MAGNETIC COUPLED DISK-LOADED WAVEGUIDE

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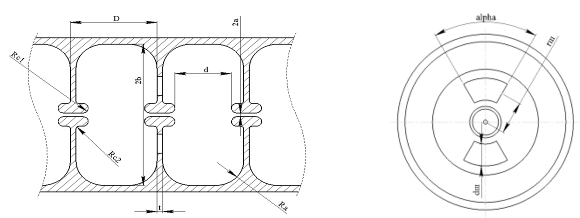
Abstract

The results of numerical simulations of electrodynamical parameters (EDP) of magnetic coupled disk-loaded waveguide (DLS) with negative dispersion are presented in this article. Different structure variants for high and low phase velocity were considered. High order modes and multipacting discharge issues were also regarded.

INTRODUCTION

The most common accelerating structure for electron linacs is DLS at travelling wave (TW) and biperiodic accelerating structure (BAS) at standing wave (SW)



a) longitudinal section b) transversal section

Figure 1: Magnetic coupled disk-loaded structure

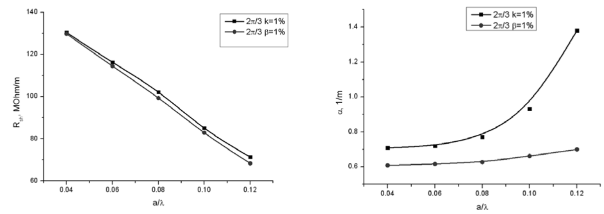
TW magnetic coupled accelerating structure (DLSM) presented at Fig.1 unites the advantages of both electric coupled DLS (small fill time) and BAS (high shunt impedance). This structure is able to work in backward wave regime at the modes less than π [1].

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, electro-dynamic 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%.



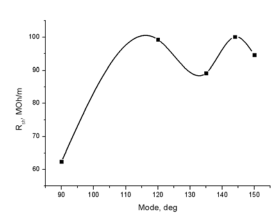
a) shunt impedance b) attenuation

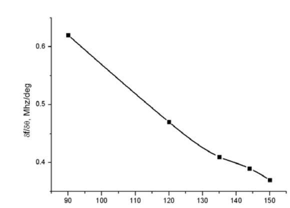
Figure 2: Parameters dependences on aperture radius

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 chosen as an operating mode for DLSM.

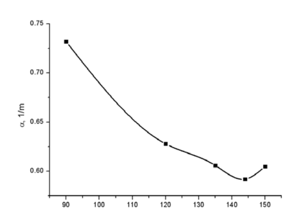
Operating Mode Optimization

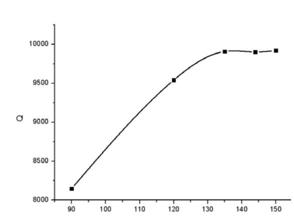
Second, it is necessary to optimize the operating mode of the structure, in order to obtain the maximum shunt impedance and normalized field strength. Also, the coupling coefficient and group velocity should be reasonable. The group velocity has the most influence on electric field among all other parameters.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





a) shunt impedance b) frequency separation





c) attenuation d) Q-factor

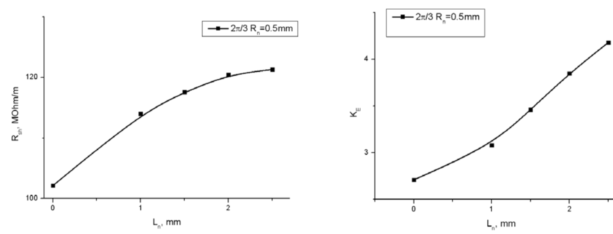
Figure 3: Parameters dependences on the operating mode for DLSM

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 mode $2\pi/3$ was chosen. Shunt impedance and normalized electric field have maximum values at these modes.

Shunt Impedance Increase

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.4. presents the dependencies of shunt impedance and overvoltage coefficient as functions of drift tube blending radius R_n and length L_n.

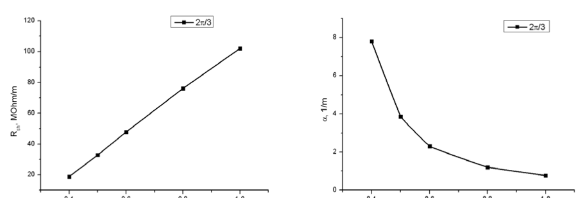


a) shunt impedance b) overvoltage

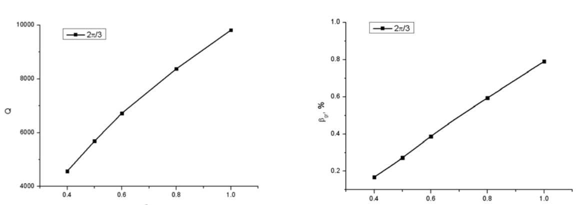
Figure 4: Parameters dependences on drift tube length

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

Low Phase Velocities



a)shunt impedance b) attenuation



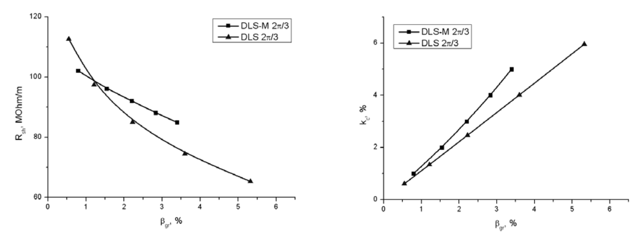
c) Q-factor d) group velocity

Figure 5: Electrodynamical parameters dependences on phase velocity

The DLS with magnetic coupling could be also designed for low beta structures without sufficient performance drop. This is important for applications like waveguide buncher with variable phase velocity for TW linear electron accelerator or heavy particle (like proton) accelerating structures. Electromagnetic parameters of DLSM were evaluated at $2\pi/3$ mode. The structure with 1% coupling coefficient operating at 5712 MHz was studied for velocities down to 0.4. Fig. 5 presents the results of r_{sh}, Q, α and β_{gr} [2] dependences on β_{ph}.

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 mode $2\pi/3$ 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 DLSM has better coupling coefficient, shunt impedance and 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 structure with β_{ph} =1 operating at $2\pi/3$ mode.

Table 1: HOM Parameters

EDC	*Type*	E_{110}	H_{111}	E_{111}	E_{112}
Frequency, MHz	DLS	8614.1	1041	12566	-
	DLSM	9075.0	6162.5	9885	11186
Q	DLS	13838	12809	8621	-
	DLSM	15094	12836	13128	8446
r_{sh}, *MOhm/m*	DLS	44.96	0.267	4.44	-
	DLSM	5.22	0.0217	1.44	0.197
k, *V/(pC*m)*	DLS	43.97	0.34	10.7	-
	DLSM	4.93	0.016	1.699	0.411
$W_{\perp}$, *V/(pC*m^2)*	DLS	17680	113.4	2796	-
	DLSM	1882	9.2	595.5	127.2

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 Q-factor, transversal shunt impedance $r_{sh\perp}$, loss coefficient k and induced transversal potential $W_{\perp}$ for identically E_{110}, E_{111}, H_{111}, E_{112} waves of DLSM and DLS with a/λ=0.1 are presented in Table 1. The two latter parameters are given per cell. Fig.7 presents the dispersion curves of the nearest HOM.

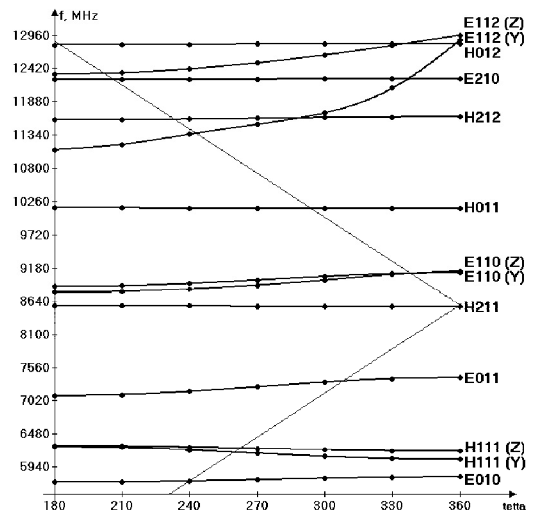
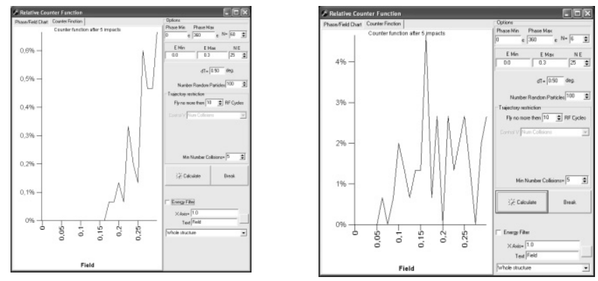


Fig.7 Dispersion curves of nearest HOM

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 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.



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 for negative dispersion at frequency 5712 MHz. The comparison of DLSM electrodynamical parameters with same of classical DLS shows the advantages of the described structure. Electrodynamical parameters for structures operating at lower phase velocity were studied. 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 occurrence.

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