Dose enhancement near metal electrodes in diamond X- ray detectors

A. Lohstroh*, and D. Alamoudi

Department of Physics, University of Surrey, SEPnet, UK

Email: A.Lohstroh@surrey.ac.uk

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www.surrey.ac.uk

Talk outline

- Context of the Radiation detector development group at Surrey
- Motivation to study (X-ray induced) currents in diamond
- Monte Carlo simulations of dose enhancement applied to diamond
- Preliminary experimental data
- Future work – parameters to be studied

Department of Physics

Part of he Faculty of Engineering and Physical Sciences (FEPS)

Physics:
Approx 30 academic staff
(~ 15 in CNRP)

University of Kent,
Queen Mary University
University of Sussex
University of Hertfordshire
Open University

Southampton University,
Royal Holloway
University of Surrey
Portsmouth University
(+ University of Oxford & Reading)

Research in Physics at Surrey

- **Soft condensed matter (SCM)**
- **Advanced Technology institute (ATI) - in collaboration with electronic engineering**
- **Astrophysics (new!)**
- **Centre for nuclear and radiation physics (CNRP)**
  - Experimental & Theoretical Nuclear Physics
  - Medical and Radiation Physics
    - Medical Physics & Imaging
    - Radiation Detector development

2 academics and approx. 15 research students & staff

Diamond for continuous current read-out

(i.e. time scale > hundreds of msec)

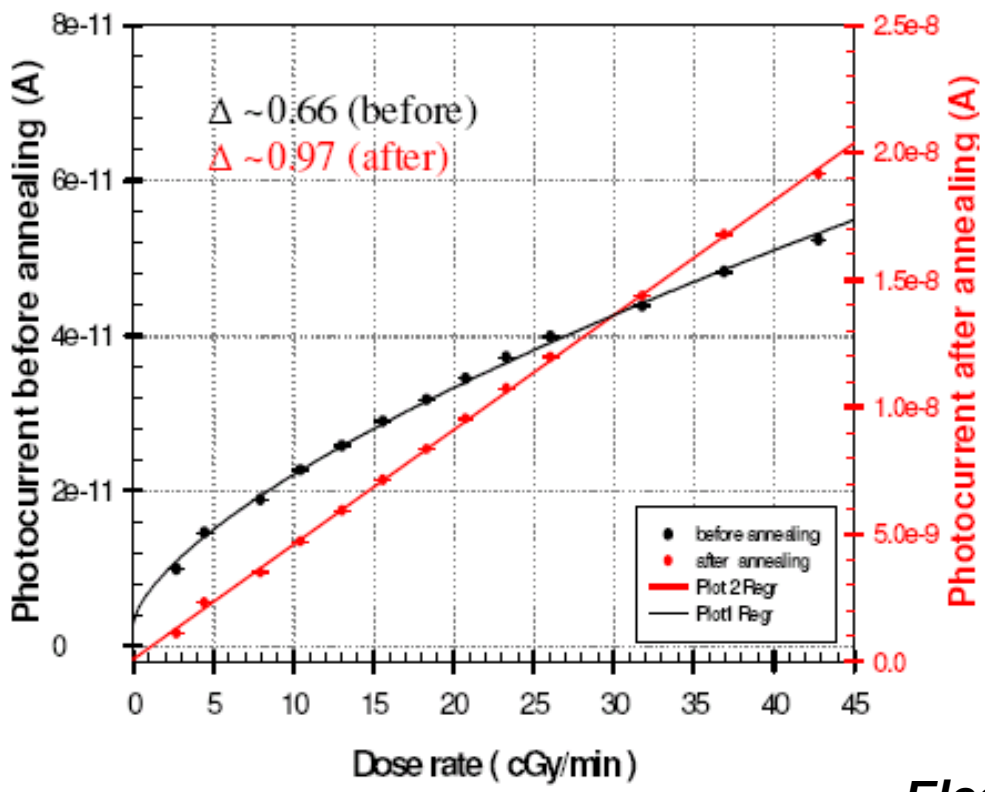
Relevant for pulse by pulse readout in terms of leakage current stability/mixed field operation

<u>Diamond suitable in:</u>

- **X-ray dosimetry**
- **UV detection**
- **High intensity ionising radiation beams**
- **Radiation hardness***
- **Neutron detection/mixed fields**
- **High intensity ionising beams**
- **High temperature detector applications**

Changes in photocurrent with electrode processing

HP-Al/Pt; (annealing at 600 C in vacuum)



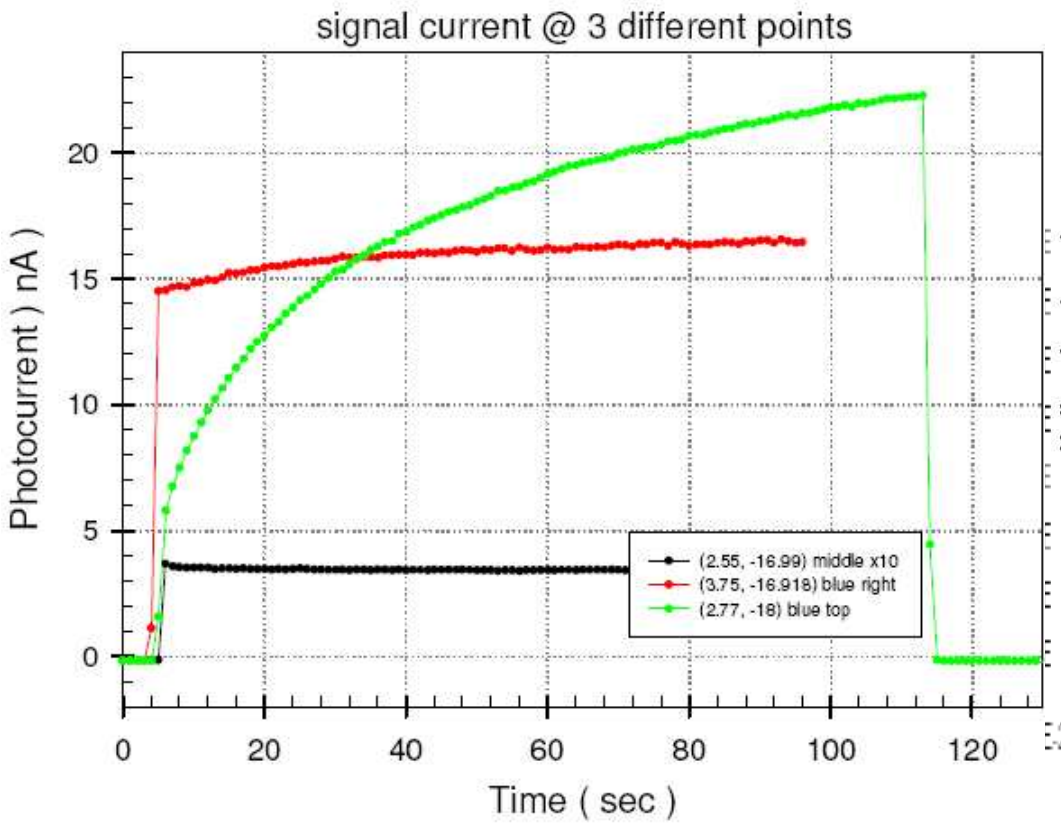
See also Gaowei et al, APL 100, 201606 (2012), who conclude

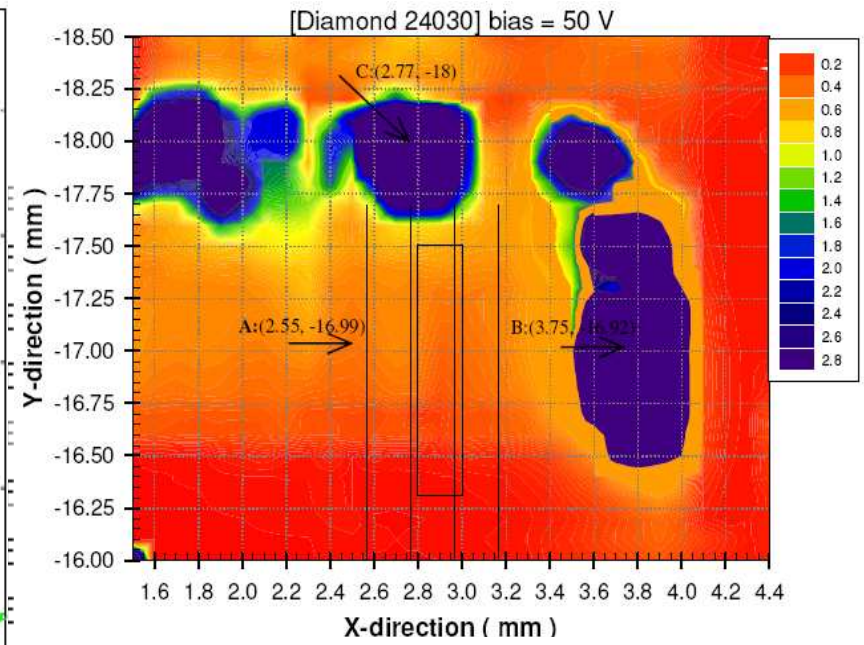
- **Barrier height reduction due to annealing (0.2 eV for Pt – thickness independent) can explain photoconductive gain and compromise oxygen termination.**

Electrode effects also observed in ToF data (DeFerme at al, Hasselt 2009)

X-ray imaging with 19/20 keV microbeam (synchrotron)

non-uniform, not electronic grade sample



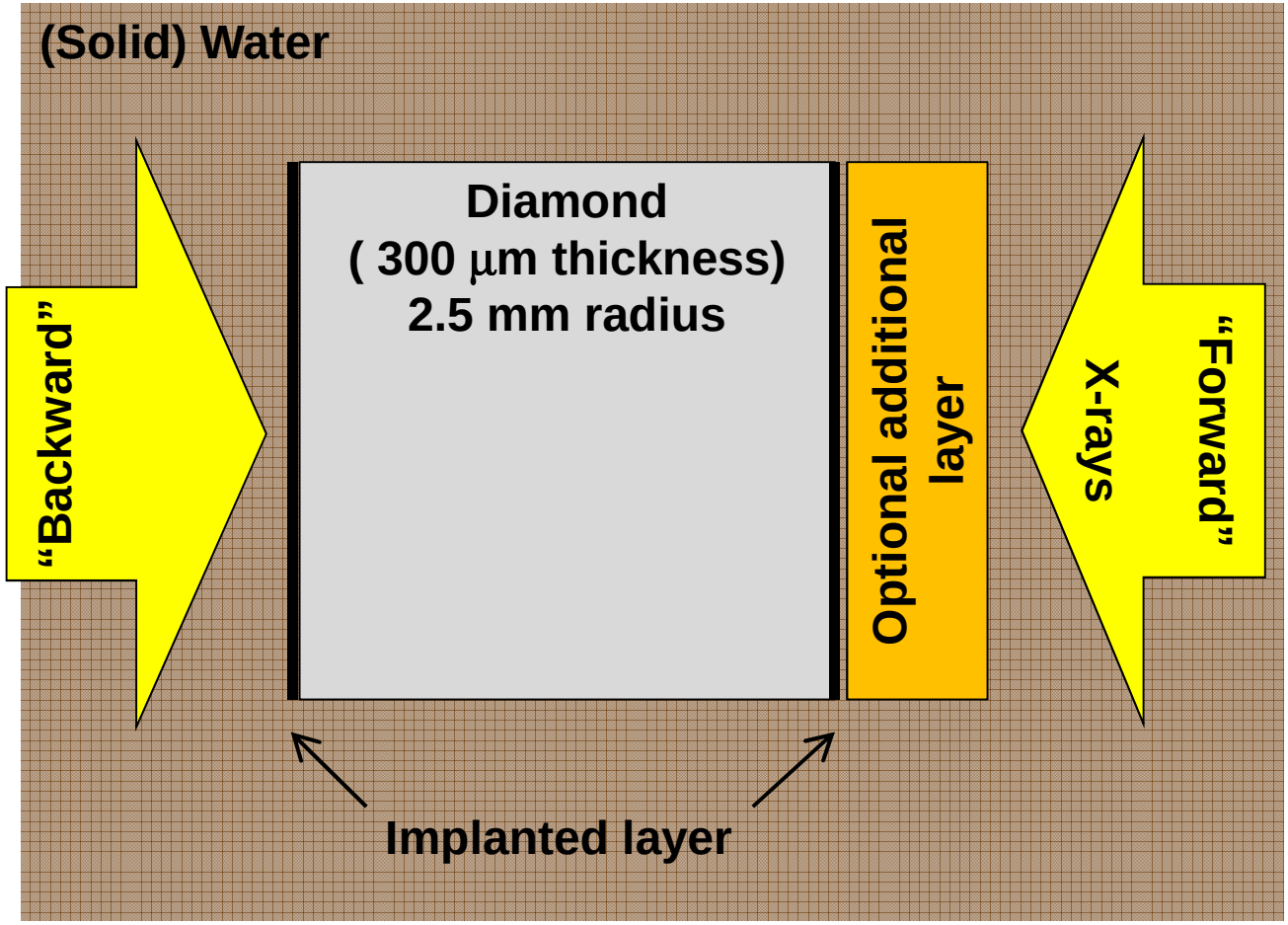


Slow but high amplitude response in areas with affected by conductive glue (silver loaded)

Simulations of dose enhancement near the metal interface

Use BEAMnrc to estimate

- **Energy transferred as function of depth within the diamond**
- **Optional layer material & thickness**
- **Incident X-ray spectrum & Direction**

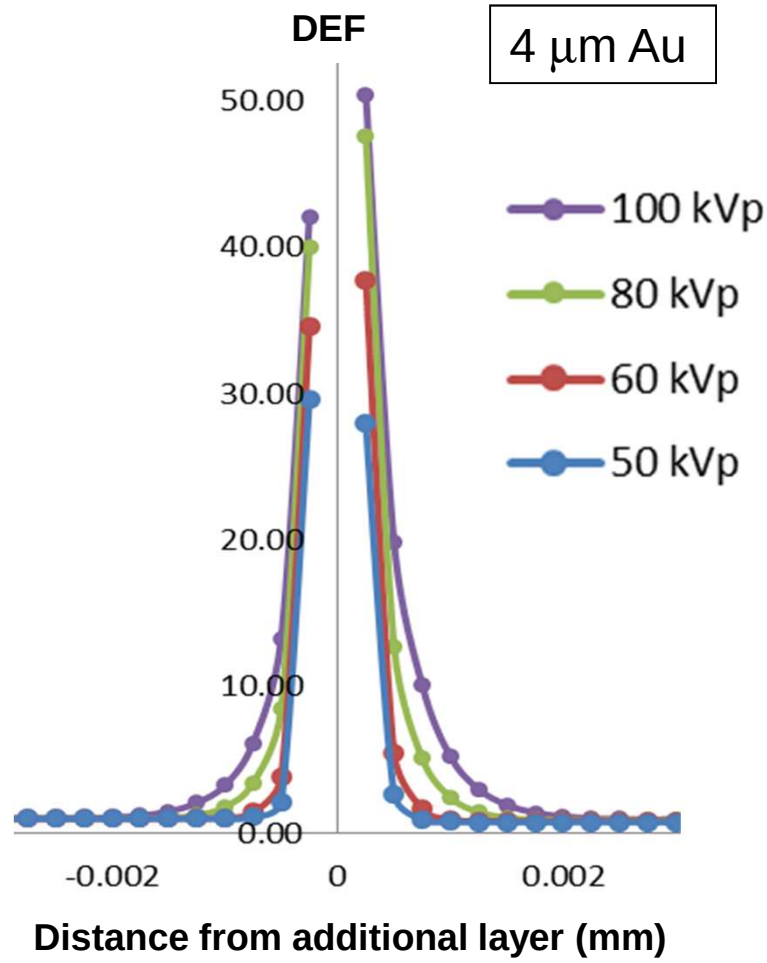


Dose enhancement factor

DEF =

$$\frac{E_{trans} \text{ with high(er) Z material}}{E_{trans} \text{ transferred with solid water}}$$

- **At 100 kVp in forward direction with Au layer – 4 μm results in max. DEF**
- **Depth affected increases with X-ray energy (as expected)**
- **Fairly symmetric, main impact within 2 μm (at energies studied)**



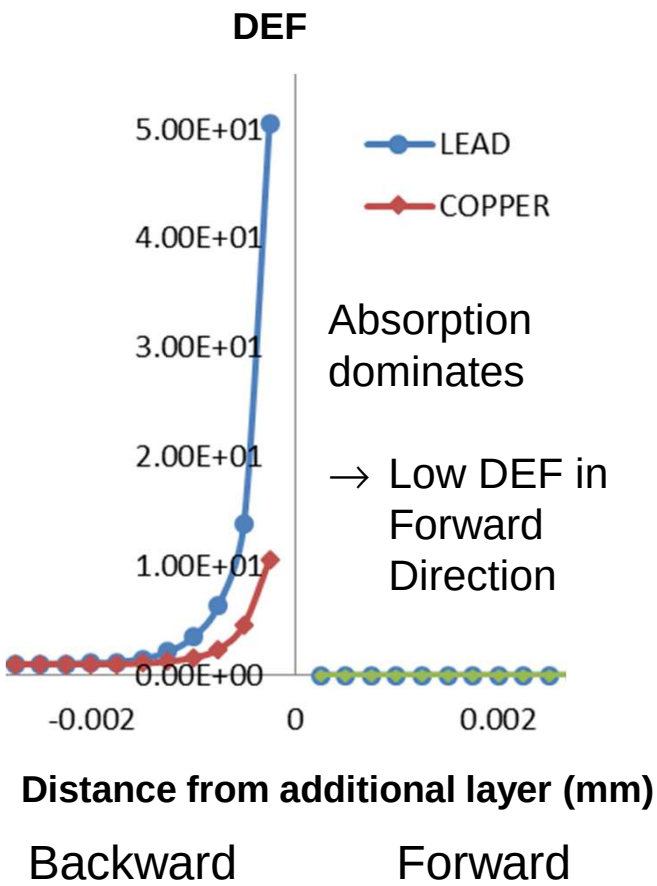
Experimentally – so far only sensitive to Integrated DEF

50 kVp, 1 cm metal

Simulate extreme (thick) and cheap additional layer, backward irradiated

Total (integrated over whole diamond thickness) DEF

Lead: 1.32
Copper: 1.05



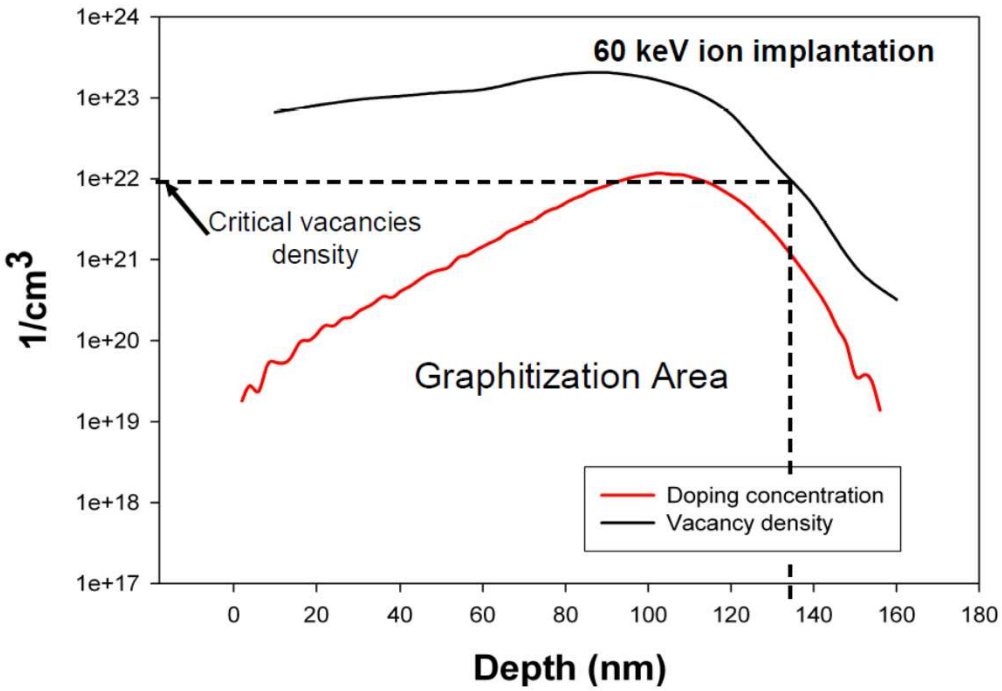
Metal-free contacts by ion implantation

Electronic grade e6 samples, comparison of Boron and Carbon implant

B/C implantation (similar depth/damage profile) into sc/pc

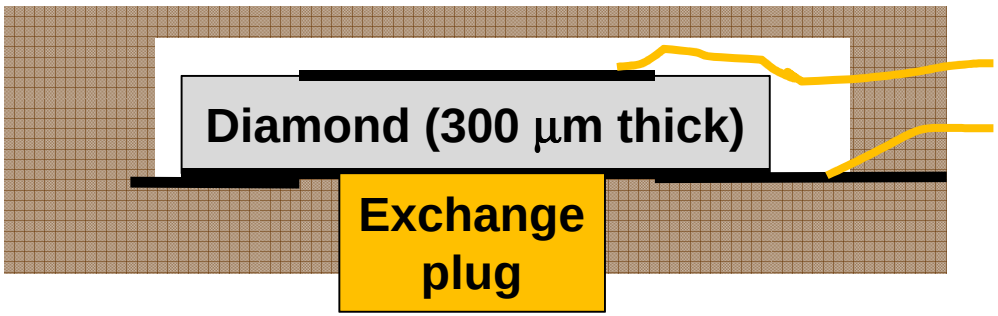
Annealing for 5 min in Nitrogen

Sulfuric acid/potassium nitride boil to re-oxide surface

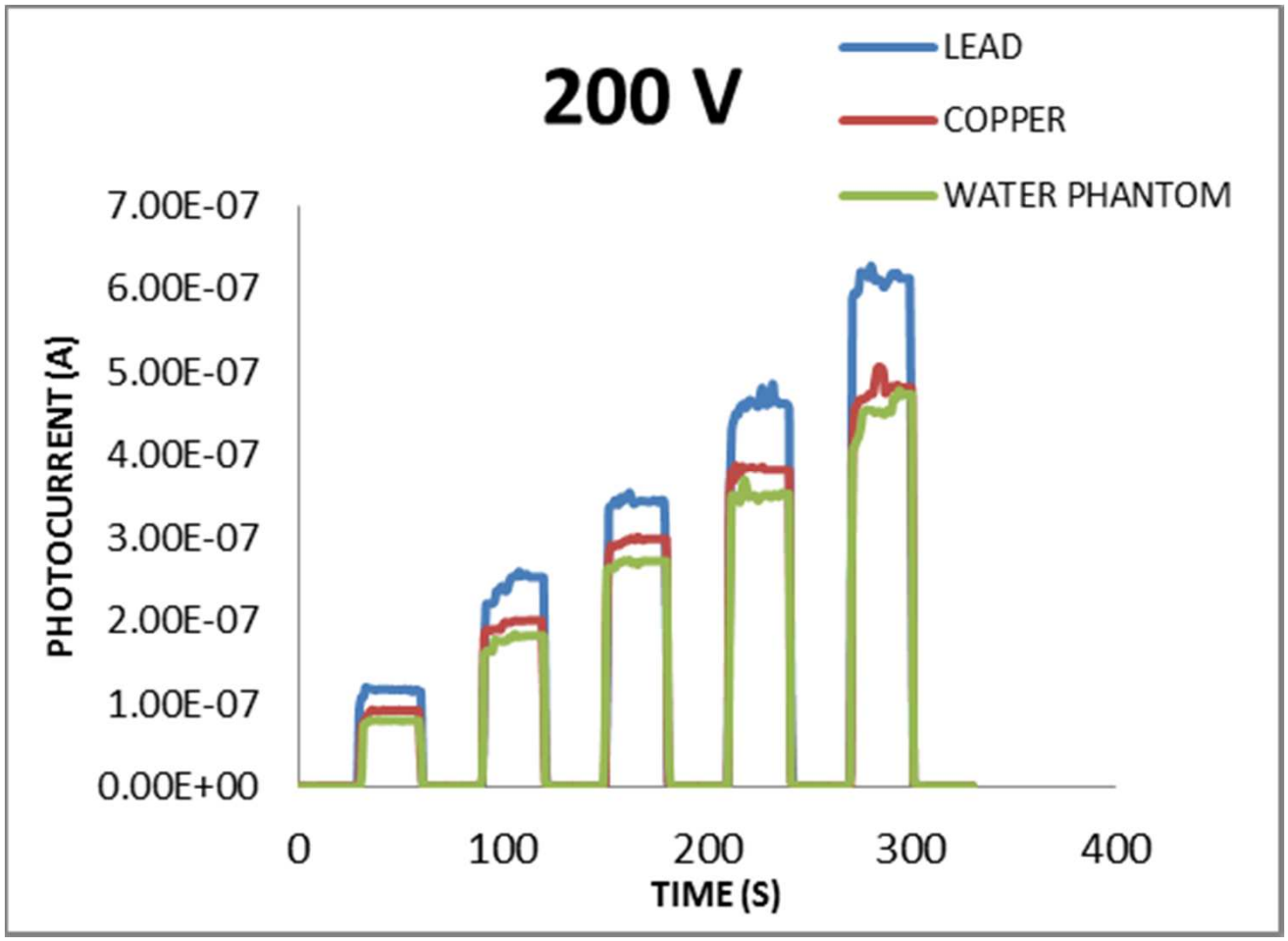


Samples mounted in solid water

Sample fixed with conductive carbon tape around the edges
24 um diameter Au wire is connected with carbon dag.



Carbon implanted sample, initial data

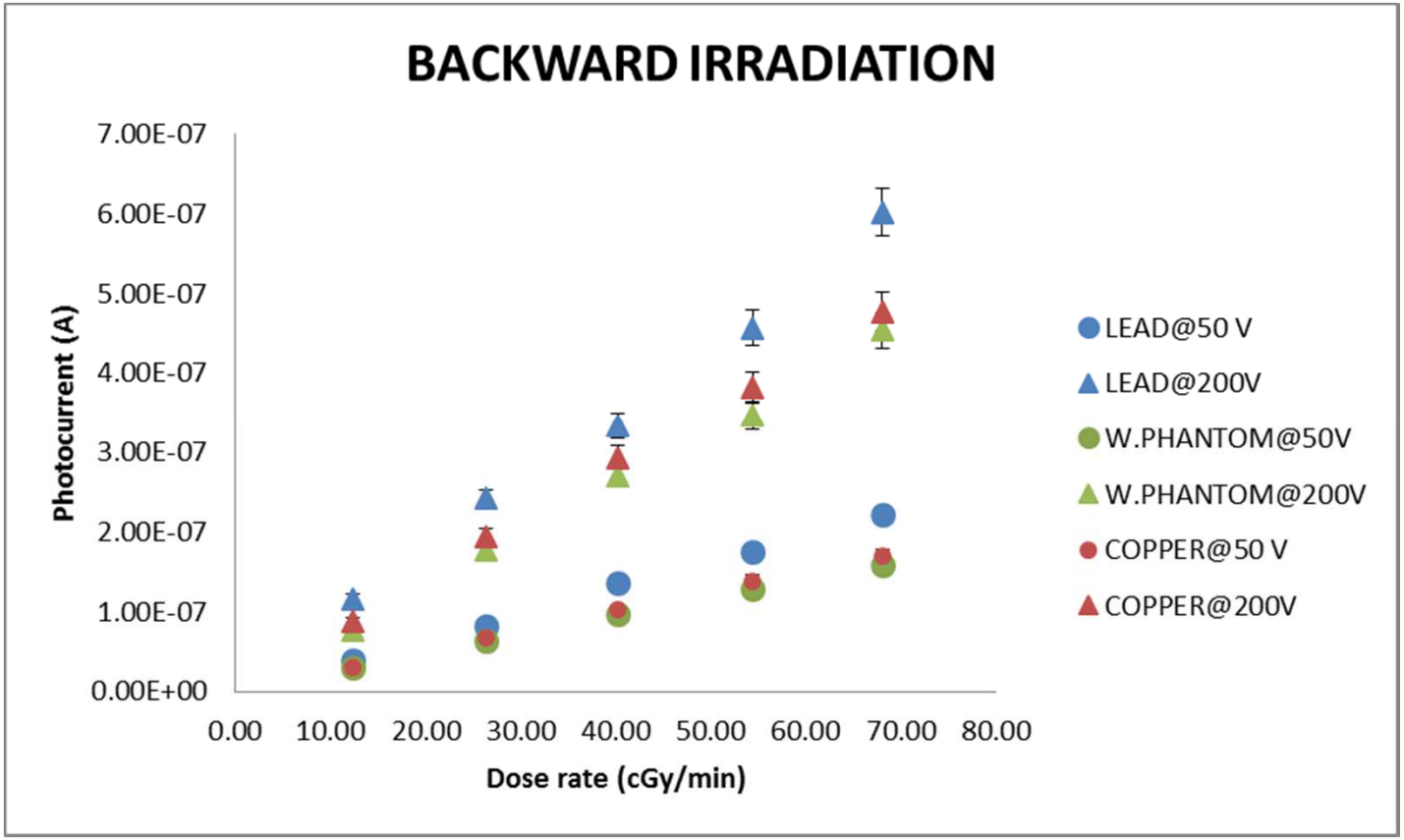


Oxford instruments Mo tube, Tube current between 0.2 and 1 mA

(approx. 12.30 to 68 cGy/min)

Preliminary results

(Current signals not perfectly stable…)



Preliminary results

(Current signals not perfectly stable…)

	Photocurrent ratio at max tube current		Simulated DEF
	50 V	200 V	
Lead	1.38	1.32	1.32
Copper	1.06	1.05	1.05

Initial result show agreement between simulated and experimental data for the carbon implanted sample – the model represents the experimental geometry sufficiently well.

Summary

- **Understanding photo-currents in diamond is important for stable device operation**

- **Many questions on the interaction between bulk / surface / irradiation regime etc are still open**

- **Developed an approach that will allow us to look for systematic behaviour as a function of energy transfer in the diamond/electrode interface region.**

Future work

- **Wider range of bias values & study both polarities**
- **Vary X-ray energy**
- **Boron implanted sample (and others?)**
- **Look at systematic changes in stability & response time ?**
- **....**
-

Thank you!

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Questions?

SEPnet South East Physics Network