Chromium Compensated Gallium Arsenide Sensors Evaluation Using Photon Counting Electronics

J. Kalliopuska[1], D. Nalyvaiko[1], V. Gnatyuk[1], S. Vähänen[1], J. Jakubek[2], S. Polansky[2], E. Maddox[3], E. Hogenbirk[3], J. Lange[4], Y. Tsujita[5], M. Kuribayashi[5], S. Mikusu[5], K. Matsushita[5] Oriane Baussens[6], Petr Smolyanskiy[7]

[1] ADVAFAB Oy, Saukonpaadenranta 2, Helsinki, FI-00180, Finland
[2] ADVACAM s.r.o., U Pergamenky 12, 17000 Praha 7, Czech Republic
[3] Amsterdam Scientific Instruments B.V., Science Park 106, 1098 XG Amsterdam, The Netherlands
[4] X-Spectrum GmbH, Luruper Hauptstraße 1, 22547 Hamburg, Germany
[5] Rigaku Corporation, 3-9-12 Matsubara-cho Akishima-shi, 196-8666 Tokyo, Japan
[6] ESRF - The European Synchrotron Radiation Facility, 71 Av. des Martyrs, 38000 Grenoble, France
[7] Institute of Experimental and Applied Physics, IEAP CTU, Husova 240/5, 110 00 Prague 1, Czech Republic

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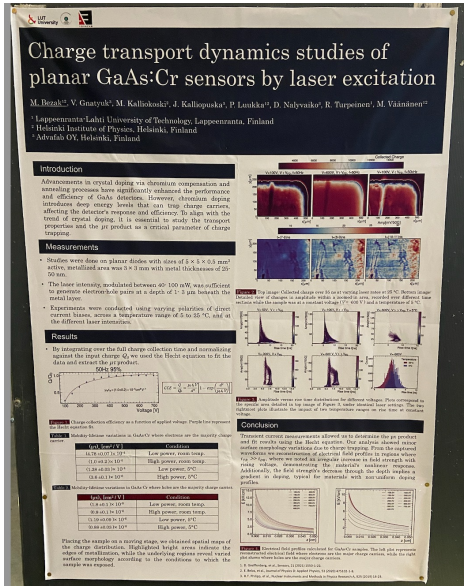
GaAs Properties and Benefits

Further information see poster #191 by **Mihaela Bezak**, Helsinki Institute of Physics: “*Charge transport dynamics studies of planar GaAs:Cr sensors by laser excitation*“



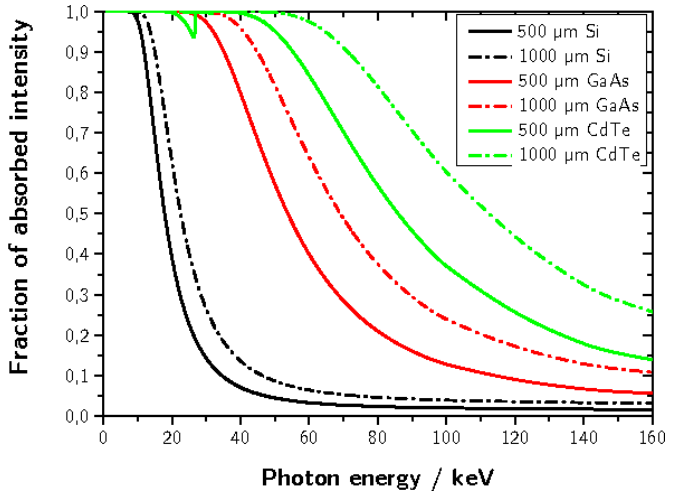
GaAs properties and benefits

Benefits:

- Higher electron mobility (2230 GaAs vs 1400 Si) => "better" charge collection
- Higher average atomic number (32 GaAs vs 14 Si) => higher radiation absorption efficiency
- **Small fluorescence probability and short distance of fluorescence photons** (50%, 11-12 keV vs 85%, 26-31 keV CdTe)
- Wider bandgap (1.43 GaAs vs 1.12 Si) => superior radiation hardness
- Better stability (<0.1% GaAs vs >1% CdTe) => stable imaging properties

Material	***Silicon***	***GaAs:Cr***	***CdTe***
Average atomic weight	14	32	50
Density (g/cm3)	2,33	5,32	5,85
Band gap (eV)	1,12	1,43	1,5
Resistivity (Ohm-cm)	~1E+4	**~1E+9**	~1E+9
Electron mobility (cm2/Vs)	1400	**1440-2230**	1100
Hole mobility (cm2/Vs)	480	400	100
$\mu\tau$ electrons	>1	**1-5E-4**	~1E-3
$\mu\tau$ holes	>1	~1E-4	1-10E-6
Stability (10 min)	<0.01%	**<0.1%**	1-10%

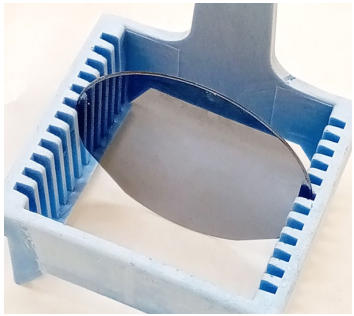
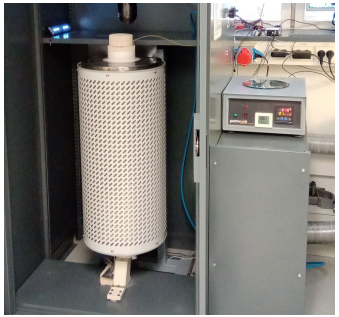
*Several sources used

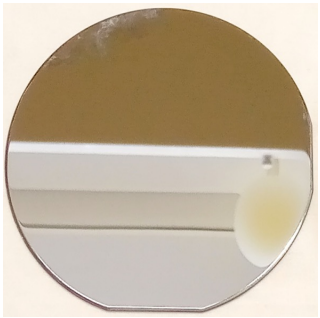
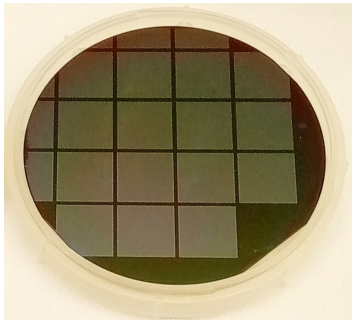
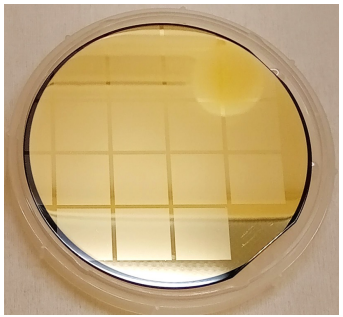
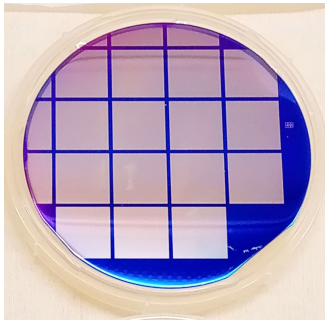
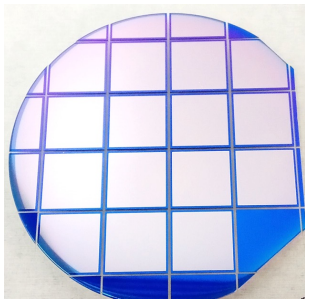


3″ Cr Compensated GaAs Wafer Processing

3” Cr compensated GaAs process flow

- Process flow: Cr sputtering, Annealing, Polishing, Passivation, Lithography, Contact metal, Lithography, UBM sputtering, Dicing and Flip-chip bonding

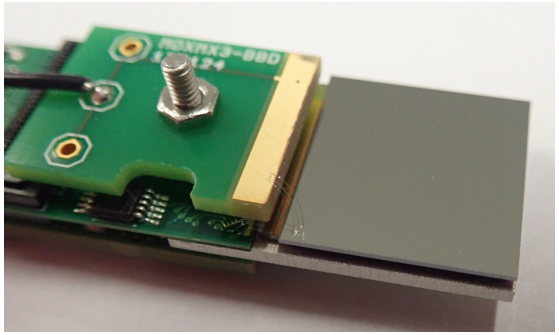

Chromium Compensated of GaAs Sensors Evaluated with TPX1

Stepan Polansky

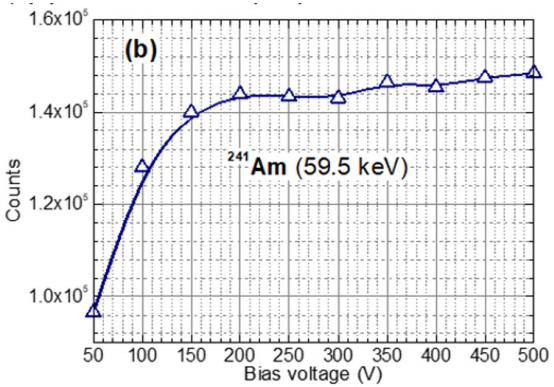
ADVACAM s.r.o

GaAs uniformity and energy resolution

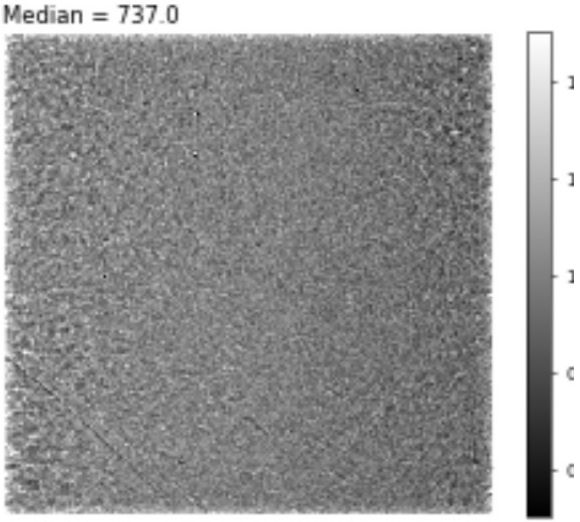
- Fluorescence of Cd target was used
- Good uniformity observed
- Optimal operation voltage for 500 um thick GaAs at 250 V



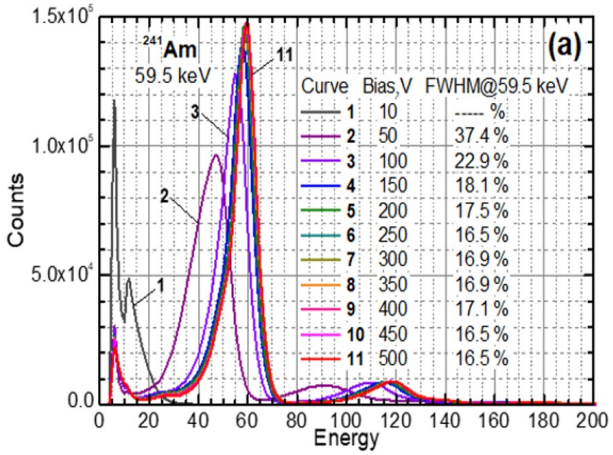
Charge collection vs bias voltage



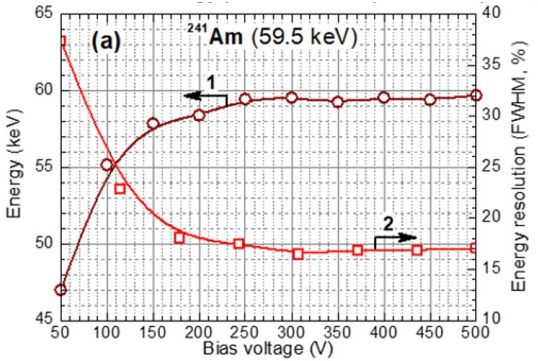
Advafab MiniPIX TPX1-GaAs 2022



Am-241 spectrum



Peak position and energy resolution



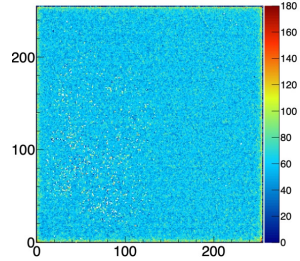
Chromium Compensated of GaAs Sensors Evaluated with TPX3

Petr Smolyanskiy, Institute of Experimental and Applied Physics

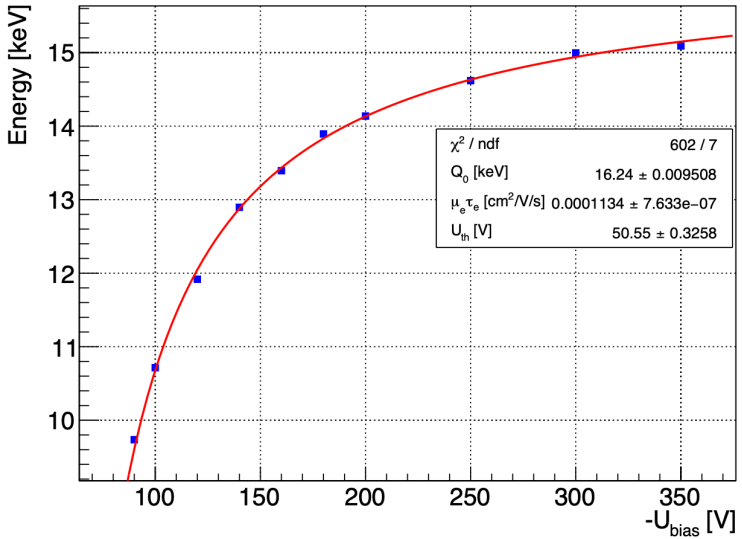
Erik Maddox, Erik Hogenbirk, Amsterdam Scientific Instruments

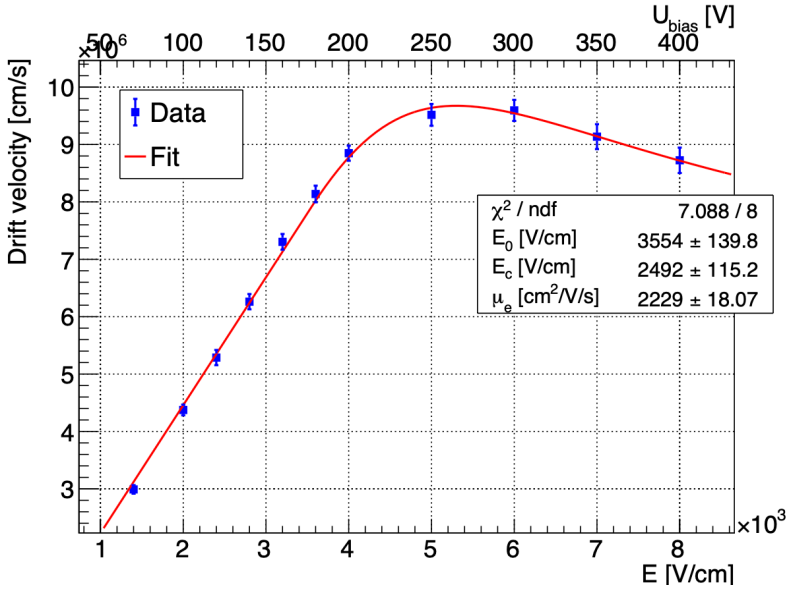
Oriane Baussens, ESRF - The European Synchrotron Radiation Facility

Charge transport properties (IEAP)



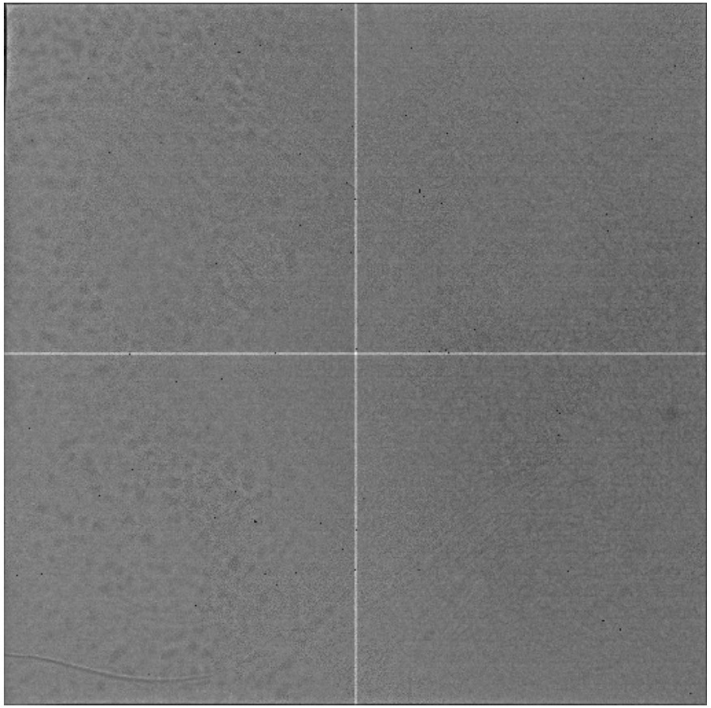
- Mobility lifetime $\mu_e \tau_e$ = 1.1 × 10−4 cm²/V/s measured using Zr XRF (16 keV)
- Electron mobility 2230 cm²/Vs and 50 ns lifetime measured using MIP 15 GeV pions

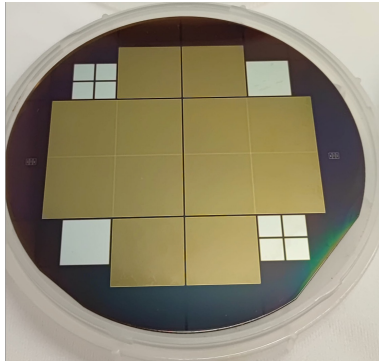


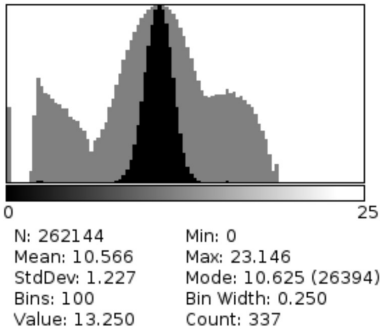


GaAs quad uniformity and spatial resolution (ASI)

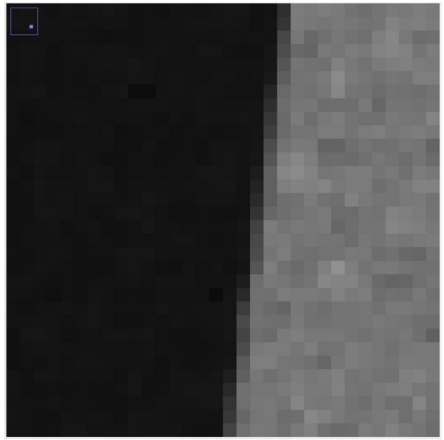
- TPX3 detector, X-ray tube 30 kVp, W target, 200 s
- Bias -200 V, leakage current 90 uA, ASIC temperature 50-60 C

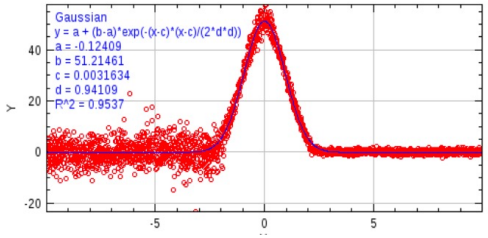






Sigma PSF = 0.9411

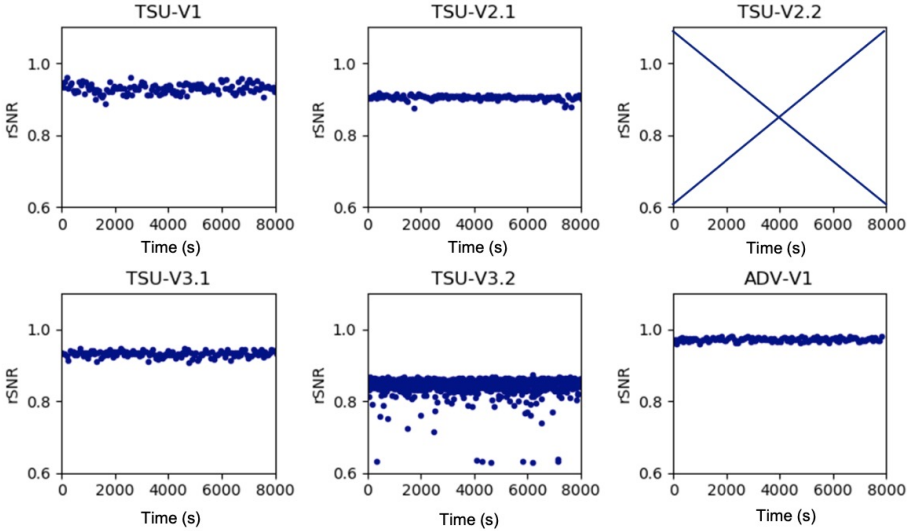


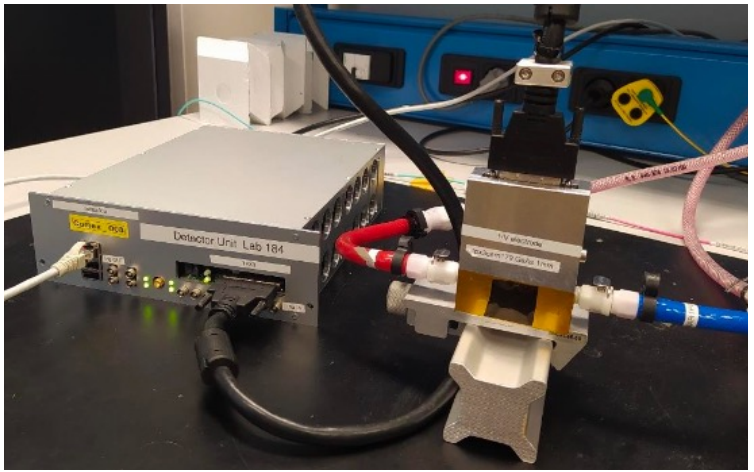


Flat field correction stability (ESRF)

- X-ray tube 25 kVp, Mo anode, 17.5 keV, 25 mA, flux 2 Mph/s/mm^2
- Relative signal-to-noise ratio (rSNR) – comparison to Poisson distribution
- ADV-V1 has the most stable response over wide energy range and best stability over time

Flat field stability (threshold 9 keV)





Chromium Compensated of GaAs Sensors Evaluated with MiniPIX Sprinter (TPX2)

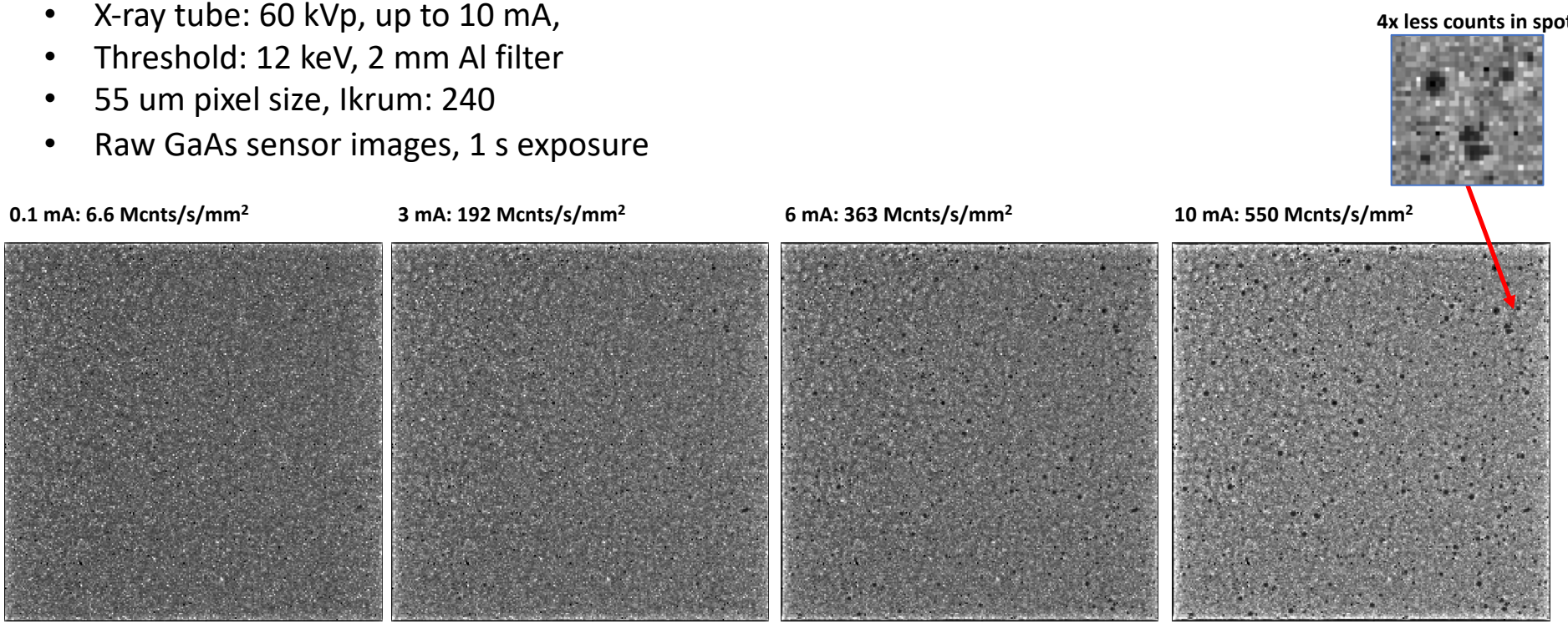
Jan Jakubek

ADVACAM s.r.o

Thursday, 4th July at 11.40, Applications session, Jan Jakubek, ADVACAM s.r.o: "*Optimization of energy resolution and/or stability for Timepix type photon counting detectors: 130 eV rms and/or images with SNR=1000 taken at 760 MCounts/mm2/s*"

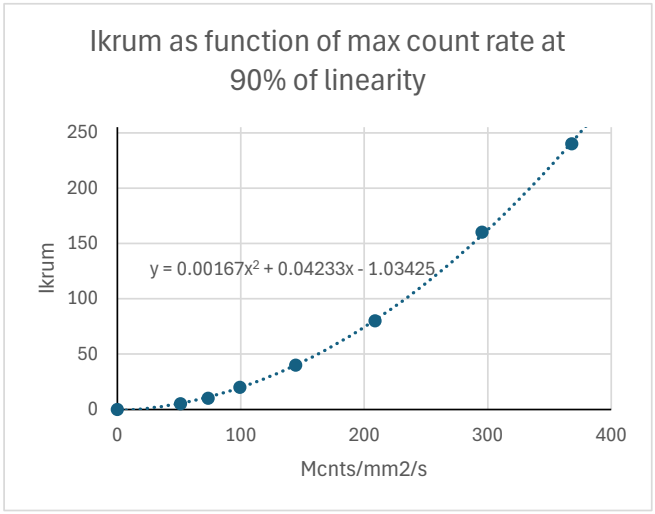
High flux operation

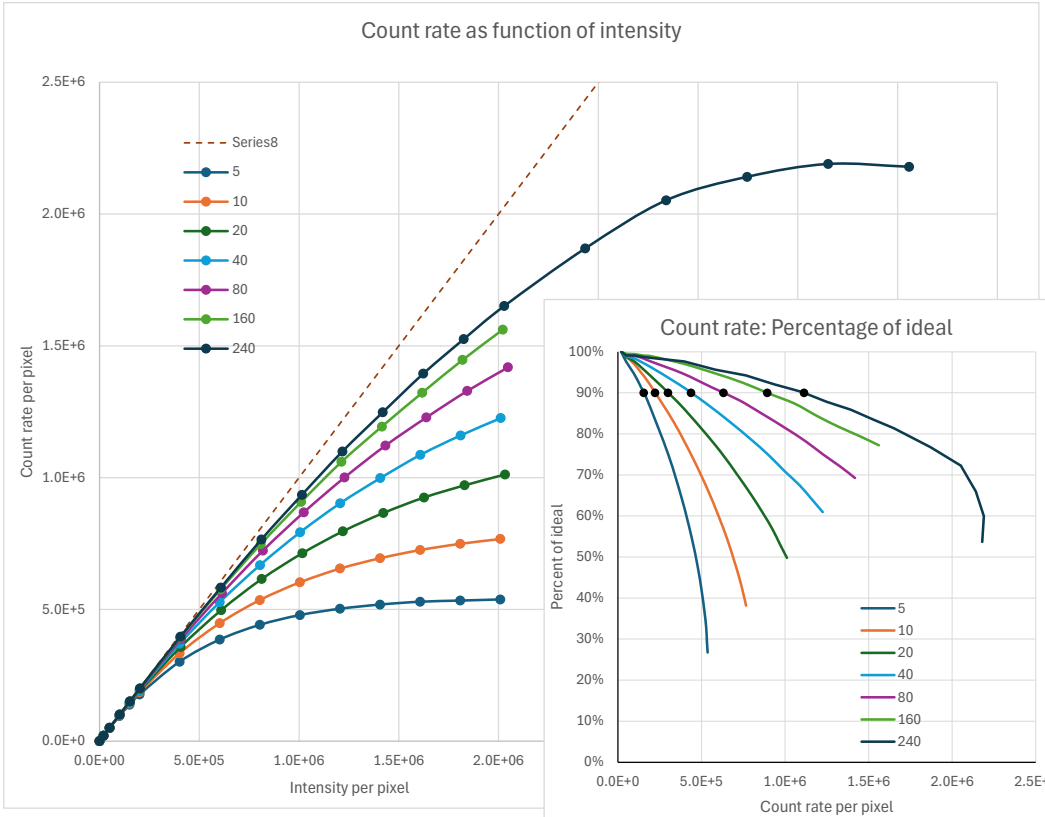
- X-ray tube: 60 kVp, up to 10 mA,
- Threshold: 12 keV, 2 mm Al filter
- 55 um pixel size, Ikrum: 240
- Raw GaAs sensor images, 1 s exposure



High flux operation

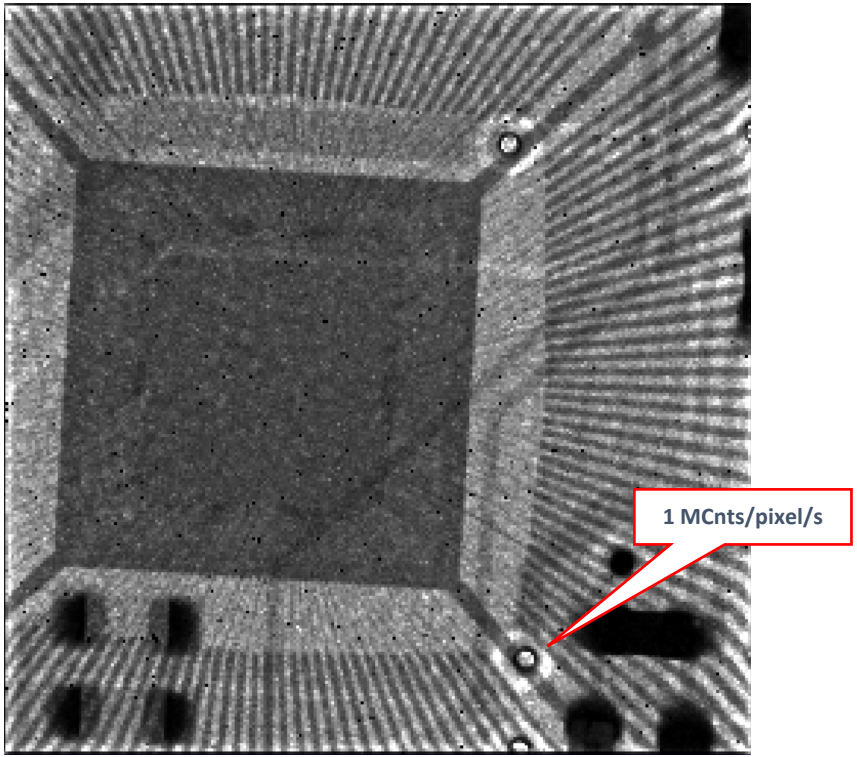
- X-ray tube: 60 kVp, up to **20 mA**,
- Threshold: 12 keV, 2 mm Al filter
- Varied Ikrum settings 5-240
- **90% max count rate** achieved with Ikrum 240 up to **370 MCnts/s/mm²**



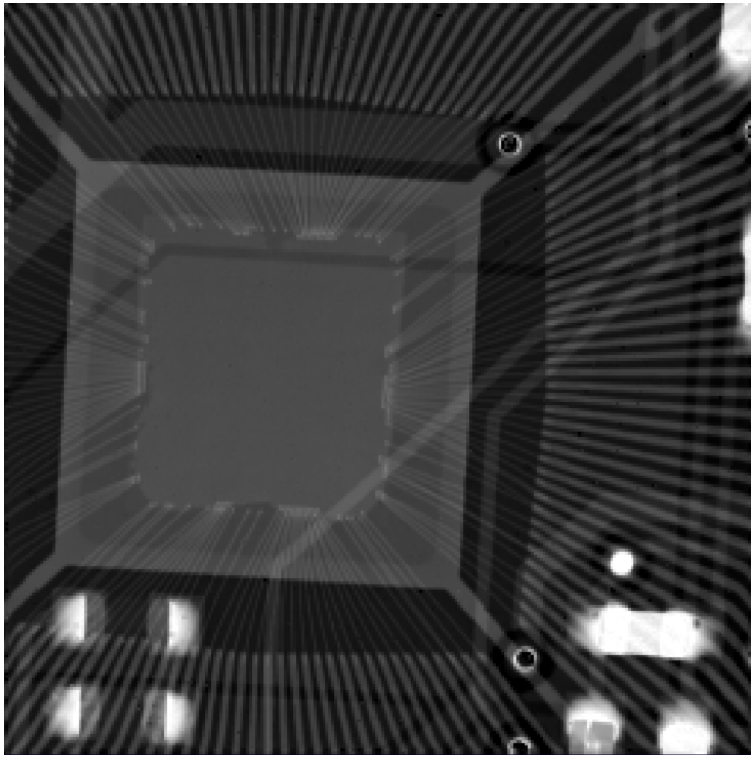


High flux operation imaging

Raw image at **370 MCnts/s/mm^2**

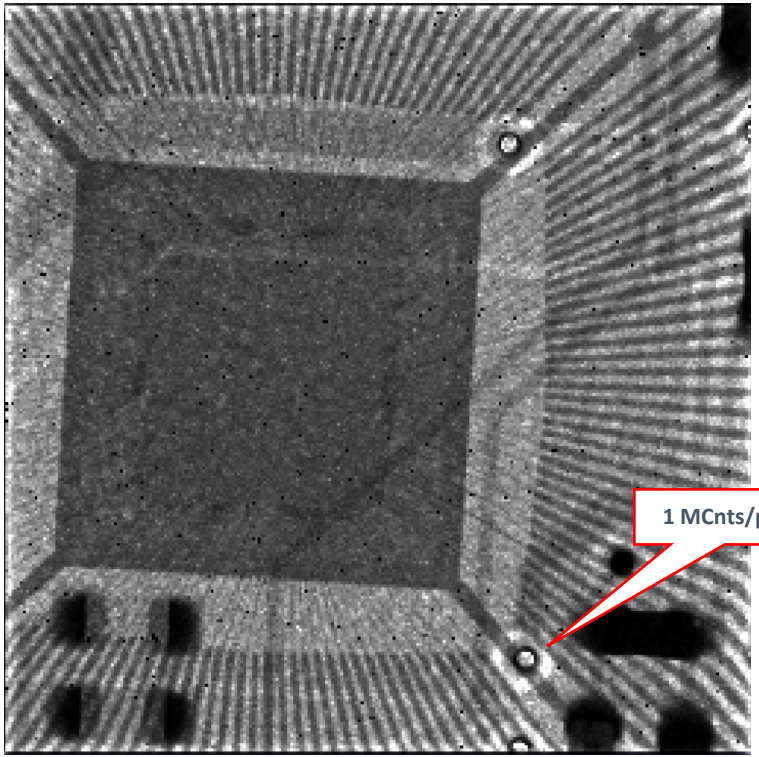


BH corrected at **370 MCnts/s/mm^2**

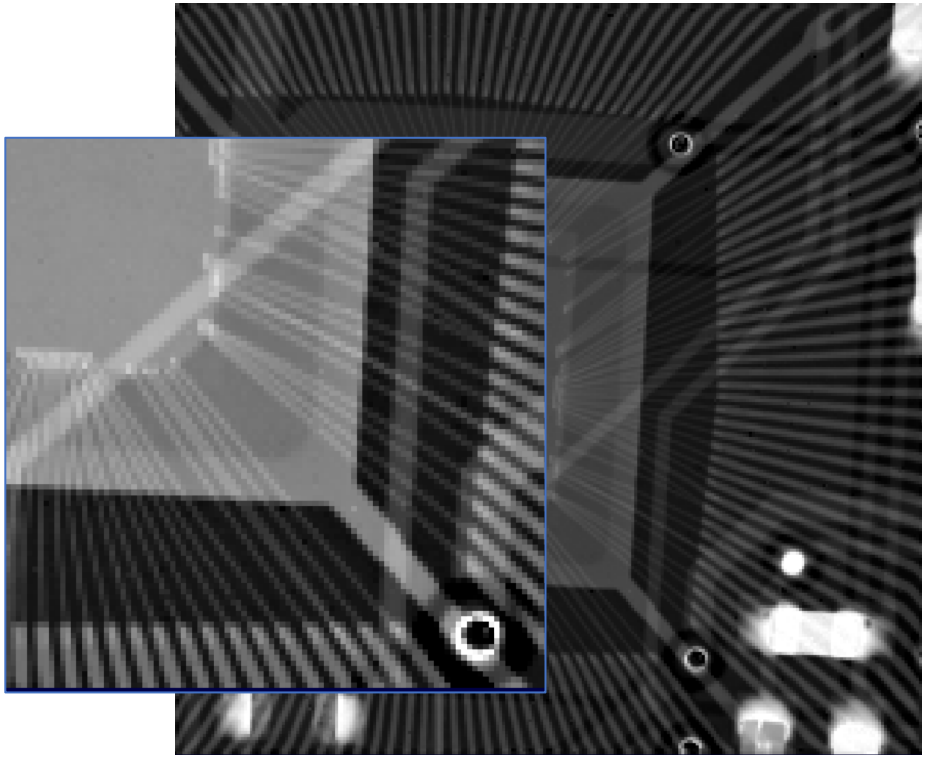


High flux operation imaging

Raw image at **370 MCnts/s/mm^2**



BH corrected at **370 MCnts/s/mm^2**



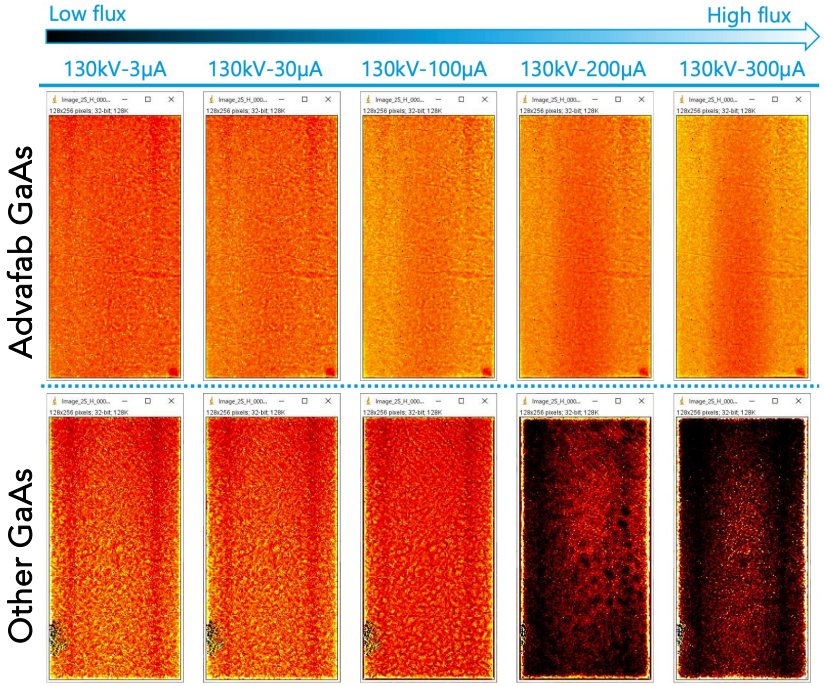
Chromium Compensated of GaAs Sensors Evaluated with UFXC32k

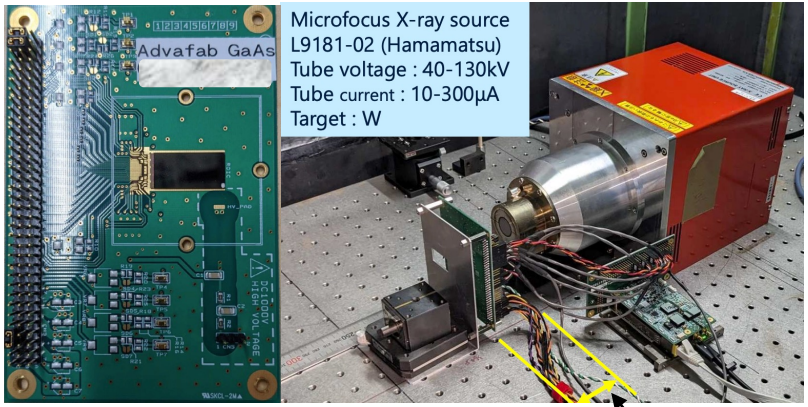
Yuya Tsujita, Masaru Kuribayashi, Satoshi Mikusu, Kazuyuki Matsushita

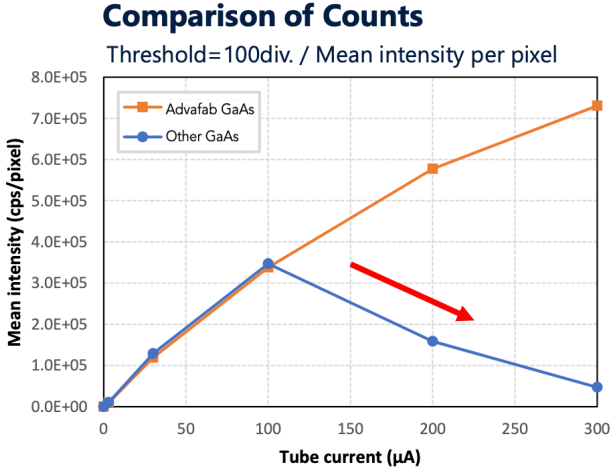
Rigaku Corporation

High flux operation

- Sensor pixel pitch of 75 um placed 80 mm away from tube
- Tube voltage 130 kV up to 300 uA







- Measured count rate up to **130 Mcnt/s/mm²**
- No observable decradation in the sensor performance

Summary and further work

- Applications foreseen in medical, mammography, small animal imaging, electron microscopy, synchrotrons and non-destructive testing of composite materials
- GaAs material is currently well suitable for photon counting applications
- Guard ring and edgeless GaAs samples are available
- Come ask for further details how to receive GaAs pixel sensor samples

Further work

- Reduce leakage current and improve energy resolution for charge integrating readout electronics and spectroscopic diodes
- Thicker sensors ~1 mm
- Larger wafer size 3” => 4”