Nextef results

CLIC09, Oct. 12-16
T. Higo (KEK)
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• Quadrant high gradient test status
  – Initial processing and power limit
  – VAC characteristics with Q-mass
  – Dark current
  – BD position
  – Light emission
• Change in T18 by high gradient processing
  – RF
  – Optical inspection
• Nextef plan
Quad #5 status
and near future plan
091005 Quad #5
Initial processing trend

- Total BD
- Total INTLK

- ACC-IN TDS Crystal
- ACC-IN TDS Crystal 113ns

Power DPO peak [MW]

RF ON (hours)

Higher target

51ns

113ns
Target = 15MW

Red = power (arbitrary unit)

Blue = Chamber vacuum [Pa]

So-called 9MW run

So-called 10MW run

Higher target
Gradient limit at 50ns

Higher target

So-called 9MW run

So-called 10MW run

Hard limit at 19MW, 59MV/m, 50ns
Run11 with higher target at 113ns

Powers at breakdown with 113ns pulse width for 60 hours

Hard limit at 14MW for 113ns pulse
ACC-IN pulse at hard limit

Limit at similar pulse heating temperature, but more precise comparison is needed.

<table>
<thead>
<tr>
<th>Tp(ns)</th>
<th>51</th>
<th>113</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power (MW)</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Ea (MV/m)</td>
<td>59</td>
<td>50</td>
</tr>
<tr>
<td>\sqrt{T_p} \times \text{Power}</td>
<td>135</td>
<td>147</td>
</tr>
</tbody>
</table>
Vacuum characteristics

• **Vacuum total pressure**
  – Base pressure at <10^{-6}\text{Pa}
  – Typically processing below 10^{-5}\text{Pa}
  – Increases every time at few to 5\text{MW} range if after RF-OFF for more than several hours

• **Mass spectrum**
  – M=2, 28 and 44 increase with RF-ON, but not M=18
    • Especially when reaching power limit
  – M=2 becomes dominant residual gas after an hour or so run
  – M=27 and 28 change in a similar manner as time, indicating hydrocarbon-origin surface contamination
First and Second QMA observations. Check QMA vacuum. QMA-Acc Chamber valve closed.

Large Peak at M=18 (Water). Need more Q mass baking.

All peaks are lowered. After Q mass baked (200deg, 2.5days).
First QMA observation with RF OFF. QMA- ACC Chamber valve opened.

Peak at M=2 (H2) largest. Water (18) becomes moderate. Others are M=28 (CO) and 44(CO2).
QMS (1): RF Power and gases

Pressure of H₂ dominated. Pressure of water is inactive.
QMS (2): Cu and Zr

No signal of Cu (M=63) nor Zr (M=89).
Breakdown pulse analysis

1002=20090920_041256_0&1 =Nominal Structure Breakdown

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Timing distribution for change $>2000$

![Graph 1: Rs nsec (Rs change $>2000$)]

![Graph 2: Tr nsec (Tr change $>2000$)]
T18 structure Function $F(z)$

Use time difference $R_s\text{(rise)} - T_r\text{(fall)}$ to calculate BD position. Function $F(z)$ is calculated from design $vg(z)$. 

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Pick up large Rs, Tr change with 50ns

Sampling cut at 448

Cut at 1000 or 2000 for timing analysis from next page.
Breakdown cell distribution $>1000$

Quad #5 BD cell distribution

DPO Run4
Rs$>1000$, Tr$>1000$

50ns higher target run

713 events were analyzed out of 1919 INTLK.
Breakdown cell distribution >2000

50ns higher target run

Mostly downstream half.

Simply increasing toward output end.

Indication of BD following some field gradient.

534 events were analyzed out of 1919 INTLK.
BD position of run11 113ns, MW

113ns higher target run

It is evident that there is difference than 50ns.

Not increasing toward output side.

Need to check the peak at cell#0.

Need to check those outside structure cell region.
Quad dark current much larger than T18

(Note: Power is just the value in the control program panel. Read 12MW as 19MW, though relative comparison between quad and T18_disk is OK without this.)
Spectrum peak at very low energy

Quad #5 Dark current spectrum
50ns, 19MW

Slit current [pA/(dp/dp)]

<table>
<thead>
<tr>
<th>4</th>
<th>3.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>2</td>
<td>1.5</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
</tr>
<tr>
<td>0</td>
<td>p [MeV/c]</td>
</tr>
</tbody>
</table>

T18_Disk
Peaks at 8MeV/c and 4MeV/c with 108MV/m

Present quad
Peak at 1.2MeV/c with 19MW → 59MV/m
Possible cause of high dark current
Field enhancement due to round chamfer

• Simulation of field enhancement
  – 1.4 ~ 1.6 at radius
  – with gap<radius/5, step<radius/2.5
• Only a few tool passes
  – to shape 50 micron radius
  – with radius tool of 2mm
    • If three passed → tangential discontinuity by about 30 degree
    • Can be relaxed by such as EP in future
Electric field enhancement in a shallow channel with round chamfer

Calculation done by T. Abe by CST MS. Waveguide field.

<table>
<thead>
<tr>
<th>Gap (micron)</th>
<th>Bump (micron)</th>
<th>Emax / Enominal</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>1.39</td>
</tr>
<tr>
<td>0</td>
<td>20</td>
<td>1.57</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>1.58</td>
</tr>
</tbody>
</table>
Other monitors for quad

- Mirror + camera
- Quad
- Qmass
- Camera
- FC-UP
- FC-Mid
- FC-DN

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Light emission observed by usual camera

• From side window
  – Can see several cells near center of structure
  – Found some BD events with a light emission from a particular cell

• View from upstream beam axis
  – Found a light emission
  – Pattern interpretation is not straightforward
  – Some event showed bright spot smaller than cell size

• Need better optical setup
  – Time gating, wider view, space resolution, etc.
Possible future program for quad #5

• NEG installation in progress in this week
  • Further run
    – Longer pulse run at 173ns
    – Evolution of dark current
  • Finish high gradient and --
    – RF check
    – Mechanical check
    – Optical inspection
    – SEM at CERN?

• Further treatment?
  – EP?
• Further high gradient test
  – Improved optical inspection
  – Change in dark current
  – Possibly higher field?

• These become good lessons for us to understand breakdown phenomena.
Change in T18 through high gradient test?
Whole history of processing of T18_VG2.4_Disk #2

MasterTable_Eacc_Trend till_090610
Input match not changed

T18_VG2.4_Disk_#2 Input coupler matching
before installation 080905
after high gradient test 090923

Reflection seen from input side [dB]

Freq [GHz]

LogMag(S11+S12) [dB] 080905
S11+S12 dB 090923
Bead pull raw data on Sep. 23
Correspond to ripple of +/-4% in Ea at output end.
Which was not before test.
Output match some change

Speculation:
Reflection changed around 11424MHz by $\Gamma=0.05$ level??
Can be source of field staggering

T18_VG2.4_Disk_#2 Output coupler matching
before installation 080905
after high gradient test 090923

Reflection seen from output side [dB] 080905

Freq [GHz] 080905 090925

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Bead pull feeding from output side

Amplitude versus Z-position

Output side

Input side
Phase advance per cell

Condition
at 22.7\textdegree C in Nitrogen
Bead pull result:
11423.2MHz $\rightarrow$ 120\textdegree/cell

delF 22.7 $\rightarrow$ 30C $\rightarrow$ -1.38MHz
delF N2 $\rightarrow$ VAC $\rightarrow$ +3.12

delF string $\rightarrow$ no string $\rightarrow$ +0.2MHz
Total delF = 1.94MHz

The structure now shows
120\textdegree/cell at 11425.1MHz

Changed by 1.1MHz through high gradient test!?!?
Should confirm carefully with SLAC tuning result.
\( \phi 4.1 \text{mm} \)

Focus within 5mm to infinity

View direction 45deg

View area 60deg
Optical inspection upstream

60.3mm
Input coupler to cylindrical TM01 line

Insertion 98.0mm for observing Iris #2. This is the best we can now, only the forward iris at an enough distance.
Optical inspection upstream and middle

- Insertion 82.7mm Iris #1 at match cell
- Insertion 98.0mm Iris #2 at first regular cell

- 161.9mm Iris #9
- 170.9mm Iris #10
Optical inspection downstream end

243.2mm Iris #18
Upside iris of last regular cell

252.2mm Iris #19
Down side iris of last regular cell

261.3mm
Last regular cell iris #20
Optical inspection result and future

• No significant variation was observed
  – Comparing input to output but

• Need to inspect with better resolution
  – Change to straight bore scope?
  – Adjust focal plane?
  – Should be improved
T18_Disk_##2 after high gradient test

tentative conclusion

• RF evaluated after high gradient test.
  – Input matching was kept.
  – Output matching changed by $\Gamma=0.05$ level.
  – Average frequency increased by 1.1MHz.
  – Field ripple $\pm 4.4\%$ near output end.

• Some change in RF performance was observed.
  – Need to compare carefully with SLAC data.
Summary and next plan

• **Quad**
  – Similar performance as quads tested at SLAC
  – More test in a few weeks
  – Inspection and think about the further test

• **T18**
  – Measurable change was observed
  – We need to remind this

• **Next plan**
  – TD18 is top priority
  – Then T24_Disk, TD24_Disk before CDR
  – followed by T18_Disk#4, ……
Nextef Configuration

KT-1
X-band

KT-2
C-band

Nextef X-band
Conclusion

• Nextef will run fully dedicated for the feasibility study of CLIC 100MV/m

• Nextef will boost peak power and high power stability by introducing pulse compression system

• We try to construct a test area in addition to Nextef for key studies