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DESY LINEAR COLLIDER ACCELERATING SECTION COUPLER

N.P.Sobenin, S.V.Ivanov, V.E.Kaluzhny, O.S.Milovanov, A.N.Parfenov, S.N.Yarigin.
Moscow Engineering Physics Institute.
Kashirskoe sh., 31, 115409, Moscow, Russia.
L.V.Kravchuk, G.V.Romanov
Institute for Nuclear Research
Moscow, 60-th October Anniversary Prosp. 7a,117312, Moscow, Russia.
N.Holtkamp
Deutsches Electronen-Synchrotron DESY,
Notkestr.85, 2000. Hamburg 52, Germany.

Abstract

The input and output symmetrical couplers for six meter long accelerating sections for the S-band Linear collider test facility at DESY have been designed and coupler model set-up has been manufactured. The methods of coupler r.f. parameter measurement and the tuning procedure have been developed end tested. The achieved results are presented. The amplitude and phase asymmetry of the accelerating field in the region of beam have been investigated.

Introduction

It's known that for the electromagnetic field symmetrization in the vicinity of the beamline inside couplers of linear accelerating sections two coupler constructions are used. In the first one a cut-off or short-circuited waveguide section is used which is placed opposite the feeding rectangular waveguide (RW) [1]. In the second construction two power feeds are used. They are situated opposite each other with respect to the coupler cavity, the power from the r.f. source being divided in a waveguide bridge [2]. For the DESY linear collider project the coupler version shown in fig.1 is being considered.It is characterized by small dimensions. Here the power is fed into the coupler through the side walls of two rectangular waveguides connected to an r.f. power source by means of T-junction, the opposite ends of the waveguides beings short-circuited.

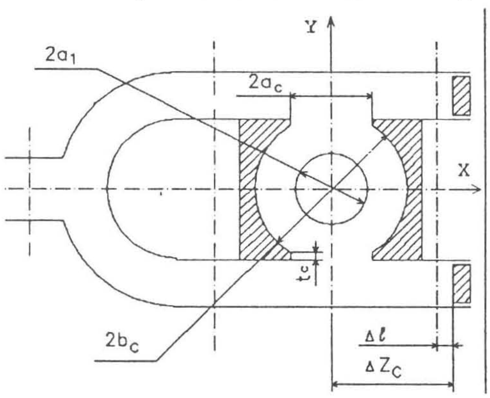

Fig. 1 Schematic geometry of DESY linear collider coupler

Modelling and main expression

Consider the principles which are basic for the tuning of the coupler with additional waveguides having short-circuited plungers.According to [3], the reflection coefficient at the input of the T-junction when the coupler is connected with an infinite uniform lossless disc-loaded waveguide (DLW) is defined as

$$\Gamma = \frac{2\chi - (2\chi - 1 - \chi_{DLW} - jQ_c\left[\frac{f}{f_c} - \frac{f_c}{f} + \frac{f_c}{f}\frac{k_0}{2}\left(\frac{k_c}{k_0}\right)^2\cos\varphi\right])\exp(j\psi)}{2\chi + 1 + \chi_{DLW} + jQ_c\left[\frac{f}{f_c} - \frac{f_c}{f} + \frac{f_c}{f}\frac{k_0}{2}\left(\frac{k_c}{k_0}\right)^2\cos\varphi\right] - 2\chi\exp(j\psi)} \quad (1)$$

Where : f_c and Q_c is the resonance frequency and Q-factor of the coupler, $\frac{K_c}{2}$ and χ are the coefficient characterizing the coupling between the coupler and adjacent DLW cell,and between the coupler and each of the rectangular waveguides, f_r and $\frac{K_0}{2}$ are the resonance frequency of the DLW cell and coefficient characterizing the coupling between adjacent cells, f and φ are correlated by the dispersion characteristic of the infinite lossless DLW,
$f = f_r\sqrt{1 - k_0 cos\varphi}$, $\chi_{DLW} = Q_c\frac{k_0}{2}\left(\frac{k_c}{2}\right)^2\frac{f_c}{f}sin\varphi$,
$\psi = \pi - \frac{4\pi\Delta l}{\lambda_w}$, λ_w is the wavelength in the RW.

In the process of coupler tuning as was shown in [3] its inner dimensions $2b_c, 2a_c, t_c$ should be chosen in such a way that the coupler own frequency f_c and loaded Q-factor Q_{cL} were equal to the values calculated in term of known values of phase shift per DLW cell φ_0 at the operational frequency

f_0 and coupling coefficients k_0 and k_c:

$$f_c = \frac{f_0}{\sqrt{1 - \frac{k_0}{2}\left(\frac{k_c}{k_0}\right)^2 cos\varphi_0}} \tag{2}$$

$$Q_{cL} = \frac{\sqrt{1 - \frac{k_0}{2}\left(\frac{k_c}{k_0}\right)^2 cos\varphi_0}}{\frac{k_0}{2}\left(\frac{k_c}{k_0}\right)^2 sin\varphi_0} \tag{3}$$

For the experimental determination of the coupler own frequency at fixed inner dimensions we have to measure the reflection coefficients for two cases. In the first one (Γ_0) the coupler is detuned and in the second one (Γ_1) the DLW first cell is detuned. Such measurement were made for several positions of the short-circuiting plungers. At every position of plungers we find the frequency f_{c1} at which $arg\Gamma_1(f_{c1}) - arg\Gamma_0(f_{c1}) = \pm\pi$. Then if $arg\Gamma_1(f_{c1} - \Delta f) + arg\Gamma_1(f_{c1} + \Delta f) = 2arg\Gamma_1(f_{c1})$ we have $\psi = \pi$, so f_{c1} is the coupler resonant frequency f_c. In case this condition for Γ_1 arguments is not met we have to change the positions of the short-circuiting plungers and repeat the measurements. It should be noticed that if $arg\Gamma_1(f_{c1} - \Delta f) + arg\Gamma_1(f_{c1} + \Delta f) > 2arg\Gamma_1(f_{c1})$ the plungers had to be displaced toward the coupler and vise versa.

In case when the coupler own frequency measured value is not equal to the calculated one according to Eq.(2) the coupler inner diameter $2b_c$ should be changed and the whole cycle of measurements repeated. In case when the coupler loaded Q-factor is not equal to the calculated one according to Eq.(3) the coupling slot width $2a_c$ should be changed [3]. By means of measurement the reflection coefficients Γ_1 and Γ_0 arguments we can experimentally determine the coupler resonant frequency f_c as well as the loaded Q-factor $Q_c/4\chi$.

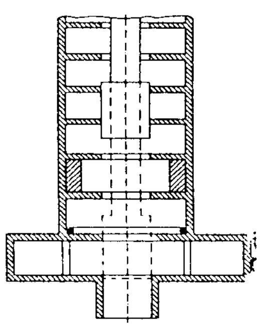

Fig. 2 Schematic drawing of experimental model for measurement of the first DLW cell parameters (f_{r1}, $\frac{k_c}{2}$)

If the second DLW cell is strongly detuned by inserting a thick ring into this cell (see fig.2) and resonant frequency of the first DLW cell is made equal to f_c (by inserting a thin ring into the first cell) there are two frequencies f_1 and f_2 at which $arg\Gamma_2(f = f_{1,2}) - arg\Gamma_0(f = f_{1,2}) = \pm\pi$, where Γ_2 - is the reflection coefficient value when the second cell is strongly detuned. The coupling coefficient between the coupler and the first DLW cell can be determined as

$$\frac{k_c}{2} = \frac{|f_1^2 - f_2^2|}{f_1^2 + f_2^2} \tag{4}$$

Notice that if the first cell frequency is equal to f_c we have $arg\Gamma_2(f = f_c) = arg\Gamma_0(f = f_c)$.

Coupler Design and Tuning

The development and experimental study of the coupler for DESY accelerating section were carried out separately for the input and output ends of the section. For this purpose DLW sections consisting of 11 cells with dimensions $a/\lambda = 0.1551$ and $a/\lambda = 0,10885$ (a is the disk aperture diameter), the structure period 33.33 mm and cell shape as in [3].

The connecting feeding guides ($72\times28.33\times4mm^3$) were fabricated out of standard rectangular waveguides with dimensions $72 \times 34 \times 4$ mm^3 , but the r.f.power divider was made from one piece copper blank. For matching of the power divider an inductive diaphragm were used. By using a symmetrical inductive iris (width 47 mm, thickness 2 mm) for the T-junction matching we obtained the experimental value of VSWR equal to 1.03. The iris was placed at the distance 111.4 mm from the T-junction fork. The calculations with MAFIA code gave the corresponding value - 36 dB.

rather The tuning to the operational frequency was carried out by means of the technique described above as well as by using absorbing loads [4]. The movable absorbing load technique enables to determine the position of iconocenter (scattering matrix element S_{11}) by means of proper choice of the shape and surface resistance of the absorbing load. The best measurement results obtained for the input and output ends of the DLW with absorbing loads having the length about $3 \div 4$ cells length. The treatment of these results according to different techniques [4] resulted in the values of $|\Gamma|$ and φ with errors $\pm5\%$, $\pm2^o$ [4].

Experimental results and impedance characteristics

The tolerance on $2a_c$ dimension was fixed as $\pm0.05mm$. The coupler inner diameter $2b_c$ tolerance should be ±0.02 mm. The plungers positions should be set with tolerance ±0.1 mm. Because the change of the coupler inner dimensions is not possible by the construction adjustment elements we have made provisions for $2b_c$ dimension variation by means of coupler wall deformations in four points. Such deformation results in the frequency change up to 4 MHz (see fig.3). Also the sealed off construction was considered in which the position of short-circuits in connecting rectangular guides can be changed by means of cylindrical tuning plunger with diameter 21 mm and maximal replacement 5 mm.

As a result of the input and output couplers tuning at the operational frequency the VSWR value practically

TABLE 1

		k_c	f_c, MHz	Q_{CL}	k_0	f_{r1}, MHz	$\|\Gamma\|$
Input	calculated	–	2981,19	51,3	0,04525	2964,65	0,0
coupler	experimental	0,0455	2981,05	52,5	–	2963,63	0,047
Output	calculated	–	2992,68	170,4	0,01423	2987,39	0,0
coupler	experimental	0,0139	2992,70	173,5	–	2987,4	0,035

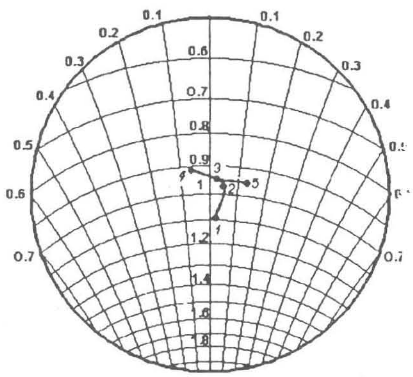

Fig. 3 Variation of the input coupler impedance with deformation of its side wall (1. $f_c = 2975.85$ MHz; 2. $f_c = 2977.3$ MHz; 3. $f_c = 2978.2$ MHz; 4. $\Delta z_c = 26$ mm; 5. $\Delta z_c = 22$ mm)

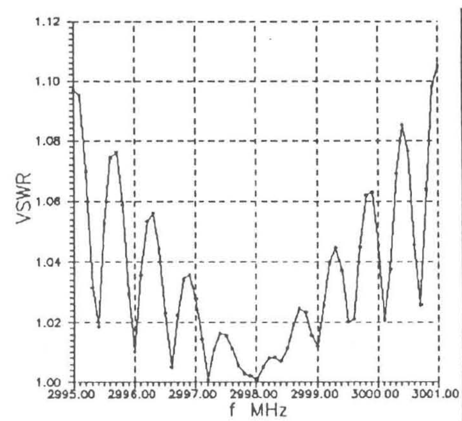

Fig. 4 The impedance characteristic of 6m length accelerating section with ideal tuned cells and matched couplers

reached equal to unity. The input coupler dimensions appeared to be $2b_c = 75.99 \pm 0.01\, mm$, $2a_c = 36.5 \pm 0.05\, mm$. The position of the short-circuing planes turned out to be at the distance $\Delta z_c \approx 24\ mm$ from the middle of slots The corresponding results for the output coupler were: $2b_c = 77.25 \pm 0.01\ mm$, $2a_c = 25.45 \pm 0.05\ mm$ and $\Delta z_c = 26\ mm$.

Experimentally determined and calculated parameters of the input and output cells are presented in Table 1, the experimentally determined parameters being related to matched couplers. Where f_{r1} is the resonance frequency of the cell adjacent to the coupler.

The impedance characteristics of the 6m length accelerating section with variable dimentions are shown in fig.4. For the field symmetrization quality evaluation the conception of average over coupler cavity length longitudional field amplitude and phase deviation taken at the distance $x = y = r$ ($r \leq a$) was introduced [5].

The field asymmetry can be discribed in terms of the parameter

$$\frac{A}{2r} = \frac{E_z(x,0) - E_z(0,y)}{r[E_z(x,0) + E_z(0,y)]} \quad \frac{\psi}{2r} = \frac{\varphi_z(x,0) - \varphi_z(0,y)}{r[\varphi_z(x,0) + \varphi_z(0,y)]} \tag{5}$$

where $E_z(x,0)$, $E_z(0,y)$, $\varphi(x,0)$, $\varphi(0,y)$ are the electric field and phase being measured when the perturbing beed is muved parallel to the z-axiz at the distance $r = x = y$.

The values of $\frac{A}{2r}$ and $\frac{\psi}{2r}$ for input and output couplers are less, then 0.0005 $\frac{1}{\mathrm{mm}}$ and 0.0002 $\frac{\mathrm{deg}}{\mathrm{mm}}$.

Conclusion

The expressions obtained in this work are in a good correspondence with the experimental results, and can be used as the basis for the coupler matching and experimental determination of the coupler parameters, the field asymmetry.

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