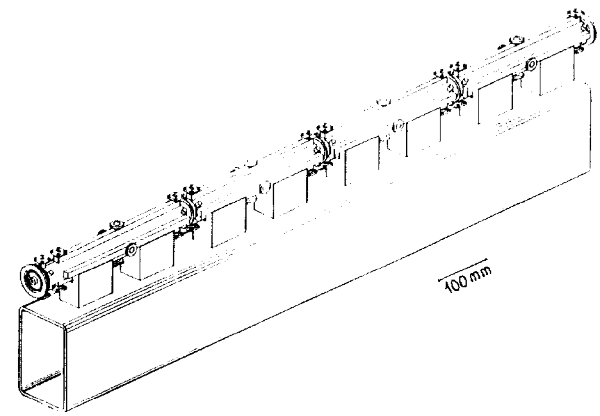

Fig.3 Conceptual design of the CLIC accelerating structure.

A cross-section of the structure is shown in Fig.4. The structure is pumped through a series of radial holes (or damping slots if incorporated) by four vacuum manifolds. If necessary these manifolds could also act as sinks for the dissipation of higher order mode energy. The four 6 mm diameter holes which provide the cooling have been positioned in such a way that two diametrically opposed recessed holes can be incorporated in case dimple tuning is required. The outer diameter of the structure is used as the reference for alignment purposes during fabrication.

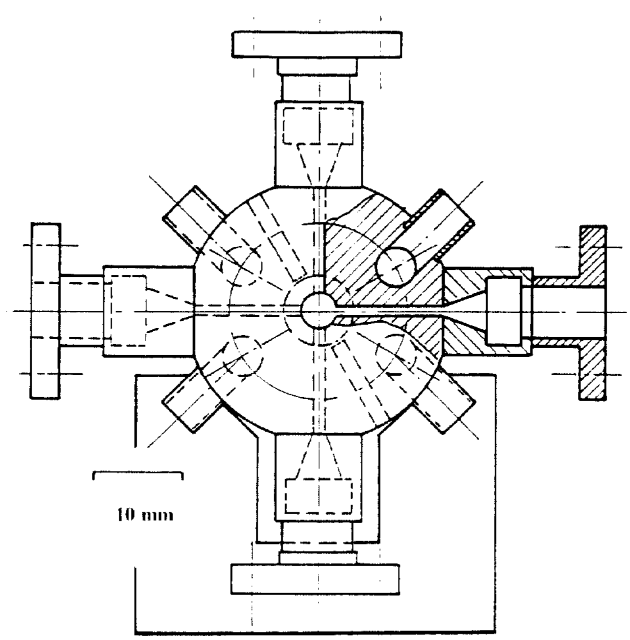

Fig.4 Cross-section of CLIC accelerating structure.

Fabrication by the machine and braze technique.

The first delivery of a small series of 35 precision machined cups has been made and frequency measurements on short test stacks (see Fig.5) are underway.

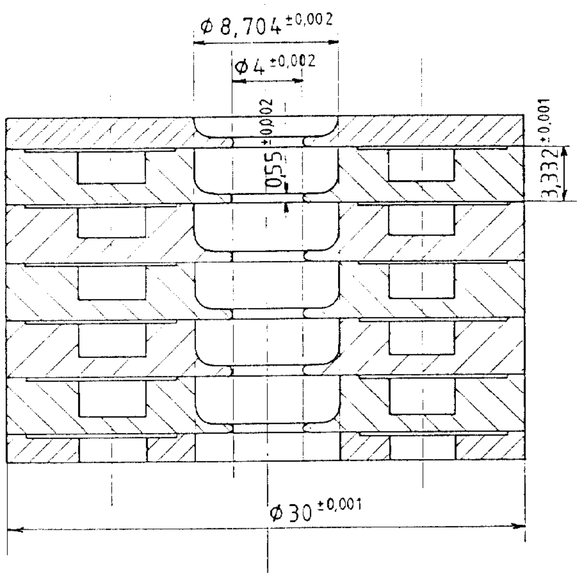

Fig.5 Test stack of machined cups (29.985 GHz).

The copper cups shown in Fig.5 were machined to 1 μm tolerances and N1 surface finish (R_a = 0.025 μm) on a Pneumo MSG−325 diamond tool lathe. This two axis machine has CNC control, closed loop laser interferometer feedback with 25 nm resolution, vibration isolation and air bearing spindle and slides. The six cell test stacks will be brazed at CERN under slight axial compression in a free hanging position after precision alignment in a V−block.

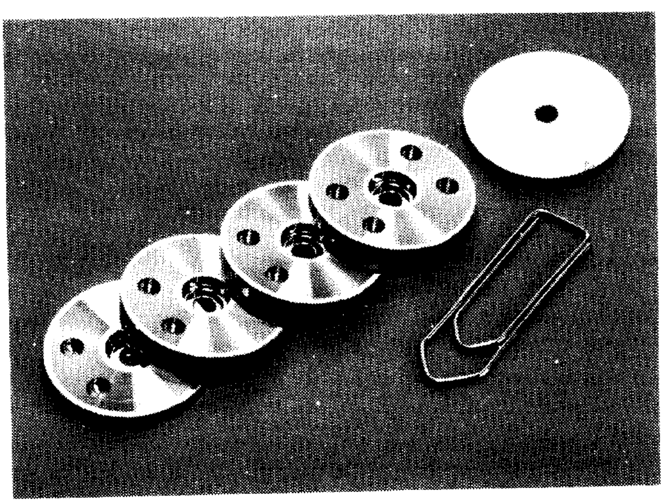

Fig.6 Precision machined copper cups.

Frequency measurements.

The resonant frequencies of the fundamental pass band of the unbrazed stack of six cells were measured at 22°C. in air. The resulting dispersion diagram is shown in Fig.7 together with the predicted computer values, the agreement is better than 0.3%.

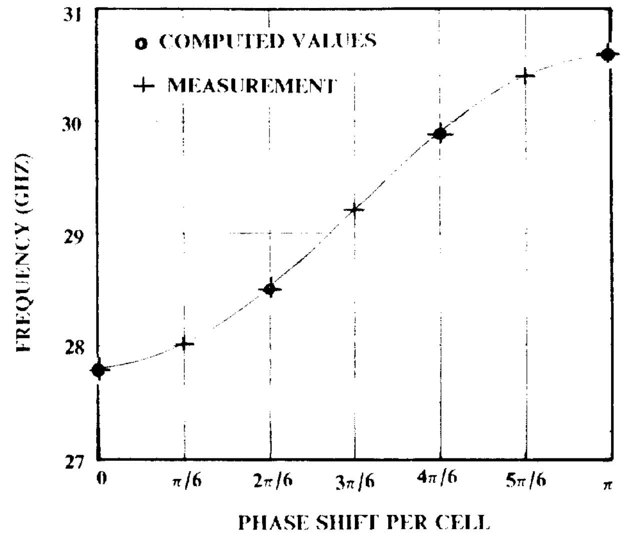

Fig.7 Measured dispersion curve for a six cell stack.

Fabrication by the electroforming technique.

Prototype work has started with the aim of fabricating complete section lengths by depositing copper onto disposable precision machined mandrels. Filling the 0.55 mm wide grooves with copper without forming voids or cracks is however problematic. Two techniques are being studied; introducing electrodes into the grooves to create a more favourable field distribution, and jet spraying electrolyte through fine nozzles onto the bottom of the grooves. Surface finish studies using aluminium test samples have shown that the aluminium surface is deteriorated during the pretreatment process (etching and zincating) even before deposition of copper begins. Much better results have been obtained by first depositing a 2 μm layer of high purity copper by evaporation under vacuum onto mandrels which have simply been degreased prior to putting them into the electrolytic bath.

Vacuum.

Estimates of the pressure on axis under full power conditions has been made for the geometry shown in Fig.5 for outgassing rates of 5×10^{-10} torr.l/s.cm^2 in the cells and 1×10^{-11} torr.l/s.cm^2 elsewhere. For radial pumping only with 0.8 mm holes linking the cells to the manifold, the pressure on axis for an installed pumping speed of 20 l/s was calculated to be 5×10^{-8} torr. For end pumping only the maximum pressure for the same pumping speed was estimated to be $1-2\times10^{-7}$ torr.

References.

[1] I.Wilson et al.,1988 Lin.Acc.Conf.,Williamsburg.
[2] URMEL+MAFIA computer codes, T.Weiland, DESY.

Acknowledgement.

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