MAGIC 3D WORK at KEK

S. MATSUMOTO

Motivation

• Observed self-excited oscillation seen in
  \( \text{XBppm} \) (the output structure is the same
  as that of \( \text{XB72K #9} \)).

• Study of the coupling between the beam
  deflecting motion and the higher order mode(s)
  in the output structure.

  \[ \rightarrow \text{needs 3D calculation.} \]

  \[ \rightarrow \text{start MAGIC3D calculation.} \]
I report 3 topics.

1. Beam deflection in a simple cavity structure
2. Magic 3D model for #9 output structure
3. Struggle to realize the deflection motion in the output structure.

**SUMMARY**

- Beam deflection in a single cavity structure is clearly seen. Simple geometrical structure may be helpful to see what happens to the beam. Quantitative analysis is still needed.

- On the other hand, there are lots of complications about the beam in the output structure. Care should be paid to the almost-degenerated higher order modes. Care also should be paid to the repetition frequency of the beam.

- Some minor technical problems remain.
MAGIC 3D model of #9 output structure

- rectangular mesh 0.5 x 0.5 x 0.5 mm
- magnetic field = solenoid 0.5 T uniform.
- beam is produced by "virtual gun".

→ virtual gun produces the beam whose parameters are specified explicitly:
  - beam energy (emission) $V(t)$
  - current density (on cathode) $\rho(r)$

→ we usually use $\rho = \text{const} (r < r_0)$, $\rho = 0 (r > r_0)$; $V(t)$
Simulation with the pulsed beam on the axis.

- $I_1/I_0 = 1.4$
- $r_0 = 3\, \text{mm}$
- $V_0 = 550\, \text{kV}$, $\mu_{\text{perp}} = 1.2$ (4.89A)
- beam repetition 11.424 GHz

Power of 55MW is coming out from the each port. (This result agrees with MAGIC 2D)
Caption: MODEL PLOT OF X1-X2 SURFACE AT I3=30

Organization:

Author:

Device:

Date: 11/07/98  Time: 07: 32

File: out9_5.m3d

Code: MAGIC3D  Version: August 1997

Run:  Page: 3
Caption: PHASESPACE Plot 3 at Time 8.666 ns

Processing: PARTICLE SPECIES: All

Author:

Device:

Date: 11/07/98   Time: 07:32

File: out9_5.m3d

Run:      Page: 1 1

Code: MAGIC3D   Version: August 1997
Caption: VECTOR Plot at Time 8.666 ns

Processing: Of Ex,Ez (V/m) at PLANE1
Plane at X2 = -267.9 µm
Caption: PHASESPACE Plot 1 at Time 8.666 ns

Processing: PARTICLE SPECIES: All
Caption: PHASESPACE Plot 3 at Time 8.710 ns

Processing: PARTICLE SPECIES: All

Organization:

Author:

Device:

Date: 11/07/98      Time: 07:32

File: out9_5.m3d

Code: MAGIC3D      Version: August 1997

Run:               Page: 47
Caption: Time History Plot 22 at Time 8.754 ns

Processing: POYNTING Poynting Pz at OUT2
Plane From (2.400cm, -1.600cm, 1.500cm) To (2.900cm, 1.600cm, 1.500cm)

Author:

Device:

Date: 11/07/98 Time: 07:32
File: out9_5.m3d
Run: Page: 105
Caption: Time History Plot 23 at Time 8.754 ns

Processing: POYNTING Poynting Pz at OUT3
Plane From (2.400cm, 1.600cm, 1.500cm) To (2.900cm, 1.600cm, 1.500cm)

Author:

Device:

Date: 11/07/98  Time: 07:32
File: out9.5.m3d

Coupling of beam motion and cavity higher mode.

- XB72K first gain cavity (+ beam ports)
- Off-axis beam is used (by virtual gun).
- Beam repetition is 15.2 GHz (~ TM11-like mode)

- Calculate this system for 120 rf (-120 x 15.2 GHz) cycles.

... equilibrium. Induced field is about 20 M/M at Z=0, Y=±6 mm.

Cal time ≈ 7h (by Pentium II 300 MHz)
EIGENMODE

Vector plot of $(E_z, E_r)$

Caption: VECTOR Plot 1 for Frequency 15.21 GHz
Processing: Cf Ex,Ey (V/m) at PHI,LO
Plane at X3 = 250.0 µm

Organization: KEK
Author: S.M.
Device: A Cavity with Beam Ports
Date: 10/24/98   Time: 18:30
File: frea.m3d
Run No: test   Page: 20

Code: MAGIC3D   Version: August 1997
Caption: CONTOUR Plot 4 for Frequency 15.21 GHz

Processing: Bz (TESLA) at PHI-LO
Plane at X3 = 250.0 um

Organization:
KEK

Author: S.M.

Device: A Cavity with Beam Ports
Date: 10/24/98 Time: 15:30
File: freq.m3d
Run No: test
Page: 27
Caption: CONTOUR Plot 5 for Frequency 15.21 GHz

Processing: Ex (V/M) at CENTER-PLANE
Plane at Xl = 0.000 m

Organization:
KEK

Author: S.M.

Device: A Cavity with Beam Ports

File: freq.m3d

Code: MAGIC3D  Version: August 1997
Run No: test  Page: 28
Caption: VECTOR Plot 3 for Frequency 15.21 GHz

Processing: Of $B_y, B_z$ (tesla) at CENTER-PLANE
Plane at $X_l = 0.000$ m

Organization:
KEK

Author: S.M.

Device: A Cavity with Beam Ports
Date: 10/24/98   Time: 18:30
File: freq.m3d

Code: MAGIC3D   Version: August 1997
Run No: test   Page: 22
Caption: PHASESPACE Plot 3 at Time 7.846 ns
Processing: PARTICLE SPECIES: All

Organization:
KEK

Author: S.M.
Device: A Cavity with Beam Ports
Date: 10/24/98    Time: 19:17
File: di3de5.m3d

code: MAGIC3D    Version: August 1997
Run No: test    Page: 57
Caption: **VECTOR Plot at Time 7.846 ns**

Processing: Of $E_x, E_y$ (V/m) at PHI-LO

Plane at $X_3 = 250.0$ um

Organization: KEK

Author: S.M.

Device: A Cavity with Beam Ports

Date: 10/24/98 Time: 19:17

File: di3de5.m3d

Run No: test Page: 53
$B_{\phi} (r=4.6\,\text{mm}, z=0\,\text{mm})$

$E_{\phi} (r=4.6\,\text{mm}, z=0\,\text{mm})$

Caption: Time History Plot 2 at Time 7.890 ns
Processing: FIELD Bz at GAPCXP
(\(-257.1\,\text{mm}, -4.800\,\text{mm}, 0.000\,\text{m}\))

Organization: KEK
Author: S.M.

Caption: Time History Plot 1 at Time 7.340 ns
Processing: FIELD Ex at GAPCXP
At (\(-257.1\,\text{mm}, -4.800\,\text{mm}, 0.000\,\text{m}\))

Organization: KEK
Author: S.M.

Device: A Cavity with Beam Ports
Date: 10/24/98 Time: 19:17
File: d3def.m3d

Run No: test Page: 162

Code: MAGIC3D Version: August 1997
Caption: Time History Plot 22 at Time 105.042 ns

Processing: POYNTING Poynting Pz at OUT2
Plane From (2.400cm, -1.600cm, 1.500cm) To (2.900cm, 1.600cm, 1.500cm)

1200 rf cycles. Search for instability
3 mm radius beam with 1 mm offset in X3.
Caption: VECTOR Plot 1 for Frequency 16.05 GHz

Processing: Of Ez,Ex (V/m) at PLANFI
Plane at X2 = -267.9 um

Organization:
KEK

Author: Kuroda/Nagaoa/S.Matsumoto

Device: #9 Output Structure 3D M2
Date: 11/20/98 Time: 12:34
File: out9_91_m3d

Code: MAGIC3D Version: August 1997

Run No: 1 Page: 21
Caption: CONTOUR Plot | for Frequency 16.05 GHz

Processing: By (TESLA) at PLANE1
Plane at X2 = 267.9 um

Organization:
KEK

Author: Kuroda/Nagaoka/S.Matsumoto

Device: #9 Output Structure 3D Mc

Date: 11/20/98 Time: 12:34

File: aut9.91.m3d

Run No: 1 Page: 23

Code: MAGIC3D Version: August 1997
off-axis beam + #9 output structure

- beam from 'virtual gun'.
- $I/I_0 = 1.4$
- beam rep @ 11.424 GHz
- offset 1mm (in the plane that contains the output ports.)

- 1200 rf cycles

\[
\begin{align*}
\text{We cannot see } & \sim 16 \text{ GHz beam modulation.} \\
\text{There is no } & 16 \text{ GHz frequency component} \\
\text{in the beam from virtual gun.}
\end{align*}
\]

I put the same structure beam but the rep rate is changed to $\sim 16 \text{ GHz}$, (16.2 GHz)

The power is very small. $\rightarrow$ small coupling between the beam and TE11-like mode.
Caption: PHASESPACE Plot 4 at Time 104.954 ns

Processing: PARTICLE SPECIES: All

Remarks: 1200 rf cycles. Search for instability
Remarks: 3 mm radius beam with 1 mm offset in X3.

Author: Kuroda/Nagaoka/S.Matsumoto

Device: #9 Output Structure, 3C MA

Date: 11/10/98 Time: 21:22

File: out9_7.m3d

Run No: 1 Page: 11

Organization: KEK

Code: MAGIC 3D Version: August 1997
Caption: VECTOR Plot 1 at Time 6.188 ns

Processing: Of Ex,Ez (V/m) at PLANE1
Plane at X2 = -267.9 um

Response of the structure by incoming wave
TE10(16GHz)

Organization:
KEK

Author: S.Matsumoto

Code: MAGIC3D Version: August 1997

Device: #9 Output Structure. 3D MA
Date: 12/10/98 Time: 21:20
File: out9_10.m3d
Run No: 1 Page: 6
Caption: VECTOR Plot 4 at Time 6.188 ns

Processing: Of Bx,By (Tesla) at PLANE3
Plane at X3 = 267.9 um

Response of the structure by incoming wave
TE10 (50GHz)

Organisation:
KEK

Author: S.Motsumoto

Device: #9 Output Structure: 3D MA
Date: 12/10/98 Time: 21:20
File: out9_10.m3d
Run No. Page: 9

Code: MAGIC3D Version: August 1997
Cavity Impedance
16.2 GHz

\[ y = m_1 \cdot m_0^2 \]

<table>
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<th>値</th>
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<tr>
<td>m1</td>
<td>0.22382</td>
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<tr>
<td>カイ 2乗</td>
<td>0.22143</td>
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<tr>
<td>R</td>
<td>0.99961</td>
</tr>
</tbody>
</table>

\[ \text{total (kw)} \]

\[ \text{yf current (A)} \]

16.2 GHz

100A 25kW extremely small power.
16.2 GHz beam repetition

Caption: PHASESPACE Plot 4 at Time 12.284 ns

Processing: PARTICLE SPECIES: All

Remarks: Beam repetition 16.2GHz, 200 rf cycles.
Remarks: 3 mm radius beam with 1 mm offset in X3. R=0.2

Organization:
KEK

Author: Kuroda/S. Matsumoto

Device: #9 Outout Structure. 3 D MA

Date: 11/25/98   Time: 10:57

File: out9_123.m3d

Run No: 1   Page: 11