ISG3 Injector Working Group (WG2)
1/26/99

NLC Damping Ring RF Cavity development

R. A. Rimmer
LBNL
outline:

Parameters

Baseline design (scaled PEP-II)

R&D
  HOM damping waveguides
  HOM loads
  Window and Coupler
  Tuner
  Tapers
  Fabrication issues

Conclusions
### Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>DR</th>
<th>PPDR</th>
</tr>
</thead>
<tbody>
<tr>
<td>frequency</td>
<td>714 MHz</td>
<td>714 MHz</td>
</tr>
<tr>
<td>number of cells</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>total voltage</td>
<td>1.5 MV</td>
<td>2 MV</td>
</tr>
<tr>
<td>voltage/cell</td>
<td>500 kV</td>
<td>500 kV</td>
</tr>
<tr>
<td>wall power</td>
<td>41.7 kW</td>
<td>41.7 kW</td>
</tr>
<tr>
<td>beta</td>
<td>5.7</td>
<td>5.7 (opt=3.1)</td>
</tr>
<tr>
<td>beam current</td>
<td>750 mA</td>
<td>800 mA</td>
</tr>
<tr>
<td>forward power/cell</td>
<td>238 kW</td>
<td>142 kW</td>
</tr>
<tr>
<td>equiv. window power</td>
<td>238 kW</td>
<td>238 kW</td>
</tr>
<tr>
<td>klystron power</td>
<td>733 kW</td>
<td>582 kW</td>
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</table>
Baseline design:

Scaled PEP-II cavity meets requirements

Peak surface field below Kilpatrick (similar to PEP-II)

Wall power density high but within design limits
(72 W/cm², c.f. PEP-II operating 67 W/cm², max design 116 W/cm²)

High window power
(238 kW, 44% area of PEP-II)

But:
Expensive to manufacture

Stresses caused by HOM-port hot spot

R&D effort focused on scaling and simplifying designs
Simple scaling of PEP-II design.
Kilpatrick criterion

\[ \frac{E}{V} = 1.54 \cdot E_k \cdot \exp \left( - \frac{8.5}{E_k} \right) \]

Field (MV/m)

Frequency (MHz)

1 MV

800 kV

PEP-14 operating

500 kV
R&D: HOM damping waveguides

Peak surface power loss at ends of HOM waveguides

look at alternative shapes
reduce heat load
eliminate iris

but:

must not lose effectiveness of damping!
Temperature distribution around HOM port

PEP2RF cav, HOM port only, 12 in. ext., 5 in. edge R, h=14.18 kW/m²/K, f=35-44 C

150 kW dissipating
REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

PARAMETERS:
- Frequency (Hz): 5.98970304000003E+08
- Maximum error of curl-curl (E): -4.97451947012453E-05
- Mean error of curl-curl (E): 1.20514168884268E-05
- Maximum error of divergence (D): 1.38860698939421E-07

COORDINATES/M:
- Full range / window:
  - [ -0.12500, 0.12500]
  - [ -0.012700, 0.012700]

SYMBOLS:
- Symbol = ERE_1
- Interpolate = 0
- Logscale = 0.
- Sx Arrow = 0.85488
<table>
<thead>
<tr>
<th></th>
<th>24/01/99 - 14:47:22</th>
<th>VERSION(V4.016)</th>
<th>DUMBELE.DRC</th>
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<tbody>
<tr>
<td>NCY/HZ</td>
<td>5.9856396800000E+08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M ERROR OF CURLCURL-E</td>
<td>7.085955518921E-06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERROR OF CURLCURL-E</td>
<td>8.657935381961E-07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M ERROR OF DIVERGENCE-D</td>
<td>1.7264923712901E-07</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M
Alternative HOM port profiles

(PEP-II, fc=600 MHz)
R&D: HOM loads

Lower beam current may reduce power but variable fill patterns may make things worse

baseline design is scaled PEP-II load

assess heating once impedance spectrum is confirmed

investigate all likely fill patterns

lower heat load would allow simpler design

must be very broad-band (900 MHz - 7.65 GHz)
Production HOM Load Tile Assembly
(AIN + 40% SiC)
PEP-II Cavity HOM's

- 4 ns bunch spacing, 5% gap, 3A
- Total power 3.6 kW
Low-End Frequency Measurement of Production Horn Load

VSWR 2:1

START 0.6000000000 GHz
STOP 1.1000000000 GHz

MARKER 1
685.0 MHz
-8.2271 dB

MARKER 2
740.0 MHz
-23.246 dB

MARKER 3
770.0 MHz
-16.228 dB

MARKER 4
715.0 MHz
-12.025 dB

MARKER 5
750.0 MHz
-19.649 dB

03 OCT 96
09:58:54
R&D: Window and Coupler

Follow PEP-II scheme

- power density similar to PEP-II
- rugged pre-stressed window
- aperture coupling into cavity
- coupler box incorporates HOM filter
PEP-II RF cavity window module
COMPRESSED ASSEMBLY SEQUENCE

1. COPPER PLATED STAINLESS STEEL WATER JACKET
2. ALUMINA WINDOW, METALLIZED AND NI PLATED
3. CRITICAL GAP AT ROOM TEMP
4. CRITICAL GAP AT ROOM TEMP
5. THE MOLY KEEPER RING COMPRESSES THE STAINLESS STEEL RING AT BRAZE TEMPERATURE FOR A SUFFICIENT REDUCTION IN DIAMETER TO CREATE 10,000PSI COMPRESSION AT ROOM TEMPERATURE
6. BRAZE FIXTURE BASE TO SET CRITICAL SPACINGS BETWEEN CERAMIC AND WATER JACKET

BRAZE USING 65/35(CU/AU) AT 1050°C WITH A HOLD PERIOD AT 450°C FOR TEN HOURS
#ARROW

| SYMBOL = ERR_1 |
| INTERPOLATE = |
| LOGSCALE... = 0. |
| MAX ARROW = 4.99560 |

| FREQUENCY/Hz | 7.7881212000000B-08 |
| MAXIMUM ERROR OF CURLCURL-E | -8.0101410233955E-06 |
| MEAN ERROR OF CURLCURL-E | 1.107450370425E-06 |
| MAXIMUM ERROR OF DIVERGENCE-D | 1.5751943216623E-07 |

REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M
RIDGED CIRCULAR WAVEGUIDE

REAL PART OF TIME HARMONIC ELECTRIC FIELD IN V/M

FREQUENCY/Hz 7.8842457600000E+08
MAXIMUM ERROR OF CURLCURL-E 4.4206121856405E-06
MEAN ERROR OF CURLCURL-E 3.87714294447513E-07
MAXIMUM ERROR OF DIVERGENCE-D 1.30037193457613E-07

COORDINATES/M
FULL RANGE / WINDOW
K [ -0.069800, 0.069800 ]
Y [ -0.069800, 0.069800 ]

SYMBOL = ERR_1
INTERPOLATE = 0
LOGSCALE... = 0.
MAX ARROW = 0.61672
P---: 3.22

#3DPLT

COORDINATES
FULL RANGE / WINDOW
[ -0.12600, 0.041275]
[ -0.12600, 0.041275]
[ -0.12600, 0.041275]
[ -0.12600, 0.076500]
[ -0.12600, 0.076500]
[ -0.12600, 0.283571]
[ -0.076500, 0.283571]

MATERIALS: T1

PROJECTION: 0.5

DESIGN RESONANT FREQUENCY: 1.498974592 GHz
W3 COUPLED AT HIR WALL STUB AT 6.3 CM IL=1.6525 WITH RIDGE IN.
COUPLING TO HIGHER ORDER MODE: EXCIT NODE TM010
3D PLOT OF THE MATERIAL DISTRIBUTION IN THE MESH

\[ \text{No ridge } \beta = 2 \]
\[ \text{Will, ridge } \beta = 7.10 \]

\[ \text{iris + ridge} \]

\[ \text{pillbox cavity} \]
High-power coupler, plan view
R&D: Tuner

Follow PEP-II scheme

water-cooled piston type tuner

moderate gap to accommodate alignment tolerances

straight Glidcop fingers with silver plating

rhodium plated tuner body

commercial actuator (if available)
PEP-II B-Factory

Tuner Plunger with Rhodium

Glidcop Fingers

Assembly

PEP-II RF Cavity Tuner
PEP-II Production Tuner

- GlidCop Fingers
- Linear bearing
- Thermocouple
R&D: Tapers

Tapers needed to transition to small beam pipe

add transverse impedance ($k_\perp$) comparable to cavity!

need long smooth transition

look at non-linear tapers

look for HOMs trapped by tapers / between cavities
Variation of shunt impedance and transverse loss parameter with beam pipe radius and addition of tapers ($\sigma = 4$ mm)

- $\Delta$ shunt impedance ($R_s$) no tapers
- $\Box$ transverse loss parameter ($k_{\perp}$) no tapers

- Two cells, 4 tapers to 15 mm
- Two cells, tapers to 15 mm
- Scaled PEP-II, tapers to 15 mm
- Scaled PEP-II, tapers to 12.5 mm
- SDR, tapers to 12.5 mm
- No tapers
R&D: Fabrication issues

PEP-II cavity successful but expensive

some simple geometry changes may simplify design
e.g.: HOM ports

reordering assembly sequence may reduce parts count
e.g.: port cooling jackets

reduced size may allow alternative materials / parts
e.g.: forgings, flanges

some ideas already tried on ALS Landau cavity

but:
Easy to spend more on R&D than saved in manufacture!
PEP-II RF Cavity produced by Lawrence Livermore National Laboratory

<table>
<thead>
<tr>
<th>Process</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>RF cavity blanks are cold formed from 1&quot; thick flat plate material.</td>
<td>Machined bowls are electron beam welded to form a cavity, then the water channels are cut into the outer contour.</td>
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<td>Machined bowls are electron beam welded to form a cavity, then the water channels are cut into the outer contour.</td>
<td>Wax is placed into the water channels prior to plating 3/8&quot; thickness of OFE copper. Note future port location.</td>
</tr>
<tr>
<td>Wax is placed into the water channels prior to plating 3/8&quot; thickness of OFE copper. Note future port location.</td>
<td>Penetrations for various ports are cut through the electroplated cavity body. Note the blue wax in 4 holes.</td>
</tr>
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<td>Full penetration EB vacuum welds attach tuner, Iris and HOM ports.</td>
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<td>The RF surface is finish turned to a 16 Ra finish using LLNL's Diamond Turning Machine #3.</td>
</tr>
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<td>The beams noses are EB welded into the cavity following a precise tuning process.</td>
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<td>The final product is cleaned for UHV and ready for shipment.</td>
</tr>
</tbody>
</table>

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Conclusions

PEP-II RF cavity is a good baseline design

Modest improvements may be worthwhile

R&D program, level of effort designed to address all issues by time of CDR