X-ray calibrations

Daniela Bortoletto, Maurice Garcia-Sciveres, Timon Heim, Richard Plackett, Maria Mironova

UNIVERSITY OF OXFORD

ATLAS EXPERIMENT

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Outline

- **Summary of X-ray calibration measurements and discussions**

- **Effects of copper layers on dose rate**

- **Requirements for the RD53A/RD53B irradiation setup**

Calibration setup

- X-ray tube with tungsten target, operated at 40kV

- 150 μm Al filter for to remove low-energy components

- Dose rate calibration using AXUVHS5 calibrated pin diodes

- Properties:
  - Sensitive depth: 50 μm
  - Sensitive area: 1 mm^2
  - Biasing voltage: 50 V

- Measures current which can be used to convert into SiO$_2$ equivalent dose

$$\text{DoseRate [rad/min]} = 51.8583 \text{ [rad/(min·nA)]} \cdot I_D \text{ [nA]}$$
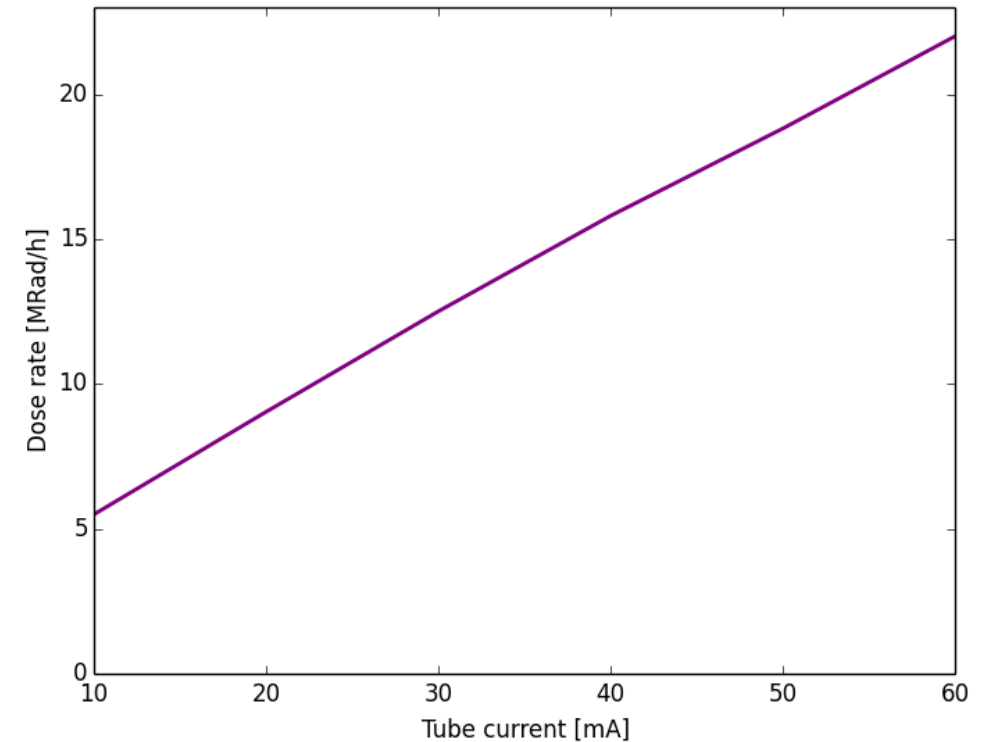Diode Name: D2
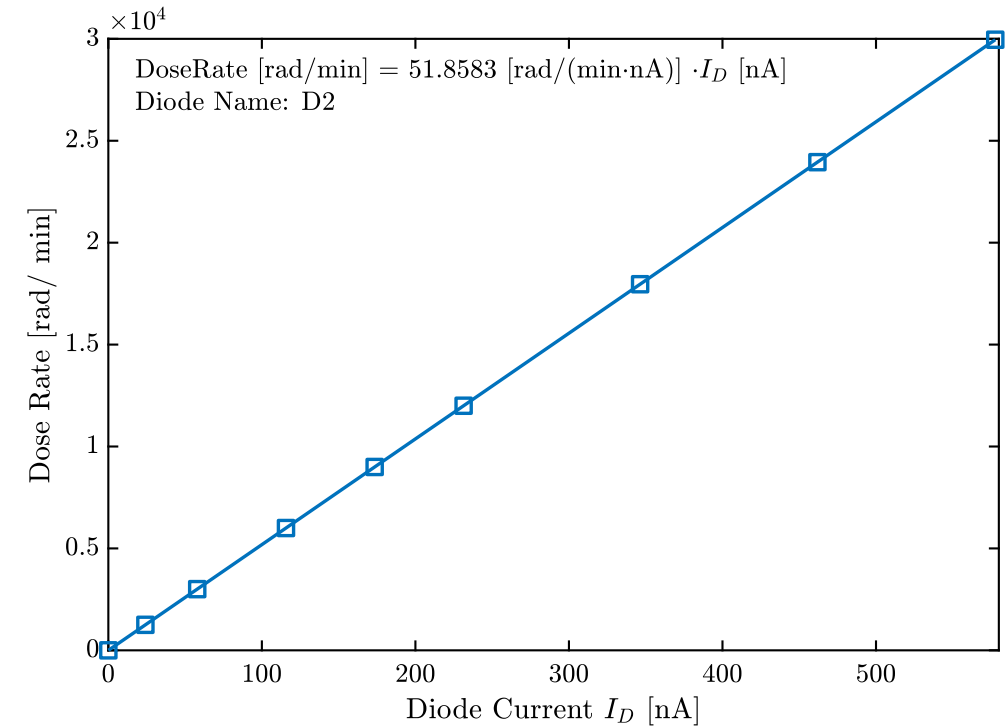
Example calibration curve for AXUVHS5 diode

Calibration measurements

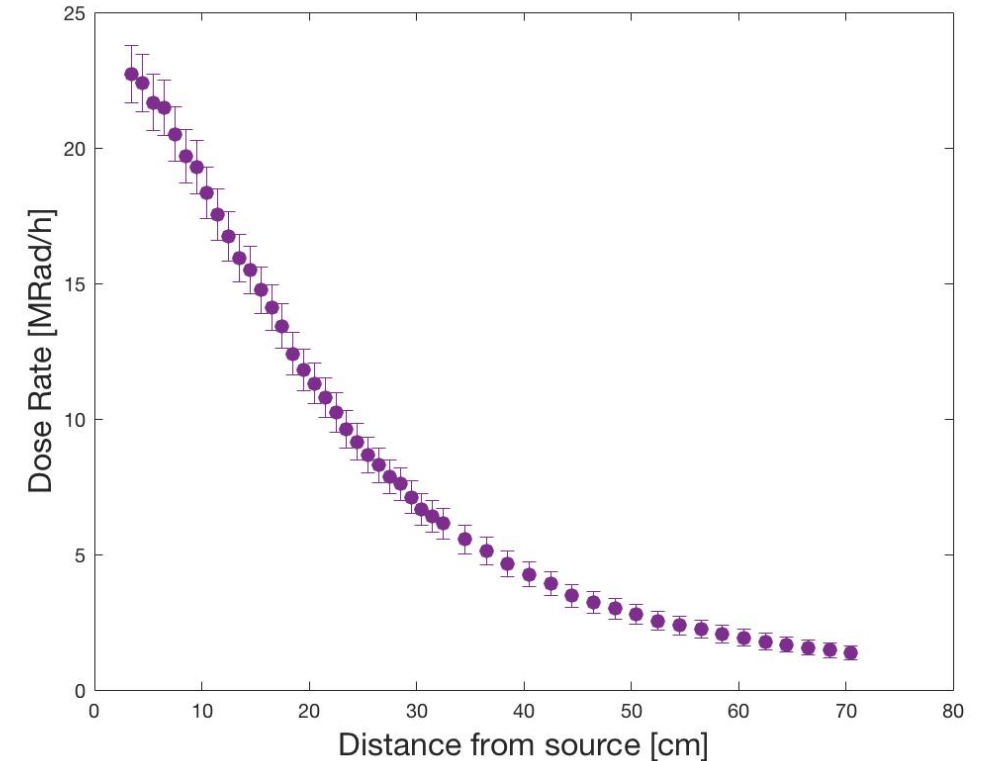Measurements to characterise X-ray system (at 40 kV):

- **Dose rate as a function of tube current**

- Dose rate as a function of distance from the tube

- Beam profile at at least two distances from the source
    - → Uniformity of the beam spot
    - → Opening angle of the beam
    - → Easiest to do with a set of x-y motion stages

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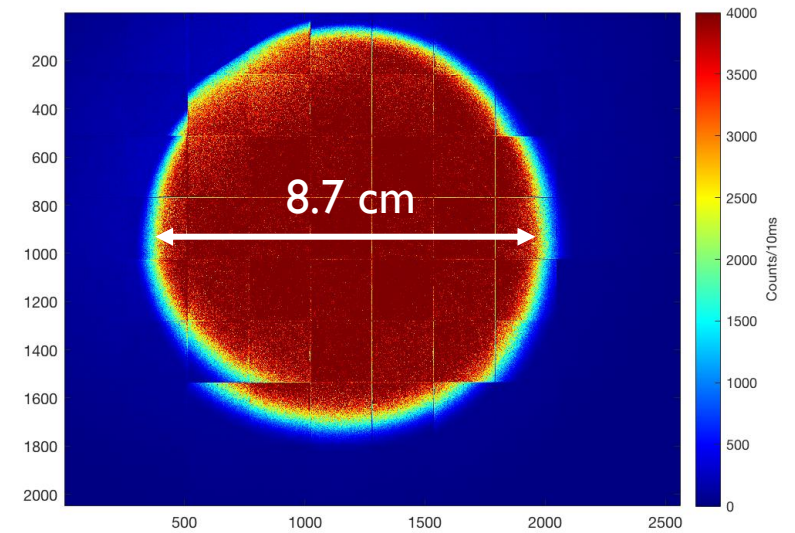 - → Easiest to do with a set of x-y motion stages
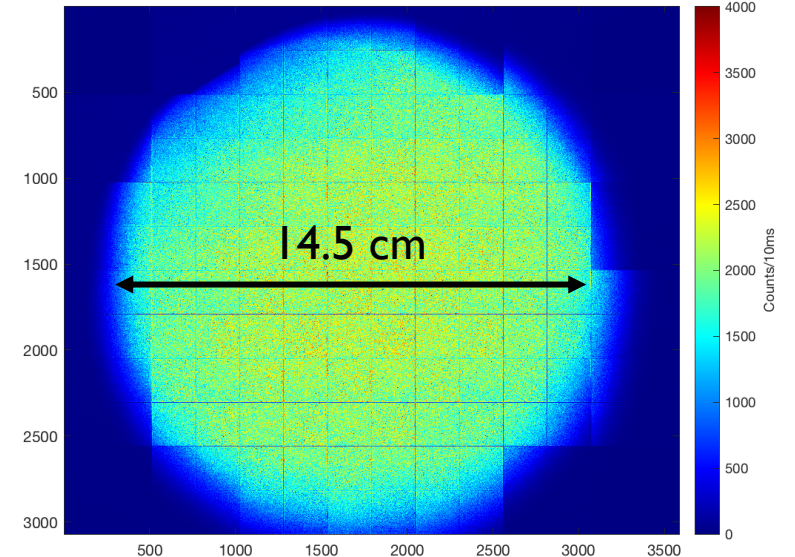
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10 cm from the source

20 cm from the source

Calibration measurements

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→ Set of results which allows to decide where to place chip for irradiation at a particular dose rate

Optional? X-ray spectrum

- Most X-ray setups use tungsten targets

→ Spectra *should* be very similar

- However, e.g. in the Oxford setup we noticed unexpected Cu lines in the spectrum

- Among others things, this will affect how much of the X-rays are absorbed in the metallisation layers
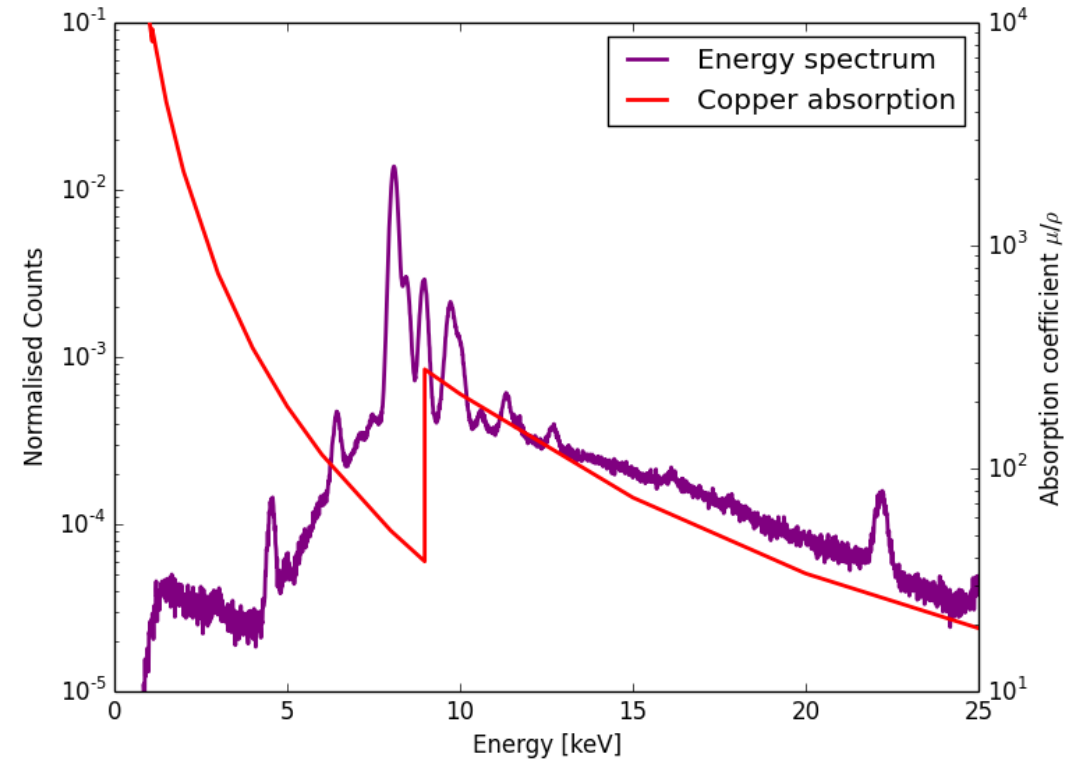
Effect of copper layers

- Copper layers on the RD53A chip will affect how much of the X-ray beam will reach the ring oscillators

- In the case of 2.7 μm of copper the attenuation would decrease the dose by 20%
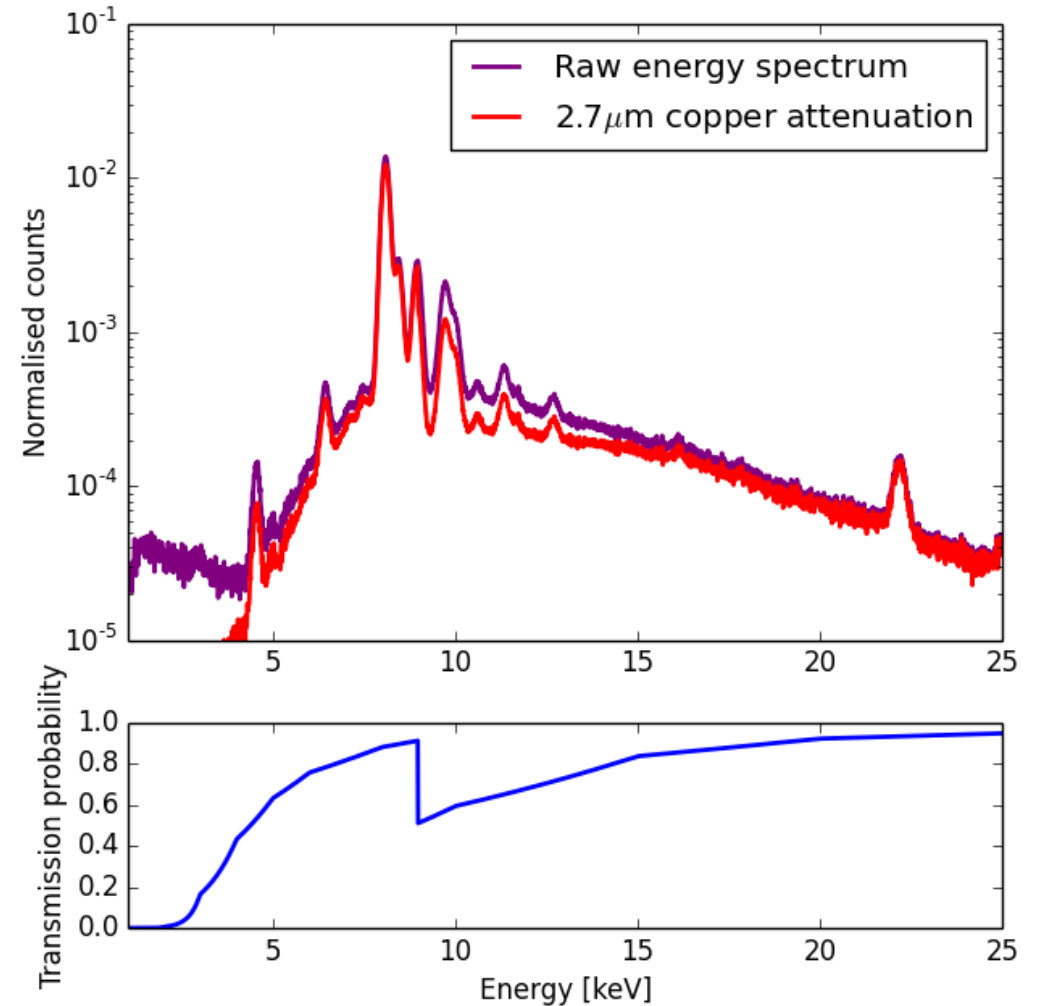
Effect of copper layers

- At the same time X-rays produce electrons in the copper layers which add to the total dose

- Effect measured by placing 5 μm copper in front of the calibration diode → ~8% effect across 50μm of diode

- But: electrons are absorbed in the first ~1 μm of silicon

- In the first 3 μm of silicon dose enhancement could increase the given dose by a factor of 2

→ **Interplay of absorption and dose enhancement quite complex**
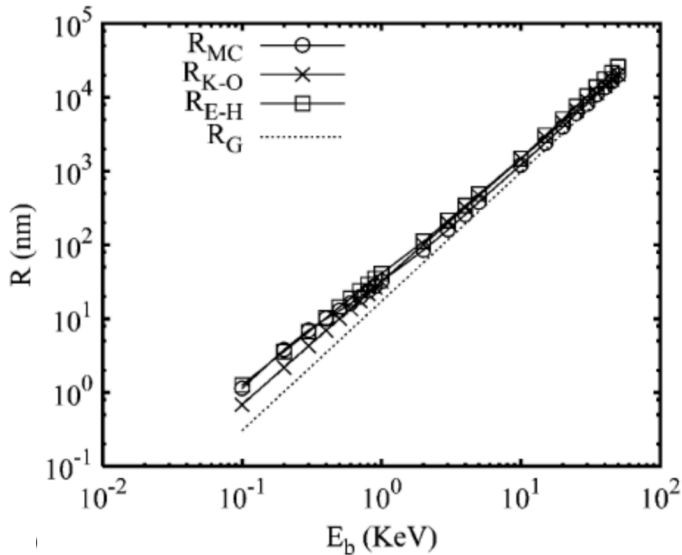
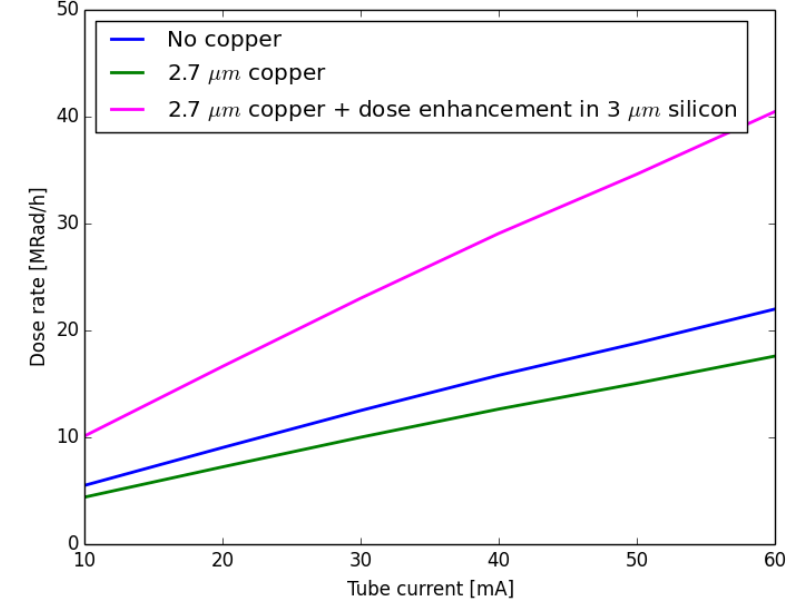*Electron range in silicon as a function of electron energy*

Measurement with 5μm copper foil
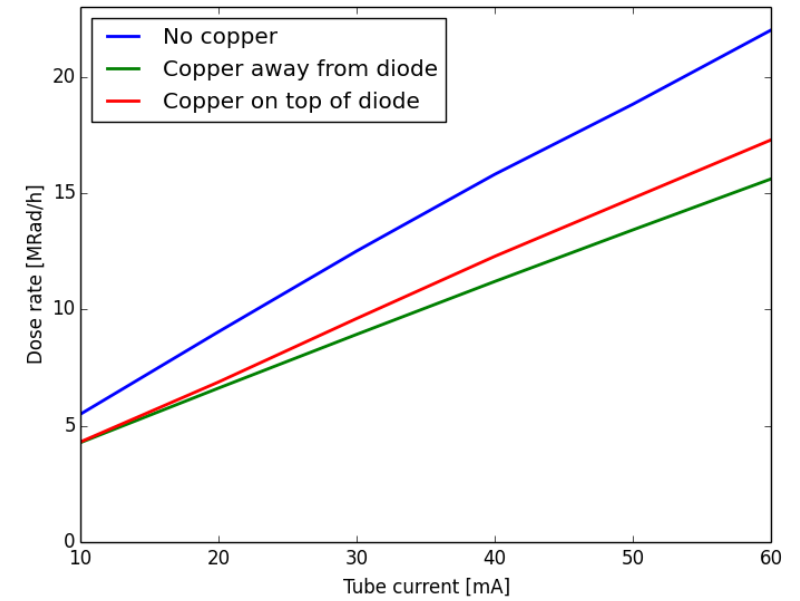
Extrapolation to the configuration in the chip

RD53B irradiations

- Before starting irradiations it is recommended to confirm the dose rate with the calibrated diode

- Perform irradiations with a 150μm Al filter, at 40kV and 50 mA (assuming a tungsten target)

- Irradiations done cold → temperature up for discussion, -10℃ would be a reasonable point

    →Impact of temperature to be studied

- Monitor temperature and VDDD voltage while irradiating → anything else?

Thank you!

Questions?