

Trad sample # 1306

27.10.2009

Irradiations.

- Module installed in the box inside T7 at 14<sup>10</sup>
- HV works as in the lab.
- Temperature reading is working  $\rightarrow 22^{\circ}\text{C}$
- LV is working except ~~inter~~ cross link between  $V_{cc}$  &  $V_{DD}$  ??

$V_{cc}$   $\nearrow$  also ramp  $V_{DD}$  to almost the same value.

- 3V3 is working if 5V is applied at the power supply.
- 16<sup>30</sup>  $\text{N}_2$  (nitrogen) supply flowed in the box.
- 17<sup>30</sup> HV bias Current 350  $\mu\text{A}$  @ 500V  
at 6<sup>30</sup> break down @ 250V  
Dry atmosphere helps!
- 21 T module =  $1^{\circ}\text{C}$ . Taken to 350V  
current  $\sim 50 \mu\text{A}$

Nitrogen flux decreased from 200 l/h  $\rightarrow$  60 l/h.



28.10.2009 8<sup>45</sup>

HV test current is not negative anymore and detector behaves as a diode.

-300V  $I_{det} = +47 \mu A$   $\theta = 1^\circ C$

+0.2V  $I_{det} \sim 1 \mu A$

g<sup>10</sup>

$V_{DD}$  set 2.3V Supply current 1.4 A  
 $V_{CC}$  set 2.1V Supply 2.03 A  
No clock

Temperature increase from  $-1^\circ C \rightarrow 10-11^\circ C$ .

stable temperature hybrid 1  $\sim 9.7^\circ C$ .

hybrid 4  $\sim 11.0^\circ C$ .

$I_{det}(@ -300V) = 85 \mu A$

g<sup>30</sup> stable condition

decide to clock the hybrids.

set 3.3V 4.8V on

$I_{DD}$  increased from 1.4 to 2.1 A.

$I_{CC}$  stable at 2 A.

$V_{DD} \downarrow 2.3V \text{ at } 1.7V$

$V_{CC} \downarrow 2.1V \rightarrow 1.9V$

Increase  $V_{DD}$  and  $V_{CC}$

$V_{DD}$  set again at 2.3V  $I_{DD} = 3.3 A$

$V_{CC}$  set again at 2.1V  $I_{CC} = 2.03 A$

stable temperature condition.  $15-17^\circ C$  on hybrid.

$V_{DD}$  at supply = 5.2V  $I_{DD} = 3.4 A$

$V_{CC}$  at supply = 4.3V  $I_{DD} = 2.06 A$

HV supply 300V  $I_{det} = 128 \mu A$

estimated silicon temperature  $\sim 10-11^\circ C$ .

g<sup>45</sup> temperature entire

Silicon HV start to discharge at 420V

increased Nitrogen flow to 110 l/h

g<sup>55</sup> Temperature seems stable hybrid 1  $T_1 \sim 16^\circ C$ .

hybrid 4  $T_4 \sim 18^\circ C$ .



10<sup>20</sup> current discharge at 450V and N<sub>2</sub> flow at 110 l/h  
came back at 300V.

10<sup>45</sup> stopped all supply for investigation of  
cooling.

10<sup>55</sup> Now chiller set at -10°C.

N<sub>2</sub> flow set at 140 l/h.

11<sup>05</sup> hybrid temp at -10°C.

Temperature set at -9°C  $I_{det} = 20 \mu A$   
at -500V

at 600V  $I_{det} = 20 \mu A$   
610V  $I_{det} \sim 1 \mu A$   
discharge

Backplane contact problem suspected!

11<sup>45</sup> Voltages set  
 $V_{DD} = 2.3 V$   
 $V_{CC} = 2.1 V$   
 $V_{AOC} = 3.3 V$ .

Temperatures on hybrids: hybrid 4  $T_4 = 7^\circ C$   
hybrid 1  $T_1 = 5^\circ C$ .

17<sup>05</sup> still stable conditions

- chiller -10°C Pressure 3.6 bars.

Nitrogen flow @ 125 l/h.

$V_{det} = 300V$   $I_{det} = 47 \mu A$  → detector temp  $\sim 1^\circ C$

$V_{det} = 500V$   $I_{det} = 53 \mu A$

at 600V start to discharge!

hyb1 temp = 5.5°C.  
hyb4 temp = 7.5°C. } Average 6.5°C.

$\Delta T = T_{hyb} - T_{det} \sim 6.0^\circ C$

17<sup>15</sup> Power set OFF.

hybrid temp  $\sim -9^\circ C$ .

17<sup>35</sup> Set chiller temperature control at -12°C.  
Monitoring program restarted.



29.10 9<sup>00</sup> Identified a slope (positive) with the temperature.

In fact the motor pump is not well insulated and freezes!

9<sup>15</sup> Stop the cooling and the fan!  
Wait for few hours to redo the insulation...

9<sup>31</sup> Beau started in T7

9<sup>20</sup>  $1.3 \times 10^{14}$  p/cm<sup>2</sup> cumulated on target.  
Maurice estimates that the detector got  $1 \times 10^{13}$ .

Current HV = 500 V  $I_{det} = 36 \mu A$   
plateau.

Chiller @ -5°C.

Hyb temp = -4°C.

30.10 7<sup>45</sup> EEPC went OFF?

Cooling is working fine.

EEPC restarted...

hybrid temp = -4°C.

Det Current @ 500 V = 1050 nA.

Damage factor  $\approx 5 \cdot 10^{-17}$  A/cm<sup>2</sup>  $\times 0.03 \times 1.5 \cdot 10^{-16}$  A/cm<sup>2</sup>  $\xrightarrow{\alpha \cdot V =}$

$$I = \alpha I_0 \phi @ 20^\circ C$$

$\rightarrow 1.5 \cdot 10^{12}$  p/cm<sup>2</sup>/jour

Gianluigi  $\rightarrow$  mention de voir quelque chose

| 9 <sup>40</sup> |                            | at supply | I     |
|-----------------|----------------------------|-----------|-------|
|                 |                            |           |       |
|                 | V <sub>DD</sub> = 2.3 V    | 5.2 V     | 3.5 A |
|                 | V <sub>CC</sub> = 2.1 V    | 4.2 V     | 2.0 A |
|                 | V <sub>clock</sub> = 2.3 V | 4.8 V     | 0.2 A |

Temperature  $hyb4 = 12.8^\circ C$   
 $hyb1 = 10.8^\circ C$ .

V<sub>det</sub> = 500 V  $I_{det} = 3.04 \mu A$   $T_{det} \approx 5^\circ C$



9<sup>45</sup> stopped voltages.

9<sup>50</sup> Temp = -4°C

V<sub>det</sub> = -500V I<sub>det</sub> = 1035 uA

10<sup>00</sup> Cooling fixed - glycol changed to -35°C.

- It was freezing at -10-12°C
- leak in the pressure gauge  
fixed

10<sup>50</sup> stable hybrid temp [-10.5°C] - radioactive glycol in recirculating bin

V<sub>det</sub> = 500V I<sub>det</sub> = 0.586 uA  
set V<sub>det</sub> for inward at 100V  
I<sub>det</sub> = 0.37 uA.

|                     |     | V <sub>supply</sub> | I(A). |
|---------------------|-----|---------------------|-------|
| V <sub>dd</sub> set | 2.3 | 5.2                 | 3.4   |
| V <sub>cc</sub>     | 2.1 | 4.2                 | 2.03  |
| V <sub>clock</sub>  | 3.3 | 4.8                 | 0.2   |

N<sub>2</sub> flow = 120 l/h  
chiller set @ -12°C

17<sup>00</sup>

hyb 1 ~ 3.8°C

hyb 2 ~ 5.7°C

I<sub>det</sub> (@100V) = 1.07 uA

20<sup>00</sup> Pressure 6.5 bar set to -5°C

31.10.09

9<sup>31</sup> Press 5.5 bar set to -12°C I<sub>det</sub> 3.05 uA  
hyb 1 9.2°C  
hyb 2 11.0°C

9<sup>50</sup>

P = 6.5 bar  
T<sub>ch</sub> -12°C

1) 3.7°C 2) 5.6°C  
I<sub>det</sub> 1.635 uA

12<sup>30</sup>

P = 6.6

Liquid level 3 l

17<sup>55</sup> Lawrence is finding the beam to center  
the box on the detector.

- Chiller Temp = -12°C.

Pressure = 6.5 bar.

hybrid temp = 3°C.

temp 2 = 5°C.

|                           | I <sub>current</sub> |
|---------------------------|----------------------|
| V <sub>dd</sub> = 2.2V    | 3.3A                 |
| V <sub>cc</sub> = 2.0V    | 2.0A                 |
| V <sub>clock</sub> = 3.3V | 0.2A                 |



$$I_{det} @ -100V = 38.6 \mu A$$

Scan 125-225 / 6um

start of irradiation @ 18<sup>00</sup> 31.10.2009

1. to 2 spill / srs cycle.

18h32 Start Scan SEC<sub>1</sub> = 0

Set 1306

AP 2171 Front 8x96

AP 2172 Back 8x96

AP 2173 Center 100x100

01.11.2009 10<sup>28</sup>

$$I_{det} @ 100V = 0.274 \text{ mA}$$

Table blocked in position 146 all night

stopped software

and restarted it at 10<sup>29</sup>.

$$SEC_1 = 25455590.$$

$$2.544 \cdot 10^7$$

Logbook blocked at 19<sup>28</sup>

$$V_{DD}, V_{CC}, V_{clock} \text{ ok} \rightarrow \begin{cases} I_{at \text{ supply}} \\ I_{DD} = 3.4 A \\ I_{CC} = 1.95 A \\ I_{clock} = 0.2 A \end{cases}$$

$$T_{hgb1} = 2.8^\circ C$$

$$T_{hgb4} = 4.8^\circ C$$

$$I_{100}^{\circ} I_{det} @ 100V = 0.293 \text{ mA}$$

N<sub>2</sub> flow ok 125 l/h

Chiller ok P = 6.5 bar.

$$T = -12^\circ C$$

13<sup>00</sup>

$$T_{hgb} 2.8^\circ C - 4.7^\circ C$$

Scan 146=30

OK Saved logbook

→ logbook run Set 1306

P = 6.5 bar

T = -12.2°C

V<sub>2</sub> = 125 l/h

I<sub>det</sub> 0.1370 mA

SEC: 2,996 · 10<sup>7</sup>

$$18^{55} T_{hgb} 2.8^\circ C - 4.8^\circ C \text{ stable}$$

$$V_{DD} = 2.1 V \quad I_{DD} = 3.5 A$$

$$V_{CC} = 2.0 V \quad I_{CC} = 1.92 A$$

$$V_{clock} = 3.3 V \quad I_{clock} = 0.2 A$$



Set  $V_{DD}$  at 2.3V      5.6V at supply  
 $V_{CC}$  at 2.1V      4.3V at supply.

$$I_{dt} @ 100V = 0.491 \text{ mA}$$

$$SEC = 3.860 \cdot 10^7$$

$$I_{DD} \text{ at supply} = 3.8 \text{ A}$$

$$I_{CC} \text{ at supply} = 1.93 \text{ A}$$

$$I_{clock} \text{ at supply} = 0.2 \text{ A}$$

Hyb Temp 4.5 - 6.5°C.  
 increased since power increased.

Set  $V_{DD}$  at 2.2V      5.5V at supply  
 $V_{CC}$  at 2.1V      4.3V at supply.

$N_2$  flow ok  
 chiller ok

2.11.2009

$$I_{dt} @ 100V = 0.714 \text{ mA}$$

$V_{DD}, V_{CC}$ , current ok.

$$SEC = 5.985 \cdot 10^7$$

$N_2$  flow ok  
 chiller ok

hybrids temp 4 - 6.2°C.

$\phi$  estimated at  $\sim 3.7 \cdot 10^{13} \text{ m}^2/\text{cm}^2$

$$I_{DD} SEC = 6.512 \pm 7 \quad 4^\circ\text{C} - 6.5^\circ\text{C}$$

$$I = 763 \text{ pA}$$

$$T_c = 6.5 \text{ bar } -12^\circ\text{C}$$

$N_2$  All ok

$$I_{dt} @ -100V = 0.800 \text{ mA}$$

$$SEC @ 15^\circ\text{C} = 7.118 \cdot 10^7$$



18<sup>40</sup> All OK

$I_{det} @ -100V = 0.854 A$

$SEC = 7.659 \cdot 10^7$

3/11

8h24 Beam OFF

11<sup>01</sup>

Stop Scan

chiller  $-12^\circ C$

idct  $1.03 mA$

6.5 hours

$-6.4^\circ C$   $-4^\circ C$

$SEC = 1.03 \cdot 10^8$

4.11  $I_{det} @ -100V = 1.1 mA$

7<sup>30</sup>

$V_{DD} = 5.5$  at supply  $I_{DD} = 3.9$

$V_{CC} = 4.8$

$I_{CC} = 1.85$

$I_{CC} \searrow$   $I_{DD} \nearrow$

stop LV and HV

hybrid temp  $\sim -10.5^\circ C$  to  $-11^\circ C$ .

$I_{det} @ 100V = 0.346 mA$ .

12-11-09

$1 SEC = 1.264 \times 10^7 \text{ protons/cm}^2$

- 125 - 225 step 6mm  $\Rightarrow$  3/11/09 8h24

$225-125 = 100/6 = 16.66 \text{ steps/scan}$

$\frac{SEC * Factor(sec)}{(steps/scan)} = \text{fluence in protons/cm}^2 \text{ scan time}$   
to (electron)

$\left[ \begin{array}{l} I \text{ vs } \Phi \\ \Phi \text{ vs time} \end{array} \right] (Temp.)$

5.11. 9<sup>20</sup>

start LV for instact of ingel.  
at supply

9<sup>45</sup>

$V_{DD} = 2.2V$

5.4V

3.6A

$V_{CC} = 2.1V$

4.2V

1.85A

$V_{clock} = 3.3V$

4.8V

0.2A.

Temperature very noisy when table inside PR  
under test for software development!



10<sup>35</sup> Problem with  $V_{cc}=2.2V$   $I_{cc}$  was 1.8 A !

| New settings      | at supply | before<br>now at 1.06 A ! |
|-------------------|-----------|---------------------------|
| $V_{cc} = 2.2$    | 5.5 V     | 4.1 A                     |
| $V_{dd} = 2.2$    | 3.7 V     | 1.06 A                    |
| $V_{clock} = 3.3$ | 4.8 V     | 0.2 A                     |

Temp  $\sim 3-5^{\circ}C$ .

$I_{det} @ -100V = 1.02 \mu A$ .

12h34 Start IRRAD7 Scan

Idle 0,9907 mA @ 100 V  
 Chiller  $-12^{\circ}C$  @ 6,5 bar  
 Temp  $3^{\circ}C$   $-5^{\circ}C$

17<sup>00</sup> changed HV supply from K6517A  
 to K2410

19<sup>50</sup> Temp on hybrid  $2-4^{\circ}C$ .

$I_{det} @ 100V = 0.959 \mu A$

22h30 check Beceen

0h15 impossible de trouver de freon (can)

Scan  $\pm 25$  mm en y !!

quelque chose a dû se passer !  
 peut-être le bruit sur la sonde de  
 température est une source d'info !!

1h05 Contrôlé la boîte avec la caméra 0

6.11.2009 Movement x y de la table OK

7<sup>20</sup> all ok except box not connected to PC.

8<sup>00</sup> Reconnected the Serial cable to FEPC.

Driver was not found!

Reinstalled Serial USB driver!

Restarted the scan!

8<sup>05</sup> stopped scan

→ Reference.

8<sup>08</sup> → Restarted the scan.

Leakage current increase to  $\sim 1 \mu A$  when there  
 is the beam! Seems OK...



8<sup>10</sup>

Now  $I_{det}$  @ 100V = 0.943 mA

10<sup>20</sup> Table OFF

Maurice decided to move to original position 211 mm.

Table was at 253 mm.

So decided to move to optimize original position.

( stopped all for now! )

14<sup>35</sup> Start Scan Previous new pos. for test

$I_{det}$  0.9758 mA

16<sup>10</sup> Table seems to be inside the beam in Y! where beam  $I \nearrow 5$  mA.

$I_{det}$  = 0.982 mA.

Pin diode @ 10  $\mu$ A 1.1V.

scan at 150 mm  $I \nearrow 1$  mA.  
to 125 mm  $I \sim$  the same.

table at 177 mm  $I \nearrow 3$  mA.

187 mm  $I \nearrow 5$  mA.

225 mm  $I \nearrow 5.2$  mA.

set table at 275 mm  $I \nearrow 5$  mA.

280 mm  $I \nearrow 1$  mA.

Found that box and detector in slot

[ 175 - 275 mm ]

16<sup>45</sup> Scan started in that range.

17<sup>30</sup>  $I_{det}$  @ 100V = 1.000 mA.

All ok so far leave for the weekend!

7.11.2009

18<sup>20</sup>

$I_{det}$  @ 100V = 1.273 mA.



Temperature  $2.6 \text{ at } 5^\circ\text{C}$

when beam ON  $I \uparrow \sim 3.6 \text{ mA}$  <sup>mt</sup>  $\sim 180$   
or table at 284

$I_{cc} \uparrow$  to  $1.57 \text{ A}$   $V_{cc} = 1.8$

Increased  $V_{cc}$  to  $2.1 \text{ V}$  or  $4.1 \text{ V}$  on supply.

$I_{cc} = 1.63$

$V_{dd} = 2.1 \text{ V}$  at supply  $I_{dd} = 4 \text{ A}$   
 $V_{dd} = 5.5 \text{ V}$

SEC = 5.562 E7

9.11.2009

7<sup>35</sup> Noticed that I received  $T_{\text{beam}}$  in the right.  
When arrived temperatures was OK.

Temperature  $2.9 \text{ at } 5.8^\circ\text{C}$ .

$I_{\text{det}} @ 100 \text{ V} = 2.064 \text{ mA}$ !

Near  $T_2$  can be as high as  $8^\circ\text{C}$ !

set Alarm at  $9^\circ\text{C}$ .

9<sup>45</sup> SEC 1.566 E8.

13<sup>30</sup> Decide to swap the DCS Temp with  
filtered capacitors.  $2.2 \mu\text{F}$ .

Now temperature stable at  $\sim \pm 0.2^\circ\text{C}$ .  
compared to  $\pm 10^\circ\text{C}$  before.

Power cycle done to test the temp

Now  $I_{cc}$  at  $1.12 \text{ A}$  instead of  $1.8 \text{ A}$ .

$\Rightarrow$  Temperature from  $2.7 \text{ K}$  by  
 $4.7 \text{ K}$  by 1.  
( $1^\circ\text{C}$  less than before).

$I_{\text{det}} @ 100 \text{ V} = 1.825$

19<sup>25</sup>

$I_{\text{det}} @ 100 \text{ V} = 1.77 \text{ mA}$

10.11.2009 Beam profile in x is bad.

$I_{\text{det}} \uparrow 2 \text{ mA}$  when there is the beam



$I_{det} = 1.300 \text{ mA}$

Appel de la salle de controle.

$SEC = 1.786 \text{ E}^8$

Temp  $2.8 - 4.7^\circ\text{C}$ .

$V_{cc}$  ramped-up since it was at  $2.0\text{V}$

→ temp increased:  $5.3 - 5.2^\circ\text{C}$ .

Beam profile is sharper but silicon does not see the beam.

11<sup>05</sup>  $I_{det} = 0.596 \text{ mA}$  at  $100\text{V}$  !!!

Don't understand the current values.

Temperature increased by  $1.2^\circ\text{C}$ .

but  $I_{cc}$  increased at  $4.2 \text{ A}$ .

$I_{det}$  now at  $1.6 \text{ mA}$ . after playing with HV and set  $I$  to plateau.

18<sup>00</sup>  $I_{det} \sim 1.1 \text{ mA}$  no beam

Boost injection distrib. problem.

stopped LV meanwhile and check IV at plateau.

Temperature on hybrids & silicon  $-10.5^\circ\text{C}$ .

$I_{det} = 0.69 \text{ mA}$  at  $100\text{V}$

0.74 110V

0.79 120V

0.84 130

0.89 140

0.92 150

160

170

180

190

200

← limited by the power supply.

Set LV up again.

11.11.2009

7<sup>20</sup>  $I_{det} \sim 0.538 \text{ mA}$

Detector I does not react with beam.

No explanation!

Box is moving and is like at position the other days!



18<sup>15</sup>  $I_{det}$  was very low

Now moved to Keithley 2410 from Nanivc.

Not a good backplane contact understood.

12.11

7<sup>45</sup> Noticed that Det current lost again!

set HV at 150V ~~and~~

$I_{det} = 4.2 \text{ nA}$ .

Temp 3.8 - 5.8.

SEC = 2.7 ES

17 h29  $I_{det}$  50  $\mu\text{A}$ !

Put Bias  $\rightarrow 200\text{V} \rightarrow 150\text{V} \Rightarrow I_{det}$  3.8 nA

T = 3.9 - 5.8°C

18<sup>30</sup>  $I_{det}$  50 nA put bias 200V  $\downarrow$

$I_{det} = 3.6 \text{ nA}$ .

SEC = 2.941 ES

$I_{det}$  did not hold at 150V

set V @ 220V where I look stable @ 5.2 nA

13.11.09

7<sup>40</sup>  $I_{det} \sim 10 \text{ nA}$  still contact problem at 220V.

Decided to leave the HV at 100V!

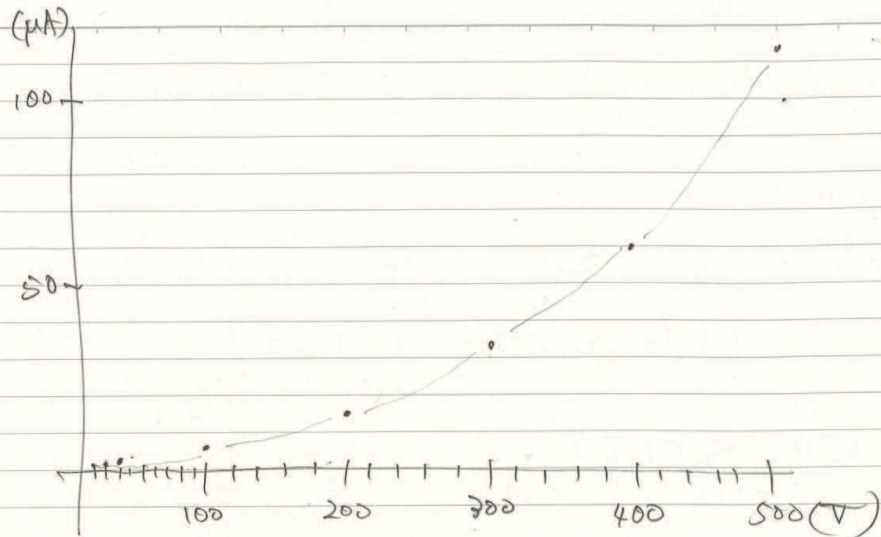
SEC = 3.21 ES

11/13

17.50

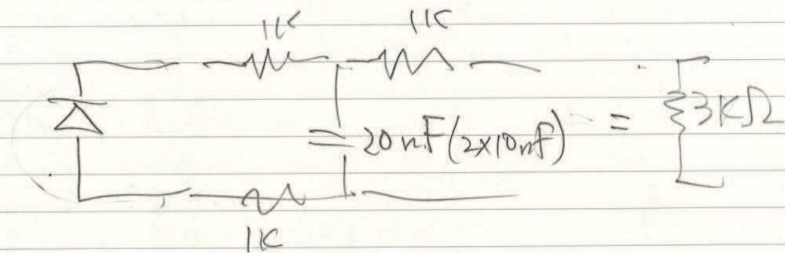
| HV  | V (V) | I (nA) | V (V) | I (nA) |
|-----|-------|--------|-------|--------|
| 10  | 0.16  | 28.5   | 280   | 28.5   |
| 20  | 0.46  | 32.3   | 300   | 32.3   |
| 30  | 0.84  | 36.5   | 320   | 36.5   |
| 40  | 1.30  | 41.2   | 340   | 41.2   |
| 50  | 1.70  | 47.6   | 360   | 47.6   |
| 60  | 2.25  | 53.2   | 380   | 53.2   |
| 70  | 2.85  | 60.0   | 400   | 60.0   |
| 80  | 3.09  | 68.9   | 420   | 68.9   |
| 90  | 4.40  | 78.6   | 440   | 78.6   |
| 100 | 5.20  | 86.9   | 460   | 86.9   |
| 120 | 6.90  | 100.0  | 480   | 100.0  |
| 140 | 8.8   | 113.0  | 500   | 113.0  |
| 160 | 11.2  |        |       |        |
| 180 | 13.6  |        |       |        |
| 200 | 16.2  |        |       |        |
| 220 | 19.0  |        |       |        |
| 240 | 22.0  |        |       |        |
| 260 | 25.7  |        |       |        |





$$R = \frac{500V}{100\mu A} = 5M\Omega$$

$$R = \frac{V}{I}$$



Forward biasing

| V (V) | I (μA) |
|-------|--------|
| 50    | 2.17   |
| 100   | 7.4    |
| 160   | 15.6   |

14.11.09

15.19

10k 3.82 μA

T: 4.2 - 6.4 °C  
Agostat - 12° 6.1 bar  
3.8888 E8

15.11

10<sup>10</sup>

$$I_{det} = 3.47 \mu A$$

$$T_m = 4 - 5.9^\circ C \quad \checkmark$$

$$SEC = 4.285 E8$$

16.11

945

$$I_{det} = 4 \mu A \text{ at } 100V$$

$$SEC = 4.787 E8$$

$$I_{det} = \begin{matrix} 50 \mu A & @ 200 V \\ 50 \mu A & @ 300 V \\ 59 \mu A & @ 400 V \\ 90 \mu A & @ 500 V \end{matrix}$$

back to 100V →  $I_{det} = 6.5 \mu A$



Temperature:  $4.1^{\circ}$   $6.4^{\circ}\text{C}$ .

17.11.09

8<sup>05</sup>

$I_{\text{det}} = 4.1 \mu\text{A}$ .

SEC = 5.229 E8.

Temp  $4.2^{\circ}\text{C}$  -  $5.8^{\circ}\text{C}$ .

18.11.09

15<sup>20</sup> BPM beam profile out

$I_{\text{det}} = 3.1 \mu\text{A}$

Temp  $\sim 4.1$  -  $6.1^{\circ}\text{C}$ .

SEC = 6.01

19.11.09

12h29 End of irradiation  $\Rightarrow$  Park position

Scans continue

SEC 6,5352 E8

20.11 7<sup>40</sup>

stopped LV on FE chips

$I_{\text{det}} = 2.36 \mu\text{A}$  @ 100V

After ramping up at 660V

$I \nearrow > 1 \text{ mA}$

Now @ 100V  $I_{\text{det}} = 0.76 \text{ mA}$ .

Temp =  $-10.7^{\circ}\text{C}$ .

23.11

14<sup>45</sup> Ramp-up temperature to get out the box tomorrow.

$I_{\text{det}}$  @ 100V = 0.63 mA  $T = -4.1^{\circ}\text{C}$ .

24.11 15<sup>15</sup> Box temperature at  $\sim 27^{\circ}\text{C}$ .