An Investigation of Model Performance of Low Frequency RF Cavities.

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Abstract

Daresbury Laboratory operates four 500MHz RF cavities in its 2 GeV electron storage ring. The short Touschek lifetime of a 500MHz bunch when in single bunch mode limits the maximum beam current achievable. By operating the storage ring at a lower RF frequency at injection, the bunch length could be increased, hence increasing the Touschek lifetime. Coaxial accelerating cavity options at 125MHz and 50MHz have been investigated and model test cavities have been manufactured. Low power measurements have been performed on these test cavities and the results have been compared with those of the computer simulation codes MAFIA [1] and URMEL-T [2].

1. INTRODUCTION

Single bunch operation on the S.R.S. has always caused problems for the operations team, bunch contamination being the primary cause. This is principally due to the Touschek lifetime of a 500MHz bunch being so short. One way of increasing the Touschek lifetime of a single bunch, is to increase the electron beam volume. By using a low frequency R.F. system at injection, the bunch length and hence its overall volume can be increased (Fig. 1).

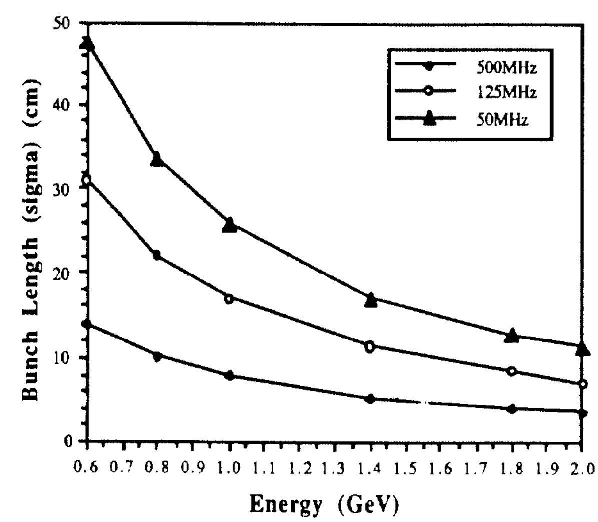

Figure 1. Effect of RF frequency on bunch length[1].

At injection, the four 500MHz cavities will be switched ON and detuned, but at zero output power. At the same time, the low frequency (LF) cavity will be tuned and set to a pre-defined power level. Four adjacent electron bunches will be injected into the Booster and by injecting at the correct phase and timing, these can be injected into a single LF bunch in the storage ring [3]. The bunch will then be ramped using the low frequency source to an energy of ~1.4GeV. At which point, the 500MHz cavities will be tuned and their power increased. The LF cavity will then be detuned and its power level reduced to zero. From this point, the energy ramp upto 2.0GeV will continue as normal. Power supply requirements for the LF system have been investigated and a 40KW Tetrode amplifier has been ordered.

2. Cavity Investigation

Prior to manufacture of an aluminium model test cavity, extensive computer modelling of various cavity geometry has been performed. Investigations of shunt impedance and also HOM spectrum as a function of geometry being the fundamental concern.

2.1 The 125MHz option

For the 125MHz system, two options have been investigated; the first is a quarter wave capacitively loaded coaxial structure (Fig. 2) and the second is a conventional re-entrant or "nosecone" design (Fig. 3).

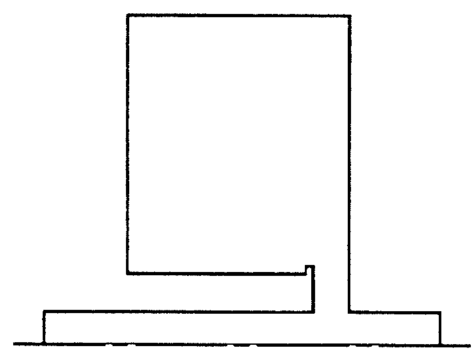

Figure 2. Coaxial Cavity Model (Type 1).

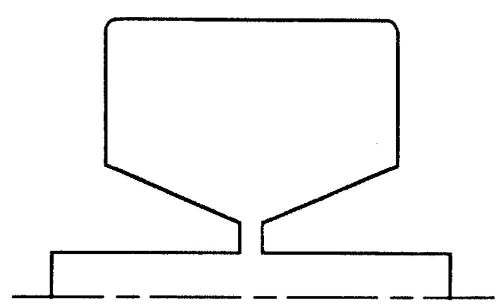

Figure 3. Re-entrant Cavity Design

[1] Calculated figures for bunch length includes microwave blowup.

Simulations of the two designs using the 3D code MAFIA and the 2D code URMEL-T enabled optimisation of the two geometries whilst maintaining the appropriate design criteria. Fig. 4 shows HOM spectra as a function of shunt impedance for each of the two designs;

Coaxial Cavity HOM's			Re-entrant Cavity HOM's		
Freq (MHz)	ZT^2 (MΩ/m)	Mode	Freq (MHz)	ZT^2 (MΩ/m)	Mode
125	3.06	Mon	125	4.12	Mon
470	6.5	Dip	542	8.37	Dip
636	6.02	Dip	617	0.23	Mon
763	1.76	Dip	680	1.88	Dip
812	4.21	Dip	748	7.96	Dip
990	0.01	Mon	941	1.49	Dip
1015	0.01	Dip	963	2.3	Dip
1016	0.27	Mon	1321	1.57	Dip
1044	1.11	Dip			
1131	0.65	Mon			
1201	3.49	Dip			

Figure 4. Significant HOM Spectra for 125MHz design options predicted by URMEL-T[2] .

As can be seen from the results of Fig. 4, both cavity geometries have potentially dangerous HOM's reasonably close to 500MHz, which may be excited by the electron beam. Further investigations would need to be completed on the chosen design to try and shift the HOM spectrum away from these inevitable cavity-beam interaction areas.

It was decided, mainly due to cost limitations on the manufacture of the final copper cavity design, that an aluminium coaxial model cavity (Type 1) be manufactured.

2.2 The 50MHz Option

The 50MHz option is basically an adaptation of the 125MHz coaxial option. By modification of the capacitive disk radius it was possible to obtain resonant frequency, however with significant reduction in shunt impedance (Fig. 5).

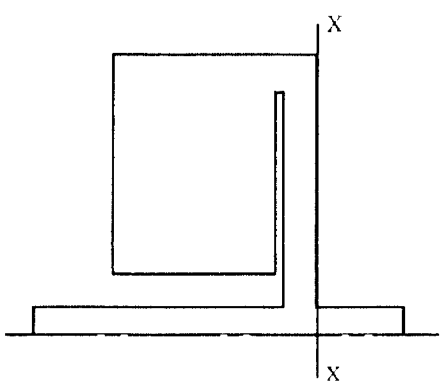

Figure 5. Modification of 125MHz capacitive disk radius.

Again URMEL-T was used to simulate the effect of increasing the capacitive disk radius and Fig. 6. shows the relationship of radius increase against resonant frequency and shunt impedance.

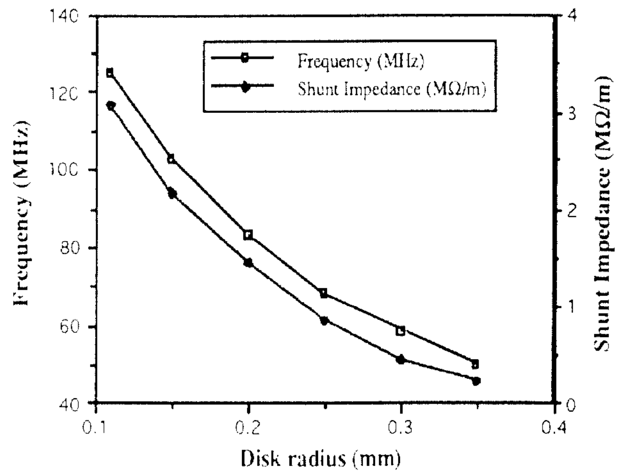

Figure 6. Variation of fo and shunt impedance as a function of disk radius

The graph shows that an increase in disk radius to 0.35m would give a 50MHz resonant frequency and a shunt impedance of 250KΩ/m. Obviously the reduction inshunt impedance to such an extent would be unacceptable as far as power supply requirements necessary, hence further investigations were performed which used the same cavity geometry as Fig.5, using symmetry about X-X (ie. everything to the left of X-X, repeated to the right of X-X).

The new geometry (Fig.7) would therefore havetwice the inductance component with negligible reductionof capacitive component and would expect to resonate atthe same frequency with twice the Ro/Qo and consequently twice the shunt impedance. The expectation is correct andURMEL-T was used to show that for the geometry of Fig. 7, the shunt impedance is increased to545KΩ with a slight reduction in resonant frequency to 49.3MHz.

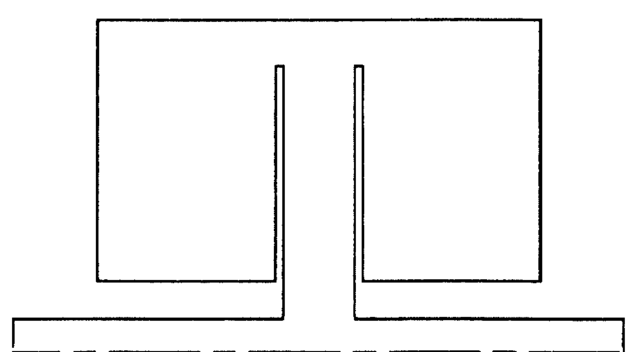

Figure 7. Double width 50MHz Coaxial cavity (Type 2).

[2] Copper cavity simulations.

3. Low Power Mesurements

Two aluminium model cavities have been manufactured, for evaluation. The first is that of Type 1 (Fig. 2), with a removable capacitive disk, so that larger disks maybe bolted on (as in Fig. 5). The second cavity is Type 2 (Fig. 7), again with removable capacitive disks, this cavity is basically two of the Type 1 cavity and therefore was designed in such a way that only half the Type 1 geometry had to be remanufactured.

Perturbation measurements [4] have been performed on the Type 1 aluminium test cavity whereby figures for Ro/Qo have been evaluated for all accelerating (or longitudinal) modes below ~3GHz. The type 1 cavity actually consists of seven separate sections carefully bolted together and the Type 2 cavity has eight. The main effect this has on the measurement of Ro/Qo is that it significantly reduces the Qo of cavity. Steps have been taken to try and minimise these effects by using copper conductive tape over each transition of the mating sections. Ro/Qo is purely a function of cavity geometry and is a means by which the effectiveness of RF cavities can be compared. Fig. 8 shows a list of all accelerating modes found, with their associated Ro/Qo contribution for the 125MHz coaxial model cavity.

URMEL-T			Perturbation Results		
Freq (MHz)	Qo	ZT^2 (MΩ/m)	Freq (MHz)	Qo	ZT^2 (MΩ/m)
124.66	13993	116.87	125.12	9000	116.88
544.31	21838	7.75	541.79	839	4.8735
725.24	18550	4.66	728.48	150	0.1
990.61	19023	0.132	none found		
1105.75	23005	0.126	1109.42	588	No Δf
1017.5	29762	0.137	1017.2	3601	0.096
1131.78	22055	7.305	1131.17	322	No Δf
			1469.49	30041	1.2638
1875.06	27001	1.898	1882.3	2939	No Δf
1987.51	35324	0.194	1977.35	15027	No Δf
2090.2	34413	0.144	2093.84	20423	No Δf

Figure 8. Longitudinal HOM Perturbation results for 125MHz Coaxial Cavity (Type 1) compared to URMEL-T predictions.

Low power measurements compared favourably with URMEL-T predictions, with the fundamental producing almost exact agreement, Fig. 9 shows the resultant $\sqrt{\Delta f/fo}$ as a 5mm radius copper bead travels the cavities length. The measurements of accelerating modes has shown no evidence of any other strong (high impedance) HOM's. To date, further investigations of tuner range and transverse acting dipole HOM's have to be completed.

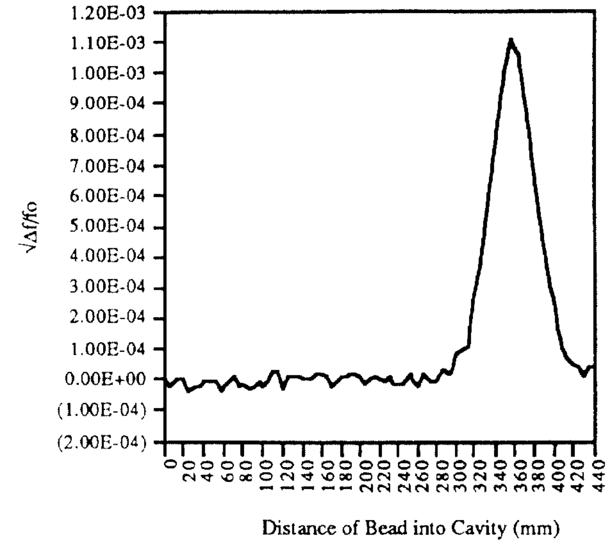

Figure 9. Perturbation Response of 125MHz cavity.

4. CONCLUSIONS

Preliminary investigations of a 125MHz coaxial cavity has proved promising. The proposed operation of a low frequency RF system in conjunction with the standard 500MHz RF syatem has proved successful at BESSY and with the potential doubling of bunch length in single bunch mode at 125MHz and a factor of 3 increase at 50MHz on the SRS, intra bunch scattering at injection could be reduced and maximum bunch current increased.

The 50MHz geometry has yet to be evaluated thoroughly, however computer simulations indicate that the geometry is feasable, with a factor of ~4 reduction in shunt impedance over the 125MHz option.

5. Acknowledgements

The author would like to thanks J.A. Clarke for his assistance in the production of this paper.

5. References

[1] The Mafia Collaboration (DESY, LANL, KFA), "MAFIA User Guide", 1988.

[2] U. Laustroer, U. van Rienen, T. Weiland, "URMEL and URMEL-T User Guide", 1987

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[4] P.A. McIntosh, "Perturbation Measurements of RF Cavities at Daresbury", these proceedings.