

REGULATION OF THE WAVEGUIDE COUPLING FACTOR OF STANDING WAVE LINEAR ACCELERATOR

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Abstract

Regulation of the waveguide coupling factor of standing wave linear accelerator allows to adjust the value of accelerated current, keeping the reflected RF power close to zero. This ensures the most efficient use of RF energy and absence of overvoltage in the waveguide elements. The paper presents studies results for various methods of coupling factors regulation with continuous wave (CW) normal conducting linear accelerator used as an example. The results of calculations and measurements on the mock-up of the accelerating structure are presented.

INTRODUCTION

Matching of the RF source and the accelerating structure (AS) of standing wave linear accelerators in traditional designs of the waveguide power coupler is ensured through selecting dimensions of the coupling iris. Iris dimensions as a rule are selected for fixed beam current loading, at that, optimum waveguide-to-AS coupling factor is determined in accordance with the following formula: $\beta = 1 + \frac{P_b}{P_w} = 1 + \frac{I_b E_b}{P_w}$, where P_w is RF power loss in the walls of the AS, I_b and E_b are current and energy of the accelerated beam. If value of the current deviates from the optimum value, a reflected wave appears, which results in lowering of the accelerator efficiency and appearance of overvoltage in the waveguide.

Industrial CW linear RF accelerators have another aspect of the matching problem. The simplest arrangement of the RF system for such accelerators is self-oscillating arrangement with AS in the feedback loop of the klystron excitation circuit [1]. In such arrangement, if the level of the reflected wave is low, klystron can operate without ferrite isolator, which simplifies the accelerator design and makes it cheaper. However, to minimize the reflected wave that adversely affects the RF source, it is necessary to be able to change the coupling factor in accordance with changes in the beam current. Possible design of the 2,856 MHz MIT storage ring cavity adjustable coupler is described in [2]. In this paper we discuss other arrangements of the coupler with coupling factor regulated over a wide range.

COMPUTER SIMULATION

We studied regulation of the coupling factor through insertion of cylindrical plungers (6 mm in diameter) to different depths into the 72x34 mm feeding waveguide perpendicular to its wide wall. Several configurations of plunger positioning were considered.

- 4 plungers near the coupling iris (Fig. 1a).
- 2 plungers opposite each other at the center of wide wall of the waveguide at some distance from the iris (Fig. 1b).
- 1 plunger at the center of wide wall.

Calculations were performed using CST Studio Suite software package [3] on the coupler model consisting of the power input cell without coupling slots in the frequency range of 2,450-2,490 MHz, which is similar to the 1 MeV CW accelerator power coupler [4].

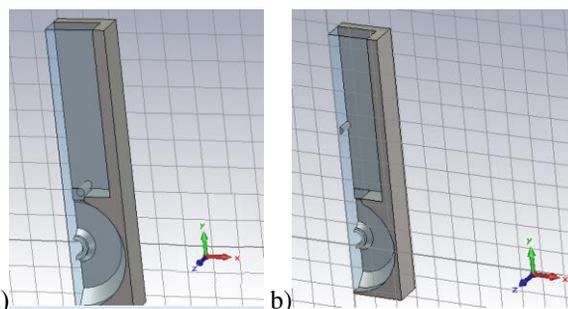


Figure 1: Models for calculating RF power coupler with adjustable coupling factor.

Feeding waveguide input port was excited by the Gaussian envelope signal. Resonance frequency f_{res} was determined by the minimum of the S_{11} parameter, and coupling factor - by the time constant τ_E of the cavity stored energy decay after the end of excitation signal: $\beta = 2\pi f_{res} \tau_E$.

One of the main criteria for evaluating calculation results was minimum shift of the resonance frequency of the power input cell and maximum range of coupling factor regulation. Resonance frequency shift results in appearance of the fields in the coupling cells located near the power input cell of the bi-periodic standing wave AS.

Calculations of the Coupler with 4 Plungers Near the Iris

Idea behind of this arrangement was regulation of the effective width of the iris by changing plunger's position. Due to symmetry a quarter of the power input cell was used in calculations (Fig. 1a). Depth of the plunger insertion L_{pl} was changed in the range of 0-17 mm (17 mm depth corresponds to closure of the opposite plungers). Fig. 2 shows the graphs of the coupling factor and resonance frequency change vs. plunger insertion depth. Without the plungers, the power coupler coupling factor was $\beta_0 = 32$, and resonance frequency was $f_0 = 2,486.9$ MHz.

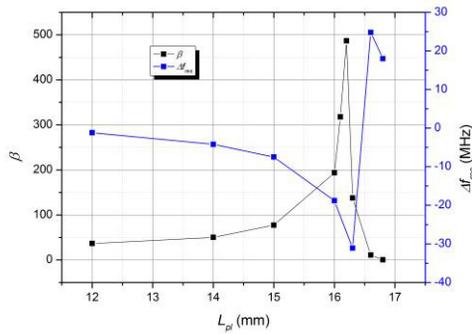


Figure 2: Dependence of coupling factor and resonance frequency shift of the power input cell vs. plunger insertion depth.

As can be seen, such plunger configuration allows to increase the coupling factor more than 10 times, however, it also causes a more than 10 MHz resonance frequency shift. To compensate the resonance frequency shift, a tuning plunger in the power coupler accelerating cell must be used.

Another problem with such plunger configuration is high strength of electric field between the opposite plungers. At the plunger insertion depth of $L_{pl} = 14$ mm (gap between plungers is 6 mm), electric field strength reaches 43% of the maximum strength of the accelerating field at the axis of the power coupler. This problem can be partially solved through increasing diameter of the plungers.

Calculations of the Coupler with 2 Plungers in the Center of Waveguide Wide Wall

Position of plungers in the waveguide was selected to minimize the power coupler accelerating cell resonance frequency shift. Figure 3 shows the graph of the resonance frequency shift vs. distance ΔY from the center of plunger to the power coupler iris at the plunger insertion depth of $L_{pl} = 13$ mm.

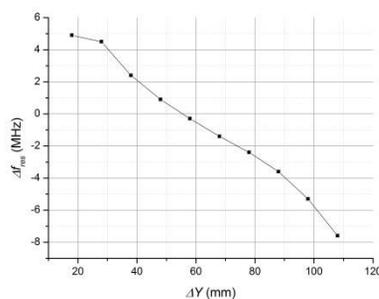


Figure 3: Resonance frequency shift vs. distance from plungers to the iris at $L_{pl} = 13$ mm.

Minimum resonance frequency shift is achieved at the distance ΔY close to a quarter wavelength in the waveguide.

Figure 4 shows graphs of the coupling factor and changes in resonance frequency vs. plunger insertion depth. As can be seen, this configuration allows to decrease the initial coupling factor by an order of magnitude with resonance frequency shift of about 1 MHz.

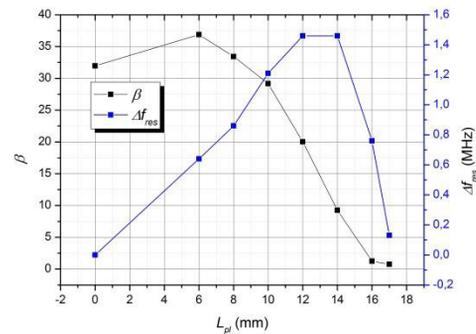


Figure 4: Dependence of coupling factor and changes in resonance frequency vs. plunger insertion depth.

Calculations done for the arrangement with one plunger located at the same distance from the iris gave similar results.

MEASUREMENTS ON A TEST STAND

To perform measurements on a real model, a mock-up consisting of 4 accelerating cells, 4 coupling cells and a power input cell located between them was assembled. Threaded holes for the plungers were made in the feeding waveguide and near the power coupler iris (Fig. 5).

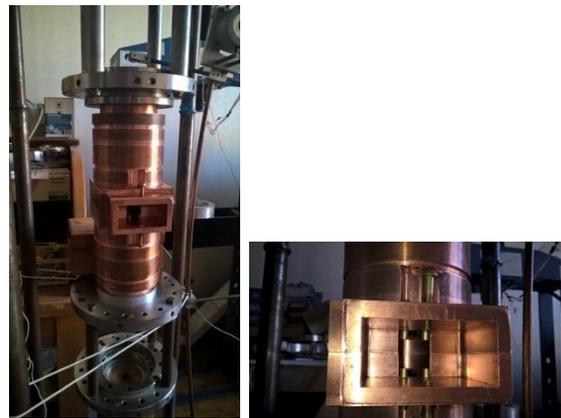
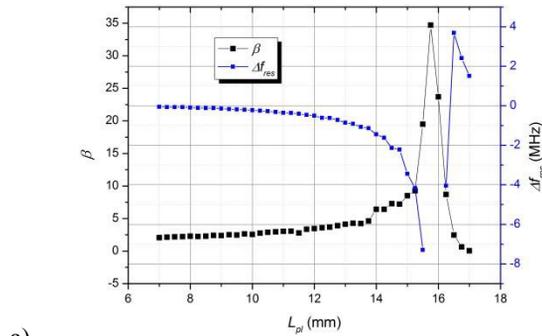


Figure 5: Picture of the mock-up.

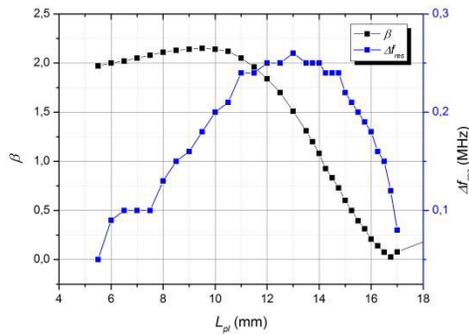
Measurements of resonance frequency, coupling factor, loaded Q, as well as field distribution using bead pull technique were performed with Agilent HP85052C vector analyzer.

Figure 6 presents results of coupling factor and resonance frequency measurement, and Fig. 7 shows field distribution for different plunger insertions depths. Measurements with four and two plungers were done with the mock-up tuned to frequency of 2,449.3 MHz and

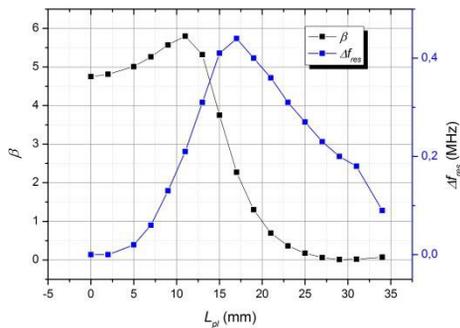
coupling factor of 1.81 with extracted plungers. For measurements with one plunger the iris width was increased to achieve coupling factor of 4.75 in order to get a wider range of regulation.



a)

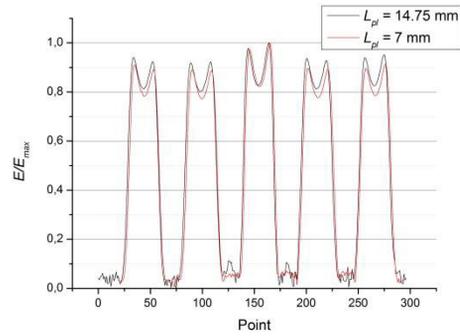


b)

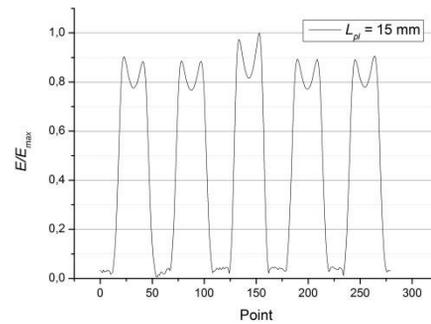


c)

Figure 6: Measured coupling factor and resonance frequency shift of the mock-up vs. plunger insertion depth for arrangement a) with plungers near the aperture, b) with two plungers in the middle of wide wall of the waveguide, c) with one plunger.



a)



b)

Figure 7: Electric field distribution at the mock-up axis a) for arrangement with four plungers and insertion depths of 14.75 and 7 mm, b) for arrangement with two plungers and insertion depth of 15 mm.

Measurements demonstrate that configuration with plungers near the aperture results in significant fields in the coupling cells.

CONCLUSION

We examined several arrangements of the RF power coupler with adjustable coupling factor. Out of them, configuration with one plunger seems to be optimum, since it ensures tenfold changes in the coupling factor without significant effect on resonance frequency and RF power loss in the walls, besides its design is the simplest. In the near future, we plan to develop a prototype of the arrangement with one plunger for the CW linac [4].

REFERENCES

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