DESY Linear Collider Accelerating Section Coupler

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Abstract

The problems of construction choice and tuning of the coupler for DESY Linear Collider accelerating section which is fed through the narrow walls of the rectangular waveguides are considered. A technique for the couplers tuning onto the operational frequency is developed.Measurements was carried out on couplers model and prototype.

1 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.

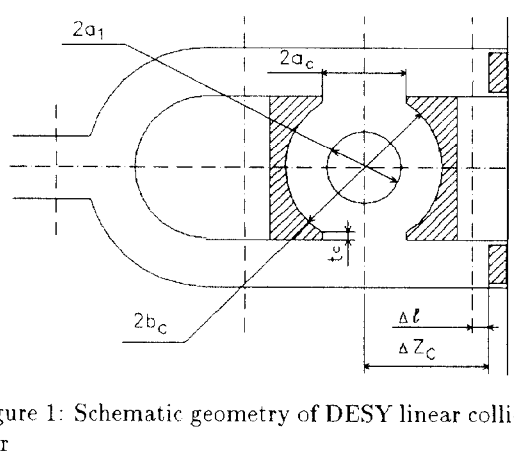

Figure 1: Schematic geometry of DESY linear collider coupler

2 TUNING METHOD

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:

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

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

In the first approximation we can assume for the chosen coupler geometry that $k_c = k_0$ at the input and output ends. 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].

3 COUPLER DESIGN

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 [4]. Keeping in mind that the sections would be operated in vacuum condition and at temperature 40^oC for the purpose of fine tuning of DLW cells to the frequency 2998 MHz the changing of cells outer diameter was provisioned by means of walls deformations in four points. For this purpose 4 holes with diameter 12 mm were drilled in each cell so that the wall thickness was 1 mm. The tuning was realized with the temperature, pressure and humidity at the moment of measurements. Accounted for thus, if these environmental parameters were $t = 18^oC$, $p = 760$ mm Hg and humidity 50% then for obtaining the operational frequency 2998 MHz the cells should be tuned to the frequency 2998.13 MHz [5].

The connecting feeding guides ($72\times 28.33\times 4\,mm^3$) 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 111.5 mm from the T-junction fork. The calculations with MAFIA code gave the corresponding value - 36 dB.

The fact that all measurements were conducted on sections consisting of cells similar to the first one (for the input coupler) and the last one (for the input coupler) is of no importance. Really the reflection coefficient computations with IMPEDANCE program [3] show that substitution of ten identical cells by ten cells with variable dimensions [4] leads to only slight variation of VSWR at operational frequency from 1.000 to 1.005 for the input coupler.

All preliminary investigations connected with the coupler optimal dimensions determination as well as measurement of its electrodynamic characteristics were carried out on models The fabrication tolerances on the coupler inner dimensions and on the short-circuiting plungers positions and those of T-junction matching elements were determined with these models schemes.

For the coupler prototype we made provisions for the construction elements soldering,as well as for replacement of choke plungers for short-circuited planes with adjustment screws and also grooves for the coupler effective inner diameter regulation.

4 COUPLER TUNING

The coupler dimensions such as the inner diameter $2b_c$, coupling slot width $2a_c$ and coupling slot thickness t_c were first calculated on the basis of approximate resonator-analogue technique [6]. The tuning to the operational frequency was carried out by means of the technique described above as well as by using absorbing loads [5].

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 [6] resulted in the values of $|\Gamma|$ and φ with errors $\pm 5\%$, $\pm 2^o$.

It's possible to study the influence of $2b_c$ and $2a_c$ dimensions variations on positions of the iconocenter in Smith's chart by using absorbing loads . The corresponding measurement results for the input and output couplers are shown in fig.2.

Since there would be no possibility of fine tuning by means of changing $2a_c$ in the working version of the coupler we have been considering a technique of fine tuning by changing the $2b_c$ and positions of short-circuited plungers. The following arguments have been considered,to get the basis of such a technique. From Eq.(1) it follows that with changing of the short-circuiting plungers positions (that is the ψ value) the reflection coefficient Γ is changed in such a way (χ, Q_0, f_0 ,$\chi_{DLW}(f_0)$, are all fixed) that in Smith chart the end of the complex vector Γ would move along

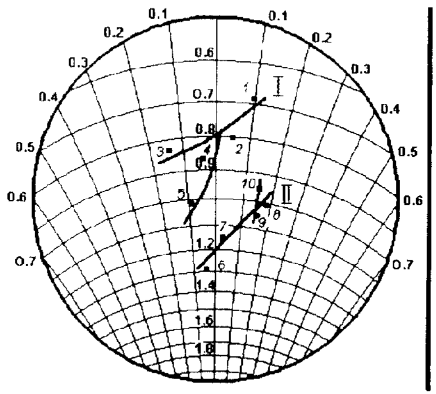

Figure 2: Impedance variations at input (I) and output (II) couplers with changing dimensions $2b_c$ and $2a_c$. 1. $2b_c = 75.50\ mm$; 2. $2b_c = 75.98\ mm$; 3. $2b_c = 76.03\ mm$; 4. $2a_c = 36.1\,mm$; 5. $2a_c = 36.19\,mm$; 6. $2b_c = 77.15\,mm$; 7. $2b_c = 77.25mm$; 8. $2b_c = 77.30mm$; 9. $2a_c = 25.45mm$; 10. $2a_c = 25.55\ mm$;

the circle passing through the point $\Gamma = +1$. When the frequency f_c changes the vector Γ end is also moving along the circle but the latter passes through the point $\Gamma = e^{j\psi}$. So the change of frequency and plungers positions leads to the replacement of the vector Γ end along crossing circles. Such circles are shown in Fig.3 for the case when the cou-

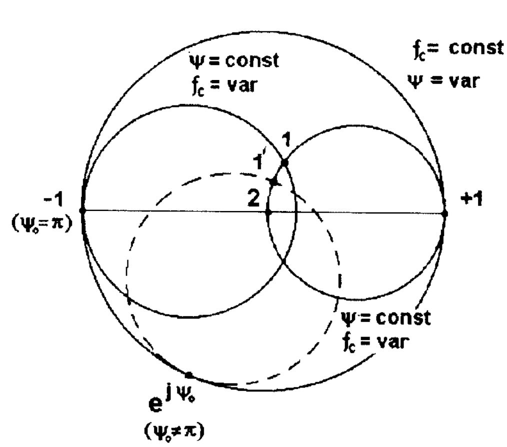

Figure 3: Schematic of overloaded coupler tuning

pling coefficient exceeds the required one (slightly overcoupled case) and the frequency f_c is less than operational one. The initial plunger position was corresponded to $\psi_0 = \pi$. When $\psi_0 \neq \pi$ we have the case marked by dashed lines in the same figure. Thus we can make a conclusion that if the circle $\Gamma(f_c)$ surrounds the Smith chart center then in some cases it's possible to improve the matching by means of plungers removing (the initial points 1 and $1'$ as well as point 2). For obtaining the matching the frequency f_c should be changed so that the initial point (1 or $1'$) would be placed on the circle $\Gamma(\psi)$ passing through Smith chart center.

It's very important to evaluate the fabrication tolerances (for dimensions $2b_c$ and $2a_c$) and that on positions of short-circuiting planes in the rectangular waveguides. The effect of $2b_c$ and $2a_c$ dimensions variations is shown in Fig.2. The tolerance on $2a_c$ dimension was fixed as $\pm 0.05\ mm$. The coupler inner diameter $2b_c$ tolerance should be $\pm 0.02\ mm$. The plungers positions should be set with tolerance $\pm 0.1\ mm$. 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. 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 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 $\Delta z_c = 26\ mm$.

5 CONCLUSION

The tuning technique developed for DESY linear collider couplers in which coupler own parameters are used simplifies the procedure of coupler inner dimensions experimental determination. This technique can also be applied for the tuning of other types of couplers.

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