STUDIES ON r.f.-STRUCTURES AT 400 Mc/s AND 800 Mc/s FOR A PROTON LINEAR ACCELERATOR

W. Bauer, H. Eschelbacher and M. Kuntze

Institut für Experimentelle Kernphysik der Technischen Hochschule und des Kernforschungszentrums, Karlsruhe, (Germany)
(Presented by W. Bauer)

In Karlsruhe we are investigating the problems connected with a superconducting linac for several GeV. In this case we cannot only consider the usual features of structures, for instance shunt impedance and bandwidth. It may be very important not to complicate the deposition of superconducting material by an inadequate structure. We believe, that from this point of view the slotted Iris structure might be preferred instead of the Clover Leaf, for instance.

In the following we should like to report about measurements, we carried through at room temperatures on several models of slotted Iris structure at 800 Mc/s. From these experiments we obtained preliminary data for our first experiment with a supereconducting structure, which we hope to carry out in the next months.

We also made experiments on a crossbar model at 400 Mc/s. In order to obtain a reasonable comparison between both structures and to collect data for the interesting energy region in which a change between structures may take place, we chose a particle velocity of $\beta = 0.5$ for both models and measured with equivalent variations parameters.

We start with the description of the models. Table I shows the relevant mechanical data for both structures. Fig. 1a is an outline of the slotted Iris model, which consisted off brass plates and brass cylinders. Each cylinder carried two coupling loops and a tuning piston. Drift tubes of three different lengths could be screwed into the plates.

The two cell crossbar model shown in Fig. 1b was machined of brass and consisted of four single rings joined together with indium wire to have good electrical contact. We could easily exchange the long drift tubes screwed into the stems.

We measured the resonance frequencies of each mode, resulting in the Brillouin-diagram, the shunt impedance and transit-time-factor for the π-mode. As we expect no representative Q-values in our demountable models we only meusured the ratios shunt-impedance/Q.

The parameters we varied in the slotted Iris model were the gap length and the slot width. We kept constant the slot angle. We measured a two cell and a three cell model.

In the crossbar model we varied only the gap length and kept constant all the other parameters. We studied two different drift tube shapes: in one series of measurements we used drift tubes of nine different lengths with rounded corners, in the other we tested five different drift tubes with flat fronts. The latter measurements were of special interest for a comparison with the calculations of G. Dôme.

The experimental arrangement for the measurement of shunt impedance after the well known method introduced by J. C. Slater was as follows. We connected a 60 db-amplifier with a bandwidth of about 100 Kc/s to the cavity so that we got a positive feedback. The amplifier worked as a lock-in-oscillator at

TABLE I

Mechanical data

	Slotted Iris	Crossbar
cell length (L)	98.5 mm	210 mm
tank diameter	288 mm	280 mm
stem »	—	21 mm
drift tube »	65 mm	65 mm
beam aperture	17.5 mm	17.5 mm
drift tube length	65 – 36 mm	125 – 61 mm
slot angle	44°	—
slot width	10 – 83 mm	—
plate thickness	6 mm	—

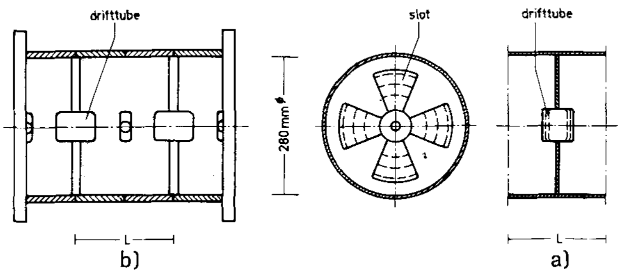

Fig. 1 - b) Cross-bar model; a) Slotted Iris-model.

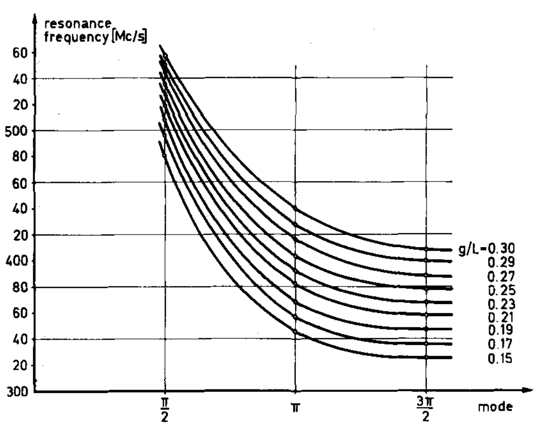

Fig. 2 - Brillouin diagram. Cross bar structure.

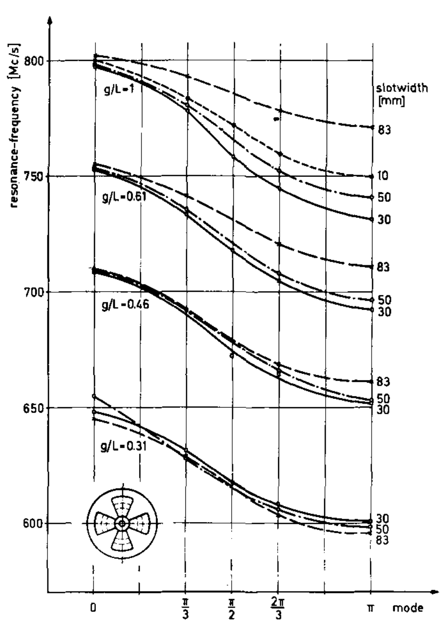

Fig. 3 - Slotted Iris.

TABLE II

Experimental results for π-mode

g/L		Frequency (Mc/s)					ZT²/Q (K-ohm/m) (scaled to β = .5)					Transit-time-factor.				
		Crossbar		Slotted Iris			Crossbar (± 0.5%)		Slotted Iris (± 5%)			Crossbar		Slotted Iris		
Cross bar	Slo. Iris	rounded corners	flat front	slotw. 3 cm	slotw. 5 cm	slotw. 8.3 cm	round corners	flat front	slotw. 3 cm	slotw. 5 cm	slotw. 8.3 cm	rounded corners	flat front	slotw. 3 cm	slotw. 5 cm	slotw. 8.3 cm
.15	.31	345.947	336.704	600.867	597.915	596.828	2.087	2.068	2.00	2.34	2.49	.901	.909	.919	.924	.915
.17		357.409					2.035					.872				
.19		359.261	363.859				2.027	1.955				.868	.864			
.21		380.674					1.884					.838				
.23	.47	392.422	383.957	652.820	653.862	661.106	1.791	1.824	1.87	2.05	2.10	.833	.844	.848	.862	.864
.25		404.166					1.762					.812				
.27		416.062	407.528				1.636	1.687				.789	.785			
.29		428.396					1.552					.756				
.31	.61	440.434	431.964	692.565	696.813	711.474	1.450	1.556	1.85	1.94	2.24	.740	.732	.801	.804	.807
1.0				731.512	740.635	771.655			0.92	1.02	1.17			.716	.736	.730

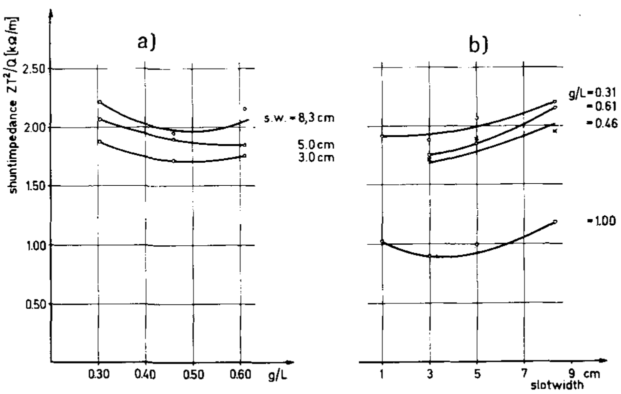

Fig. 4 - Slotted Iris.

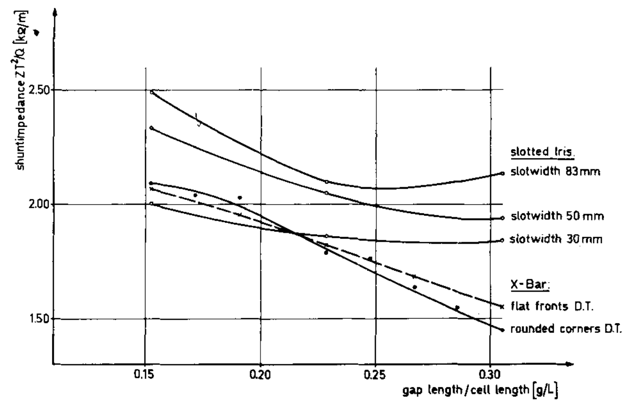

Fig. 5 - Comparison between cross-bar and slotted Iris for $\beta = 0.5$.

the π-mode frequency of the cavity, and followed the frequency perturbations by the brass ball, which we pulled along the axis of the cavity. The central frequency of the amplifier was adjustable in the region between 300 and 600 Mc/s. With this arrangement the frequency is kept at an accuracy better than $\pm$ 100 c/s and therefore the shunt impedance could be calculated with a mean square deviation of 0.5%. We found out, that this method is about ten times more accurate than using a r.f.-generator and an indicator for the resonance maximum. The results on slotted Iris reported here are measured with the second method and therefore the values of shunt impedance have an error of 5%.

Fig. 2 gives a summary of our frequency measurements on the crossbar model. It is shown the frequency versus the mode in form of a Brillouin diagram, with the gap length as parameter. The bandwidth does not depend on the gap length. The π-mode frequencies increase linearily with g/L. We have calculated the values of π-mode frequencies from the formula given by G. Dôme and found our measured figures about 5% lower.

The corresponding diagram for the slotted Iris shows Fig. 3. There are four families of curves for different ratios of gap length/cell length. Parameter is the slot width. It can be seen that there is a preferred geometry with regard to the bandwidth. (Bandwidth is here defined as the relative difference between the frequencies of 0-mode and π-mode). For $g/L = 1$ (no drift tubes) and 0.46, and for $g/L = 0{,}61$ and 0.31 there are maxima in bandwidth for a slot width of 3 cm and 5 cm, respectively.

Increasing the slot width, that means primarily, making the coupling stronger gives not always higher bandwidth. The reason for this may be, that near the center the electric field participates more and more in coupling, increasing the π-mode-frequency. The best values of bandwidth we obtained with the slotted Isir are between 8% and 9%.

The values of shunt impedance of the slotted Iris are plotted in Fig. 4a versus g/L and in Figure 4b versus slot width. There is a minimum of shunt impedance /Q at $g/L = 0.46$ for all slot widths. A remarkable difference of a factor of nearly two in shunt impedance is seen between a structure without drift tubes and a drift tube structure.

Fig. 5 gives a summary of our measured shunt impedances.

In order to compare the results of the slotted Iris and the crossbar we scaled the values of shunt impedance to a frequency, which corresponds to a particle velocity $\beta = 0.5$ at the given cell length L. The two lower curves represent two series of crossbar measurements with flat fronted drift tubes and round cornered ones. The curves are in reasonable agreement with values we calculated from G. Dôme's formula. The three curves above give the values for slotted Iris with different slot widths. They are about 25% higher than the corresponding crossbar values.

This may justify our decision, to use the slotted Iris structure for our first superconducting experiment, because it is known, that for this structure the shunt impedance increases with particle energy.

Table II summarizes the measured results.

DISCUSSION

NISHIKAWA: What mode do you use?

BAUER: We use the π- mode for both structures.