Electrodynamic Characteristics Data on Slot Aperture Structures for Linear Collider

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Abstract

Electrodynamic characteristics as well as dispersion curves, shunt impedance, Q-factor etc. are presented for structures which have a slot shape aperture. Using of this structure is proposed for construction on future e+e- linear colliders. There is a special interest for a measuring a focussing gradient of accelerating field and a overstrength electric field coefficient. All this characteristics are parametrized as a function of loading coefficient.

1 INTRODUCTION

By working out of the high energy colliders there is a actual problem of a beam driving in a high accuracy along a collider length. For diminishing of beam transverse nonstability in a considerable part of the collider it may be used of BNS-effect [1]. But for this it's necessary to introduce a scattering of the bunch energy longitudinal distribution. It leads to a frequency dispersion of particle transverse oscillation during of a acceleration because of a chromatic magnet focussing system. A bunch displacement from the maximum of accelerating wave produces inadmissible energy spectrum expansion at the final part of collider.

It's known that a relativistic bunch moving with deflection from disk center of axial-symmetric structure is tested no focussing force influence because of the compensation between an electric field radial component and a magnet field azimuth component. By change of aperture shape to nonaxial-symmetric (f.e., a slot) RF-focussing appears [2,3].

Electrodynamic characteristics of nonaxial-symmetric structure (as a slot aperture disk loaded waveguide) for wide range of typical size are considered.

2 METHODS OF ELECTRODYNAMIC CHARACTERISTICS INVESTIGATIONS.

All future collider projects are based $\Theta = 2\pi/3$ mode oscillation at the main accelerator structure with the relative phase velocity value $\beta_{ph} = 1.0$, load coefficient $a/\lambda = 0.10 \div 0.24$ (where a - halfheight of the aperture, λ - wave length) [4]. So the characteristics were investigated at the mentioned range.

For the using of the data for the collider construction and the beam dynamic estimate the next universal parametrized characteristics have been obtained:

-dispersion curves $f_p = F(\Theta)$ and Fourier expansion coefficients of resonance frequency: $f = C_0 + \sum_{l=1}^{\infty} C_l cos(l\Theta)$

- $a/b = F(a/\lambda)$,where b - waveguide radius;

-group velocity $\beta_{gr} = F(a/\lambda)$;

-sensitivity functions $\frac{\partial f}{\partial(2a)}$ and $\frac{\partial f}{\partial(2b)}$

-Q-factor $Q = F(a/\lambda)$,shunt impedance $r_{sh} = F(a/\lambda)$ and a ratio $\frac{r_{sh}}{Q} = F(a/\lambda)$

-normalized focussing gradient [5]

$$G_x(x,0)_n = \frac{\partial^2 E_{z_0}(x,0)/E_{z_0}(0,0)}{\partial x^2} = F(a/\lambda)$$

$$G_y(0,y)_n = \frac{\partial^2 E_{z_0}(0,y)/E_{z_0}(0,0)}{\partial y^2} = F(a/\lambda)$$

-overstrength electric field coefficient $K_{ov} = \frac{E_{Smax}}{E_{z_0}} = F(a/\lambda)$, where E_{Smax} - electric field amplitude at the most electric breakdown dangerous place of the disk surface.

E_{z_0} - electric field amplitude on the structure axis.

S-band resonant section assemblies consisting of five identical cells and two halfcells were developed and studied for the purpose of electrodynamic characteristic investigation. $2\pi/3$ mode oscillation are exited in the assembly with the $\beta_{ph} = 1.0$ (Fig.1).

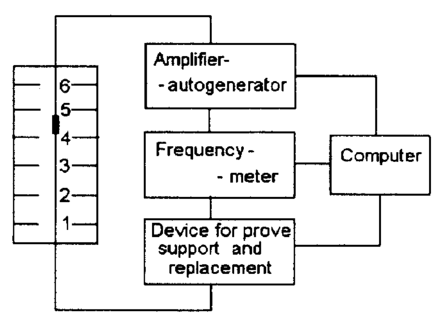

Figure 1: Experimental installation

The measurement installation based on the reactive probe technique consists of five elements: an experimental assemblies, an amplifier-autogenerator, a frequency-meter, a device for probe support and replacement on 3 directions, a personal computer for automatic assignment of parameters and experimental data treatment [6,7].

Measurement error of dispersion curve, group velocity, shunt impedance and Q-factor is not more some percent; focussing gradient and overstrength coefficient does not exceed ±10%.

The method of the focussing gradient definition was tested by code MAFIA-3D. 3 variants of structure geometry have been calculated; values of measured and calculated characteristics coincide at the error interval.

3 ELECTRODYNAMIC CHARACTERISTICS OF THE SLOT STRUCTURES.

The experimental cells with different height of aperture were manufactured for the characteristic measurement as function of the load coefficient a/λ . Part of cell sets has rounded boundary with $R = t/2$, where t - disk thickness. Character sizes of the slot structures, the resonance frequency and group velocity are given in Table 1.

Table 1: Sizes of the investigated structures

$2a$, mm	$2b$, mm	a/b	$f_{2\pi/3}$, MHz	a/λ	t/λ	β_{gr}
15*	83.88	0.18	2805.9	0.07	0.045	1.004
15	83.88	0.18	2797.5	0.07	0.045	1.001
20*	85.70	0.23	2799.9	0.09	0.045	1.002
20	85.70	0.23	2787.1	0.09	0.045	0.998
25	88.00	0.28	2774.3	0.11	0.045	0.994
30	91.00	0.34	2753.1	0.14	0.045	0.986
35	93.25	0.38	2796.4	0.16	0.045	1.001
40	93.25	0.43	2862.8	0.19	0.045	1.024

* - with rounded.

Table 2: Calculated Q-factor for some slot structures

a/λ	t/λ	Q
0.070	0.045	15080
0.125	0.038	15700
0.150	0.055	15150
0.175	0.055	15400
0.200	0.055	15350

By small change of a and b it has been obtained sensitivity function for $a/\lambda = 0.16$. $\frac{\partial f}{\partial 2a} = 0.012\ \frac{MHz}{\mu m}$, $\frac{\partial f}{\partial 2b} = -0.032\ \frac{MHz}{\mu m}$, $\frac{1}{f^2}\frac{\partial f}{\partial 2a} = 1.5\ \frac{MHz}{\mu m}$, $\frac{1}{f^2}\frac{\partial f}{\partial 2b} = -4.1\ \frac{MHz}{\mu m}$, The error equals 5%.

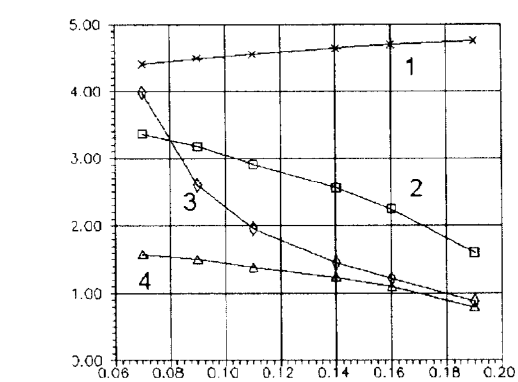

Figure 2: 1 - $Q\lambda^{-\frac{1}{2}}10^4$, $m^{-\frac{1}{2}}$ 2 - $r_{sh}Q$, $\frac{k\Omega}{m}$; 3 - $E_{z0}\lambda P^{-\frac{1}{2}}10^2$, $\frac{kV}{MW^{1/2}}$; 4 - $r_{sh}\lambda^{-\frac{1}{2}}10$, $M\Omega m^{-\frac{1}{2}}$;

The dependencies of $r_{sh} = F(a/\lambda)$, $\frac{r_{sh}}{Q} = F(a/\lambda)$, $Q\lambda^{-\frac{1}{2}} = F(a/\lambda)$ and $\frac{E_{z0}\lambda}{\sqrt{P}} = F(a/\lambda)$ (P - power flow)

Table 3: Focussing gradient for slot structures

a/λ,	$G_x(0,0)_n$	$G_y(0,0)_n$	$\frac{G_x(0,0)_n}{f_0^2}$	$\frac{G_y(0,0)_n}{f_0^2}$
	$\frac{1}{m^2}$	$\frac{1}{m^2}$	$\times 10^{-16}\ \frac{s^2}{m^2}$	$\times 10^{-16}\ \frac{s^2}{m^2}$
0.07	-1770	2270	-2.26	2.90
0.09	-1720	2190	-2.19	2.80
0.11	-1650	2100	-2.10	2.69
0.14	-1640	1920	-2.10	2.45
0.16	-1560	1720	-2.00	2.23
0.19	-1480	1570	-1.92	2.01

Table 4: Focussing gradient ($E_{z0} = 100\ MV/m$)

a/λ	$f = 14.6\ GHz$		$f = 29\ GHz$	
	$G_x(0,0)$ $\frac{T}{m}$	$G_y(0,0)$ $\frac{T}{m}$	$G_x(0,0)$ $\frac{T}{m}$	$G_y(0,0)$ $\frac{T}{m}$
0.07	−50.5	64.6	—	—
0.09	−48.8	62.4	—	—
0.11	−46.8	59.9	—	—
0.14	−46.8	54.6	—	—
0.15	—	—	−97(90)*	113(87)*
0.16	−44.6	49.7	—	—
0.19	−42.8	44.8	—	—
0.20	—	—	−87(83)*	93(81)*

* - according [3,8]

are given in Fig.2 (experimental data) and Table 2 (data calculated by MAFIA-3D) [3,8].

Experimental values of the normalized focussing gradient for different a/λ are shown in Table 3. In Table 4 there are data of the focusing gradient, determined in the case of accelerating gradient 100 MV/m at the 14 GHz and 29 GHz. The data in the parenthesis were calculated by MAFIA [3].

A character of $G_x(0,0)_n/f_0^2$ and $G_x(0,0)_n/f_0^2$ as function of a/λ is shown in Fig.3.

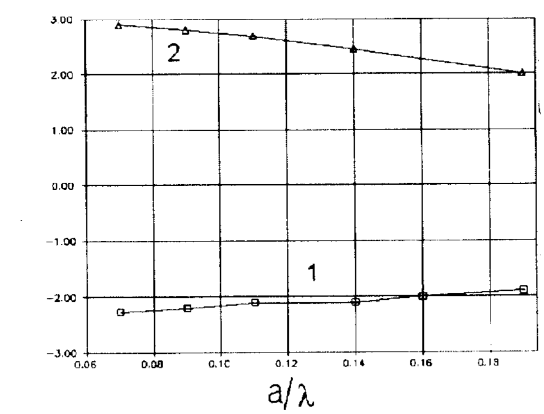

Figure 3: 1 - $\frac{G_x(0,0)_n}{f_0^2} * 10^{-16}$, $\frac{s^2}{m^2}$; 2 - $\frac{G_y(0,0)_n}{f_0^2} * 10^{-16}$, $\frac{s^2}{m^2}$

The measurement of overstrength electric field coefficient has a special interest because the calculation by computer code is very complicity (increase used processor time and memory). It's no acceptable and possible in any case from a limitation of computer power. This experiment is based on the reactive probe technique. A small dielectric probes of rectangular shape (such size is $1 \times 1 \times 0.5\ mm^3$) were used for this measurement. It was replaced along disk surface with a discretization step equals near 0.5 mm. In Fig.4 there is a dependence $\xi_s = \frac{E_s(s)}{\sqrt{PQ}}$ for the disk #3

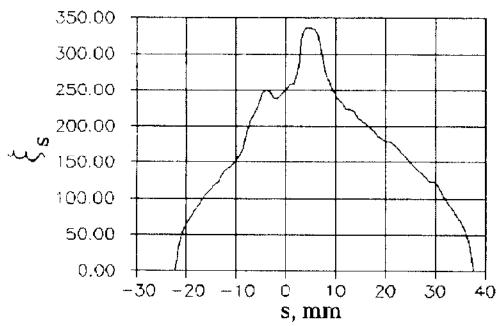

Figure 4: Dependence of ξ_s along surface of disk #3, $x = 0$

(see Fig.1) and coordinate $x = x_0$ (the center of the slot board). Here there are 2 different picks of electric field strength.

Values of ξ_s for different disks of experimental assembly are shown in Table 5.

Table 5: Values of electric field strength at the disk surface

	disk 2		disk 3		disk 4	
	139	121	336	262	354	271
	130	117	294	232	336	253
	118	111	235	174	299	220
	129	117	294	232	342	256

The graphic of $K_{ov} = F(a/\lambda)$ for structure with $R_c = \frac{t}{2}$ is plotted in Fig.5.

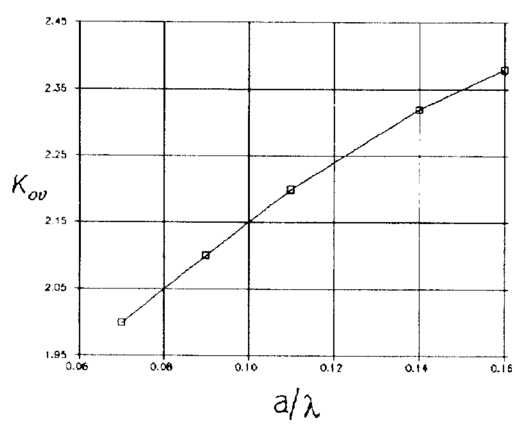

Figure 5: Dependence of $K_o v$ as function of a/λ

4 CONCLUSION

Created installation and methods may be used for a total investigation of nonaxial-symmetric structure with acceptable error and time.

The mentioned data were used for elaboration acceleration accelerating-focussing structures for future linear colliders as well as calculation of beam dynamic.

5 ACKNOWLEDGMENT

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