



TOMSK STATE UNIVERSITY

**Sapphire X-ray sensors:
construction and characterization**

Workshop on sapphire detector construction

11-01-2024

remote meeting

Anton V. Tyazhev

antontyazhev@mail.ru

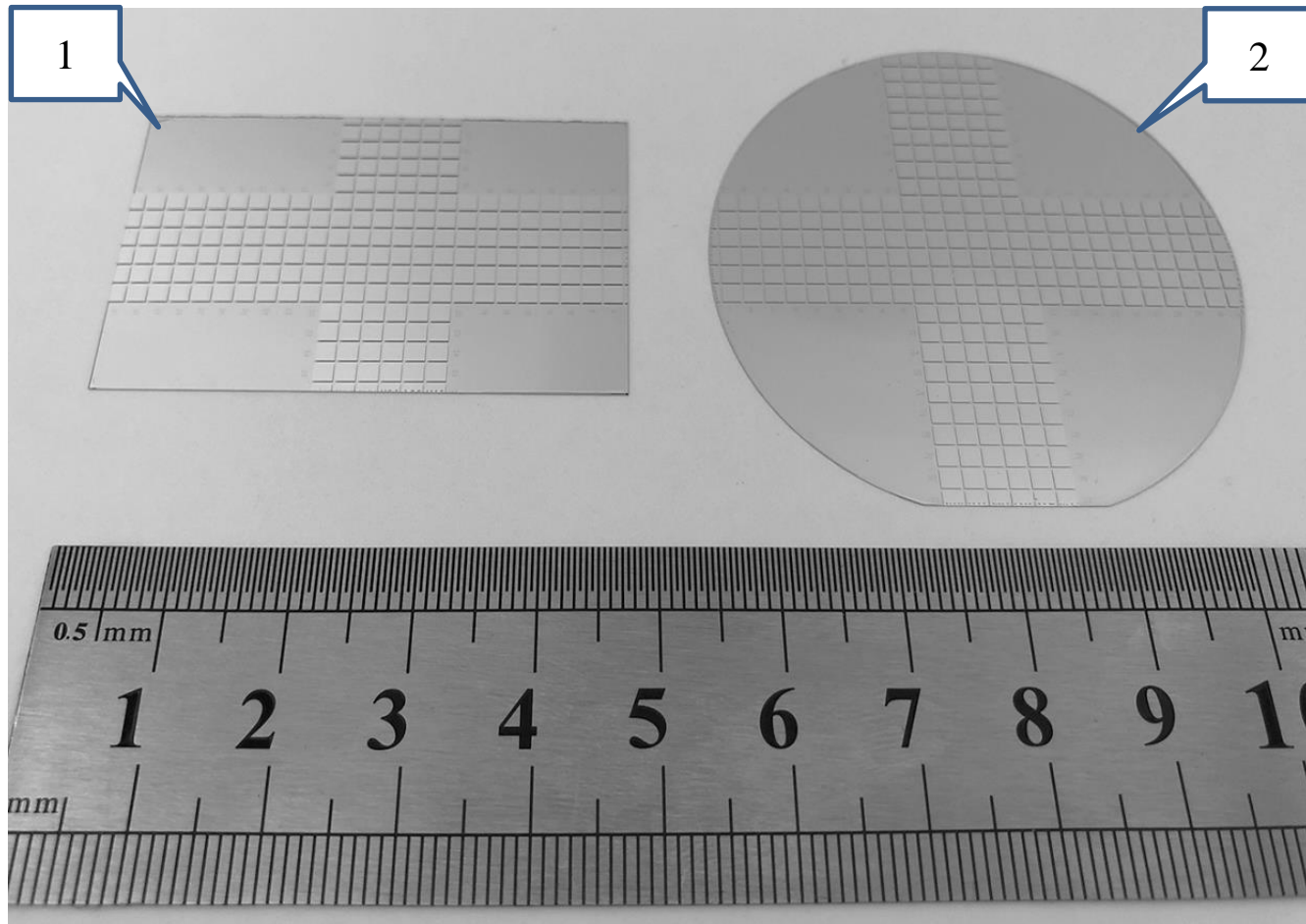
R&D Center «AET»

Tomsk State University,

Tomsk, Russia

Sapphire X-ray sensors characterization

Characterization of sapphire wafers produced by TSU



1 - Wafer # 1; 2 – Wafer # 2, 3

- Pixel and backside metal contacts are made of 0.2 μm thick Al film. The film was deposited with magnetron sputtering.
- Pixel pitch is 2 mm and interpixel gap of 0.2 mm

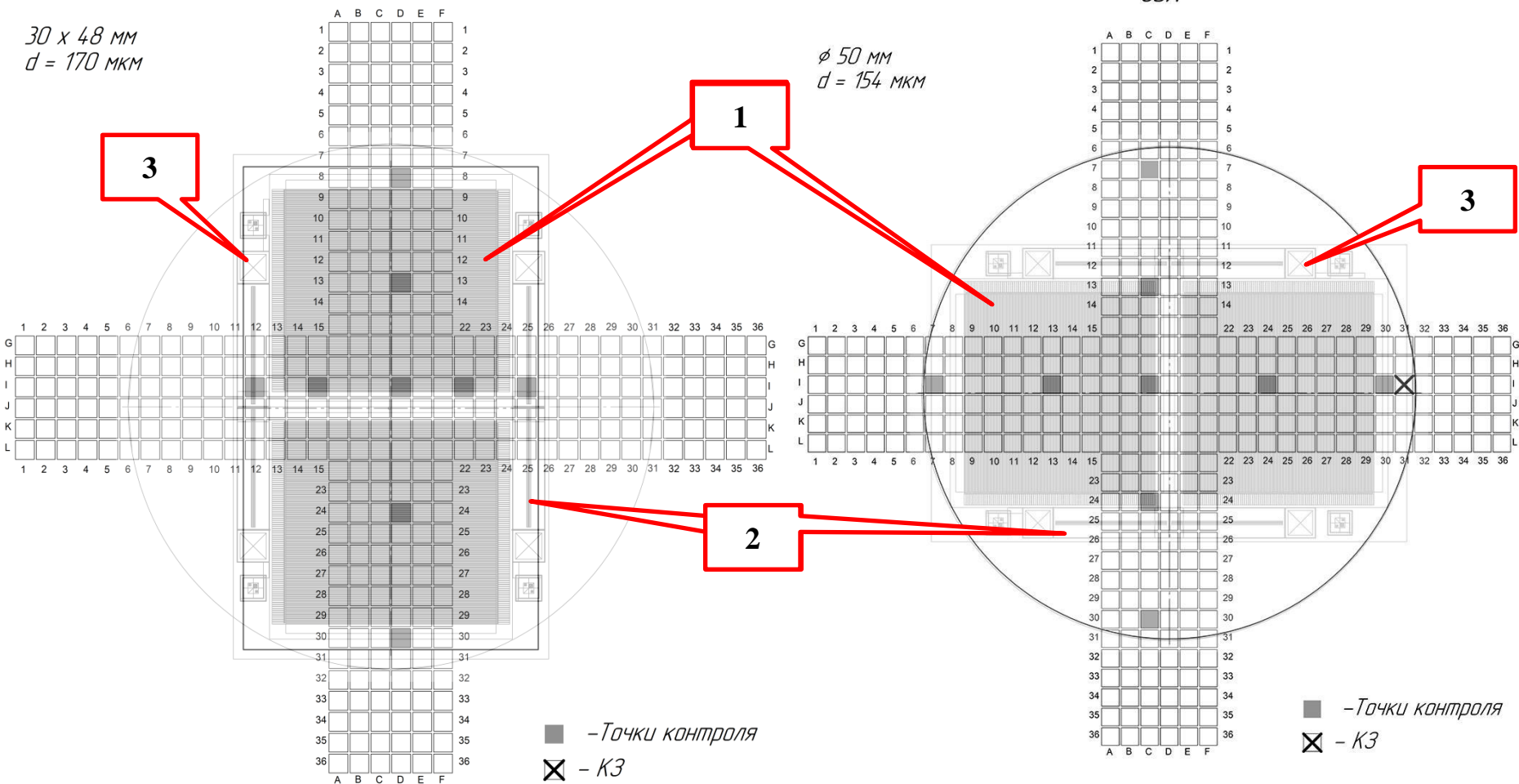
Overlay of microstrip sensor layout and pixelated wafer layout

Monocrystal

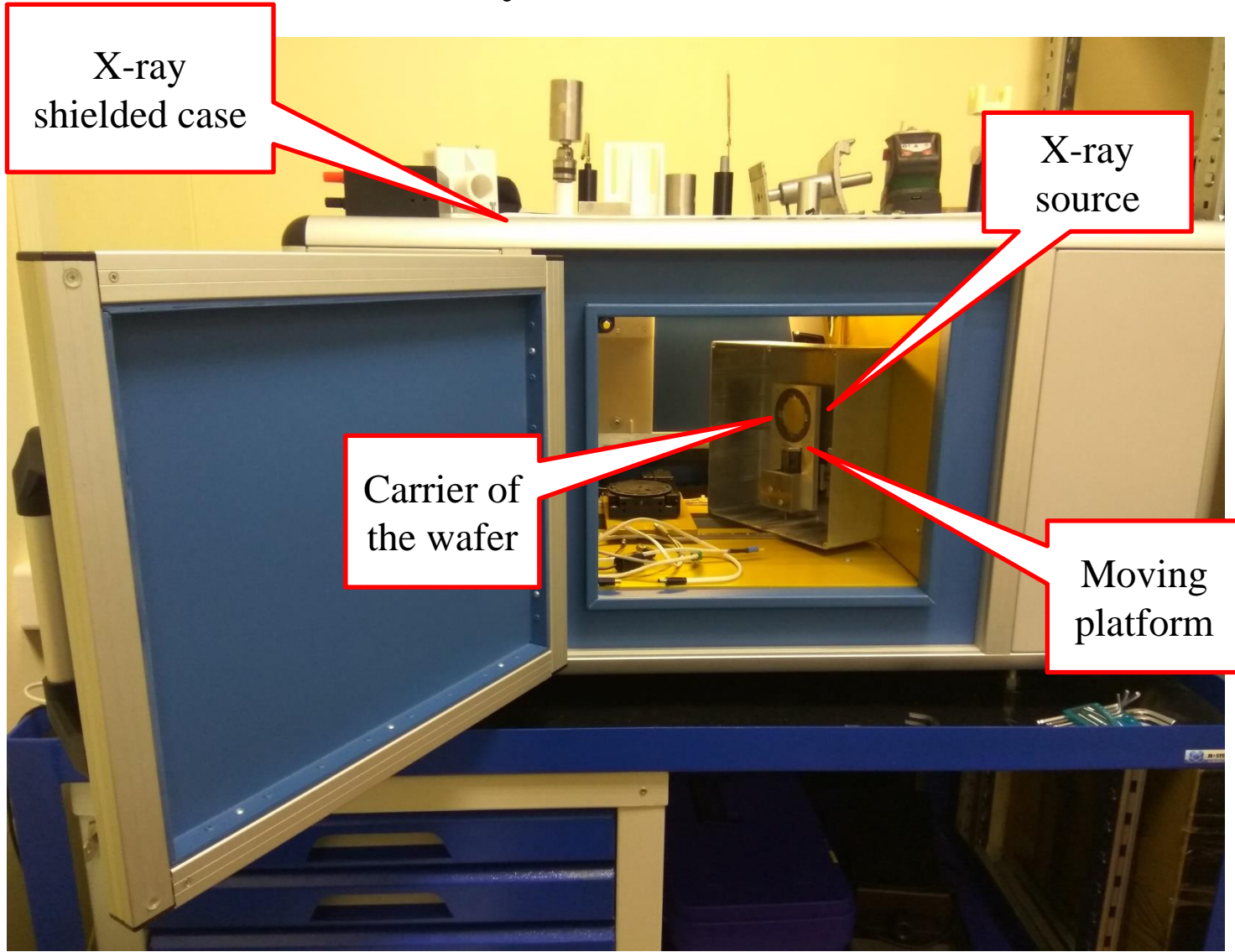
30 x 48 MM
d = 170 MKM

USA

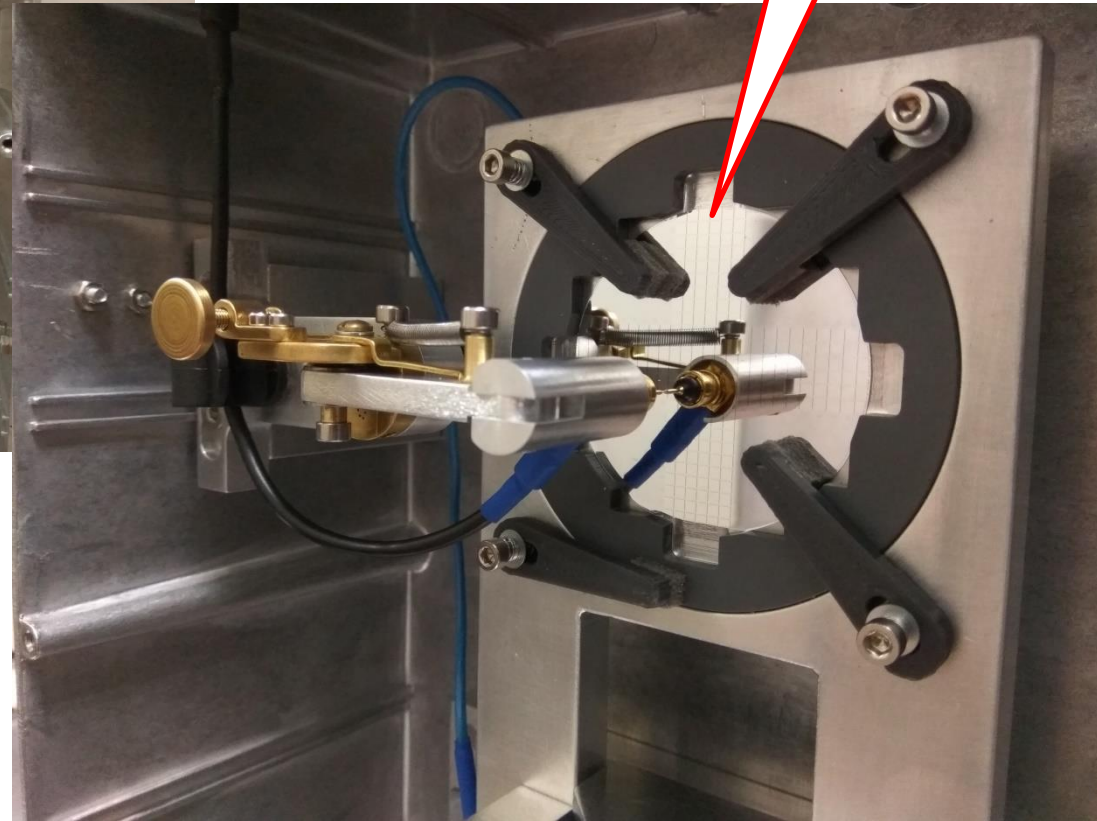
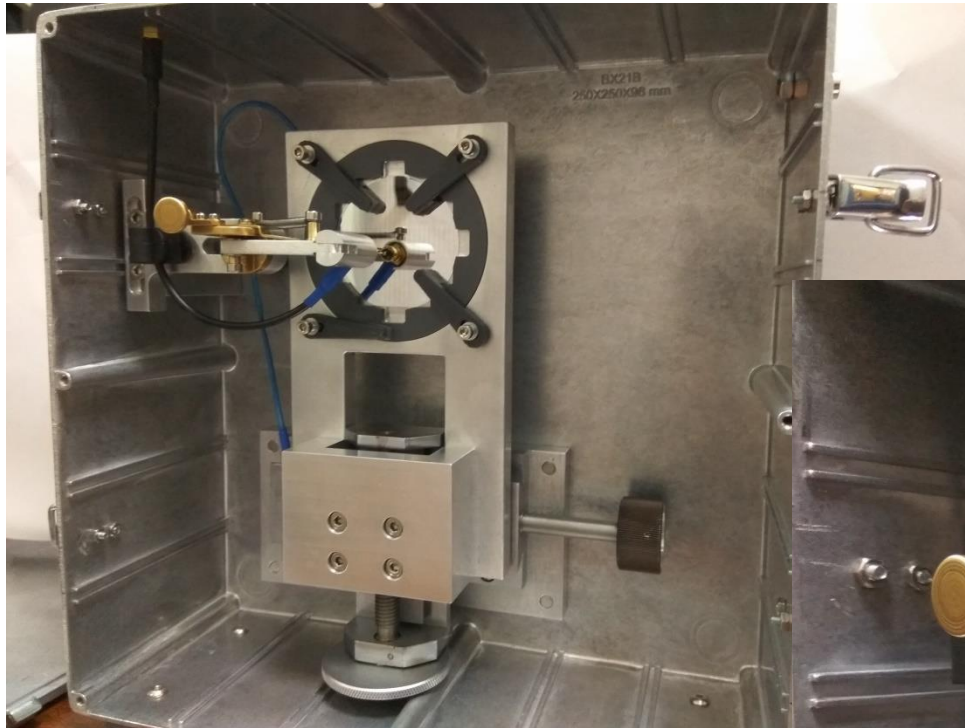
∅ 50 MM
d = 154 MKM



X-ray test bench



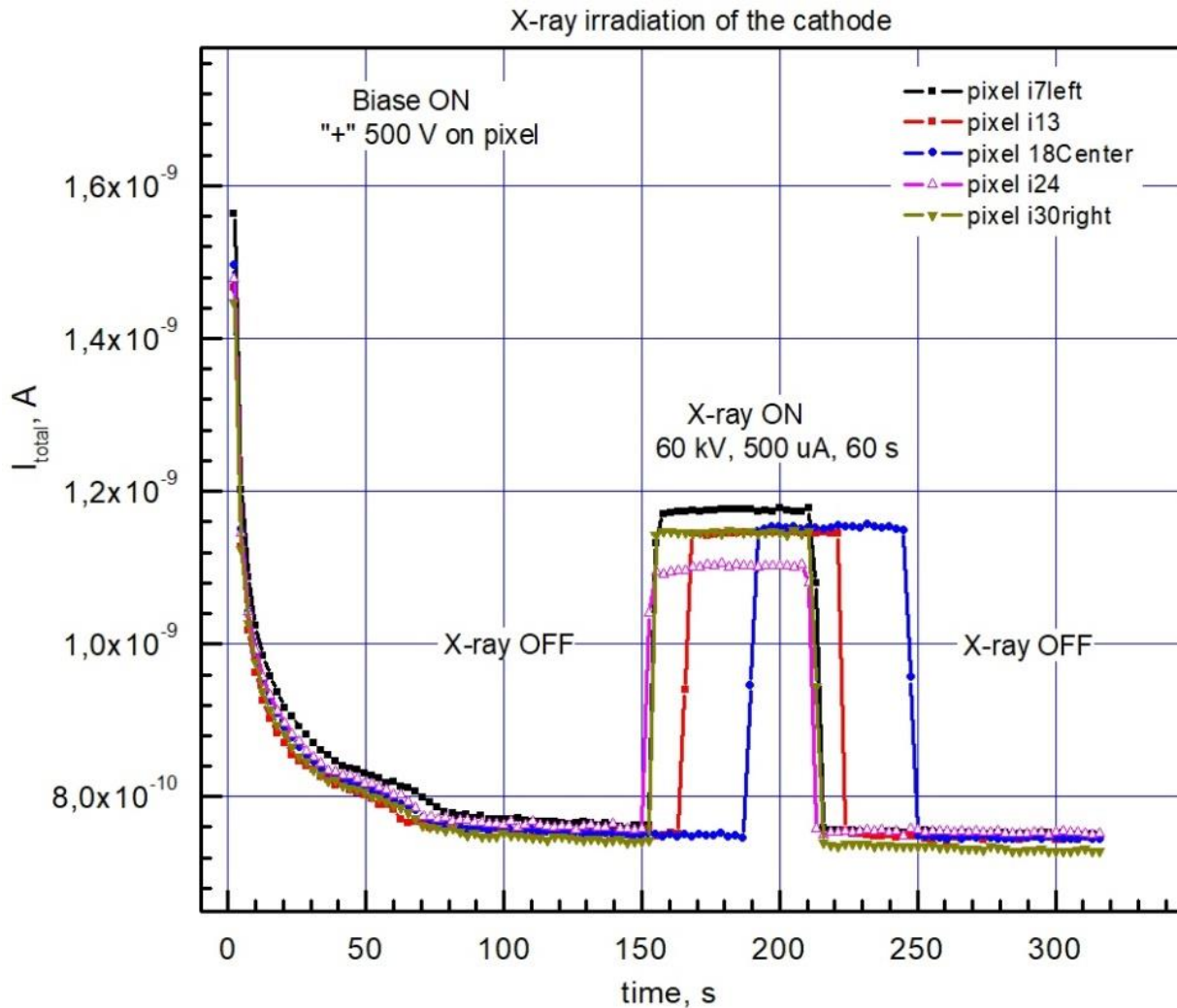
Moving platform with pixelated wafer



Pixelated
wafer

Sapphire wafer # 3. Test points location

Dark and photocurrent of sapphire pad sensors irradiated with X-ray beam



X- ray source:

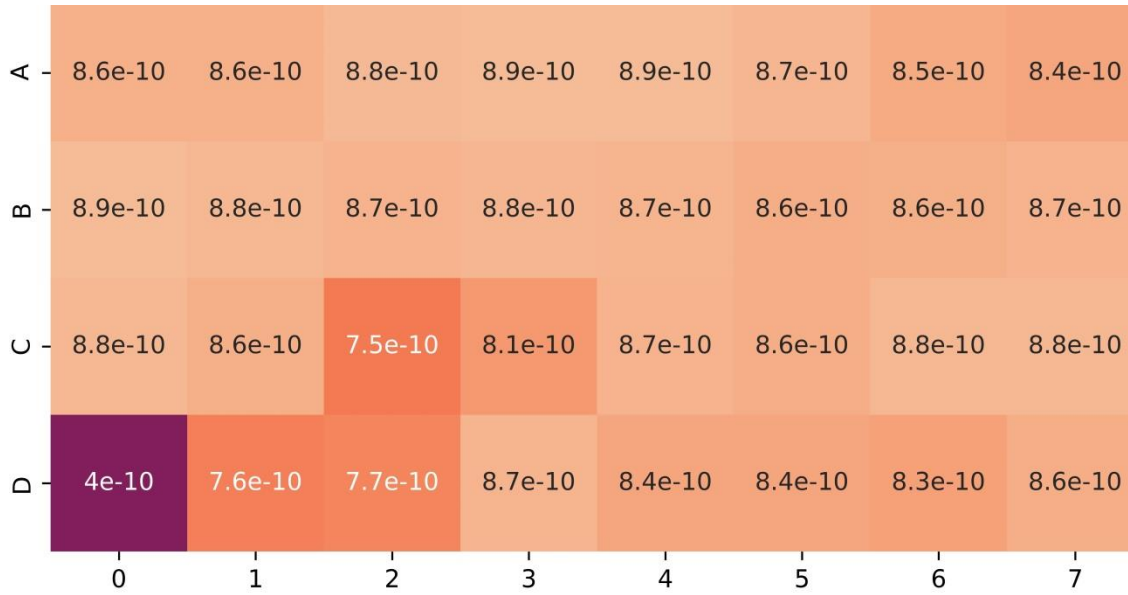
W anode X-ray tube

60 kV, 500 μ A

60 s x-ray pulse duration

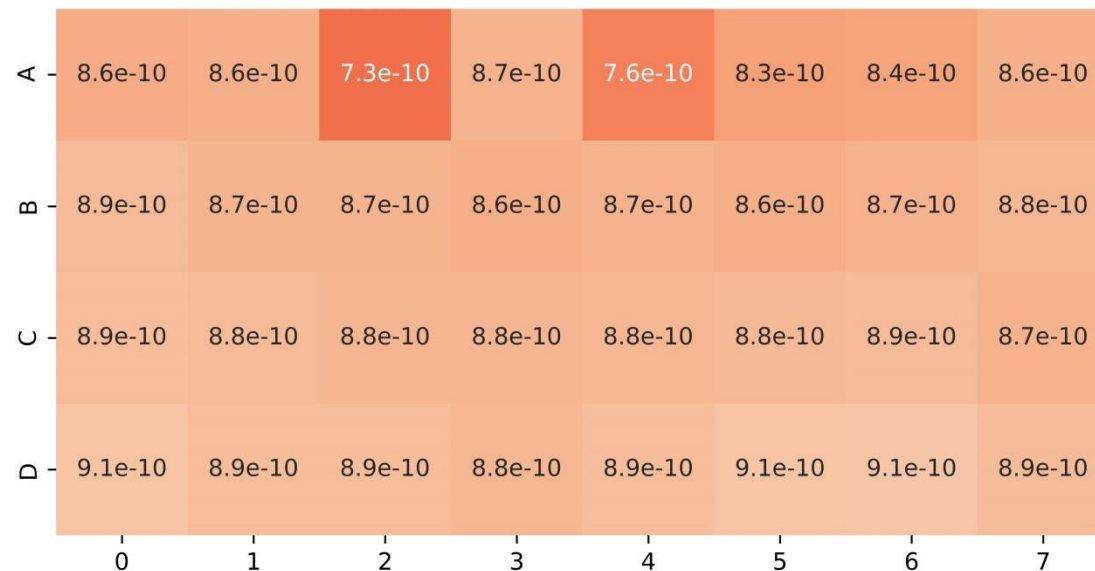
Steady-state photocurrent mapping under X-ray beam

«Monocrystal» plate # 1



«Monocrystal» plate,
150 um thickness

«Monocrystal» plate # 2

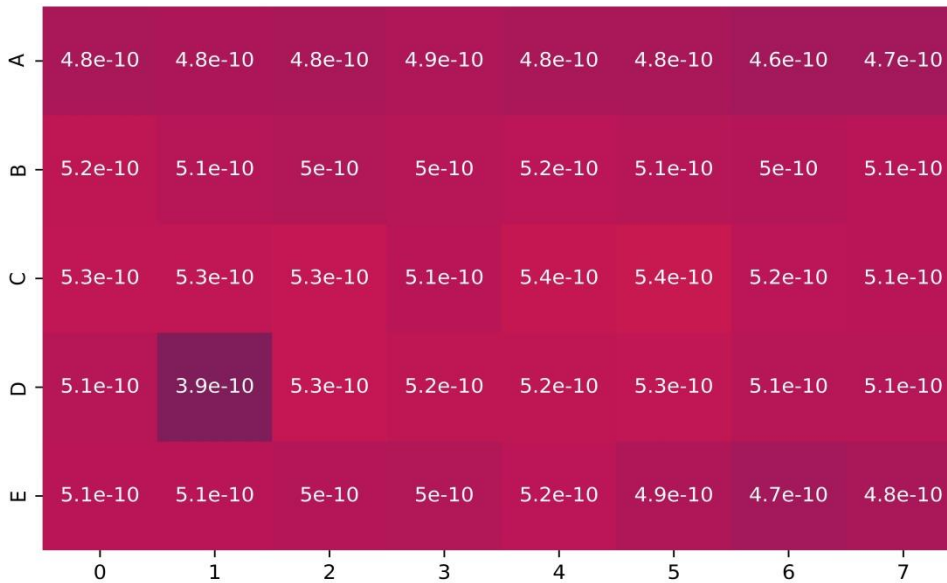


X- ray source:
W anode X-ray tube,
60 kVp, 500 uA,
60 s X-ray pulse duration

Sensor bias: 500 V

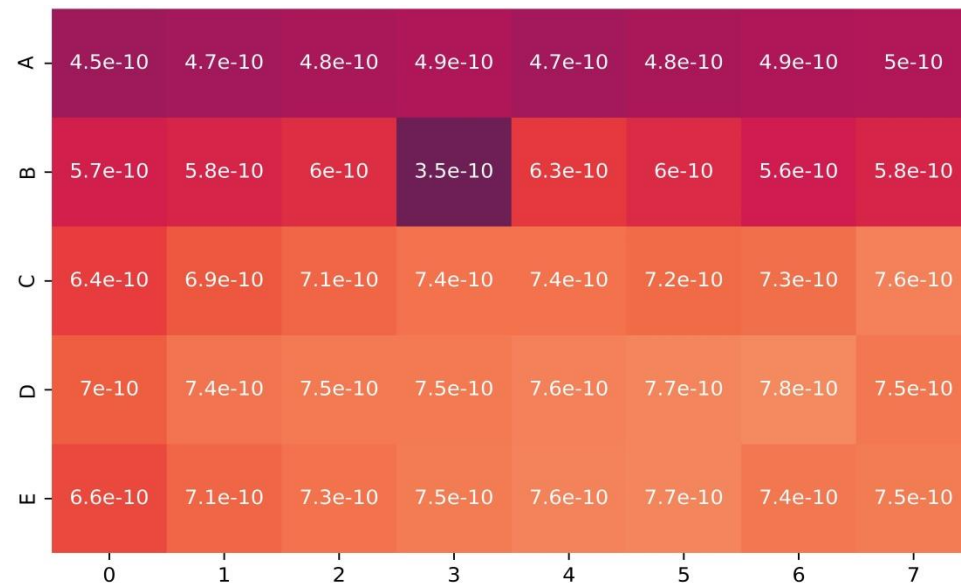
Steady-state photocurrent mapping under X-ray beam

«US» wafer # 1



«US» wafers,
150 um thickness

«US» wafer # 2



X- ray source:

W anode X-ray tube,

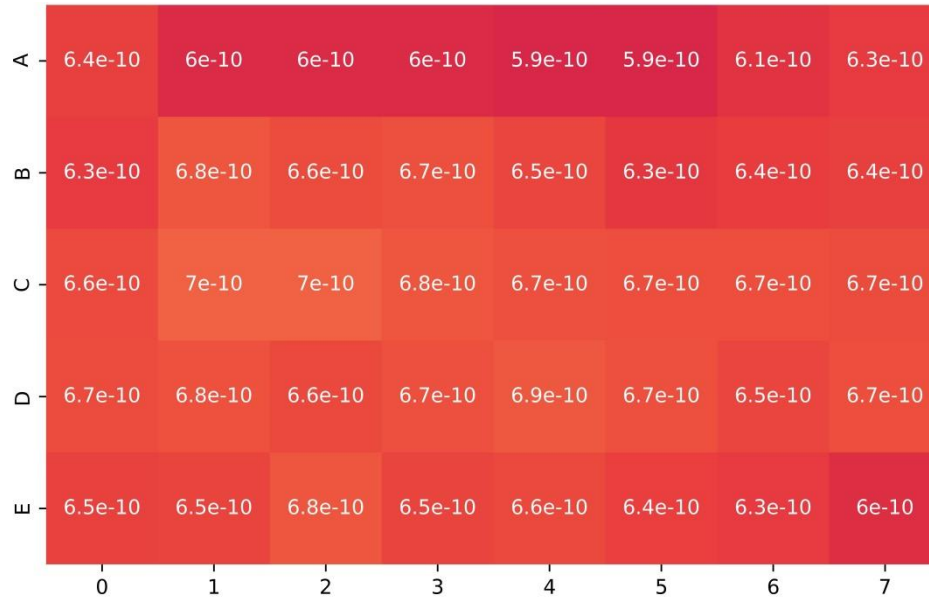
60 kVp, 500 uA,

60 s X-ray pulse duration

Sensor bias: 500 V

Steady-state photocurrent mapping under X-ray beam

«Wuppertal» wafer # 1



«Wuppertal» wafers,
100 um thickness

X- ray source:

W anode X-ray tube,

60 kV_p, 500 uA,

60 s X-ray pulse duration

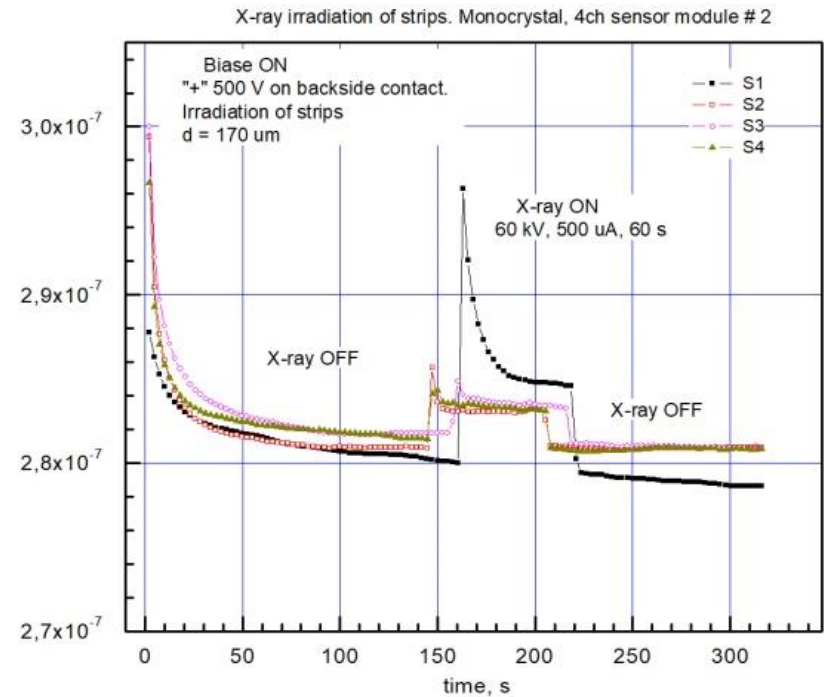
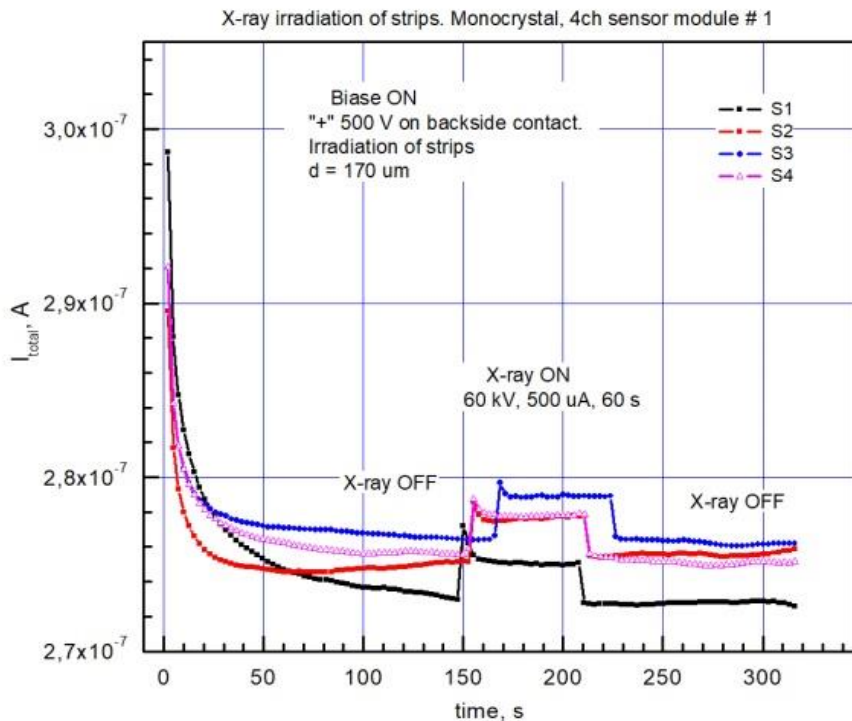
Sensor bias: 500 V

«Wuppertal» wafer # 2



Testing of 4 channel sensors

Photocurrent under X-ray irradiation



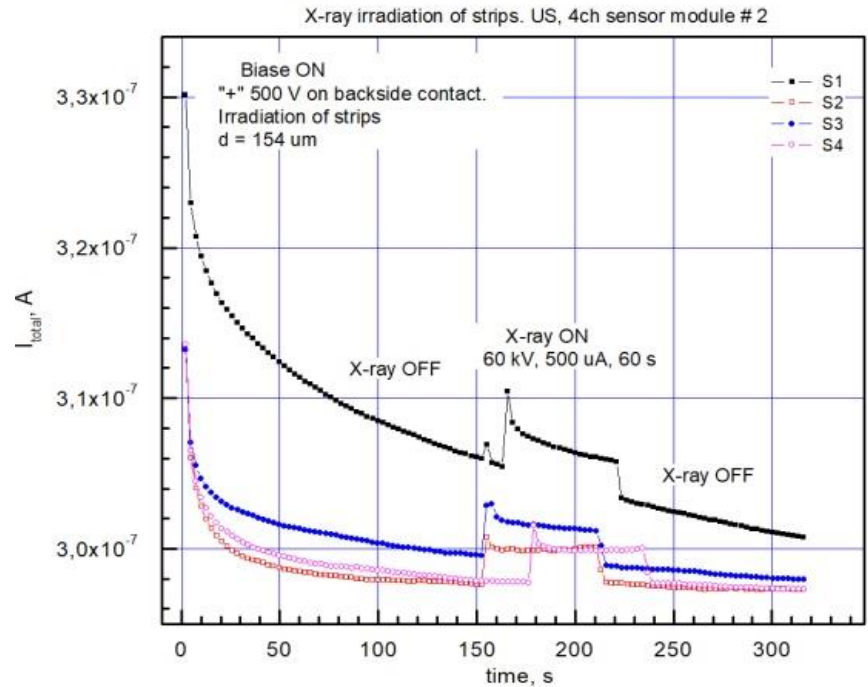
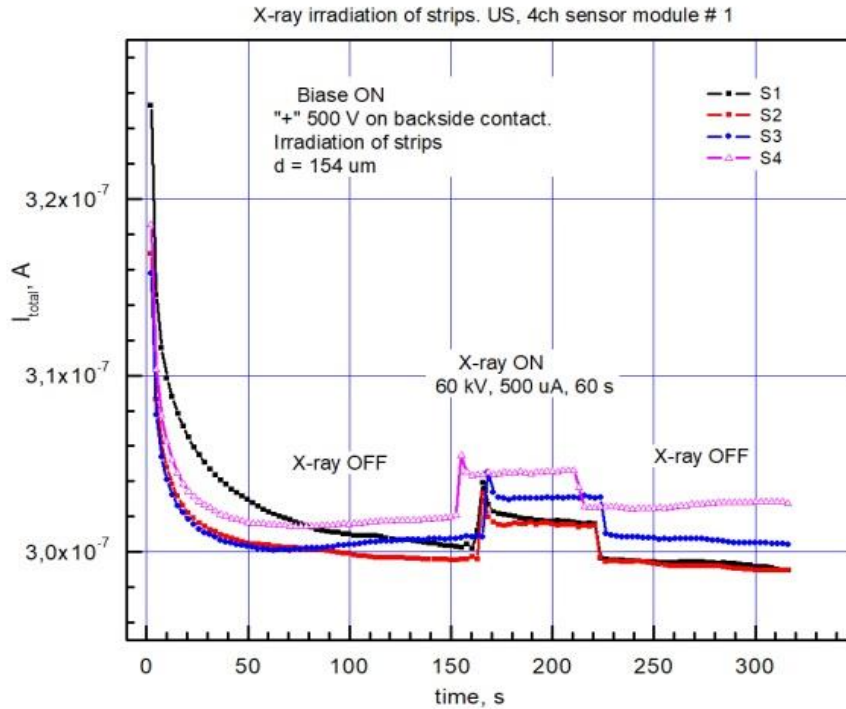
X- ray source:
W anode X-ray tube,
60 kVp, 500 uA,
60 s X-ray pulse duration

Sensor bias: 500 V

«Monocrystal» plate,
150 um thickness

Testing of 4 channel sensors

Photocurrent under X-ray irradiation



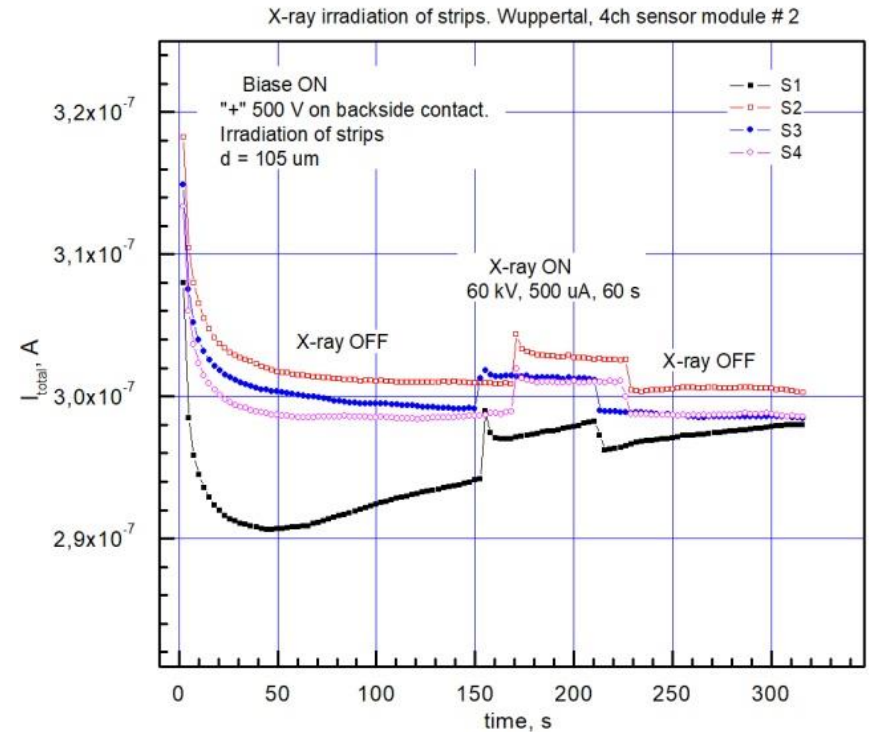
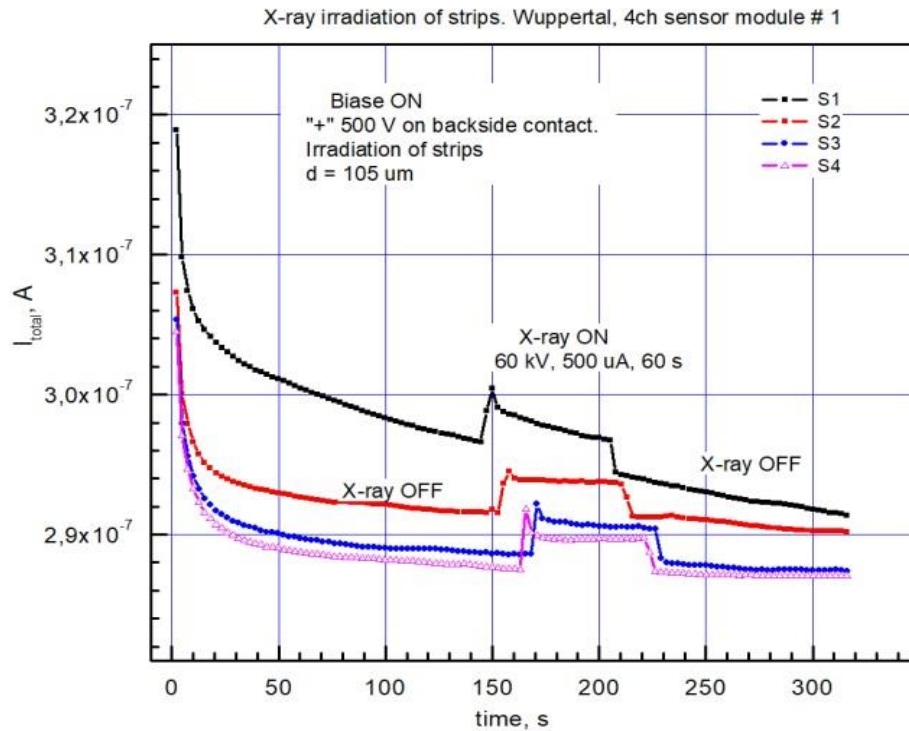
X- ray source:
W anode X-ray tube,
60 kVp, 500 uA,
60 s X-ray pulse duration

Sensor bias: 500 V

«US» wafers,
150 um thickness

Testing of 4 channel sensors

Photocurrent under X-ray irradiation



X- ray source:

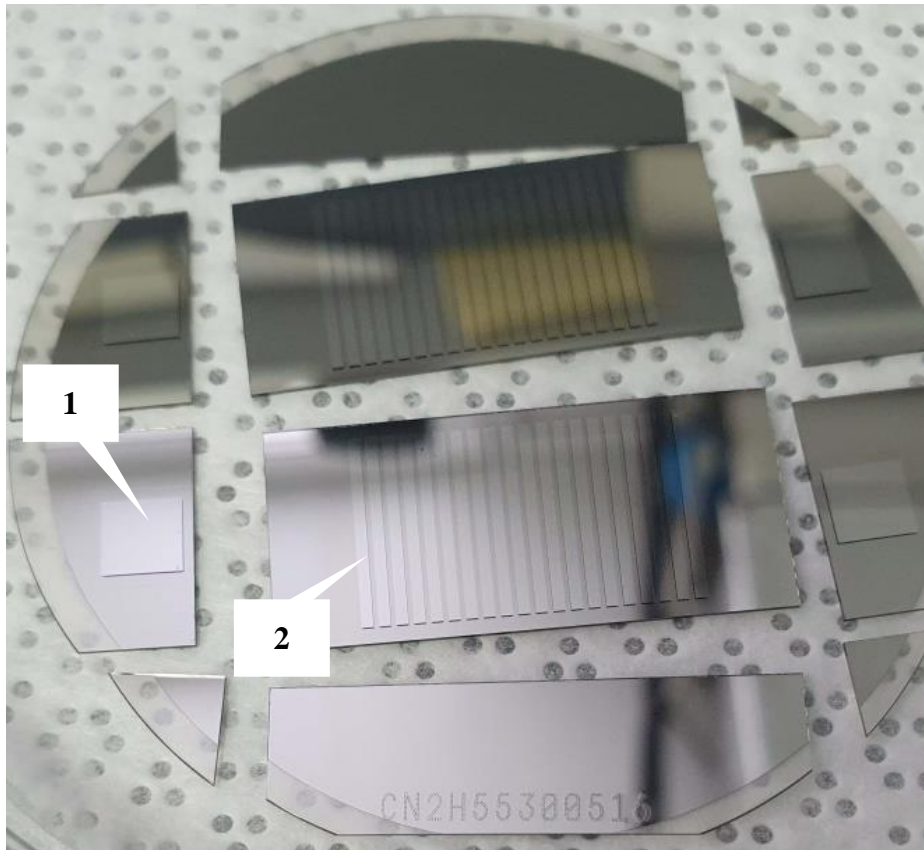
W anode X-ray tube,
60 kVp, 500 uA,
60 s X-ray pulse duration

Sensor bias: 500 V

«Wuppertal» wafers,
100 um thickness

Testing of pad sapphire sensors

Photocurrent under X-ray irradiation



1 - Pad sensors, sizes of $2.5 \times 2.5 \text{ mm}^2$

2 – Strip sensors

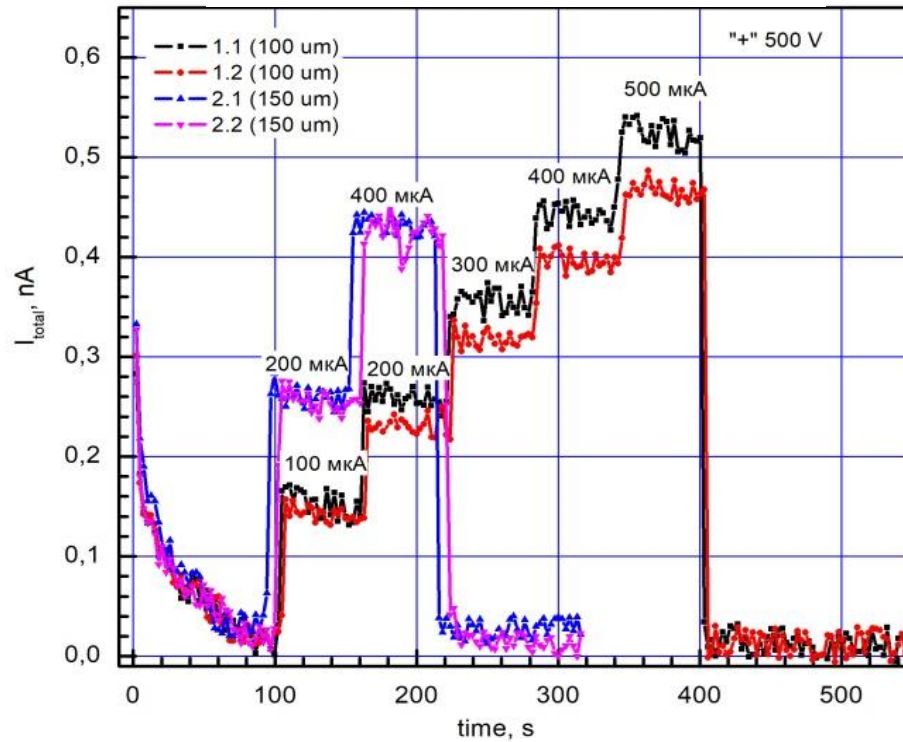
Channels #	20
Strip length, mm	12;
Strip width, mm	0.7;
Strip pitch, mm	1;
Metallization	1 um Al
on both sides	

«Monocrystal» plate, 100 um thickness
«Wuppertal» wafers, 100 um thickness

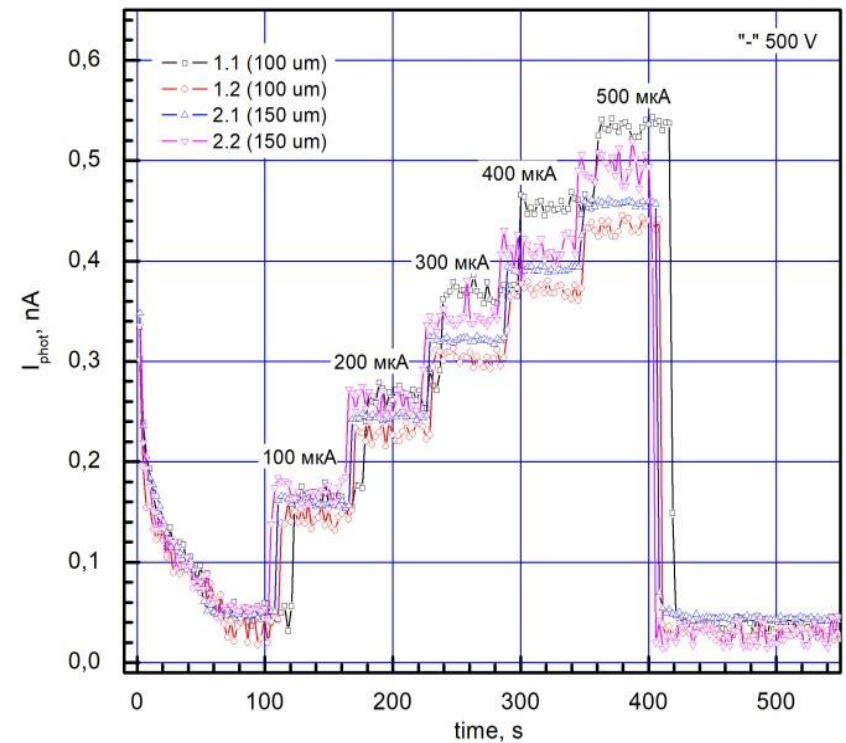
Pad sapphire sensors

Photocurrent under X-ray irradiation

Cathode irradiation



Anode irradiation



X-ray source:

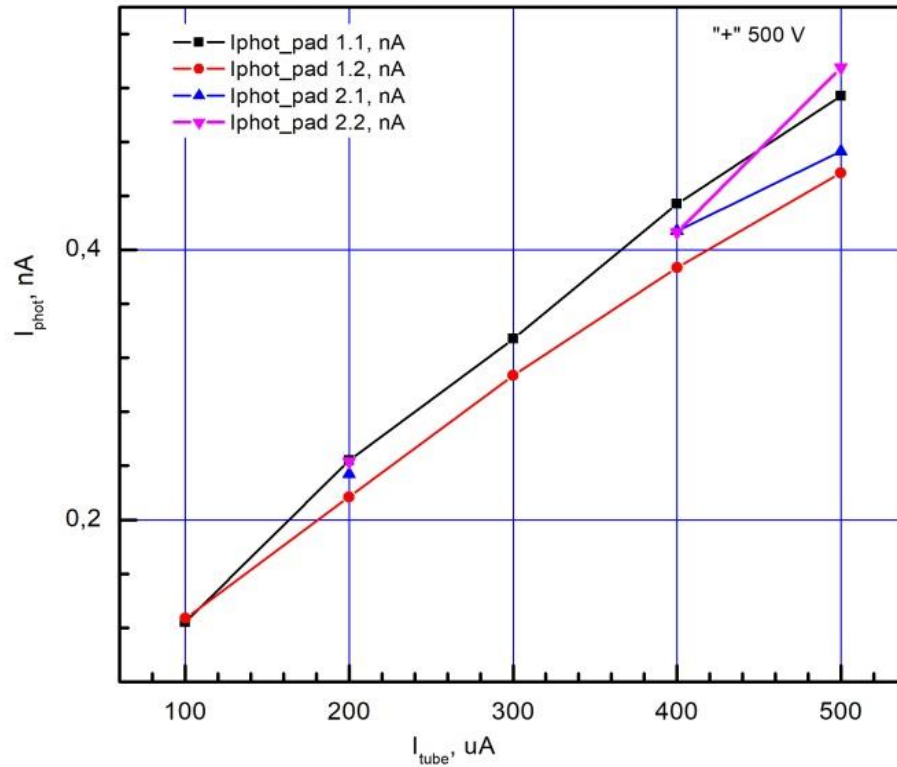
W anode X-ray tube,
60 kVp, 500 μA ,
60 s X-ray pulse duration

Sensor bias: 500 V

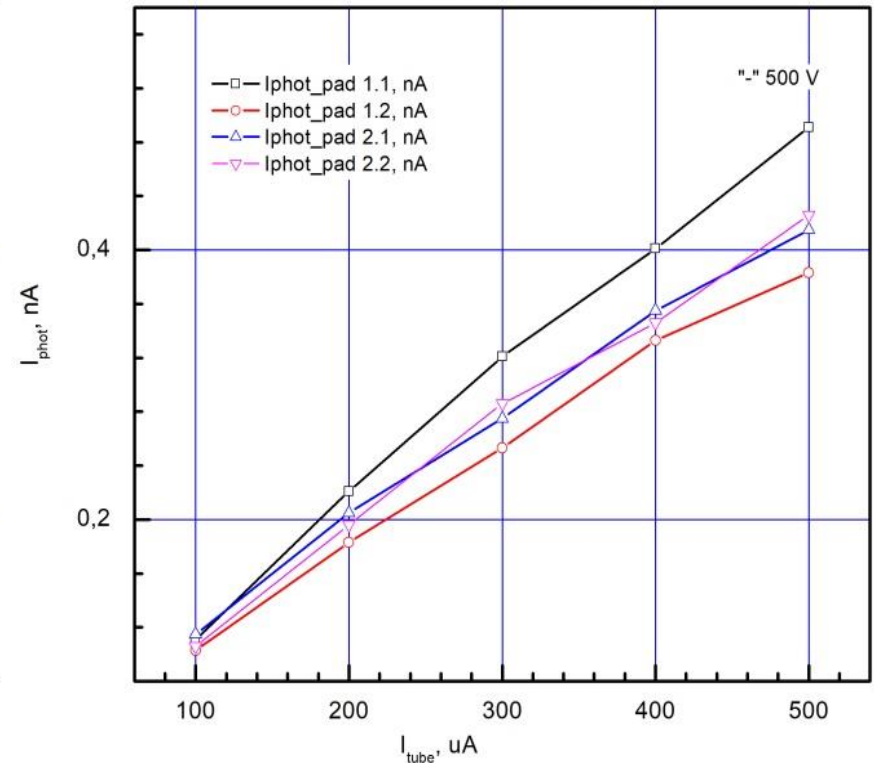
Pad sapphire sensors

Photocurrent under X-ray irradiation

Cathode irradiation



Anode irradiation



X- ray source:

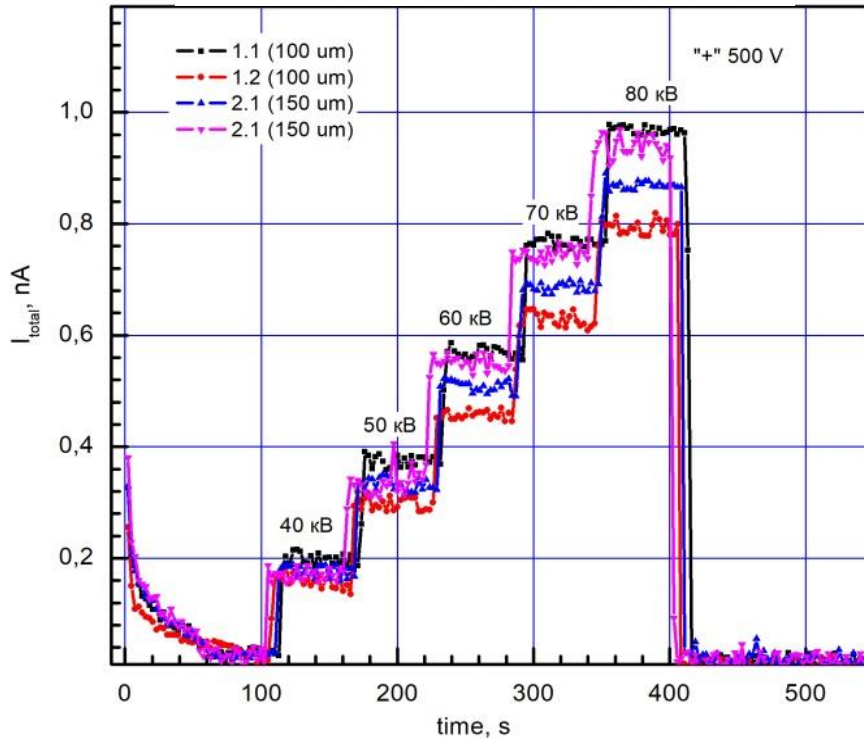
W anode X-ray tube,
60 kVp, I_{tube} variable
60 s X-ray pulse duration

Sensor bias: 500 V

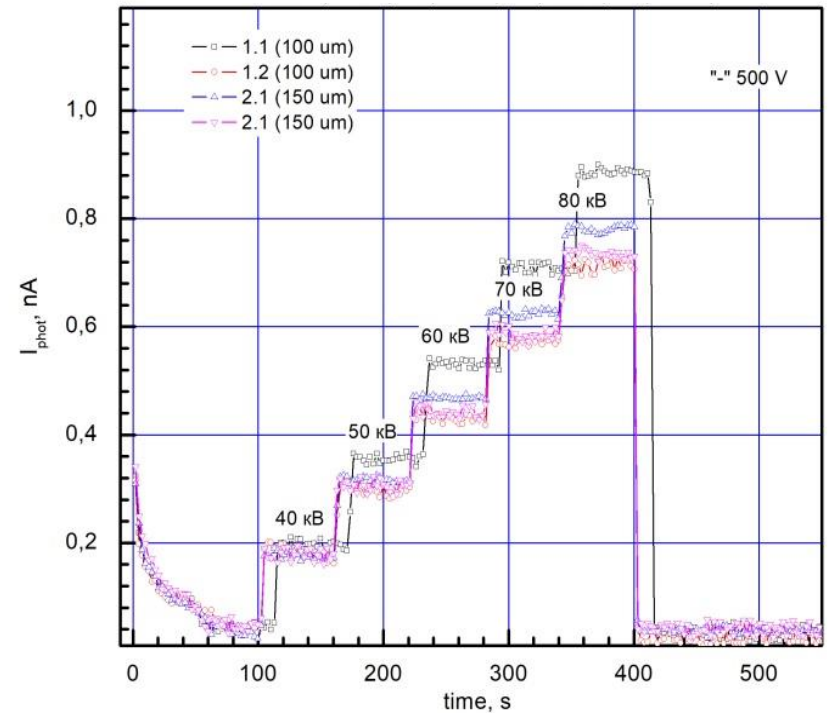
Pad sapphire sensors

Photocurrent under X-ray irradiation

Cathode irradiation



Anode irradiation



X-ray source:

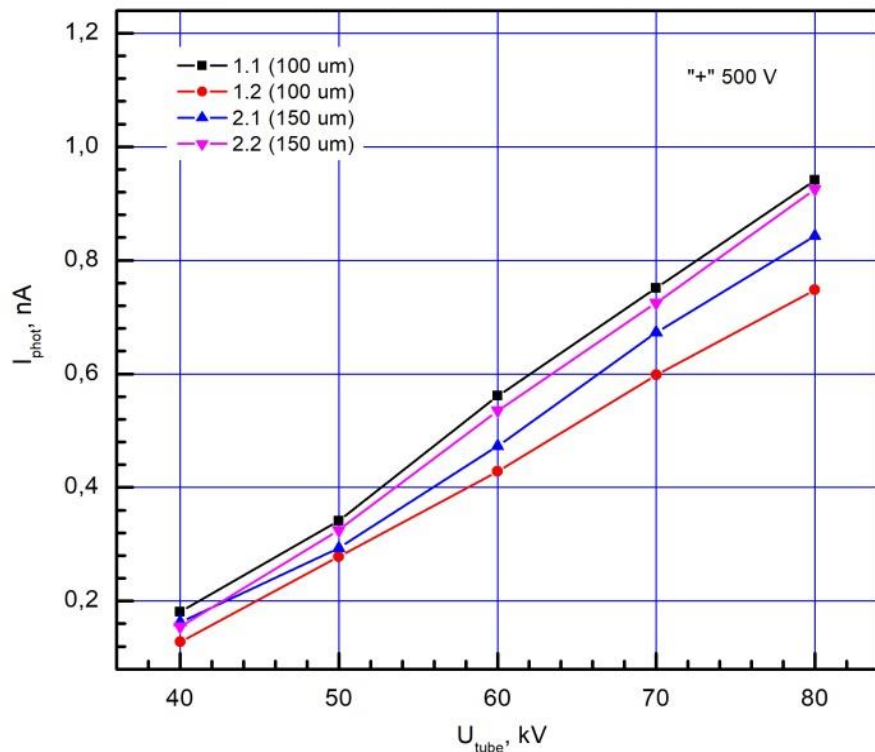
W anode X-ray tube,
Variable kVp, 500 μ A,
60 s X-ray pulse duration

Sensor bias: 500 V

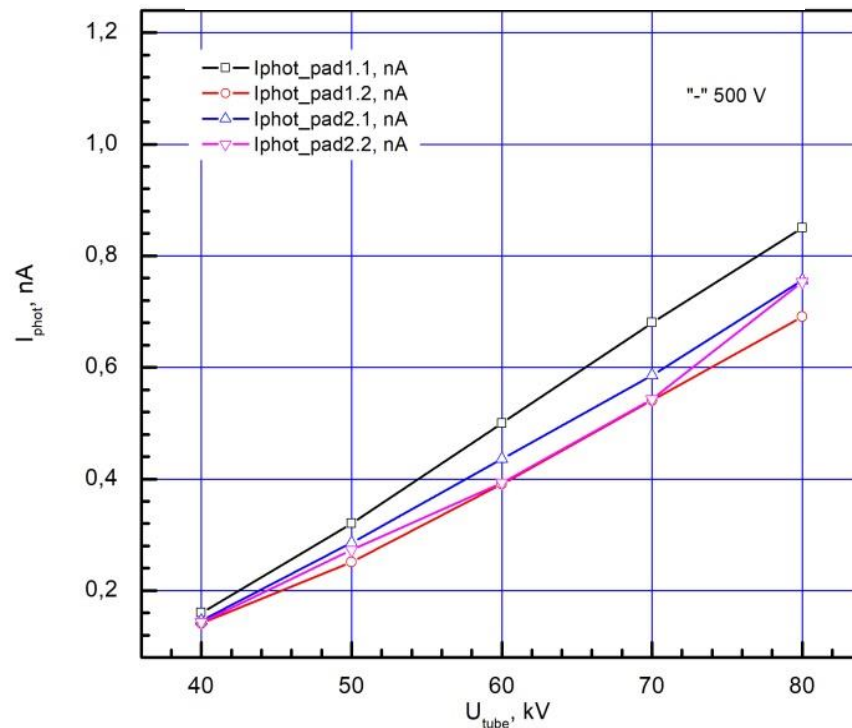
Pad sapphire sensors

Photocurrent under X-ray irradiation

Cathode irradiation



Anode irradiation



X-ray source:

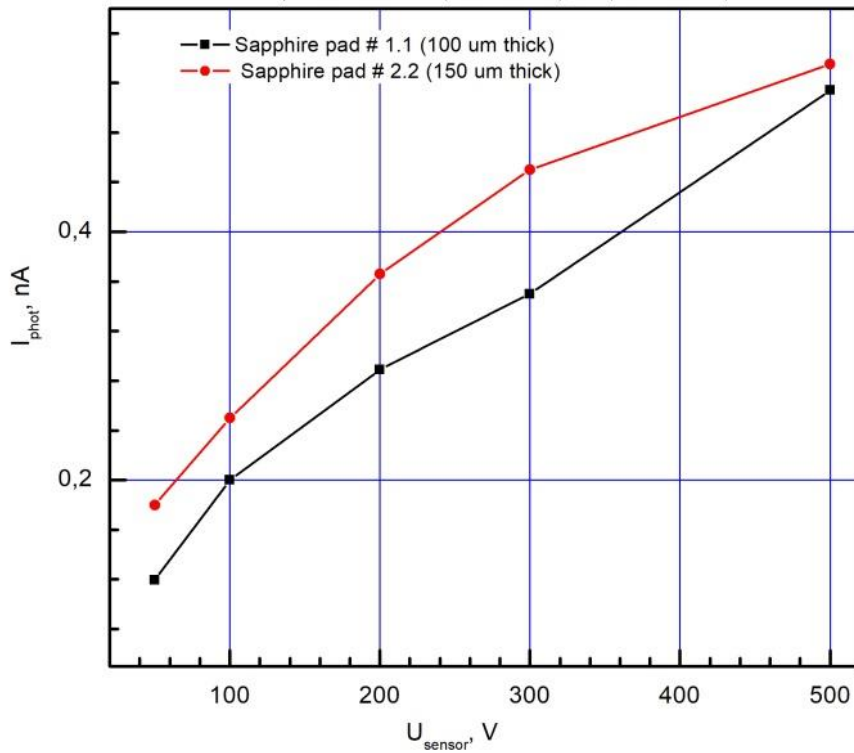
W anode X-ray tube,
Variable kVp, 500 μA ,
60 s X-ray pulse duration

Sensor bias: 500 V

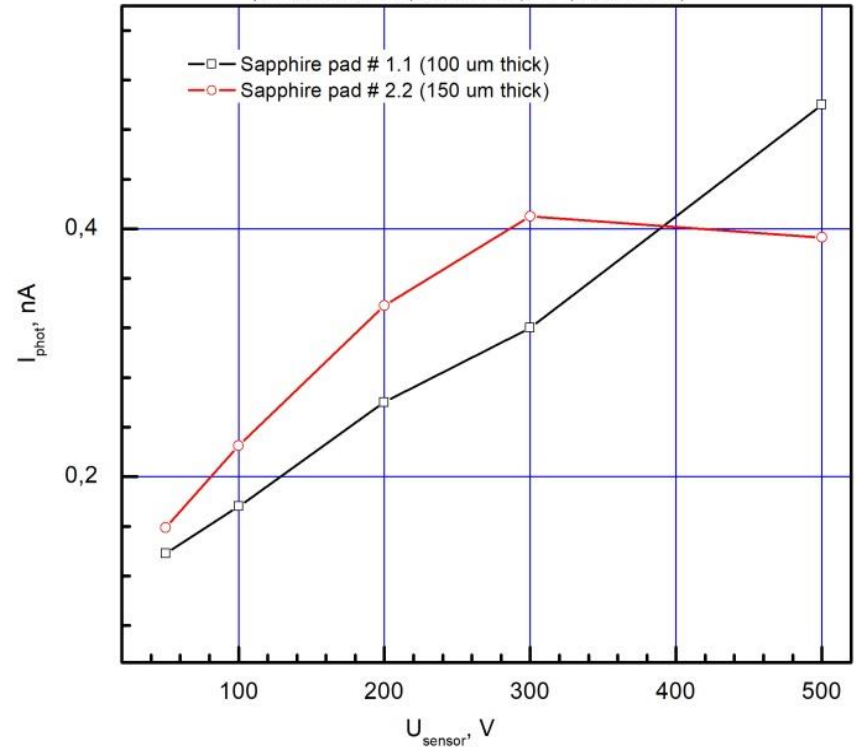
Pad sapphire sensors

Photocurrent under X-ray irradiation

Cathode irradiation



Anode irradiation



X-ray source:

W anode X-ray tube,

60 kVp, 500 μA ,

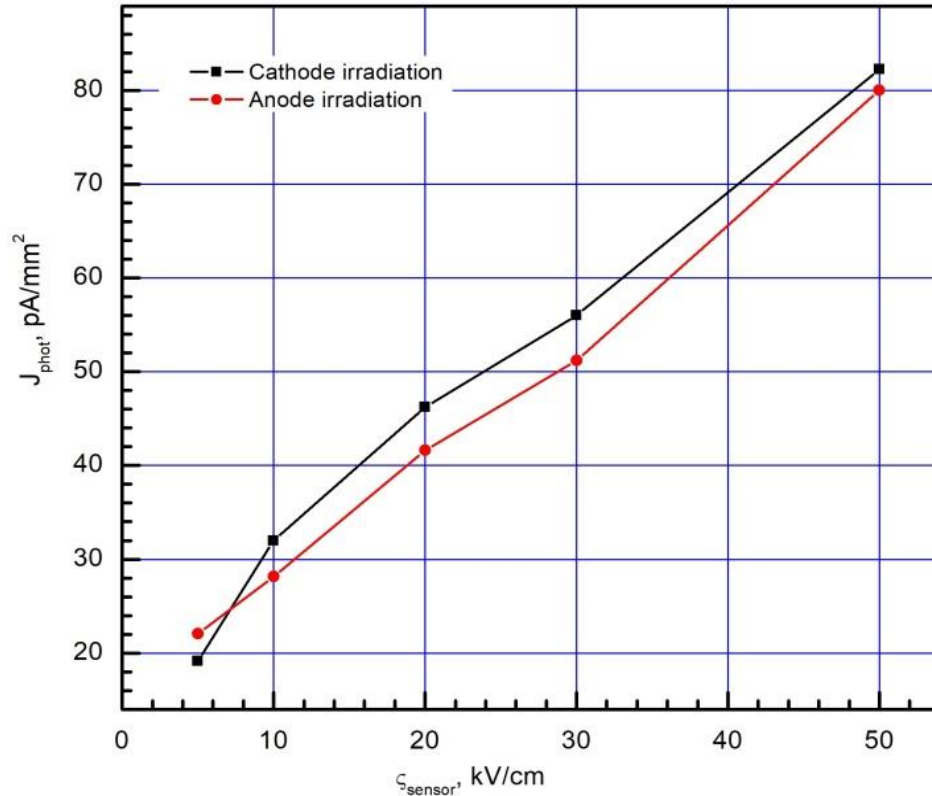
60 s X-ray pulse duration

Sensor bias: Variable

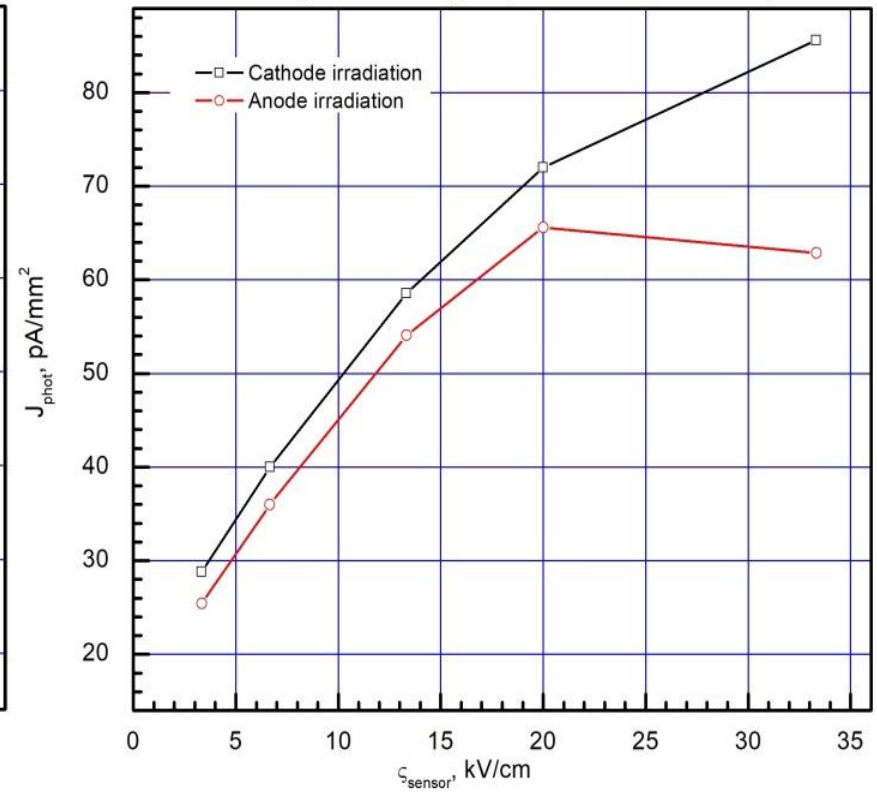
Pad sapphire sensors

Photocurrent under X-ray irradiation

pad 1.1 (100 μm)



pad 2.2 (150 μm)



X-ray source:

W anode X-ray tube,
60 kVp, 500 μA ,
60 s X-ray pulse duration

Sensor bias: Variable

Conclusion

Sapphire X-ray pad sensors were produced and tested under X-ray beam irradiation

It was shown that sensors have close to linear photocurrent dependence on X-ray tube current and X-ray tube bias

It was demonstrated absence of long term polarization effect under low intensity X-ray beam

Thank you for your time !