FFAG 2004 Workshop, Vancouver
19th April 2004

HFSS Calculations of 200 MHz Cavity

Amiya Mitra

OUTLINE

- HFSS simulation of 200 MHz single cell Cavity
- RF parameters
- E and H field plots
- Influence of beam aperture
- Acknowledgment and References

1.0 Introduction

The dimensions of the 200 MHz single cell elliptical cavity is very close to the 200 MHz single cell Nb-Cu cavity (courtesy of Roberto Losito, CERN).

A 3D rf software, High Frequency Structure Simulator, HFSS, Ansoft Corporation has been used to simulate the single cell cavity.

No attempt has been made to optimize the rf parameters (Epk / Eacc, Bpk / Eacc, R/Q) in this HFSS simulation.

The electric field components of the accelerating mode along the beam axis and off beam axis are obtained from HFSS.

The final shape will be dictated by the required beam aperture for FFAG application, optimized rf parameters and the geometry needed for the requirements for film deposition of Niobium on Copper using sputtering technique.

2.0 Computed RF Parameters and higher order modes

Table 1 shows the computed rf parameters obtained from HFSS. 15 modes including the fundamental mode are shown in table 2.

Table 1: Computed RF Parameters

Parameter	Value	Unit
Cavity Diameter	1400	mm
Beam Tube Diameter	300	mm
Cavity Length (without beam tube)	700	mm
F	200	MHz
$G = R_s \cdot Q$	250	Ω
R_{shunt} / Q	121	Ω
Epk / Eacc	1.7	
Bpk / Eacc	5.0	mT /(MV/m)
Eacc / √(J)	0.55	MV/m /√(J)

Table 2: 15 Modes Calculated with HFSS

Mode	**F MHz**
1	199.45
2	280.5
3	283.1
4	373.62
5	374.0
6	400.44
7	404.96
8	420.64
9	434.92
10	450.03
11	459.35
12	483.63
13	493.07
14	495.62
15	510.02

2.1 Sample Calculation

Sample calculation for the 200 MHz single cell cavity for accelerating voltage of 10 MV and a bandwidth of 200 Hz is listed below:

Bore diameter 300 mm
Effective length 1 m

R/Q = 121
Gradient = 10 MV/m
Accelerating Voltage = 10 MV

Q_o = 6×10^{9}
Q_l = 10^{6}
Bandwidth 200 Hz

Generator Power required = 400 KW

Stored Energy = 330 Joules
E_{peak} = 17 MV/m
H_{peak} = 50 mT

2.2 E and H field plots

3D plots of E and H fileds in the cavity are shown in figures 1 and 2. Figures 3 to 5 are rectangular plots obtained from HFSS field calculator. The Z axis is the beam axis.

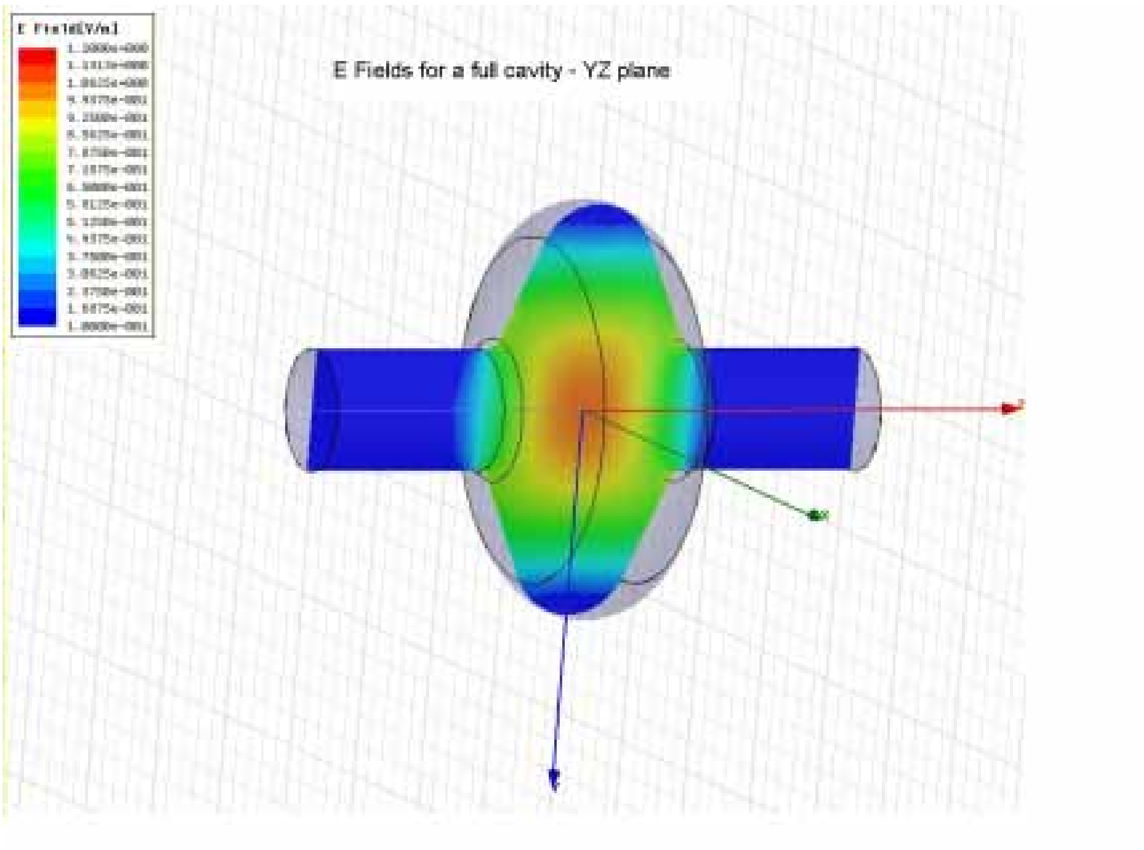


Figure 1: E fields in the cavity in YZ plane.

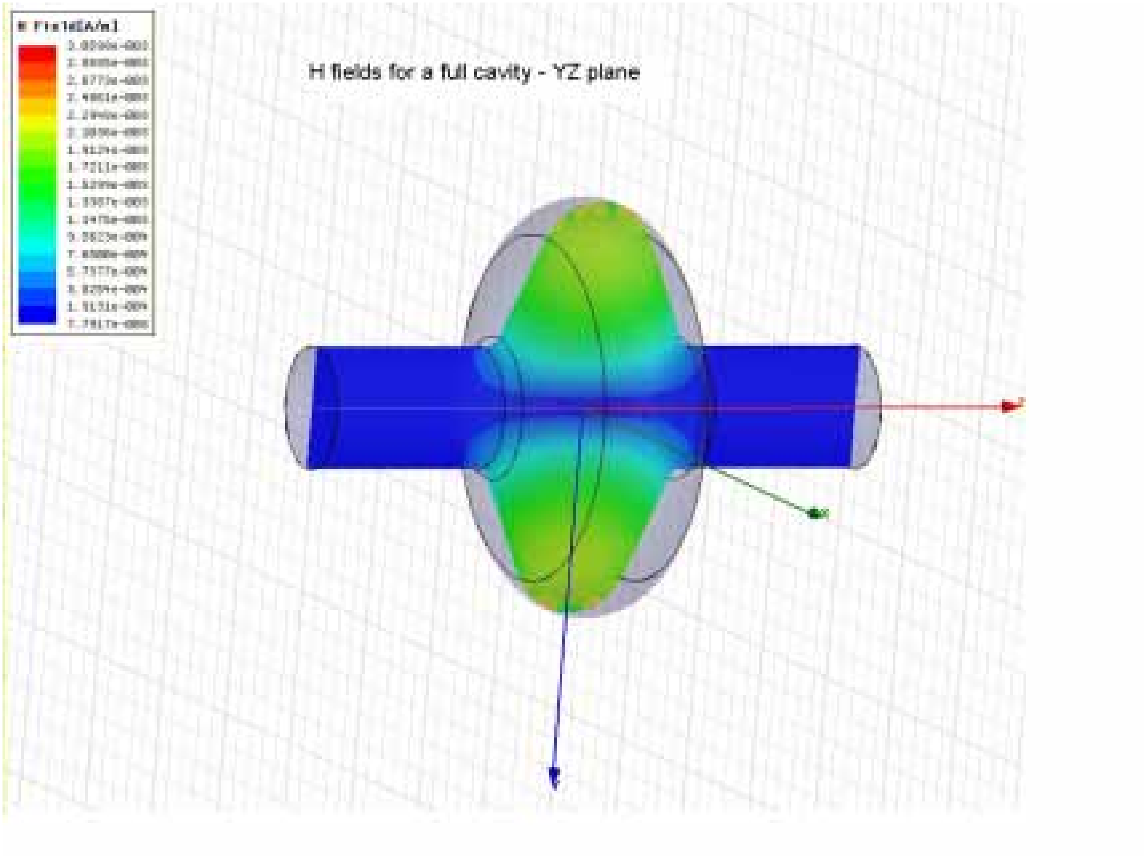


Figure 2: H fields in the cavity in YZ plane.

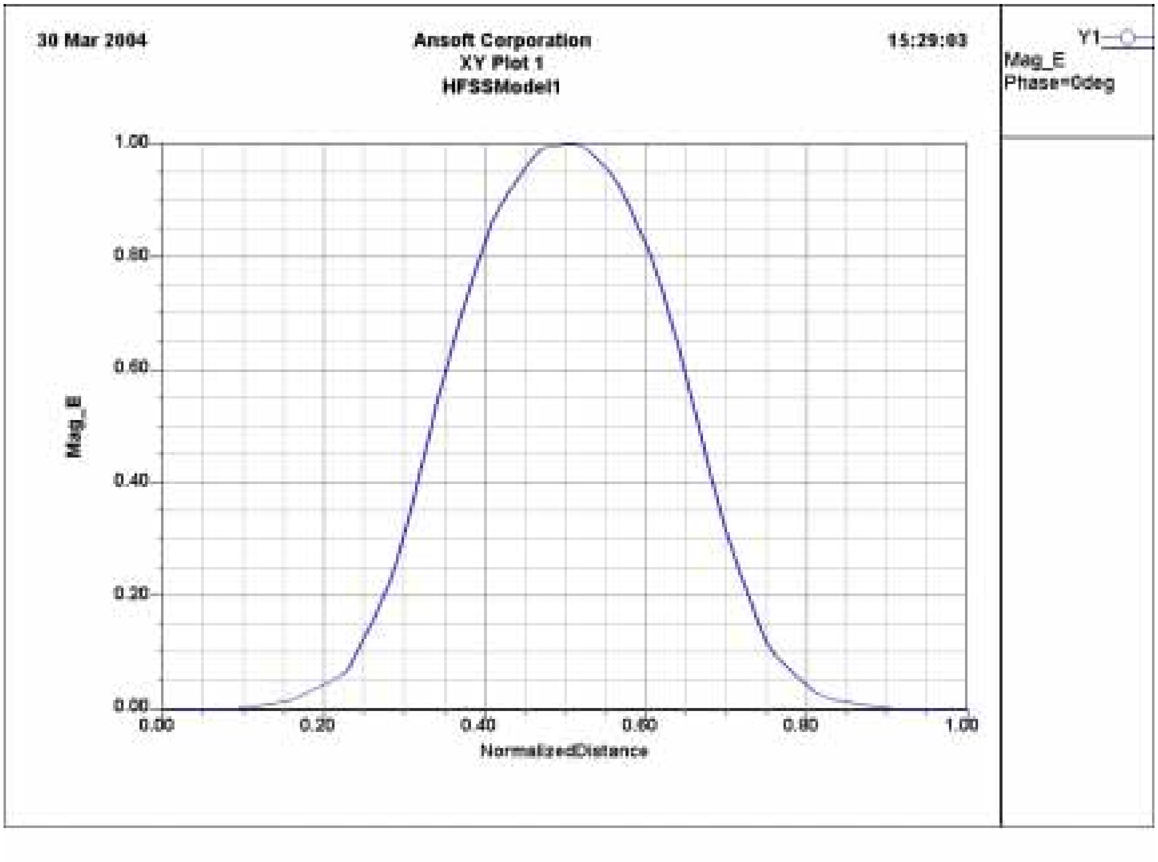


Figure 3: Magnitude of E field of the accelerating mode along beam axis (Z axis)

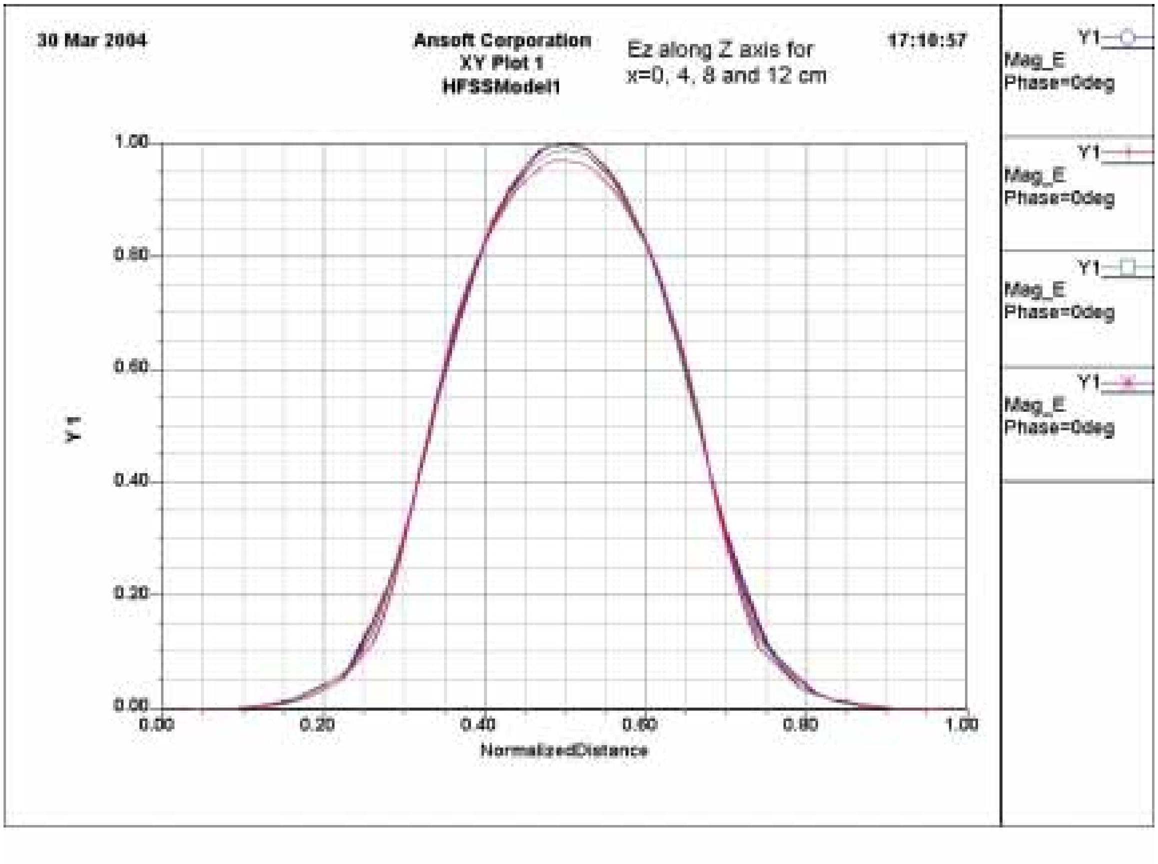


Figure 4: Ez components of accelerating field along Z axis for different offsets along x axis.

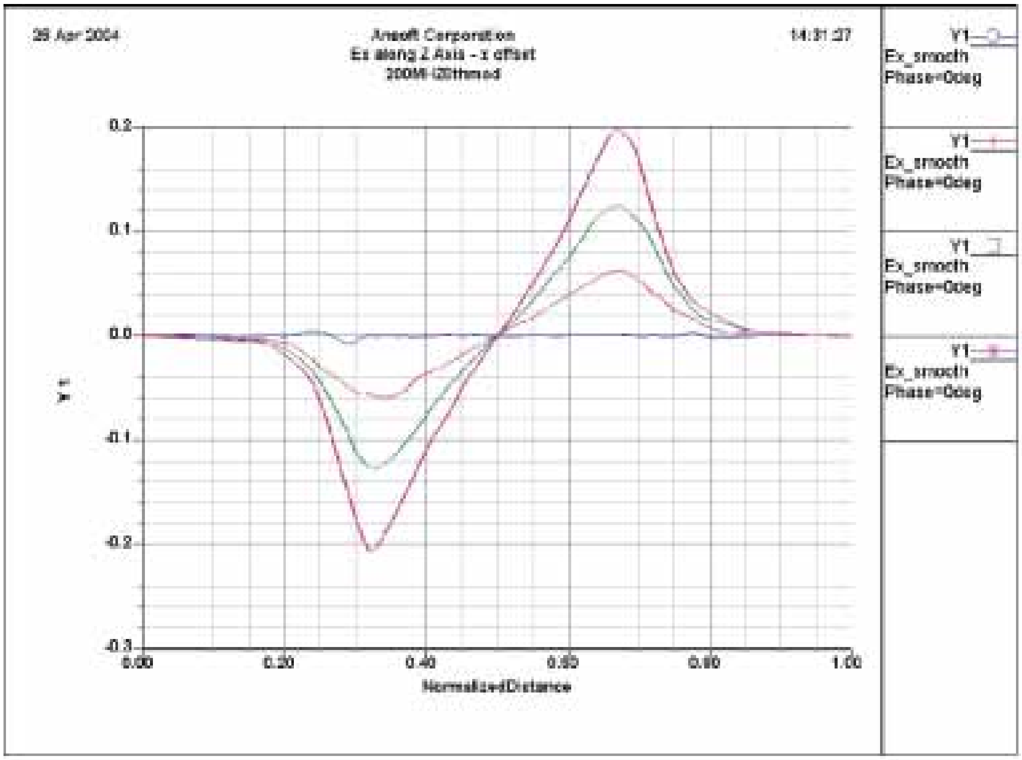
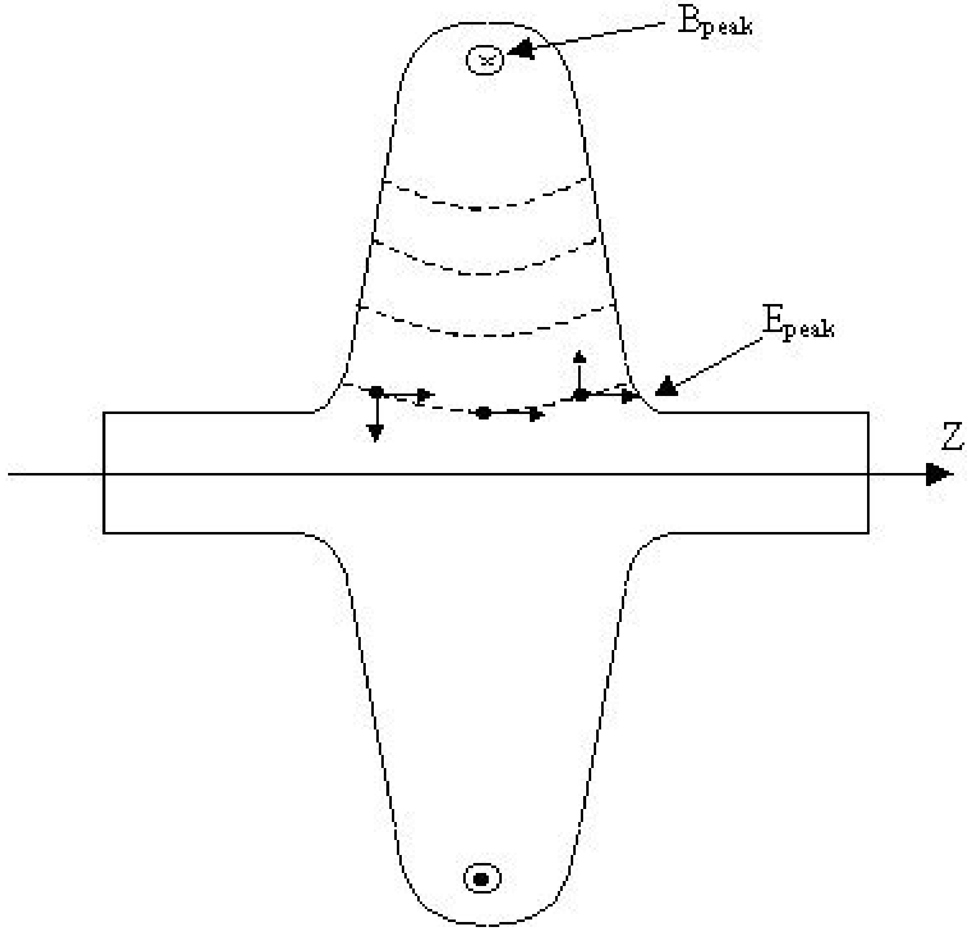


Figure 5: Ex components of accelerating field along Z axis for different offsets along x axis. The offsets are 0, 4 , 8 and 12 cm for blue, brown, green and red respectively.

3.0 Cavity performance

Cavity performance with respect to cavity shape and beam aperture are outlined.

3.1 Cavity shape



High ratio of B_{peak} / E_{acc} at equator is responsible for thermal break down

High ratio of E_{peak} / E_{acc} at iris leads to field emission

Figure 6: 2D sketch of the cavity showing E_{peak} and B_{peak} locations.

3.2 Beam Aperture

- Cavity diameter / beam aperture ratio must be maintained to keep leakage through the beam hole to minimum
- For the same resonant frequency, increasing beam aperture will cause the cavity to be narrower resulting in higher E_{peak} and H_{peak}
- Increasing beam aperture will reduce shunt impedance and R/Q
- For same Q and energy gain (accelerating voltage) more power will be required for larger beam aperture
- Higher Order Modes can be coupled easily through larger beam aperture.
- Larger beam aperture gives more flexibility to optimize sputtering

4.0 Acknowledgment and References

[1] Private communication, Nafeesa Mehboob, Co-op student, Windsor University, ONT

[2] Private communication, Roberto Losito, CERN

[3] Peter Schmuser, "Basic Principles of RF Superconductivity and Superconducting Cavities," SRF 2003 Workshop, Lubeck, Germany, September 8-12, 2003.

[4] R.L. Geng et al, "200 MHz NB-CU Cavities for Muon Acceleration," SRF 2003 Workshop, Lubeck, Germany, September 8-12, 2003.

[5] R.L. geng et al, "First RF test at 4.2K of a 200 MHz Superconducting Nb-Cu cavity," 2003 Particle Accelerator Conference, Portland, OR, USA, May 12-16, 2003.

[6] H. Padamsee et al, "Superconducting Cavities at 200 MHz- Fabrication and Performance", CERN / Cornell collaboration report.