Study of radiation damaged diamonds at Zeuthen

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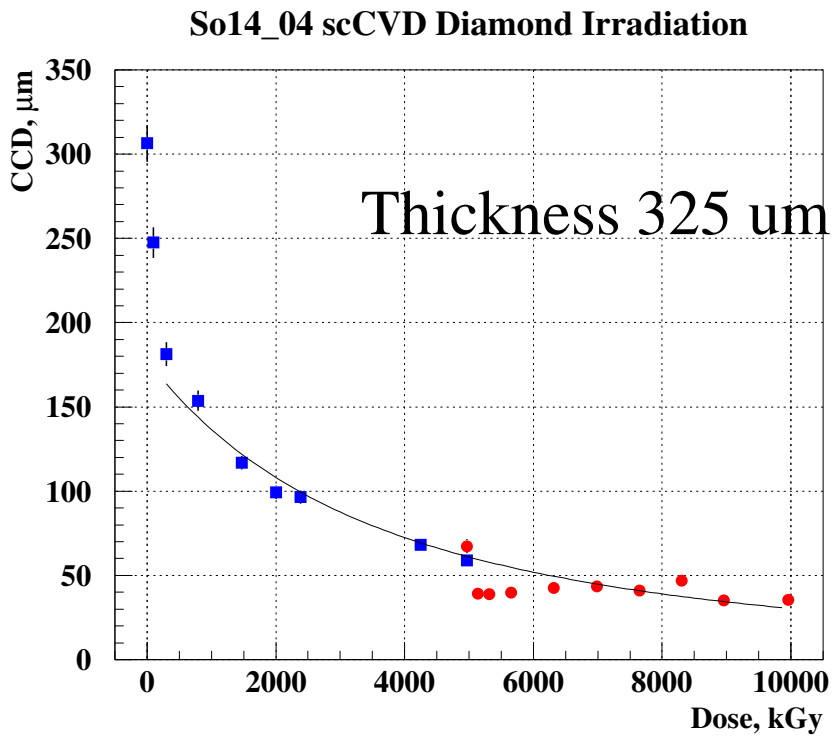
DESY, Zeuthen

Diamond detector radiation hardness

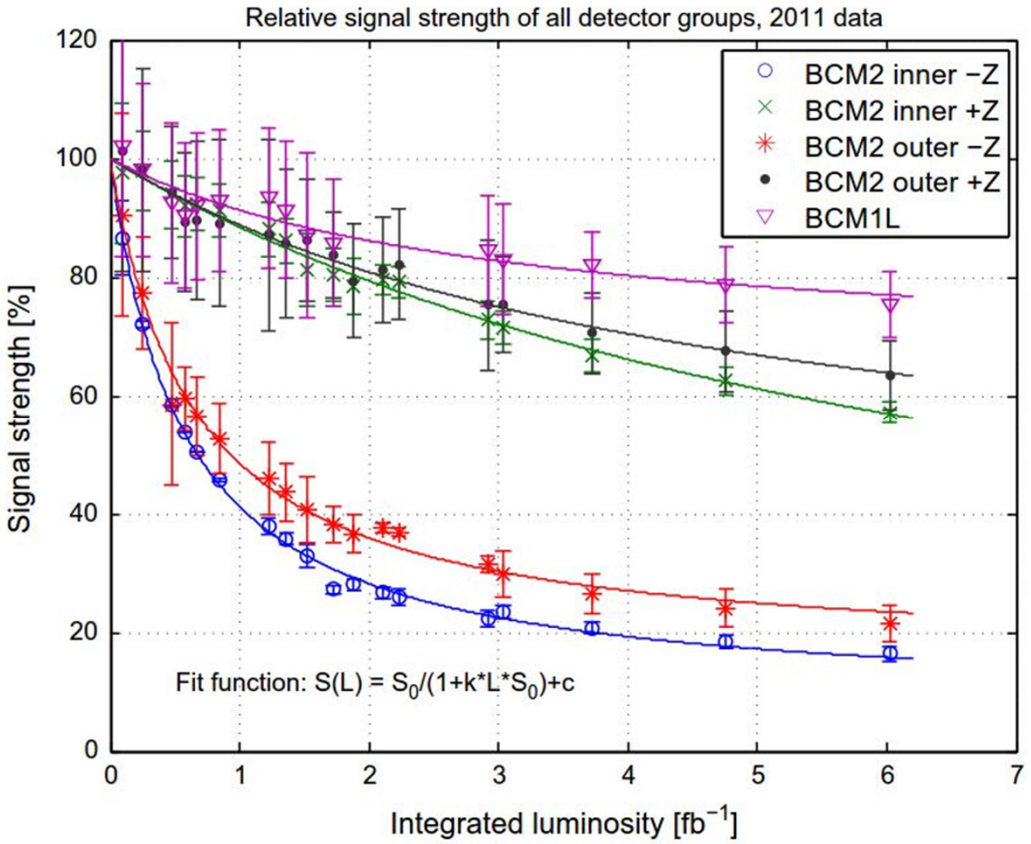
Diamond – So14-04, SC CVD by E6, irradiated to 5 MGy @ 2007
+ 5 MGy more @ 2008 => Total ~10MGy (~10^{16}) by 10MeV electrons

Charge collection efficiency goes
From 100% to ~ 10%
MIP signal still visible

10 MGy for diamond roughly
correspond to 10^{16} n/cm^{-2} for Si



Diamond detector radiation hardness



Hadron fluence (simulations)

~ 10^{13}

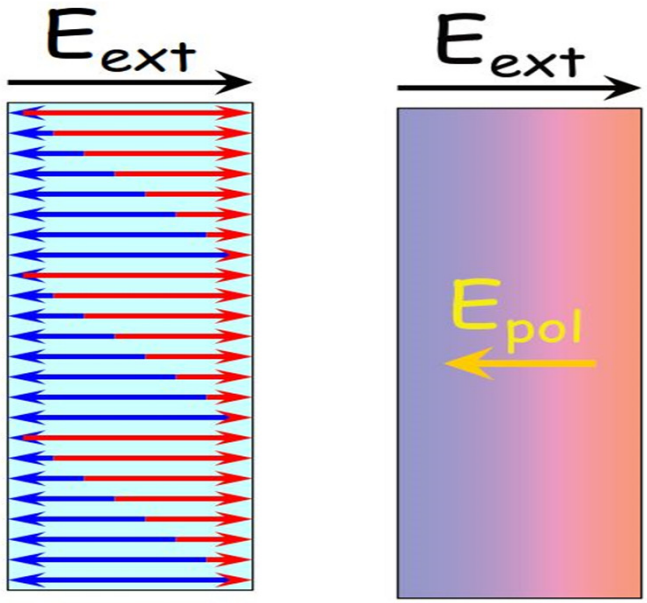
~ 10^{14}

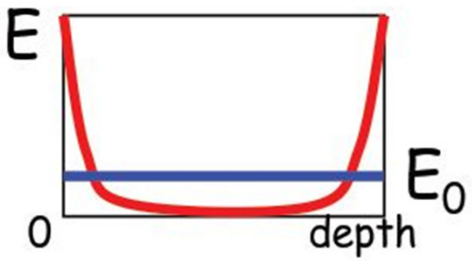
Relative (to unirradiated) signal size loss in diamond detectors in CMS luminosity monitor during 2011 run

Why CCE decreases?

Particle knocks atoms out of the crystal lattice – introduces defects
These defects act in two different ways in diamond.

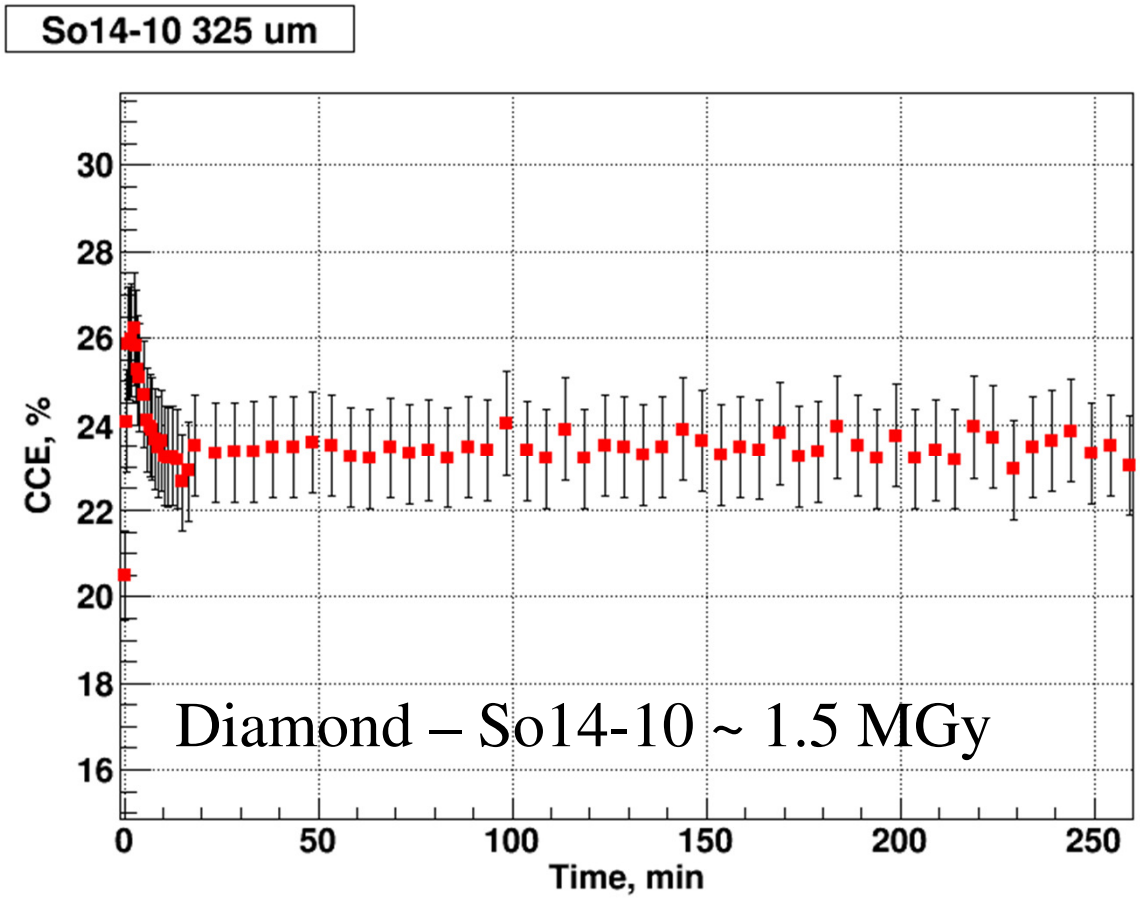
1. Act as a charge carrier traps => reduce collected charge directly.
2. Polarisation: If the charge carrier trapping is not homogeneous => spatial charge => internal field => reduction of effective collecting field => reduce collected charge.





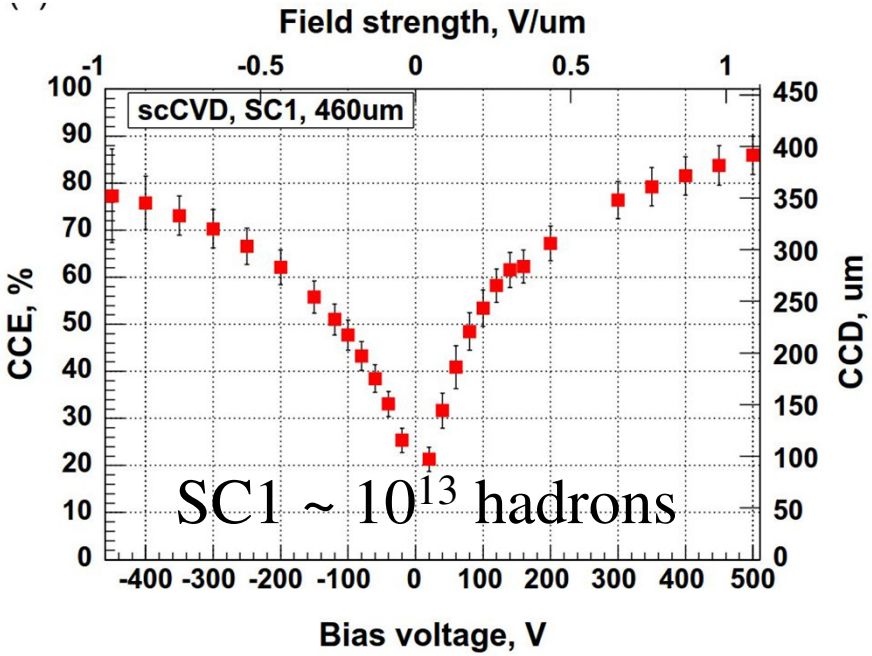
Typical CCE over time for damaged diamond

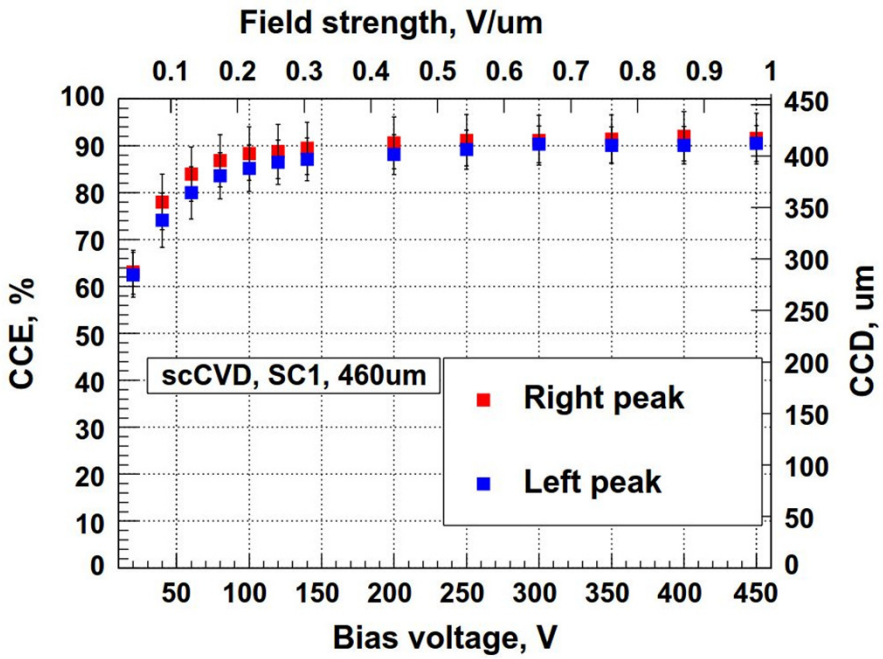
Diamond was “reset” by UV lamp for ~ 20 min before the first measurement. CCE was measured over time. @ 300V



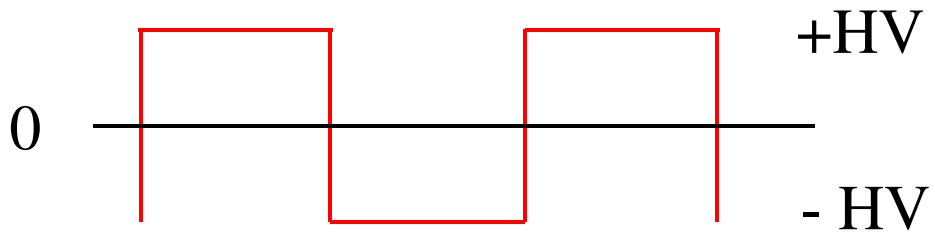
After switching on HV and source:
Fast (few minutes) increase in CCE
Relatively slow decrease in CCE over next 20-30 minutes
Stable signal

Possible solutions – switched high voltage





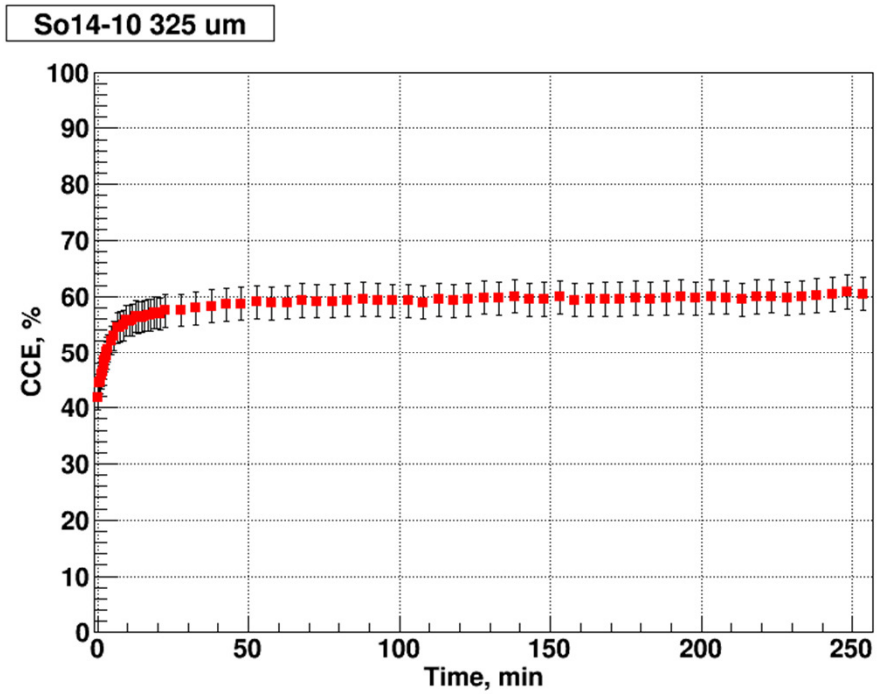
Obvious improvement

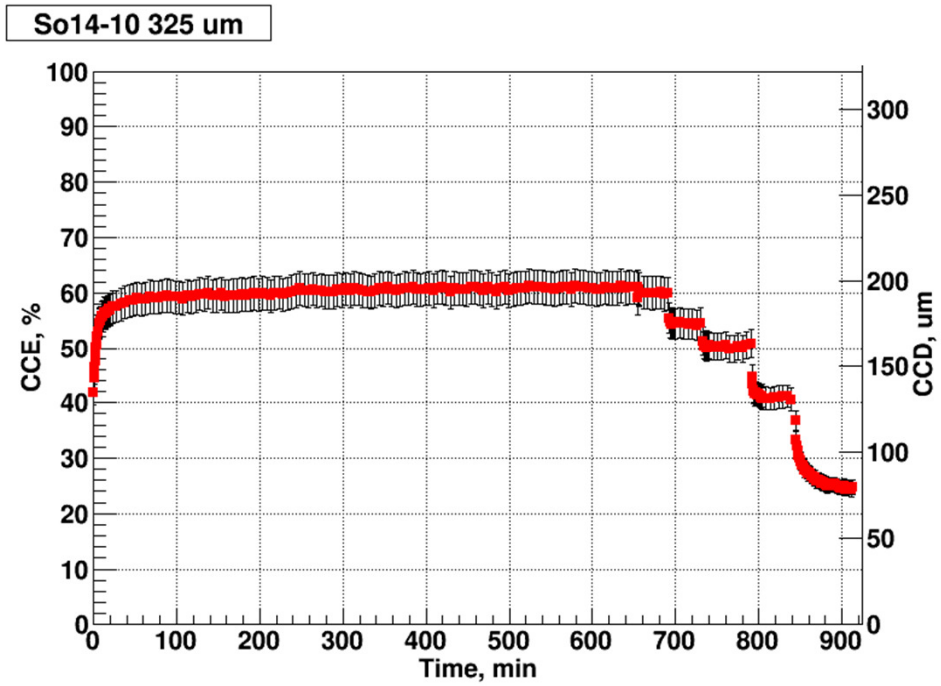


~ 0.1 – 1 Hz

Another possible solution - Illumination

Same process with illumination by red LED (635nm, 1.95eV)



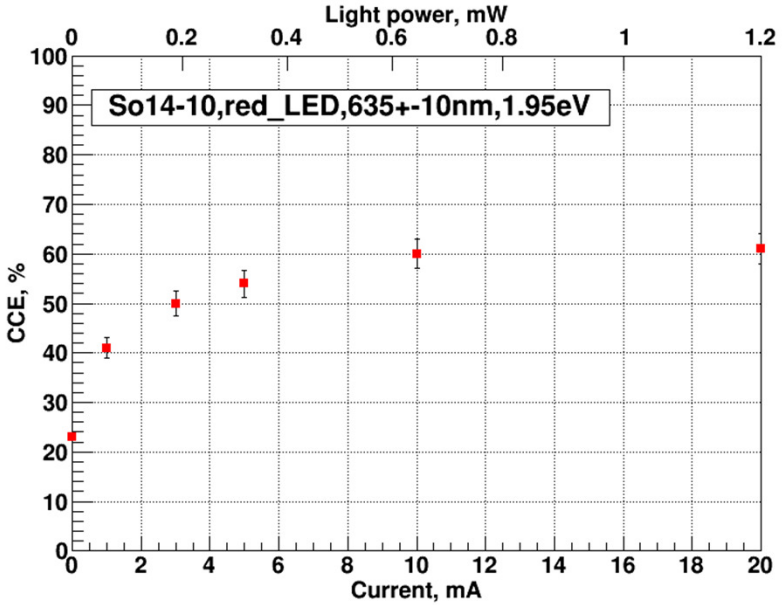


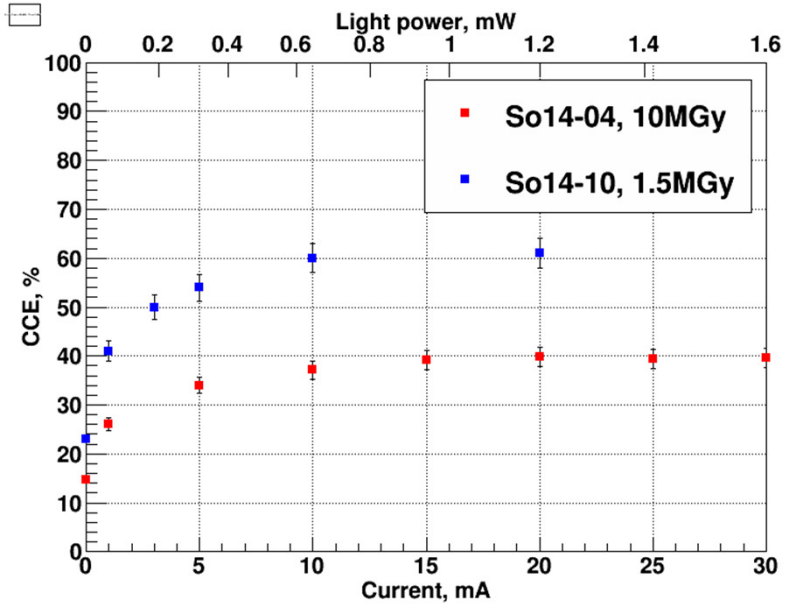
Slow (~20-30 min) increase in CCE to 60% from stable 23%

Stable effect over 10 hours

Steps are testt of different light intensities

Illumination





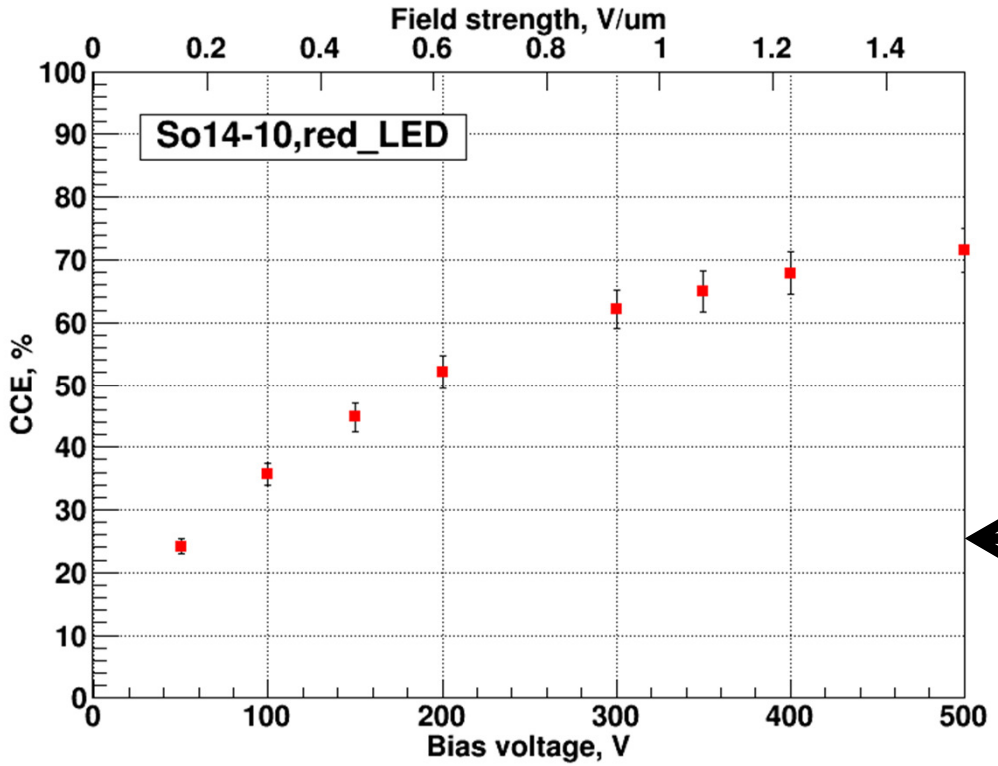
Effect depends on the intensity of light

There is a saturated value

Saturation is at similar power for two samples with order of magnitude difference in damage, i.e. does not depend on damage.

Amount of recovered CCE close to 2.5 times “stable” value for both

CCE vs HV

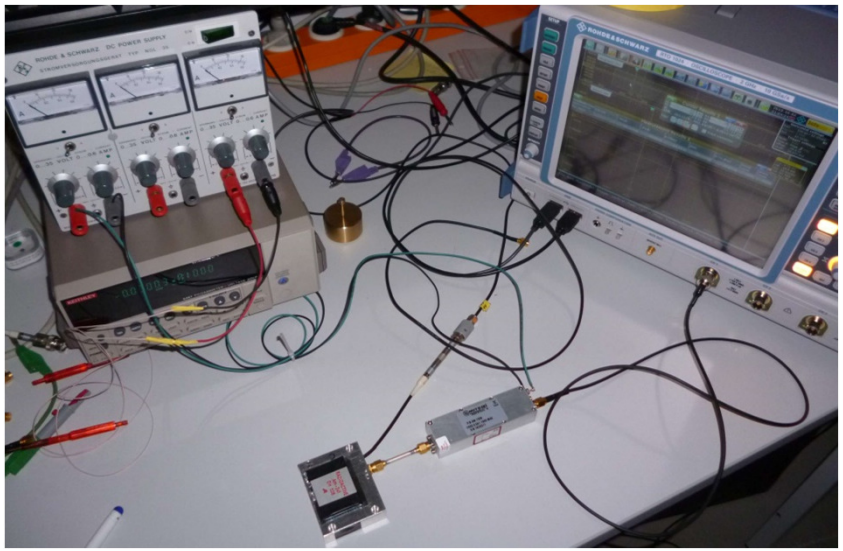


~ 25% CCE saturated without illumination

CCE vs HV still looks like it should for damaged diamond – no CCE saturation at low voltages (was ~100% @ 80V before irradiation)

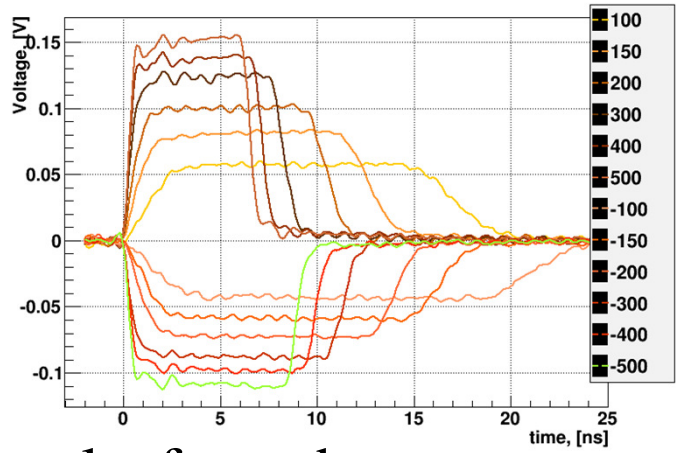
TCT

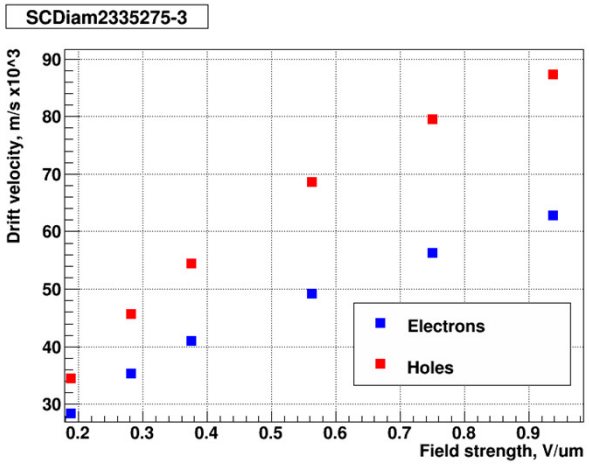
Transient Current Technique



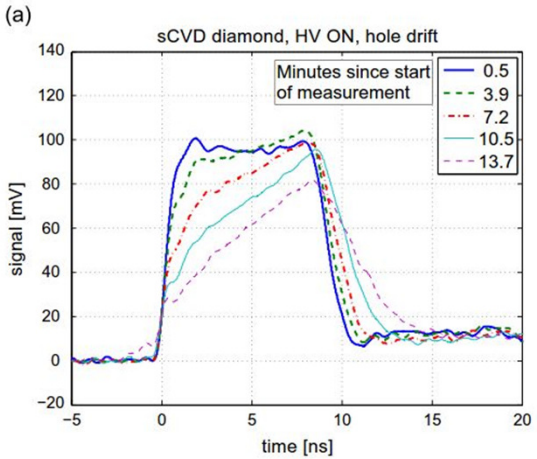
Inject a large amount of charge carriers near the surface and
Look at the transient current during charge transport in the detector
Allows to see the difference between electron and hole components
Allows to measure drift time => drift velocity => mobility
Allows to see the influence of internal field

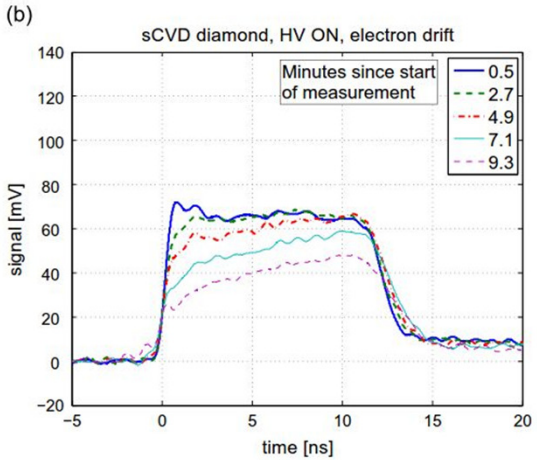
TCT





Results from the current setup – undamaged diamond





What is possible:
Onset of the polarisation field – Moritz Guthoff

Conclusion

It is possible to improve CCE of radiation damaged diamond detectors
with both alternating HV (homogeneous space charge)
and light illumination (probably preventing formation of strong the space charge).

Both methods show significant improvement in CCE.

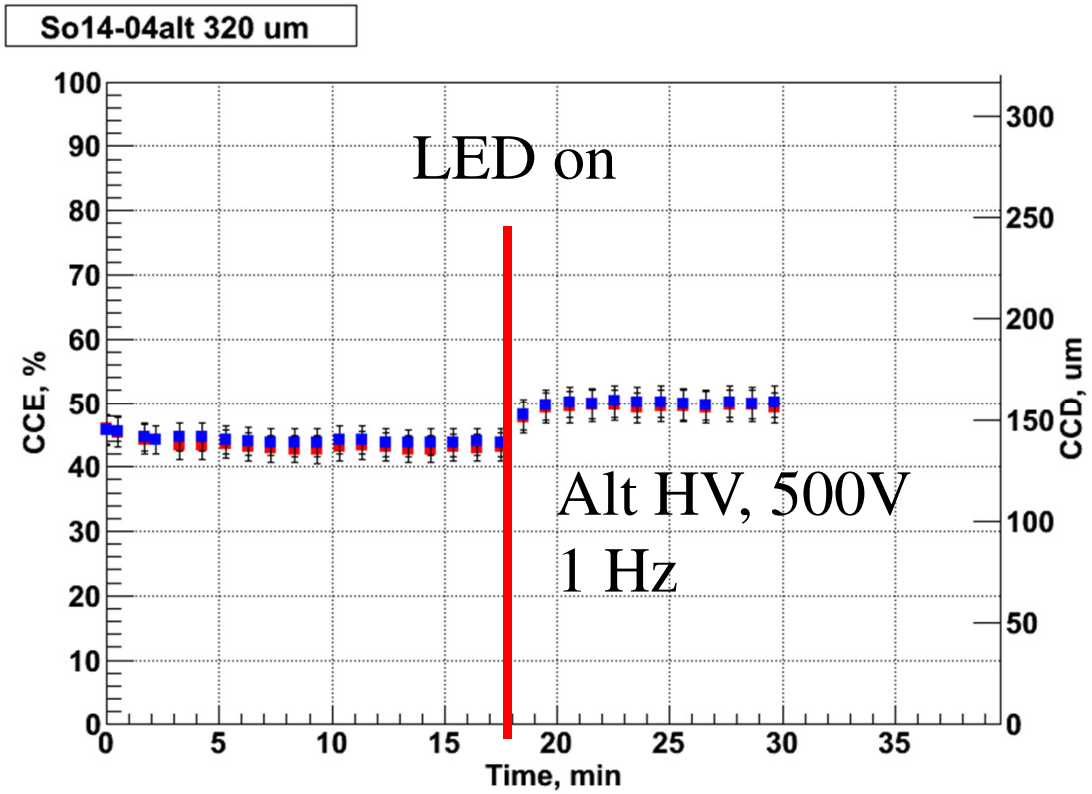
Effect of light illumination on CCE depends on light intensity and It is saturated at some light intensity. The saturation value does not depend on damage amount.
Probably will depend on intensity of charge carrier generation (radiation intensity). – going to check this right after the workshop
TCT setup functional – could be used for research

Backup

Light power

For comparison purposes only
The light power in the LED beam spot was measured by Advatec optical power meter.
I tried to keep the beam spot on diamond under study to the same size for all LEDs. No idea how much of the actual beam power was coupled to the sample.
For comparison, typical light intensity of ambient light in the lab is ~ 100-150 μW for 10x10mm light sensor.

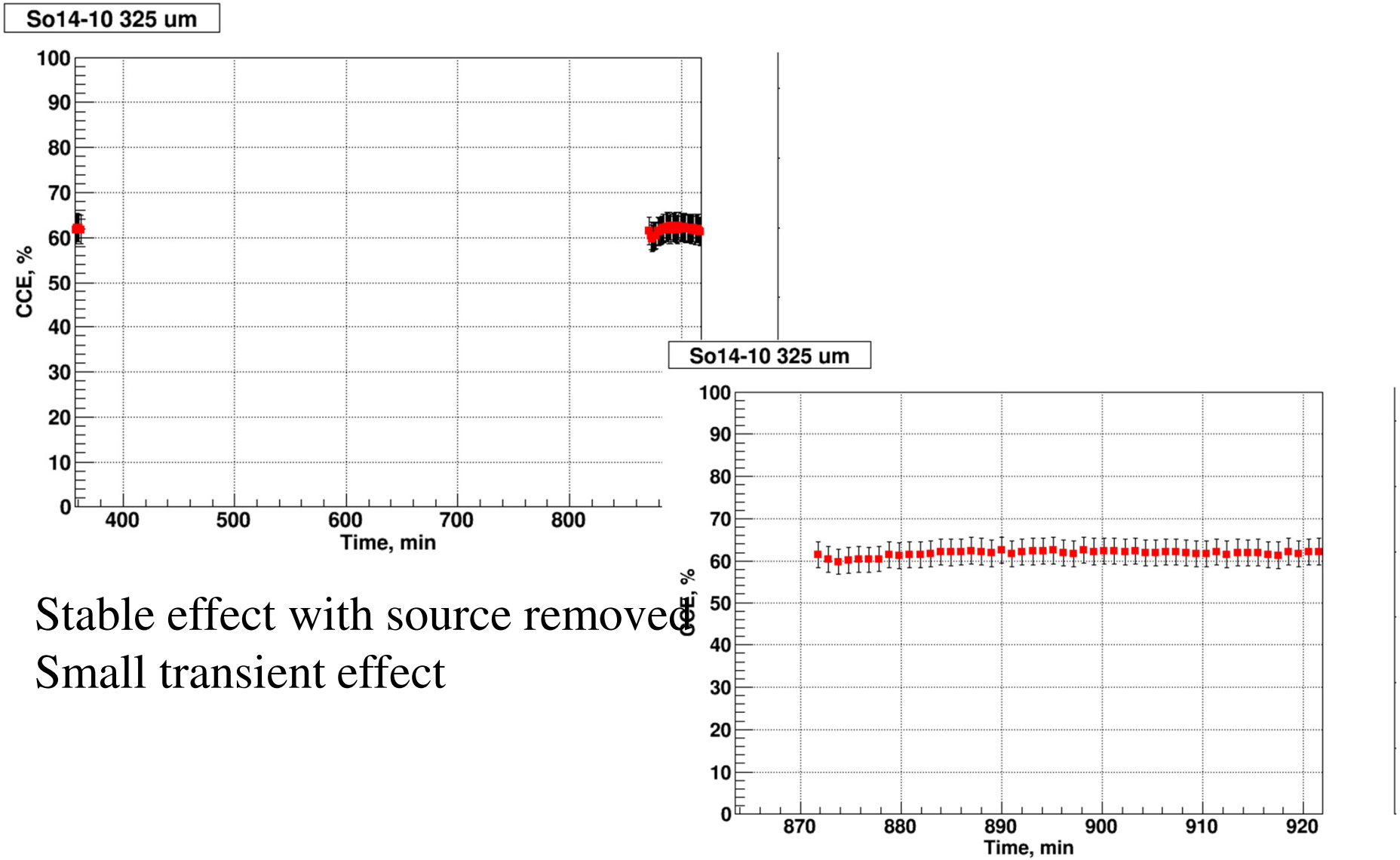
Light + alt HV



Alt. Voltage + RL is even better.

2013 fast test, not repeated so far

No source



Stable effect with source removed
Small transient effect