OPERATING FREQUENCY AND ACCELERATING STRUCTURE GEOMETRY CHOSE FOR THE HYBRID TRAWELLING WAVE ELECTRON LINEAR ACCELERATOR

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Abstract

For the compact electron linear accelerating structure based on the hybrid scheme which consists from SW biperiodic structure buncher and TW DLS with magnetic couple TW accelerating part, the best option for the operating frequency and cells geometry has been chosen. Comparative calculations for the DLS cells with magnetic couple and without it, on the different operating frequencies and with the different couple coefficient were carried out. The best option will be manufactured, measured and used in the accelerator structure.

ELECTRO-DYNAMICS PARAMETERS

In this paper we use some specified parameters to describe the efficiency of the accelerating structures [1].

Coupling coefficient – describes the width of the dispersion curve $k_c = \frac{|f\pi - f_0|}{f\frac{\pi}{2}}$, where $f_\pi, f_0, f_{\pi/2}$ – are the frequencies π, 0, π/2 respectively;

Phase velocity $v_{ph} = \frac{\omega}{k_z}$, where ω is the circular frequency and k_z is the longitudinal wave number;

Group velocity $v_{gr} \frac{d\omega}{dk_z}$;

Shunt Impedance per unit length $r_{sh} = \frac{\left(\int_0^z Ezdz\right)^2}{Ploss*l}$;

T – transit time factor ;

Q - quality factor $Q = \frac{\omega W}{Ploss}$, where W-is the stored energy and Ploss –is the dissipated power in walls;

α – attenuation coefficient $\alpha = \frac{\omega}{2v_{gr}Q}$;

Normalized electric field strength $\frac{E_z\lambda}{\sqrt{P}} = \sqrt{\frac{2\pi\lambda r_{sh}}{Q\beta_{gr}}}$.

DIAPHRAGM-LOADED STRUCTURE

Diaphragm – loaded structure (DLS) [2] (see Fig.1) is the most common geometry type for using it in travelling wave electron linear accelerator. But the disadvantage of this geometry is small coupling coefficient and small group velocity i.e. structure filling time. But the shunt impedance is relatively high.

For working mode 2π/3 (D=βλθ/2π) electro dynamical parameters of the DLS with different a/λ at S band – 2997.2 MHz were calculated [3] and compared (see Table 1.). All data are in this table are matched with the DLS catalogue [4].

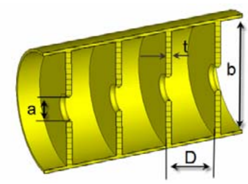

Figure 1: DLS geometry.

Table 1. S band different DLS geometry

Parameter	Value			
a/λ	0.06	0.08	0.1	0.12
k_c, %	0.008	0.03	0.09	0.19
r_{sh}, MOhm/m	111	106	102	96
Q	13800	13800	13800	13800
T	0.61	0.62	0.63	0.64
E_{acc}, MV/m	37	36	35	34
β_{gr}	0.00007	0.0002	0.0008	0.0016
α, м $^{-1}$	33	11	2.8	1.5
K_E	2.22	2.33	2.46	2.59
$E\lambda/P^{1/2}$, $Ohm^{1/2}$	8500	4900	2400	1700

From the Table 1 results we can see, that the group velocity is very small, i.e. it is needed to increase coupling coefficient by inventing a magnetic coupling.

MAGNETIC COUPLED DIAPHRAGM-LOADED STRUCTURE

By putting radial slits in the maximum magnetic field concentration area we increase the connection between the cells [5] thereby obviously we increase the value of the coupling coefficient. Construction and dimensions of DLS-M are presented on Fig. 2. DLS-M was constructed and tuned for S-band -2997.2 MHz and L-band -1818 MHz, working on $^{2\pi}/_{3}$ mode. To design a linac that uses DLS-M as an accelerating structure it is necessary to find its optimal dimensions in order to obtain the best electro-dynamic parameters (EDP). The most significant parameters are: shunt impedance per unit length rsh, normalized electric field strength $E\lambda/P^{1/2}$ and overvoltage K_E. These parameters dependencies from coupling coefficient, group velocity and a/λ are presented on Fig. 3 and Figure 4 for different frequencies. Data calculations are present in Tables 2-5 for the S-band and L-band. On the Fig.5 is shown the comparison of the dispersion

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curves for S band DLS and DLS-m structure. The coupling coefficient was tuned by phi changing.

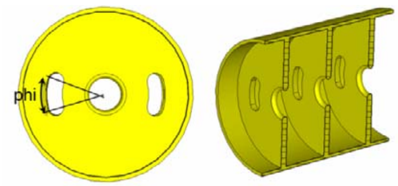

Figure 2: Magnetic coupling.

Table 2. EPD for DLS S-band (upper number) and L-band (lower number) at constant k_c=1%

Parameter			**Value**		
a/λ	0.04	0.06	0.08	0.1	0.12
k_c, %			1.00		
r_{sh},	116.5	111	106	100	95
MOhm/m	71	68	62	52	42
Q	13600	13400	13400	13300	13200
	17830	17820	16298	15695	14551
T	0.60	0.61	0.62	0.63	0.63
	0.65	0.68	0.5	0.5	0.6
E_{acc}, MV/m	38.1	37.3	36.4	35.5	34.5
	16.62	16.28	15.22	14.19	13.15
β_{gr}	0.01	0.009	0.009	0.009	0.01
	0.009	0.009	0.005	0.005	0.005
α, м $^{-1}$	0.24	0.26	0.27	0.27	0.24
	0.12	0.12	0.24	0.23	0.3
K_E	2.5	2.6	2.6	2.8	3.3
	2.73	2.78	2.79	3	3.2
$E\lambda/P^{1/2}$,	735	720	705	690	675
$Ohm^{1/2}$	1000	942	858	799	687

Table 3. EPD for DLS S-band (upper number) and L-band (lower number) at constant k_c=1.5%

Parameter			**Value**		
a/λ	0.04	0.06	0.08	0.1	0.12
k_c, %			1.50		
r_{sh},	113	109	104	99	93
MOhm/m	70	95	60	50	42
Q	13000	13000	13000	13000	12900
	17560	17170	15753	15220	14670
T	0.61	0.60	0.64	0.63	0.63
	0.65	0.68	0.5	0.5	0.5
E_{acc}, MV/m	38.2	37.5	36.6	35.6	34.6
β_{gr}	0.014	0.014	0.014	0.013	0.014
	0.013	0.013	0.007	0.007	0.005
α, м $^{-1}$	0.18	0.18	0.18	0.19	0.19
	0.08	0.08	0.17	0.17	0.2
K_E	2.8	2.8	2.9	3.0	3.1
	2.55	2.72	2.9	3.2	3.3
$E\lambda/P^{1/2}$,	625	615	600	605	570
$Ohm^{1/2}$	842	797	737	696	587

Table 4. EPD for DLS S-band (upper number) and L-band (lower number) at constant k_c=2%

Parameter			**Value**		
a/λ	0.04	0.06	0.08	0.1	0.12
k_c, %			1.00		
r_{sh},	111	107	102	95	91
MOhm/m	72	61	58	48	38
Q	12700	12700	12700	12400	12600
	16880	16390	15348	14740	13640
T	0.64	0.65	0.66	0.67	0.69
	0.66	0.67	0.5	0.5	0.6
E_{acc},	38.3	37.6	36.7	35.7	34.6
MV/m	17.17	16.14	15.15	14.09	13
β_{gr}	0.018	0.018	0.017	0.017	0.018
	0.018	0.018	0.01	0.01	0.01
α, м $^{-1}$	0.14	0.14	0.15	0.15	0.15
	0.06	0.06	0.13	0.14	0.15
K_E	2.8	2.9	3.0	3.1	3.2
	2.36	2.69	2.8	3.2	3.6
$E\lambda/P^{1/2}$,	550	540	545	530	500
$Ohm^{1/2}$	770	666	659	614	603

Table 5. EPD for for DLS S-band (upper number) and L-band (lower number) at constant β_{gr} =0.01

Parameter			**Value**		
a/λ	0.04	0.06	0.08	0.1	0.12
β_{gr}			0.01		
r_{sh},	104	95	84	72	61
MOhm/m	77.5	70	62	54	44
Q	13200	13500	13500	13100	12400
	16160	16200	16382	16100	16000
T	0.57	0.58	0.59	0.59	0.58
	0.57	0.58	0.59	0.59	0.6
E_{acc},	27	26	25	24	23
MV/m	12	11	10	9	9
k_c, %	1	1.1	1.15	1.21	1.3
	1.14	1.15	1.16	1.18	1.18
α, м $^{-1}$	0.24	0.23	0.23	0.24	0.25
	0.12	0.14	0.18	0.2	0.21
K_E	1.52	1.71	1.9	2.18	2.5
	2.76	2.89	3.2	3.4	3.5
$E\lambda/P^{1/2}$,	700	665	625	585	555
$Ohm^{1/2}$	945	823	700	588	531

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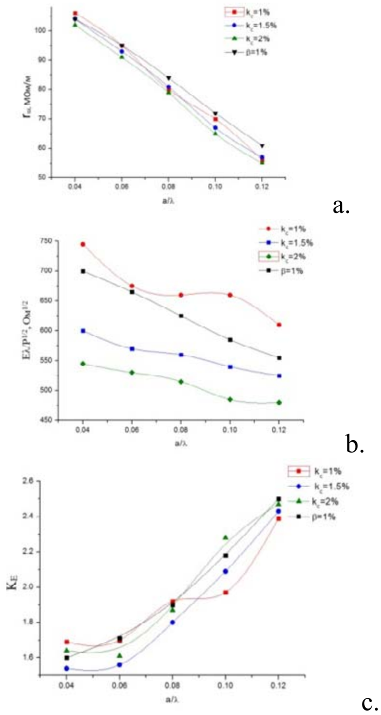

Figure 3: Electro dynamical parameters dependencies on aperture radius for S-band: a)Shunt impedance per length, b) Normalized electric field strength, c) Overvoltage.

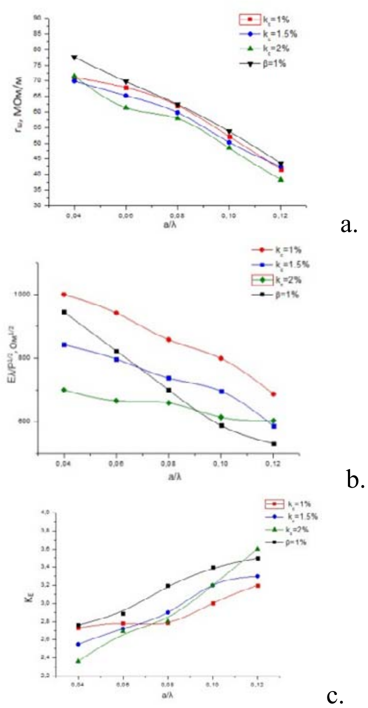

Figure 4: Electro dynamical parameters dependencies on aperture radius for L-band: a)Shunt impedance per length, b) Normalized electric field strength, c) Overvoltage.

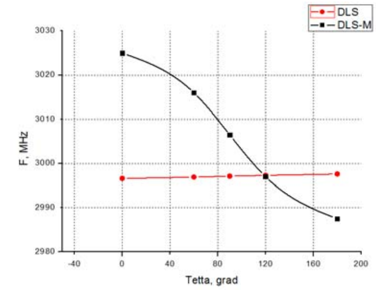

Figure 5: Dispersion curves for the S-band DLS (red) and DLS-m (black).

CONCLUSION

The best results were shown by S – band DLS-m structure with a/λ=0.08 and K=1% (see Table 6). This geometry has the appropriate shunt impedance, small fabrication sizes (speaking about frequency) and overvoltage smaller than 3.

Table 6. EDP of the chosen cell

r_{sh}, MOhm/m	Q	T	E_{acc}, MV/m
104	13000	0.64	36.6
β_{gr}	α, м $^{-1}$	K_E	$E\lambda/P^{1/2}$, $Ohm^{1/2}$
0.014	0.18	2.9	600

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