# USE OF WAVEGUIDE PROBES AS BEAM POSITION AND TILT MONITORING DIAGNOSTICS WITH BASELINE AND ALTERNATIVE SUPERCONDUCTING DEFLECTING CAVITIES FOR THE APS UPGRADE*

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*Abstract*

A set of superconducting deflecting cavities were studied for the APS Upgrade. A TM-mode baseline deflecting cavity design has been developed and prototyped, while an alternative design based on a TE-like mode is being studied. Waveguide field probes associated with the baseline and alternative superconducting deflecting cavities are explored as beam position and tilt monitoring diagnostics. Microwave Studio was used to simulate the technique of detecting the fields excited by a Gaussian bunch passing through the cavities to determine beam position relative to the electrical center. Probes installed on the horizontal midplane in the beam pipe are promising diagnostics for monitoring beam position and tilt in both designs. The probes in the power coupler also work as beam position monitors for the alternative deflecting cavities.

## INTRODUCTION

A set of superconducting deflecting cavities were studied for the Advanced Photon Source (APS) Upgrade. A TM-mode baseline deflecting cavity design has been developed and prototyped [1], while an alternative design based on a TE-like mode is being studied [2-3].

Waveguide field probes associated with the baseline TM-mode superconducting deflecting cavities have been explored as beam position and tilt monitoring diagnostics [4]. The probes installed on the horizontal midplane in the beam pipe were sensitive to the beam vertical position. The signals from the beam pipe probes were proportional to the beam vertical positions. However the probes in the fundamental power coupler (FPC), high-order-mode coupler (HOM), and low-order-mode coupler (LOM) cannot detect the deflecting dipole mode, which is sensitive to the beam vertical position. The boundary of the HOM in the baseline deflecting cavities was improved and Microwave Studio [5] was applied on the baseline structure again in this paper.

The alternative TE-mode superconducting deflecting cavity is totally different from the baseline TM-mode one. It became attractive due to its special advantages. It was necessary to investigate the waveguide probes as beam position and tilt monitoring diagnostics with alternative deflecting cavities by using Microwave Studio.

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## FIELDS IN THE BEAM PIPE OF THE BASELINE DEFLECTING CAVITY

The HOM of the baseline deflecting cavities was bent to be perpendicular to the plane of the Cartesian coordinate system, shown in Figure 1. The boundary conditions were improved compared to the previous one in [4].

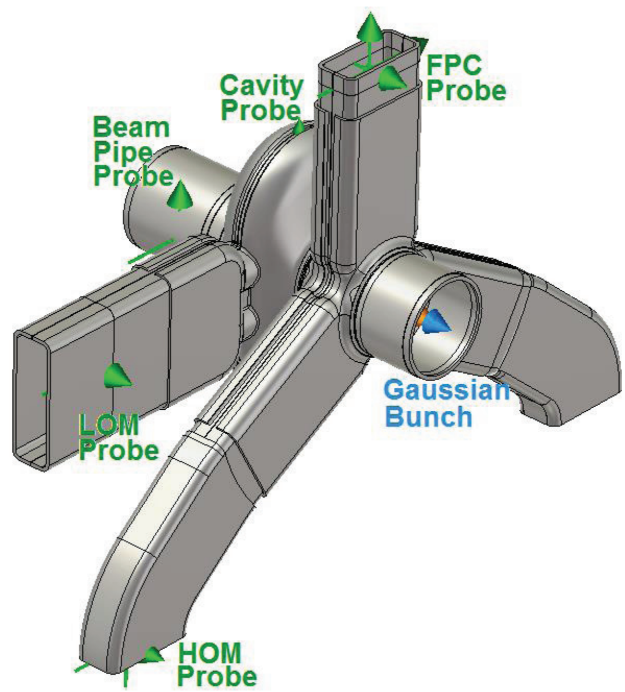


Figure 1: Baseline TM-mode superconducting deflecting cavity and the associated waveguides with the probes.

The simulation progress was identical to one in [4] and the conclusion was similar. A Gaussian bunch was launched at different vertical offsets (y = 0/1/2 mm) while there was no rf generator. The bunch charge was 15.65 nC with rms bunch length of 10.05 mm and passed through the deflecting cavity.

The deflecting dipole mode $TM_{120}$ in a rectangular cavity (or $TM_{110}$ in a circular cavity) is proportional to the beam vertical position.

Figure 2 shows the spectra of the electro-magnetic fields at the probe in the beam pipe of the baseline TM-mode deflecting cavity. The deflecting dipole mode $TM_{120}$ (2.841 GHz) leaks into the beam pipe and shows linear sensitivity to the vertical beam position with the probe in the horizontal midplane. The beam pipe probe shows response that is proportional to the vertical beam position




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and can be used as a beam position and tilt monitoring diagnostics.

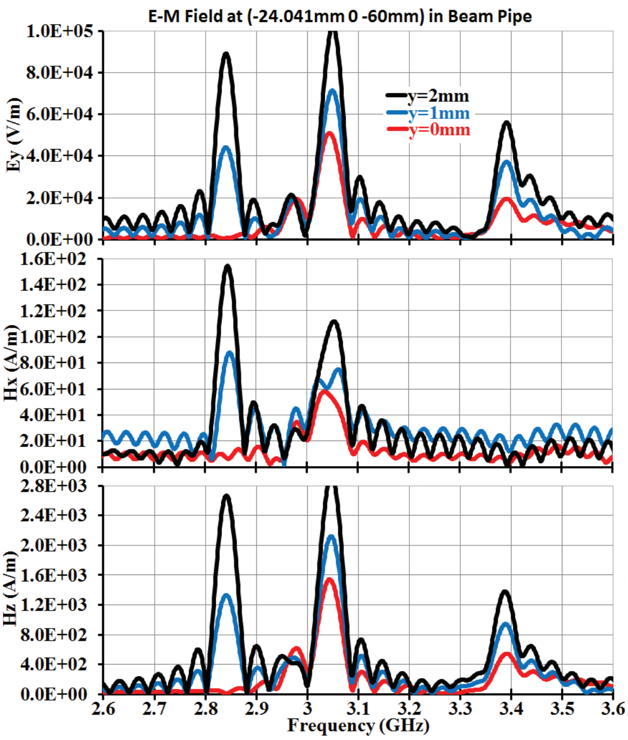


Figure 2: Electro (top) and magnetic (middle & bottom) field spectra for different vertical beam positions at the beam pipe probe in the baseline TM-mode deflecting cavity design. Deflecting mode $TM_{120}$ is at 2.841 GHz.

## FIELDS IN THE BEAM PIPE OF THE ALTERNATIVE DEFLECTING CAVITY

Figure 3 represents the alternative TE-mode superconducting deflecting cavity design. The probes were set up in the deflecting cavity, beam pipe, and power coupler. The same Gaussian bunch passed through the alternative TE-mode deflecting cavity.

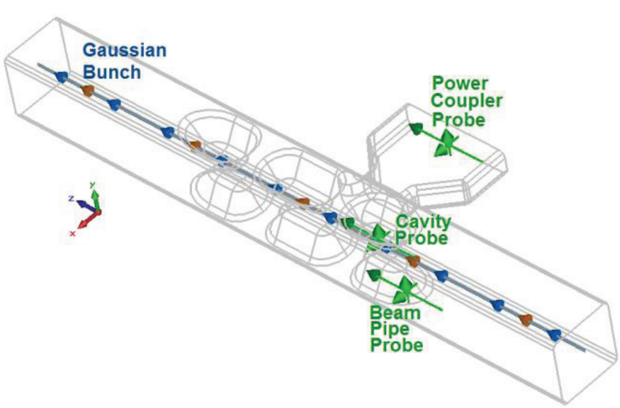


Figure 3: Alternative TE-mode superconducting deflecting cavity and the associated waveguides with the probes.

Figure 4 shows the spectra of the electro-magnetic fields at the beam pipe probe of alternative TE-mode deflecting cavity. Similar to the baseline deflecting cavity, the deflecting dipole mode $TE_{103}$ (2.814 GHz) in the beam pipe shows linear sensitivity to the vertical beam position with the probe in the horizontal midplane. The beam pipe probe shows response that is proportional to the vertical beam position and can be used as a beam position and tilt monitoring diagnostics.

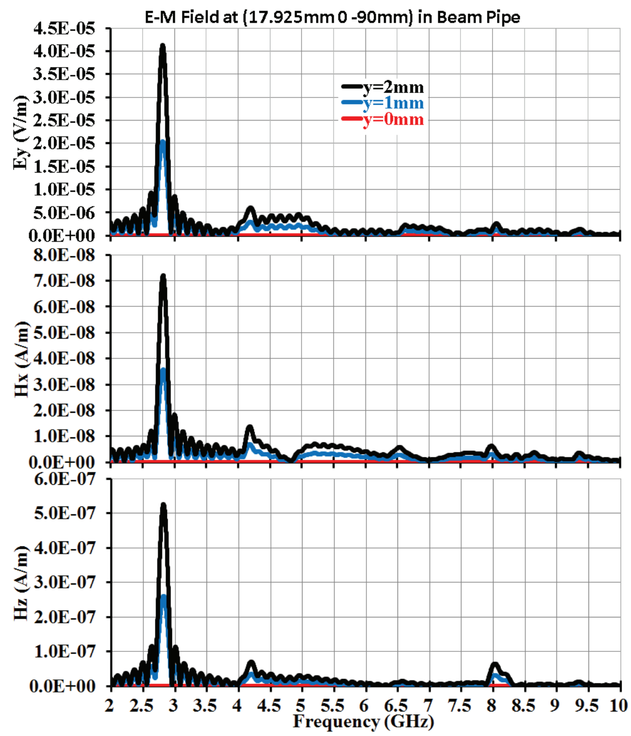


Figure 4: Electro (top) and magnetic (middle & bottom) field spectra for different vertical beam positions at the beam pipe probe in alternative TE-mode deflecting cavity design. Deflecting $TE_{103}$ mode is at 2.814 GHz.

Figure 5 shows the electro-magnetic field patterns at 2.814 GHz for beam y = 2 mm on the plane including the beam pipe and power coupler probes.

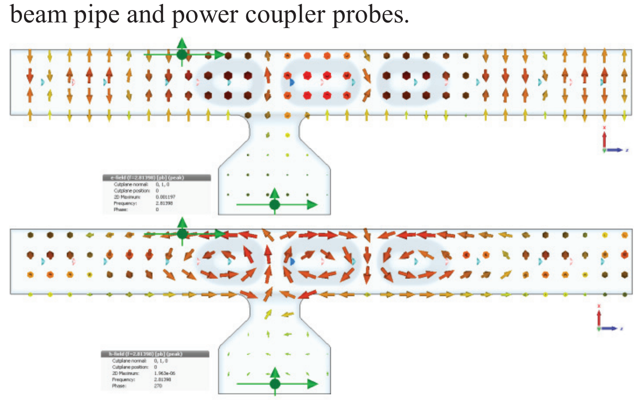

Figure 5: The $TE_{10}$-like electro (top) and magnetic (bottom) fields at frequency 2.814 GHz for beam y = 2 mm on the plane of y = 0 mm, where the beam pipe and power coupler probes were located (green arrows).

## FIELDS IN THE POWER COUPLERS OF THE ALTERNATIVE DEFLECTING CAVITY

Figure 6 demonstrates the spectra of the electro-magnetic fields at the probe in the power coupler of the alternative deflecting cavity. Different from the situation in the baseline TM-mode deflecting cavity, the electro-magnetic fields in the power coupler of the alternative TE-mode deflecting cavity illustrates linear sensitivity to the vertical beam position. The power coupler probe shows response that is proportional to the vertical beam position and can also be used as a beam position and tilt monitoring diagnostics.

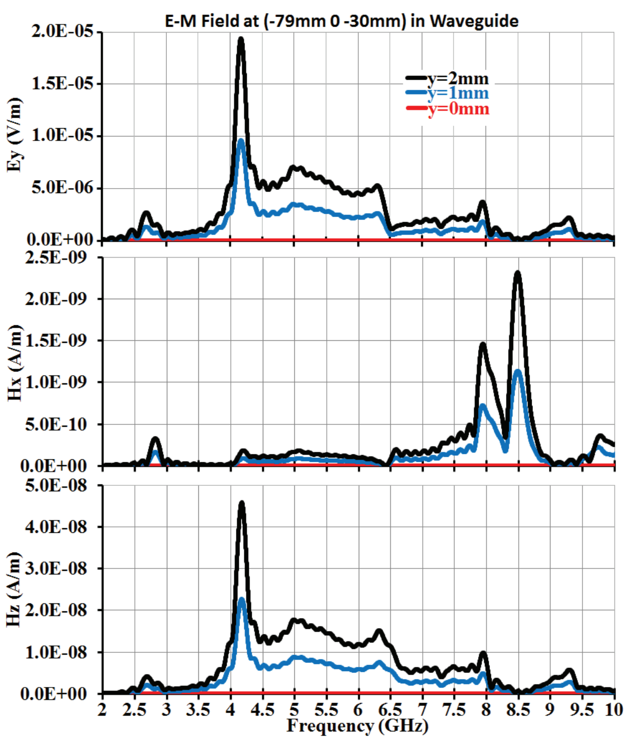


Figure 6: Electro (top) and magnetic (middle & bottom) field spectra for different vertical beam positions at the power coupler probe in the alternative TE-mode deflecting cavity design. The mode at 4.170 GHz may be $TE_{112}$.

Figure 7 shows the electro-magnetic field patterns at 4.170 GHz for beam y = 2 mm on the plane including the beam pipe and power coupler probes.

## SUMMARY

Using a Gaussian bunch launched at different vertical positions and passing through the baseline or alternative deflecting cavity, the electro-magnetic fields excited by the beam were simulated without an rf generator.

The probes installed on the horizontal midplane in the beam pipe were sensitive to the beam vertical position for both baseline and alternate superconducting deflecting cavities. The signals from the beam pipe probes were proportional to the beam vertical positions.

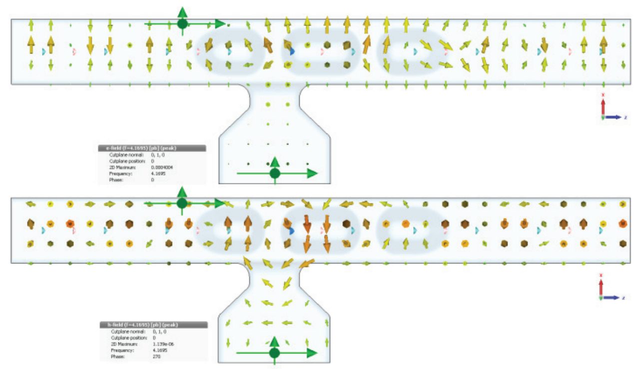

Figure 7: The $TE_{11}$-like electro (top) and magnetic (bottom) fields at frequency 4.170 GHz for beam y = 2 mm on the plane of y = 0 mm, where the beam pipe and power coupler probes were located (green arrows).

Different from the situation of the baseline superconducting deflecting cavity, the signals from the probes in the power coupler were also proportional to the beam vertical position in the alternative deflecting cavity.

## ACKNOWLEDGMENT

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