Design of Multiple-beam Klystron Cavities

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Abstract: *In this work the design of multiple-beam re-entrant cavities with 4, 6, and 8 beam tunnels for a 350 MHz is presented. These cavities can be useful in a multiple-beam klystron development for proton linac including spallation neutron source applications. The study was carried out using the electromagnetic tool CST Microwave Studio.*

Keywords: Multiple-beam klystron cavity, MBK, spallation neutron source, SNS.

Introduction

Klystron amplifiers play a critical role in high-energy accelerators such as proton accelerators for Spallation Neutron Source [1]. Among klystron designs there is a multiple-beam version. There are numerous advantages to the multiple-beam klystron (MBK) compared with a conventional single beam klystron. In these amplifiers, a high total beam current is achieved by dividing the electron beam into multiple beamlets. Additionally, one of the most important advantages afforded by the MBK configuration is a reduction in operating voltage relative to conventional single-beam klystrons.

In this work are presented some designs of multiple-beam cavities to be used as an interaction structure for a multiple-beam klystron. Some examples to 4, 6, and 8 beam cavities are simulated and the results are compared. Cavity simulations have been performed using CST Microwave Studio [5].

The re-entrant cavity characteristics

Relevant geometric re-entrant cavity parameters are presented in Table I while Fig. 1 shows the cavity geometry. The starting point to find these parameters was a theoretical approach used to find the resonant TM_{010} mode, at 350 MHz, of single beam cavity. After this finding, the CST Microwave Studio was run to find the geometric parameters of a multiple beam cavity.

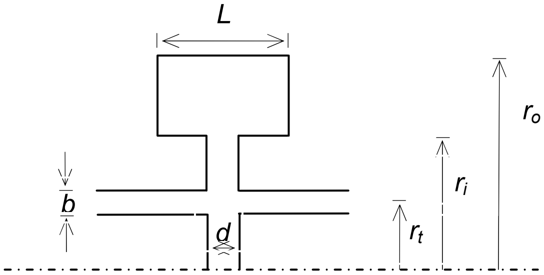

Figure 1. Cross-section of a re-entrant cavity for multiple-beams under study.

Table I. Re-entrant cavity parameters

Quantity	4 beams (mm)	6 beams (mm)	8 beams (mm)
Length L	94.0	94.0	94.0
Outer cavity radius r_o	200.0	200.0	200.0
Inner cavity radius r_i	160.0	160.0	160.0
Gap width d	20.0	20.0	20.0
Tunnel length	114.0	114.0	114.0
Tunnel axis radius r_t	80.0	80.0	80.0
Tunnel radius b	8.0	6.0	4.0

Results

Tables II to IV summarizes the simulation results obtained running CST Microwave Studio with input data shown in Table I. It is possible to see the first resonant modes for the three cavities under study. It is also to see the unload Q-factor, Q_0, increases with the frequency, as expected.

Table II. 4-beam cavity mode separation.

Mode number	f (MHz)	Q_0
1	350.9	7860
2	666.6	8806
3	970.3	10068

Table III. 6-beam cavity mode separation.

Mode number	f (MHz)	Q_0
1	350.7	7814
2	666.4	8790
3	970.2	10116

Table IV. 8-beam cavity mode separation.

Mode number	f (MHz)	Q_0
1	352.3	7802
2	671.3	8757
3	979.7	9969

Besides the unloaded Q-factor, another relevant figure of merit is that relating the re-entrant cavity with its ability in doing work on an electron beam. It is defined as the ratio of the shunt resistance R_{sh} and Q_0 and writes,

$$\frac{R_{sh}}{Q_0} = \frac{\left[\int_{-\infty}^{\infty} \vec{E}(r = r_t, z) \cdot \hat{a}_z dz \right]^2}{2\omega_0 W} \tag{1}$$

where $\vec{E}(r = r_t, z) \cdot \hat{a}_z$ is the axial component of the electric field calculated on the tunnel axis and W is the total electromagnetic energy storage in the cavity. The knowledge of R_{sh}/Q_0 is fundamental to describe the power balancing between the RF field in the cavity and the electron beam. Table V shows the R_{sh}/Q_0 for the three cavities under study and for the TM_{010} mode. It is possible to note a little decreasing of R_{sh}/Q_0 with the number of beam tunnels.

Table V. R_{sh}/Q_0 for the three cavities under study.

Mode	**R_{sh}/Q_0 (Ω)**		
	4 beams	**6 beams**	**8 beams**
TM_{010}	37	34	32

Conclusion

In this work the design of multiple-beam re-entrant cavities with 4, 6, and 8 beam tunnels was presented. The relevant results were: the unload Q-factor increases with the frequency and R_{sh}/Q_0 decreases with the number of beam tunnels.

Acknowledgments

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