C-BAND MAGNETIC COUPLED ACCELERATING STRUCTURE OPTIMIZATION

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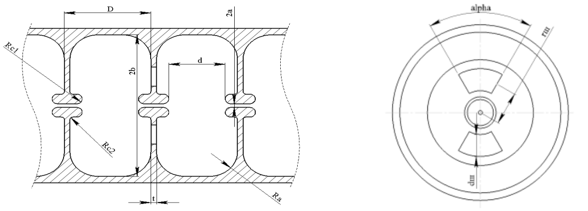
Abstract

This paper presents the results of a research that analyzed the possibility of using a magnetic coupled disk-loaded structure (DLSM) as an accelerating structure. DLSM seems to have decent advantages comparing to the classical electrical coupled structure (DLS). The electrodynamics parameters of such a structure at various modes in C-band for a wide range of phase velocities as a function of aperture radii and coupling slot sizes are presented. Both forward and backward travelling wave regimes are considered. The essential parameters are compared to those of classical DLS. The design of an input coupler to the accelerator consisting of this type structure cells is also presented.

INTRODUCTION

The most common accelerating structure for electron travelling wave (TW) linacs is a disk-loaded waveguide (DLS), which has high shunt impedance and is simple to produce. Standing wave (SW) linacs usually use a biperiodic accelerating structure (BAS) working at $\pi/2$ mode. Because of considerable reduction of on-axis coupled cell length they have higher shunt impedance, but also much longer RF power fill time.



a) longitudinal section b) transversal section

Figure 1: Magnetic coupled disk-loaded structure.

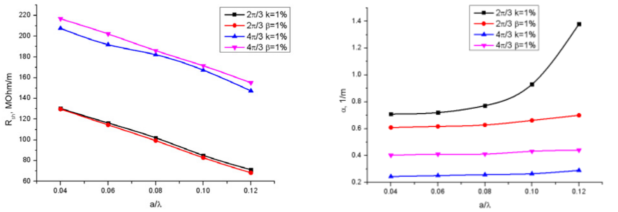
TW magnetic coupled accelerating structure (DLSM) presented at Fig.1 unites the advantages of both electric coupled DLS (small fill time) and BAS (high shunt impedance). This structure is able to work either in backward wave regime at the modes less than π (DLSM-N) or in forward wave regime at the modes greater than π (DLSM-P) [1,2].

STRUCTURE OPTIMIZATION

To design a linac which use DLSM as an accelerating structure it is necessary to find its optimal dimensions in order to obtain the best electrodynamical parameters. These parameters are the following: shunt impedance r_{sh}, normalized electric field strength $E\lambda/P^{1/2}$ and attenuation α. It is important to know their dependences on operating mode θ, group velocity β_{gr} and coupling coefficient k_c. This optimization was done for the frequency equal to 5712MHz.

Aperture Radius Optimization

First, electrodynamical parameters dependences on aperture radius to wavelength ratio a/λ were found. At each value of a/λ the coupling holes dimensions were adjusted to make either coupling coefficient or relative group velocity equal to 1%.



a) shunt impedance b) attenuation

Figure 2: Parameters dependences on aperture radius.

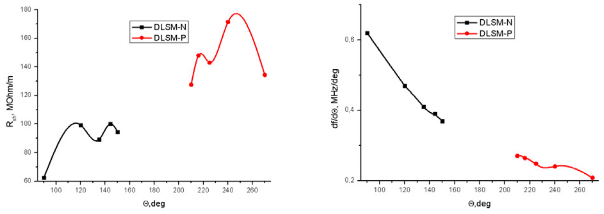
The larger aperture radius means the larger acceptance but also the larger electric coupling. To retain the chosen coupling coefficient it is necessary to increase the magnetic coupling. Besides, the large aperture reduces the electric field concentration near the axis, thus leading to shunt impedance decrease and overvoltage coefficient K_E increase. The results are presented at Fig.2. The $2\pi/3$-mode was an operating mode for DLSM-N, and $4\pi/3$-mode for DLSM-P.

Operating Mode Optimization

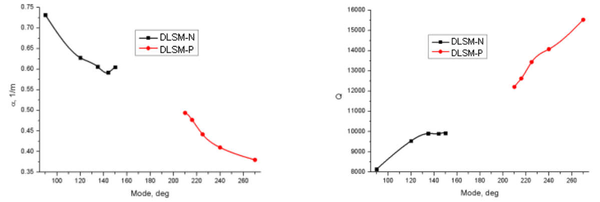
Second, it is necessary to optimize the operating mode of the structure, in order to obtain the maximum shunt impedance and normalized field strength. Also, the coupling coefficient and group velocity should be reasonable. The group velocity has the most influence on electric field among all other parameters. Thus, the coupling holes dimensions were adjusted to make β_{gr} equal to 1%.

Another important parameter is a frequency separation between the nearest modes. The higher it is, the less sensitive is the accelerator to frequency deviations.

Shunt impedance, frequency separation and attenuation dependences on the operating mode are presented at Fig.3. During the optimization, a/λ was equal to 0.08. According to these results, the optimal operating modes are *2π/3* for backward wave and *4π/3* for forward wave regimes. Shunt impedance and normalized electric field have maximum values at these modes. For the DLSM-N structure frequency separation between the nearest modes is better than for the modes greater than π. For DLSM-P these parameters differ much less.



a) shunt impedance b) frequency separation

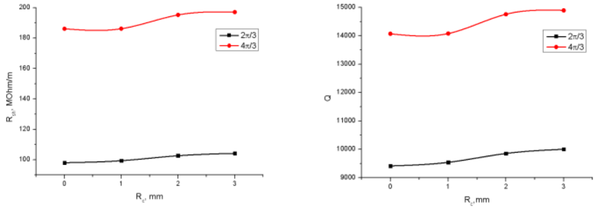


c) attenuation d) Q-factor

Figure 3: Parameters dependences on the operating mode. (left for DLSM-N, right for DLSM-P)

Shunt Impedance Increase

In order to increase the quality factor of the structure, it is necessary to reduce the RF losses in the conductive walls. This can be achieved by blending the inner surface of the cells. Shunt impedance and Q-factor dependences on the blending radius are presented at Fig.4.

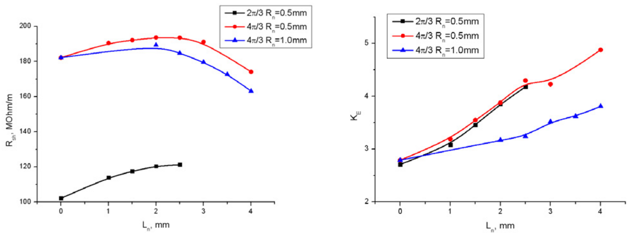


a) shunt impedance b) Q-factor

Figure 4: Parameters dependences on cell blending radius.

Unfortunately, in this type of structure the blending radius can't be increased too much because of its intersection with the coupling hole.

All previous results were obtained for the structure without drift tubes. But inserting a drift tube can help to concentrate the electric field near the axis and provide an RF-focusing of the particles. It is necessary to regard its influence on the electrodynamical parameters and to estimate the practicality of such an insertion. Fig.5. presents the dependencies of shunt impedance and overvoltage coefficient as functions of drift tube blending radius R_n and length L_n.



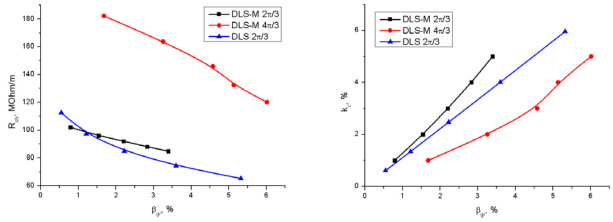
a) shunt impedance b) overvoltage

Figure 5: Parameters dependences on drift tube length.

These results indicate the practicality of small dimensional drift tubes insertion, because the shunt impedance and electric field strength are slightly increased.

Comparison with DLS

Now it is interesting to compare electrodynamical parameters of DLSM with the same of classical electric coupled DLS. The latter structure has no magnetic coupling holes, thus only the aperture radius a/λ defines both coupling coefficient and group velocity. Fig.6 shows compared parameters of DLSM working at modes $2\pi/3$ and $4\pi/3$ with $a/\lambda=0.08$ and parameters of DLS working at mode $2\pi/3$ as functions of their group velocities.



a) shunt impedance b) coupling coefficient

Figure 6: Parameters dependences on group velocity.

These graphs show that though DLS has better coupling coefficient, DLSM structure is more advantageous regarding the other parameters which are important in the meaning of beam dynamics.

HIGH-ORDER MODES

The high-order modes (HOM) electrodynamical parameters were calculated for DLSM-P structure with $\beta_{ph}=1$ operating at $4\pi/3$ mode. HOM can dramatically influence on the quality of the accelerated beam. In this structure the dipole modes are presented with 2 polarizations. The values of transversal shunt impedance $r_{sh\perp}$, loss coefficient k and induced transversal potential $W_\perp$ for E_{110}, E_{210}, E_{112}, H_{111}, H_{211},H_{212} waves are presented in Table 1. The two latter parameters are per cell. Fig.7 presents the dispersion curves of the nearest HOM.

Table 1: HOM Parameters

Wave	***a/λ***	***F*, MHz**	**$r_{sh\perp}$, MΩ/m**	***k*, GV/s**	**W$_\perp$, TV/s*m**
H_{111}	0.1	6162	$22*10^{-3}$	1.148	0.6453
E_{110}	0.08	9134	4.13	250.8	148.5
	0.1	9075	5.22	345.2	131.8
	0.12	8867	9.81	1105	299.8
H_{211}	0.1	8549	$0.2*10^{-3}$	0.0132	389.7
H_{212}	0.1	11597	$1.5*10^{-3}$	0.1075	2332
E_{210}	0.1	12237	$25*10^{-3}$	1.411	29000
E_{112}	0.08	11684	1.704	199.0	92.14
	0.1	11186	0.198	28.7	8.904
	0.12	11162	0.072	7.944	1.712

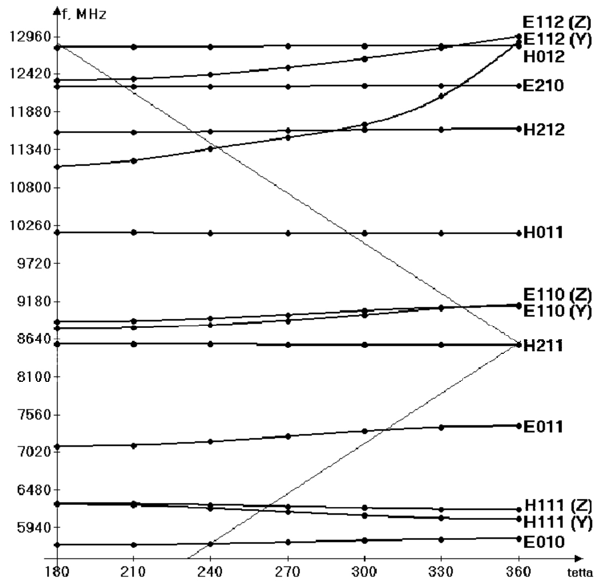
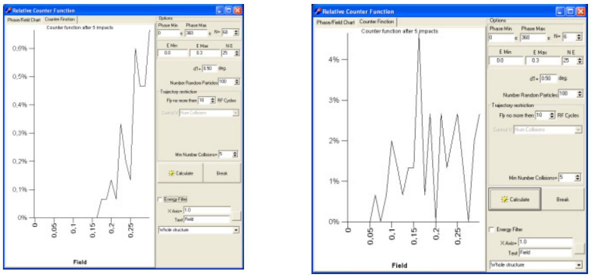


Figure 7: Dispersion curves of nearest HOM.

The simulation results confirm that dipole E_{11}-like waves bring the most significant influence on a beam as they have the highest transversal shunt impedance among all HOM. This structure has a good frequency separation (over 3GHz) between operating E_{01} and dangerous E_{11} pass bands. The values of loss coefficients and transversal induced potentials are reasonable.

MULTIPACTING DISCHARGE

The calculations of multipacting discharge in DLSM-P structure operating at $4\pi/3$ mode with a/λ=0.8 and β_{ph}=1 were provided using MultP-M code [3]. The simulations were done for the initial phases ranges from 0 to 360 degrees with a 6 degrees step and the field strengths range from 0 to 30 MV/m. Fig.8 demonstrates the relative counter functions in DLS and DLSM structures. Only particles with 5 or more collisions were taken into account. The simulations were over after 10 RF periods. These graphs show that the increase of electrons number occurs while the on-axis field strength is higher than 15 MV/m.



Phase Min 0 Phase Max 360 N= 60
E Min 0.0 E Max 0.3 N E 25
dT= 0.50 deg.
Number Random Particles 100
Trajectory restriction
Fly no more then 10 RF Cycles
Min Number Collisions= 5
X Axis= 1.0
Text Field
Whole structure

Phase Min 0 Phase Max 360 N= 6
E Min 0.0 E Max 0.3 N E 25
dT= 0.50 deg.
Number Random Particles 100
Trajectory restriction
Fly no more then 10 RF Cycles
Min Number Collisions= 5
X Axis= 1.0
Text Field
Whole structure

a) DLSM b) DLS

Figure 8: Relative counter functions.

Comparing the results for DLS and DLSM it comes clear that the presence of coupling holes considerably improves multipacting discharge resistance.

CONCLUSIONS

The electrodynamical parameters of the magnetic coupled disk loaded structure have been calculated both for positive and negative dispersions at the frequency 5712 MHz. These simulations were provided for the various geometrical parameters and operating modes in order to achieve its optimal performance.

The comparison of DLSM electrodynamical parameters with same of classical DLS shows the advantages of the described structure. The possibilities of the future parameters improvement due to the cell blending and drift tubes insertions were also showed.

High-order modes parameters of this structure were calculated, which demonstrated the reasonable cell performance in meaning of HOM. The simulations of multipacting discharges proved that magnetic coupling holes help to reduce the probability of this discharge occurance.

Future plans include the cell prototype creation and beam dynamics simulation of DLSM based accelerators.

REFERENCES

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