TARGET OF SIMULATIONS AT E.S.R.F

DEVELOPING A PROTOTYPE OF NORMAL CONDUCTING CAVITY (at 352.2 MHz) TO ATTENUATE HIGHER ORDER MODES WITH RIDGE WAVEGUIDE DAMPERS INCLUDING FERRITE

BASED ON R&D OF "EU PROJECT"

MAX-lab

BESSY

SRS

National Tsing Hua University (NTHU)
1- OPTIMISATION OF THE BODY (*Naked Cavity*)

2- OPTIMISATION OF THE FERRITE LOADED RIDGE WAVEGUIDE

3- SIMULATION OF THE GLOBAL CAVITY : BODY + 3 DAMPERS

4- COMPARISON : MAFIA / GDFIDL FOR SIMULATION OF THE BESSY II CAVITY (*a design which doesn’t use Ferrite*)
**1 - FIRST STEP : OPTIMIZATION OF THE BODY**

- **Superfish (2D)** calculates Eigenvalues and main parameters of RF *symmetrical* cavities.
- **GDFIDL (3D)** is used as Eigenvalue or Time domain solver for *arbitrary* RF structures.

<table>
<thead>
<tr>
<th>TYPE OF CAVITY</th>
<th>SIMULATION TOOLS</th>
<th>f&lt;sub&gt;RF&lt;/sub&gt; (MHz)</th>
<th>Q</th>
<th>R/Q (Ohms)</th>
<th>R (k Ohms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaled BESSY II Cavity Optimised</td>
<td>SUPERFISH</td>
<td>352.222</td>
<td>49844</td>
<td>148.981</td>
<td>7426</td>
</tr>
<tr>
<td></td>
<td>GDFIDL</td>
<td>352.171</td>
<td>51180</td>
<td>149.140</td>
<td>7633</td>
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<tr>
<td>Scaled BESSY II Cavity Not Optimised</td>
<td>SUPERFISH</td>
<td>352.078</td>
<td>46039</td>
<td>128.196</td>
<td>5902</td>
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<td>LEP Model Cavity / ESRF</td>
<td>URMEL [Dr H.Henke / Dr T.Weiland - 1984]</td>
<td>353.5</td>
<td>47300</td>
<td>142.4</td>
<td>6736</td>
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<td>SUPERFISH</td>
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<td>47864</td>
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<td>BESSY II</td>
<td>MAFIA [Dr F.Marhauser / Bessy - 2000]</td>
<td>499.842</td>
<td>38018</td>
<td>128.139</td>
<td>4872</td>
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<td>SUPERFISH</td>
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<td>GDFIDL</td>
<td>499.256</td>
<td>40553</td>
<td>128.535</td>
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</table>

(* PERFECT BODY WITHOUT HOLE *)
GDFIDL is a Finite Difference solver for the Maxwell and Helmholz equations. Can be used as Eigenvalues or Time domain solver for arbitrary rf structures.

<table>
<thead>
<tr>
<th>MODE TYPE</th>
<th>FREQUENCY (MHz)</th>
<th>Q</th>
<th>R (kΩ)</th>
<th>R/Q (Ω)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-E-1</td>
<td>352.171</td>
<td>51180</td>
<td>7633</td>
<td>149</td>
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<tr>
<td>0-M-1</td>
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<td>42533</td>
<td>554</td>
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<td>0-M-2</td>
<td>865.408</td>
<td>40758</td>
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<td>0-E-3</td>
<td>896.959</td>
<td>94489</td>
<td>586</td>
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<td>0-E-4</td>
<td>1111.37</td>
<td>50231</td>
<td>418</td>
<td>8</td>
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<tr>
<td>0-M-3</td>
<td>1173.40</td>
<td>82536</td>
<td>490</td>
<td>6</td>
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</tbody>
</table>

- Conditions: simulation of half cavity with electric or magnetic boundary for a meshing of 2 mm.
- Notations: m-E-n or m-H-n, m for azimuthal dependency, n as sequential index.
Conditions: Simulation on only 200 meters of half the cavity with magnetic boundary for a meshing of 2 mm. (No offset on transverse plane)

Remark:
For modes which should have a high Q value, the calculated impedance isn’t accurate. It’d require a longer wake length.
2 - SECOND STEP : OPTIMIZATION OF FERRITE LOADED RIDGE WAVEGUIDE

WITH 3D SIMULATION SOFT: High Frequency Structure Simulator (HFSS®)

HFSS is based on a Finite Element Method with adaptive mesh refinement. Eigenmodes of arbitrary RF structures are solved, including materials losses.

BASIC MODEL (Longitudinal cut)

Waveguide part long enough to attenuate the \( f_{RF} \) mode

\[
P/P_o = \exp \left[ -(4.\pi.Z / \lambda)(1-(\lambda_c / \lambda)^2)^{1/2} \right]
\]

Here, for: \( z = 0.25 \text{ m} \) \( \Rightarrow P/P_o \approx 0.07 \)

\( f_c = 435 \text{ MHz} \)
**A- BASIC FERRITE MODEL**

*Effect induced by variation of Ferrite thickness (e)*

- $f_{RF} < f_{CRWG} < f_{0M1}$
- $f_{CRWG} = 435$ MHz
- $e = 6.350$ mm
- $e = 3.175$ mm
- $e = 1.5875$ mm
B- TAPERED FERRITE MODEL

No Ferrite Step
Effect induced by variation of Ferrite thickness (e) for **BASIC MODEL (BM)** and **TAPERED FERRITE MODEL (TFM)**

- TFM - e = 12 mm
- TFM - e = 3 mm
- TFM - e = 6 mm

- BM - e = 6.350 mm
- BM - e = 3.175 mm
- BM - e = 1.5875 mm

Frequency (MHz)

<table>
<thead>
<tr>
<th>S11</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
</tr>
<tr>
<td>0.7</td>
</tr>
<tr>
<td>0.6</td>
</tr>
<tr>
<td>0.5</td>
</tr>
<tr>
<td>0.4</td>
</tr>
<tr>
<td>0.3</td>
</tr>
<tr>
<td>0.2</td>
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<tr>
<td>0.1</td>
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<tr>
<td>0.0</td>
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</table>

TFM

Frequency (MHz)
C - TILE FERRITE MODEL

⇒ TO OBTAIN AN HOMOGENEOUS REPARTITION OF THE ABSORBED POWER

TILES WITH PROGRESSIVE THICKNESS

NO STEP
RESULTS OF SIMULATIONS TO COMPARE 3 TYPES OF FERRITE LOADED RIDGE WAVEGUIDE MODELS

- BASIC MODEL - $e = 1.5875$ mm
- TAPERED MODEL - $e = 12$ mm
- TILE MODEL - $e : 1$ to $20$ mm
EVOLUTION OF DENSITY POWER ABSORBED BY FERRITE
FOR 3 MODELS: BASIC, TAPERED, TILE

(FOR 1W INCIDENT)

Absorbed Power (W)

Frequency (MHz)

TILE MODEL (7 Tiles, e = 1/1.5/3/4/6/8/20)
BASIC MODEL (e = 1.5875 mm)
TAPERED MODEL (e = 12mm)
3 - THIRD STEP : THE GLOBAL CAVITY
- Body + 3 Dampers -

⇒ With GDFIDL only

VIEW OF THE WHOLE CAVITY

Including Ferrite

VIEW OF THE WHOLE CAVITY
For material properties at 500 MHz

⇒ The TILE MODEL is a better absorber than the BASIC one

✓ Conditions : Simulation on 600 meters and 2 mm meshing. (No offset on transverse plane)
ZZOOM ON BANDWITH : 0.9 to 2.2 GHz

BODY + 3 RIDGE WAVEGUIDES : WITHOUT FERRITE
BODY + 3 DAMPERS : TILE MODEL
BODY + 3 DAMPERS : BASIC MODEL

HOM max for 300 mA / 18 cavities
HOM max for 500 mA / 18 cavities
HOM max for 1A / 18 cavities
### Study of the fundamental mode only - 2 mm meshing

<table>
<thead>
<tr>
<th>Parameters</th>
<th>BODY</th>
<th>BODY + 3 WAVEGUIDES : WITHOUT FERRITE</th>
<th>BODY + 3 DAMPERS : BASIC FERRITE MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{RF}$ (MHz)</td>
<td>352.222</td>
<td>345.676*</td>
<td>345.584</td>
</tr>
<tr>
<td>Q</td>
<td>49844</td>
<td>46645</td>
<td>46084</td>
</tr>
<tr>
<td>R/Q ($\Omega$)</td>
<td>148.981</td>
<td>145.923</td>
<td>145.130</td>
</tr>
<tr>
<td>R ($k\Omega$)</td>
<td>7426</td>
<td>6807</td>
<td>6688</td>
</tr>
</tbody>
</table>

**Remark:**
Insertion of Ridge Waveguides had induced a huge shift on the fundamental frequency
4- COMPARISON MAFIA / GDFIDL FOR SIMULATION OF BESSY II CAVITY

(3 Circular Waveguides with Coaxial Transition DAMPERS)

- STRUCTURE WITHOUT ABSORBING MATERIAL -

Wake on 400 meters and a 4 mm meshing
ZOOM ON BANDWITH : 0.6 to 1.2 GHz
ZOOM ON ON BANDWIDTH: 1.2 to 1.8 GHz

Graph showing frequency response with peaks at different frequencies.
CONCLUSION ON SIMULATION TOOLS AND RESULTS

1) ASPECTS ALREADY DEALED WITH:

✓ SIMULATIONS WITH 3 RF SIMULATION SOFTS HAS BEEN DONE:
  . **SUPERFISH** : Perfect for optimisation of simple symmetrical Body
  . **HFSS** : Adapted for S parameters studies (even including absorbing materials)
  . **GDFIDL** : Usefull for H.O.M studies of complex Cavities even including ferrite

✓ THE MAIN ELEMENTS OF THE CAVITY HAVE BEEN STUDIED GLOBALY:
  BODY, RIDGE, FERRITE

2) … POINTS TO DO:

✓ STUDY OF TRANSVERSE H.O.M

✓ OPTIMISE THE “TILE” MODEL AGAIN TO ABSORB SUFFICIENTLY H.O.M WITHOUT THE FUNDAMENTAL ONE (by changing width and gap of the ridge and the length of the waveguide)

✓ OBTAIN A FUNDAMENTAL MODE WITH A FREQUENCY CLOSER TO 352.2 MHz

✓ THERMAL STUDY OF THE CAVITY

✓ …

The End - Thank You! Questions? ...