STRUCTURE STUDIES FOR AN S-BAND LINEAR COLLIDER

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ABSTRACT

The accelerating structure for a future linear collider has to reach a number of goals which are mainly determined by the beam dynamics. Questions of detuning and damping are adressed in order to reduce beam breakup thresholds in this very long linear accelerator operating with bunch trains much longer than the filling time of the structure. On the other hand the reduction of the linear costs for production and assembly plays a central role for the development of these travelling wave sections. Geometric simplicity and easy handling have to be a dominant feature to reduce machining costs. The main rf-parameters are reviewed and calculations and measurements concerning tolerances, tuning and damping are presented.

1 INTRODUCTION

The accelerating structure for a future linear collider has to fulfill many requirements, partially influenced by the tolerable costs per meter but mainly dominated by aspects given from the cumulative beam breakup instability driven by each section itself. The optimum structure from our point of view is characterized by:

- a simple geometric design which is easy and cheap to fabricate with reasonable tolerances (≈ 10 to 20 μm)
- a design that intrinsically avoids the instability by detuning, damping or a combination of both.

The rf-properties of S-band sections are well known and only an overview over the parameters chosen for the DESY/Darmstadt collider is presented. The first experience with a couple of test cavities being produced by the local industry was, that the price drastically increases if the specified tolerances on the transverse cavity dimensions are below 5 μm where diamond machining and special lathes have to be used. The compromise chosen in our case is to relax the tolerances and first sort the cavities after applying a simple quality control and second tune the sections by deforming the cavity walls. It is obvious that for power consumption reasons the shunt impedance should be as high as possible and therefore no degradation due to surface irregularities can be accepted. Therefore the surface finish has to be less than 300 nm which has been achieved with standard cutting tools.

2 RF-PARAMETERS

The reasons for choosing the rf parameters given in table 1 have already been described elsewhere [1, 2]. Nevertheles it should be emphasized, that the reason for choosing long accelerating sections (6 m) is the reduced number of couplers, input windows or valves and a simpler power distribution system. On the other hand, with longer sections and with a fixed filling time, the average iris diameters would become to large in order to achieve the desired shunt impedance. This results in a trade-off between loss in average shunt impedance using long rf-sections as well as constructional feasibility versus a larger number of input and output couplers which provide other difficulties and costs. Therefore two six meter long sections per klystron are considered which seems to be a reasonable compromise. Having in mind a future energy upgrade by doubling the number of klystrons, underlines this decision because every section may than be connected to one klystron.

section length	m	6
attenuation	neper	0.57
peak power per input	MW/pulse	75
power dissipated per section	MW/pulse	51
iris size	a/λ	1.6–1.3
filling time	nsec	790
shunt imped. variation	MΩ/m	45–61
number of cells		180
average power per meter	kW	≈ 1.3

Table 1: Main parameters for the S-band section.

3 CELL GEOMETRY

The geometry of a single cell cavity, a so called *cup*, recently being built is shown in figure 1. The six meter long disc loaded structure consists of 180 single cups. In order to provide a constant accelerating gradient along the waveguide each cell should have a slightly different geometric shape. Due to the comparatively simple geometry of the disc loaded structure the strategy was to use single cell shapes to be produced easily by conventional machining with reasonable tolerances. The shape of the cavity itself and of the outside walls are a compromise between simplicity and mechanical or rf-requirements. A drawing is presented in fig. 1 and many details are similar to other designs [4].

- The cells should be machined in one piece to form *cups* instead of having a ring and an iris made separately.
- The cups nest into each other to perform a self alignment after being assembled and pressed together.
- The electric contact between two cups is defined by the copper on copper junction to provide excellent rf properties (high Q values).
- A round corner with a large radius of 10 mm instead of a square corner was included at the left hand side next to the cavity wall and the iris. This asymmetric corner makes the cavity asymmetric with respect to the middle plane of cell. This effect does not harm the rf properties but complicates somewhat the tuning process.

Additionally cells with half a cavity on both sides of the iris are still under consideration and may have the advantage of more rigidity and higher symmetry.

The specified tolerances are $\pm 10\,\mu$m for the most sensitive dimensions as for the cavity diameter and the iris diameter This would result in a frequency error of ± 420 kHz per cavity.

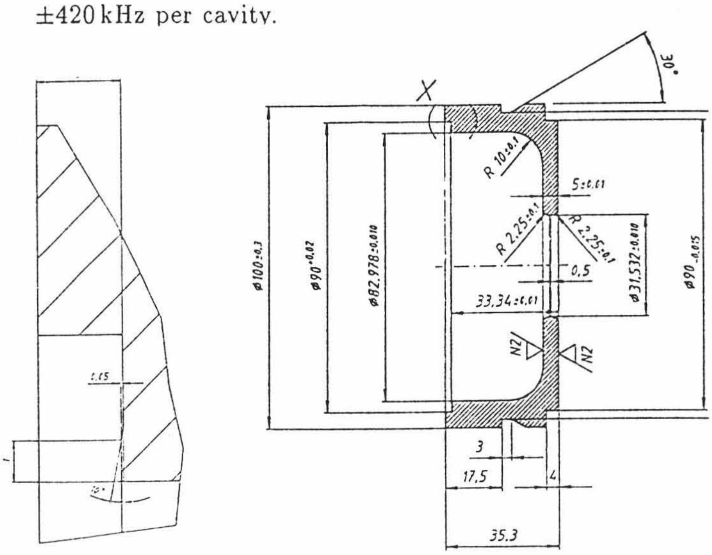

Figure 1: Single cell geometry.

A photograph of cells recently being finished is shown in fig. 2.

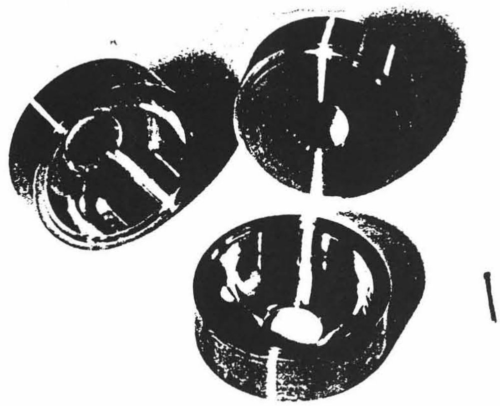

Figure 2: Photograph of cells recently produced for first Test measurements using 6-cell test stacks.

4 TUNING

In order to relax tolerances for the production of the single cells, a possibility for every cell must be foreseen to tune the resonant frequency. Therefore a recess in the cavity close to the inside wall has to be provided which allows mechanical deformation of the cavity wall. In figure 3 a geometry is presented which has been used to calculate the center shift using a single deformation with a diameter of 6 mm and a height of 1 mm in a single cell (π-mode).

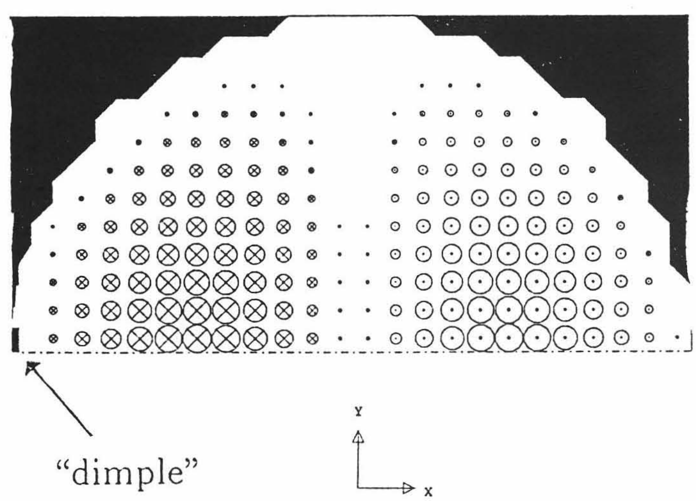

Figure 3: Geometry which has been used to calculate the center shift of the TM11 like dipole mode in a single cell due to a single deformation with a diameter of 6 mm and a height of 1 mm.

Four recesses have to be distributed over the cavity circumference in order to provide a symmetric deformation. This will avoid a shift of the electric center of the cavity compared to the outside wall which is the only reference to align the cups with respect to the outside support structure. Such a "dimple", only on one side, would lead to a center shift about 10 μm, which is proportional to the change in volume, providing a tuning range of $\approx$450 kHz for the accelerating mode. This shift would lead to an excitation of beam breakup modes although the beam passes the single cavities with respect to the geometric center. Because the center shift is of the order of the straightness which has to be achieved over the 6 m long section it has to be reduced. Having symmetric deformations avoids the center shift to a large extent and is undispensable in our case.

5 TEST RESULTS

For a test stack setup with 6 cells, mechanically clamped together, rf-measurements have been performed to determine the frequency of the $2\pi/3$-accelerating mode and the group velocity. The 6-cell cavity is shortened in the middle of both endcell-irises in order to provide a periodic boundary condition. The modes which now can be measured in every passband have a phase advance between $0\pi/6$ to $5\pi/6$, whereas the π-mode can not be measured because it would require an open boundary condition in both end cell irises. A cosine function is fitted using these six frequencies to calculate the dispersion diagram and the group velocity from the derivative of it. The measured frequency deviates by not more than 0.016 % which is well within the limits of tuning. The rms maching error one would deduce for a single cup given by this deviation is of the order of only $\pm 3\mu$m on the radii but it has to be kept in mind, that the field distribution of every mode averages over the six cells which will reduce the effect of a single error.

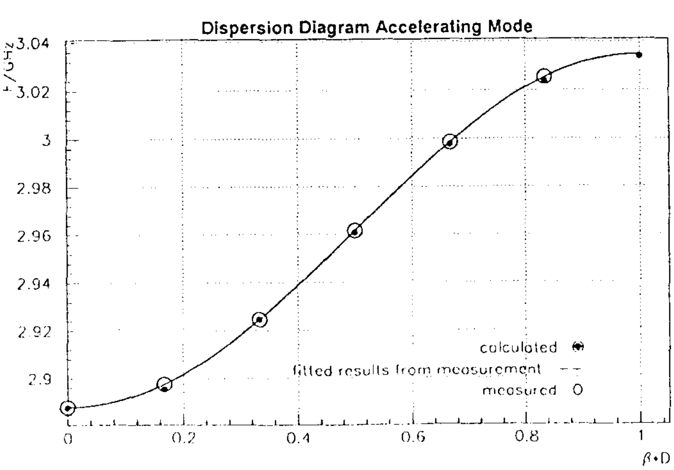

figure 4: dispersion diagram of the accelerating mode passband including the frequencies calculated by mafia.

The difference between design- and measured group velocity is 0.04% of c which corresponds to a 0.1 % error. The dispersion diagram including the measured and calculated frequencies (by MAFIA [3]) are shown in fig. 4. The q values have been determined roughly by measuring the width of the resonances and are around q=10 000 which is mainly determined by the unsufficient electric contact of the cell to cell joints which are not brazed together yet.

A second set of cavities has been machined on a different lathe, delivering the some order of achievable machining tolerances but with a systematic difference in the resonant frequency. In order to perform a quick quality control a single cup rf measurement has been developped. The resonant frequencies of the single cups can be measured with respect to each other but without any reference to the $2\pi/3$-mode frequency. In table 2 the rms deviation for the two sets of cavities is given. The rms deviation indicates in both cases a fabricational precision for the single cup production of $\pm 7\mu$m (less for the second set).

# of cav.	rms-dev of f_0/ [%]	mech. toler. / μm
5	0.019	± 7
10	0.016	± 6

Table 2: Single cell test results

This is just the limit which has been specified for the first test stacks. The large coupling between the cells and the the use of the $2\pi/3$ mode reduces the effect of the single cell error to the limit given before.

6 SUMMARY AND OUTLOOK

The cell geometry is chosen in order to ease the cavity production and reduce processing time. The dimensional tolerances which have been achieved for the first test cells are well within the limits of what is tolerable for an S-band accelerating section. By the end of this year the cup design will be finished and the 180 different cells for a single 6 m long section can be ordered. The first section, should be ready by the middle of 1993.

References

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