# BIDIRECTIONAL COUPLER OPTIMIZATION IN WR284-TYPE WAVEGUIDE*

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*Abstract*

In the Advanced Photon Source linac gun test area at Argonne National Laboratory a new S-band ballistic bunch compression (BBC) gun is being tested [1]. It was determined that a WR284 waveguide bidirectional coupler with a directivity of greater than 30 dB and a coupling of –57 ± 1 dB was desired for evaluation of waveguide rf power conditions. Numerical simulations were performed using the High Frequency Structure Simulator (HFSS) [2] and experimental models were built to determine the optimal dimensions of the bidirectional coupler assembly and the orientation of the loop coupler element. Magnetic and electric fields in the coupler were adjusted by modifying the coupling of the fields as well as the capacitance of the coupling loop.

## INTRODUCTION

The rf operating frequency of the APS linac is 2.856 GHz [3] with waveguide peak power greater than 200 MW. The WR284 bidirectional coupler used is a high-power, high-vacuum design commercially obtained. The coupler is being redesigned in order to improve performance in the linac gun test area, to gain better control of the performance of the directional couplers used for linac operation, and to acquire proper knowledge to fabricate future bidirectional waveguide couplers in WR340-type waveguide.

## MEASUREMENT SETUP AND PROCEDURE

The tests were performed using an HP8510 network analyzer. The test setup consisted of two WR284 waveguide-to-N-type transitions, two WR284 waveguide straight pieces, and a 6.5-inch waveguide adapter piece shown in Fig. 1. The waveguide straight pieces were inserted between the directional coupler and the transitions to ensure that any residual fields in the coax-to-waveguide transition would not be included in the measurements. Network Analyzer calibration and proper rf measurement techniques are essential to achieve accurate data results [4].

The 99.5% pure alumina ceramic windows that were used had a permittivity of 9.6 and very low loss. For test purposes, the windows were not brazed in the housing to facilitate changes made to the coupler assembly. If an unbrazed window moves during the rf measurements, the data may be inaccurate and nonrepeatable. Therefore a spring assembly, shown in Fig. 2, was devised to temporarily hold the windows and the coupler elements in place and to ensure good electrical contact during the rf measurements.

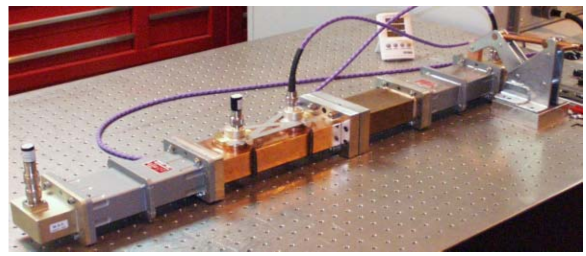

Figure 1: The rf measurement setup.

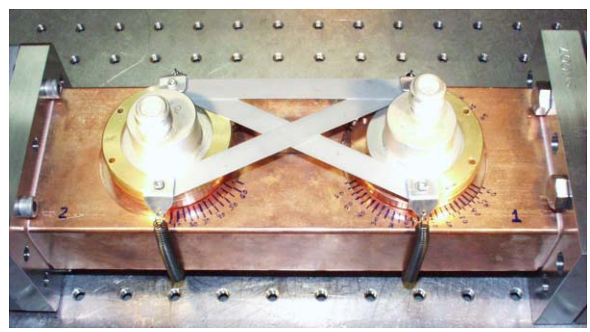

Figure 2: Coupler with spring assembly.

## COUPLER PARAMETERS

In the process of tuning the coupler assemblies for maximum performance, a number of parameters were adjusted, as shown in Fig. 3. The resultant change in the coupler was evaluated as a function of these variables.

The rf data were taken after the following changes were made to the directional coupler assembly (see Fig. 4): iris diameter was enlarged, different disc thicknesses were placed under the ceramic window to vary the iris height, different spacer thicknesses were placed above the ceramic window to change the pickup height, different coupling elements were used, and element coupling loops were bent to different angles.

The directivity of the coupler is most dependent upon the orientation of the coupler element with respect to the transverse plane of the waveguide. In the test set-up, the coupler element may be freely rotated within the window assembly. It was determined that the best isolation occurred when the pickup bend was oriented approximately 10° from the transverse plane toward the direction of power flow. However, the precise angle is dependent upon the permittivity of the ceramic window

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that is used. In the case where a vacuum seal is not necessary and an air dielectric is essentially all that separates the coupler element from the waveguide, a 28° angle produced the best results.

The coupling is moderately dependent upon the iris height and pickup height. It varies about 1 dB per 0.01 inches for the iris height and about 0.5 dB per 0.01 inches for pickup height. However, the coupling is mostly dependent upon the iris diameter. The iris diameter does not strongly affect the directivity and, as a result, may be adjusted nearly independently of the directivity.

For optimal tuning, the pickup distance, pickup height, and iris height were modified to observe trends. In some cases, their effect on the overall operation was found to vary depending on the exact orientation of the coupler element, as will be discussed in the next section.

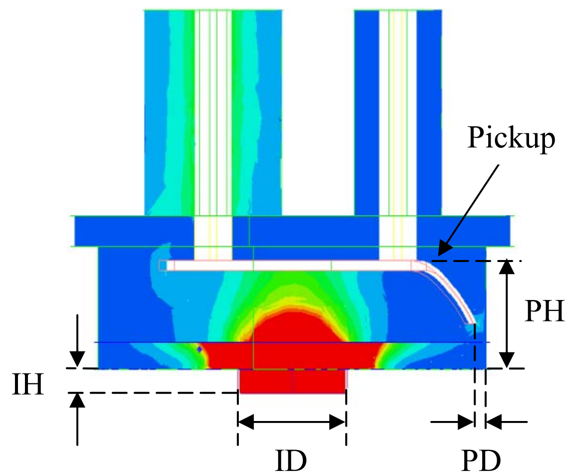


Figure 3: Electric field magnitude in coupler element. Parameters associated with the simulations and measurements are defined as follows: PH: Pickup Height, PD: Pickup Distance, ID: Iris Diameter, IH: Iris Height.

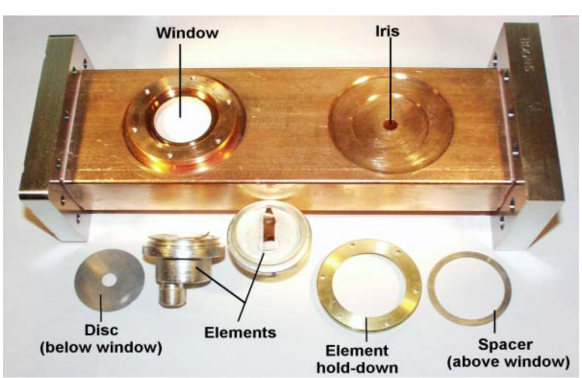


Figure 4: Coupler components.

## MEASUREMENT AND SIMULATION DATA

Since the coupling does not vary as substantially as the isolation when the coupler is rotated, the angle producing maximal isolation also creates maximal directivity. However, the response is very sharp and requires precise positioning. The process of tightening the coupler can make perceptible changes in these values, and care must be taken to limit the error. Figure 5 shows a plot of the measured and simulated directivity for 180° of rotation of the coupler element. The angle is calculated from the axis of the pickup to the transverse plane of the waveguide.

The original coupler assemblies produced a coupling value that was lower than the required level. Increasing the housing iris diameter in both ports by 10%, from 0.312 inches to 0.345 inches, increased the coupling by approximately 4 dB.

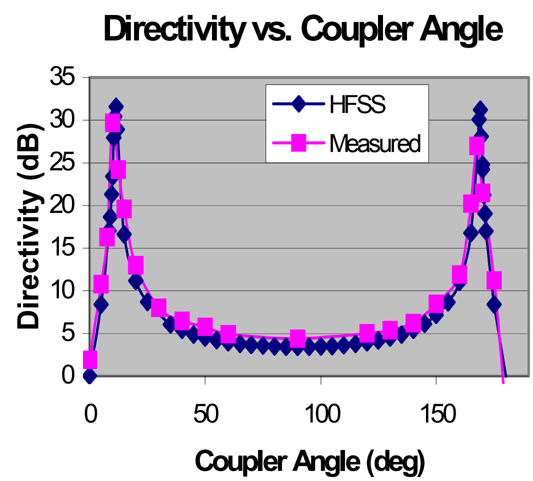


Figure 5: Directivity with respect to element angle of rotation from simulated and measured data.

Adding discs under the window to change the iris height did not make large changes to the directivity. However, adding several 0.006-inch spacers above the window caused substantial changes in the directivity as shown in Table 1.

Table 1: Effect on the Directivity Due to Increase in Pickup Height above the Nominal Value of 0.265 inches

| Spacer | Directivity |
|---|---|
| No spacer | 30.3 dB |
| 0.006″ | 31.4 dB |
| 0.012″ | 33.2 dB |
| **0.018″** | **36.2 dB** |
| 0.024″ | 31.6 dB |
| 0.030″ | 29.4 dB |

Simulation results found that the effects of the pickup distance and the pickup height were dependent on the orientation of the coupler element. If the coupler element was imprecisely oriented by more than half of a degree, some of the parameters shown in Fig. 3 produced differing effects.

For precisely aligned coupler elements, an increase in the pickup height was found to increase the directivity up to 6 dB. A change in the pickup distance showed little change in directivity once a minimum distance was reached and before the distance became too great. For coupler elements that were slightly off the optimal orientation, an increase in the pickup height had little effect. Also, the directivity became much less uniform and began to degrade as the pickup distance was adjusted.

Optimized dimensions for the directional coupler assembly are shown in Table 2. A plot of the surface current can be seen in Fig. 6. The coupler element is rotated to achieve maximum isolation from forward-directed power traveling into the page. In this figure, the waveguide is, in fact, excited with a field traveling out of the page. The field plot shows the coupling of the fields into the large signal port and the small resistive port.

Table 2: Optimal Parameters Determined from Simulations with HFSS

| Parameter | Dimension |
|---|---|
| Angle | 11.75° |
| Iris Diameter | 0.4 in |
| Pickup Distance | 0.025 in |
| Iris Height | 0.065 in |
| Pickup Height | 0.286 in |

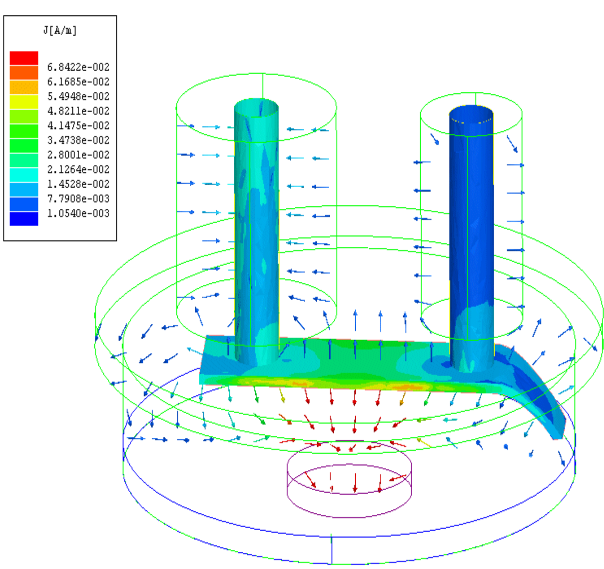


Figure 6: Surface currents on the pickup and inner conductors, and electric field vectors along a cross section of the coupling element.

## CONCLUSIONS

Opening the iris diameter was necessary to achieve the desired increase in coupling. The iris diameter does not strongly affect the directivity and, as a result, may be adjusted nearly independently of the directivity. It was found that the coupler is highly sensitive to the orientation of the pickup loop and must be precisely aligned. In addition, the location of the pickup above the coupling iris was a major contributing factor to optimizing the performance of the coupler. The experimental and simulation results that were presented will also aid in the future development of bidirectional couplers in the WR340 waveguide.

## ACKNOWLEDGMENTS

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