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Digital X-ray portable scanner based on monolithic semi-insulating GaAs detectors:

General description and first "quantum" images

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OUTLINE

- **MOTIVATION**
  - GaAs material properties
  - Line scan operation
- **DETECTORS**: LEC SI GaAs strip line in edge on configuration
  - Characterization of tested detectors
  - Etched trenches in strip line technology
  - Tests of parallel strip connection
  - Microfocus beam tests
- **SCANNER CONSTRUCTION**
- ***FIRST IMAGES* OBTAINED WITH X-ray SCANNER**
- **CONCLUSIONS**

MOTIVATION

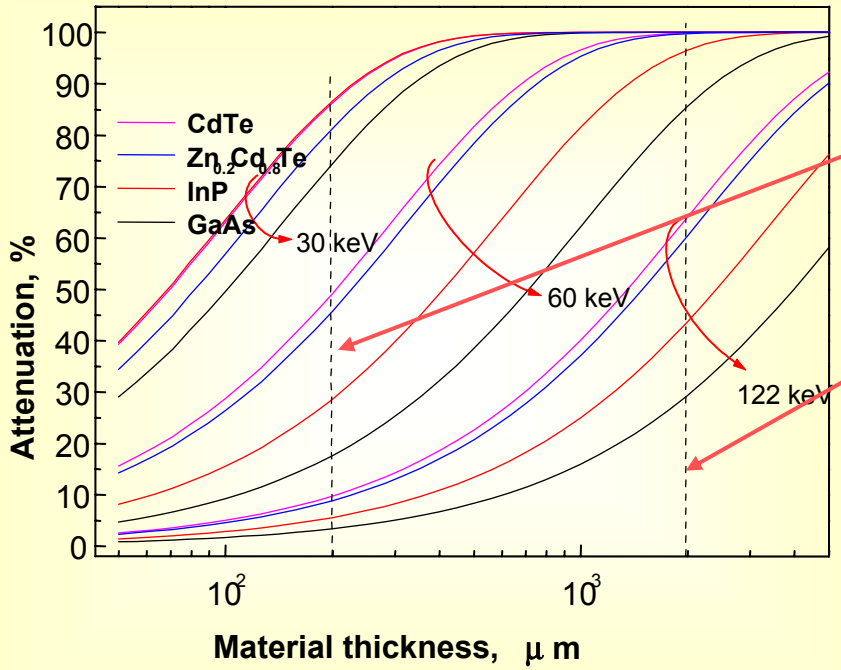
GaAs MATERIAL PROPERTIES

- ✓ Radiation hardness
- ✓ Low cost
- ✓ Fast
- ✓ Wide band gap – operation at RT
- ✓ Highly developed technology processing
- ✓ Easily commercially available

LINE SCANNING TECHNIQUE IN RADIOGRAFIC IMAGING

- ✓ Technical simplest solution
- ✓ Low cost
- ✓ Useful for fast testing of detector applicability in X-ray imaging
- ✓ High quality of X-ray image (good scattered rejection)
- ✓ Useful for many industrial and even medical applications

CHOICE OF GaAs DETECTOR – X-ray SOURCE GEOMETRY



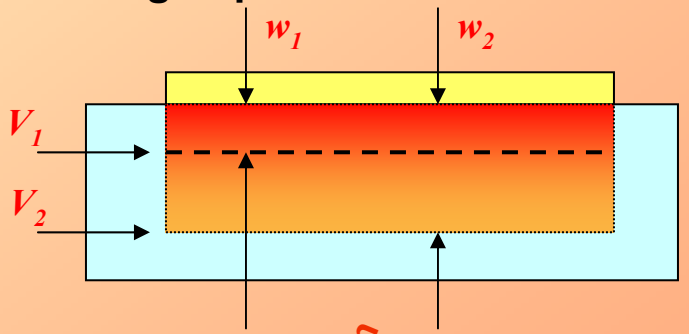
Two modes of detector irradiation:

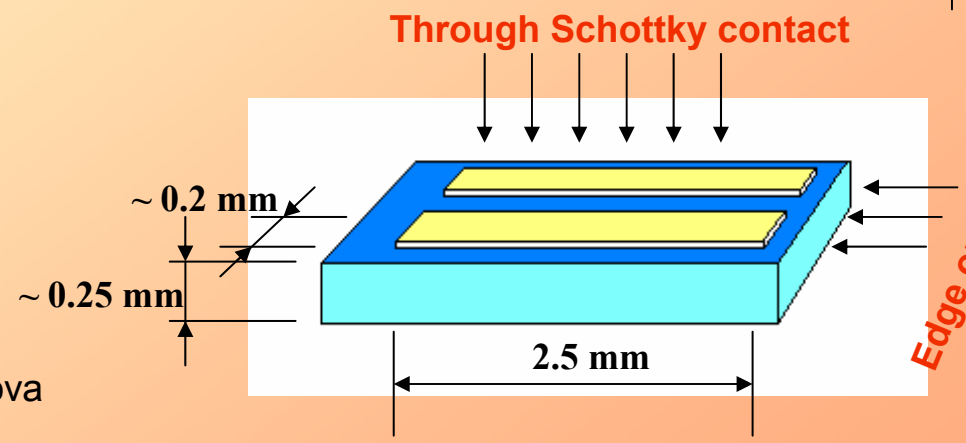
Through Schottky contact:

- **absorption length 0.25 mm 25% @ 60 keV**

Edge on configuration:

- **absorption length 2.5 mm 85% @ 60 keV,**
- **high spatial resolution**





CHARACTERIZATION OF INVESTIGATED STRIP LINE DETECTOR

Substrate: 250 μm of bulk undoped LEC SI GaAs - (CMK Ltd, Žarnovica, Slovakia) with resistivity of 5.2×10^7 Ωcm and Hall mobility of 5200 – 5800 $cm^2V^{-1}s^{-1}$

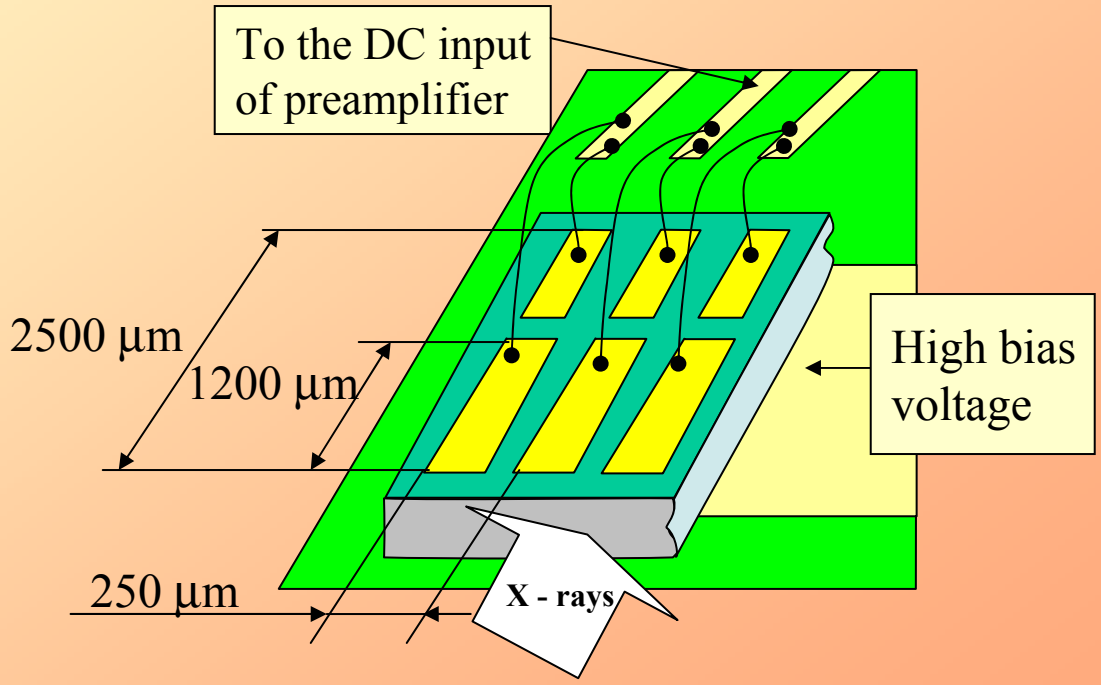
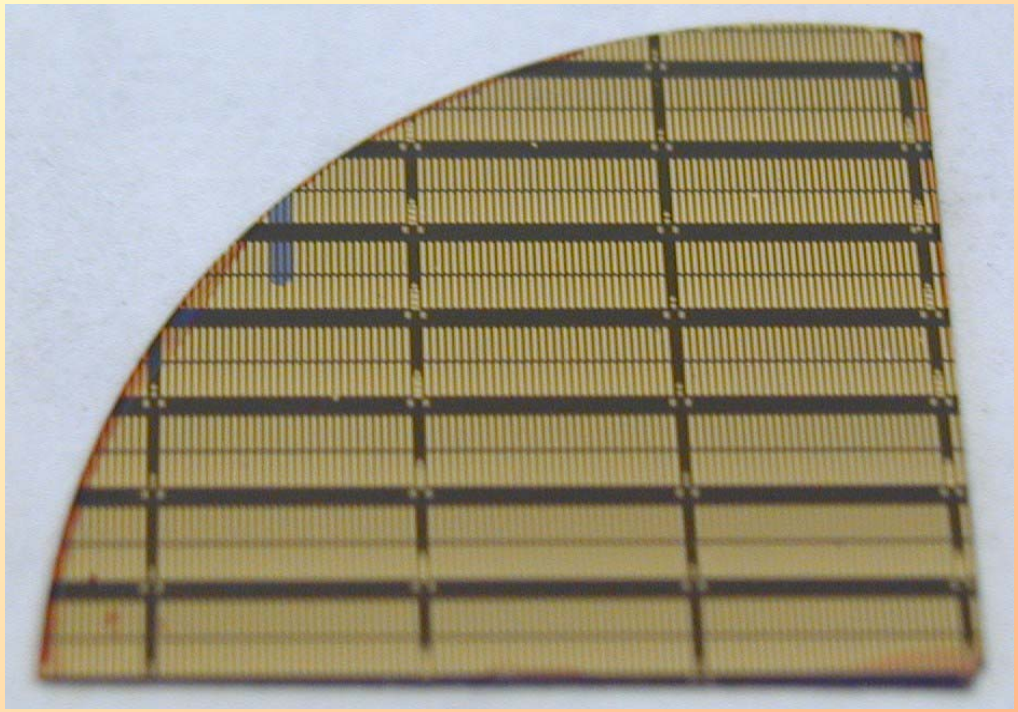
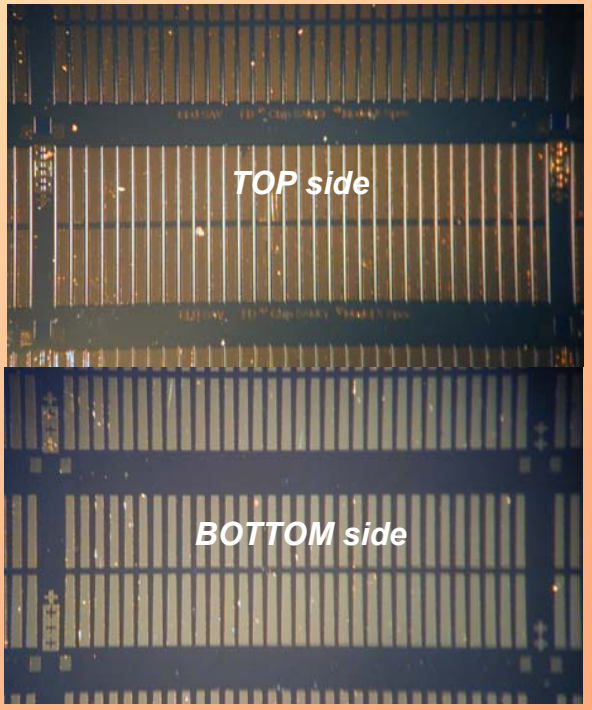


Photo and schematic view of monolithic strip line detector segment

SI GaAs strip line detector: SAMO-*XS*

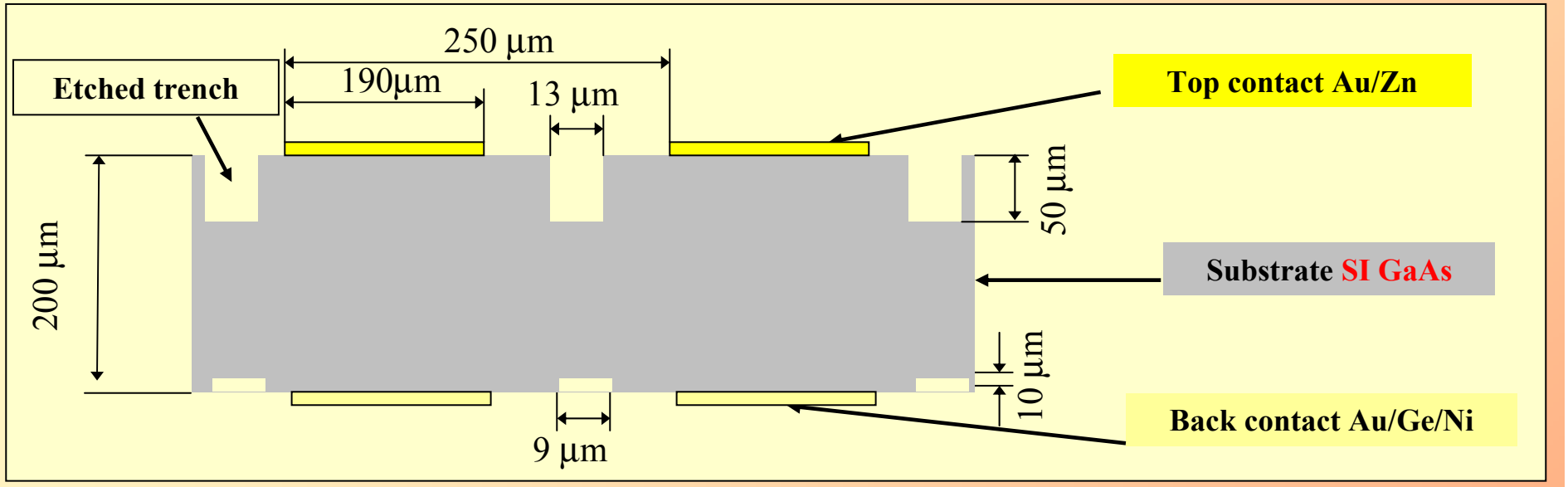
Number of strips in line	Pitch (mm)	Absorption length (mm)	Size of line detector (mm)	Effective absorption volume of strip (mm^3)	Maximum thickness of detector field (mm)
32	0.25	1.20 0.25	8 x 3.5	0.10 0.18	0.2 – 0.3

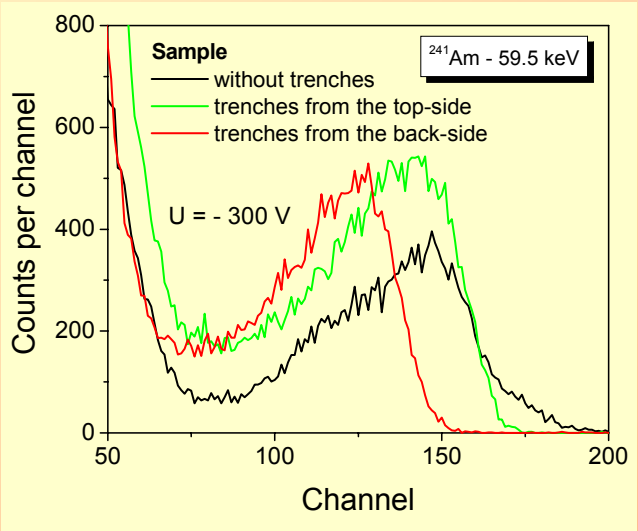


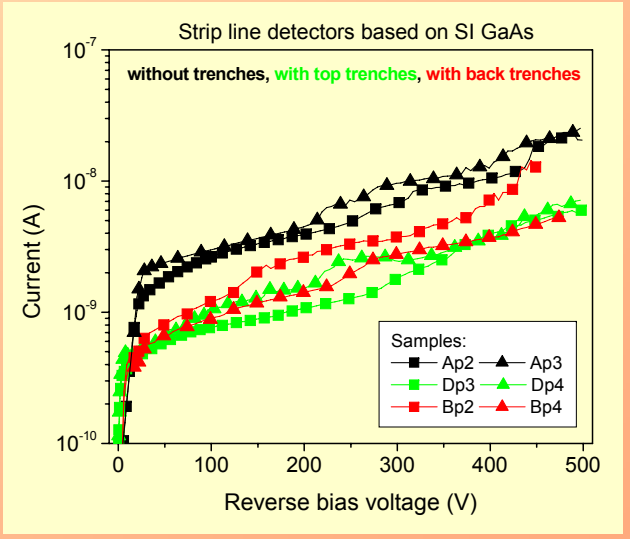


ETCHED TRENCHES IN TECHNOLOGY OF STRIP LINE DETECTORS

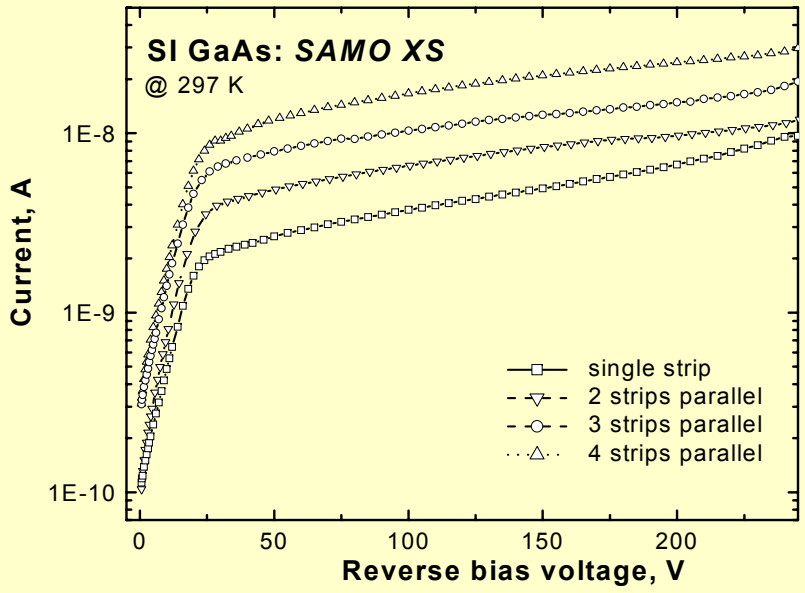
Trenches creation: RIE (reactive ion etching) technique, additional photolithographic masking (frame of 8 μm)

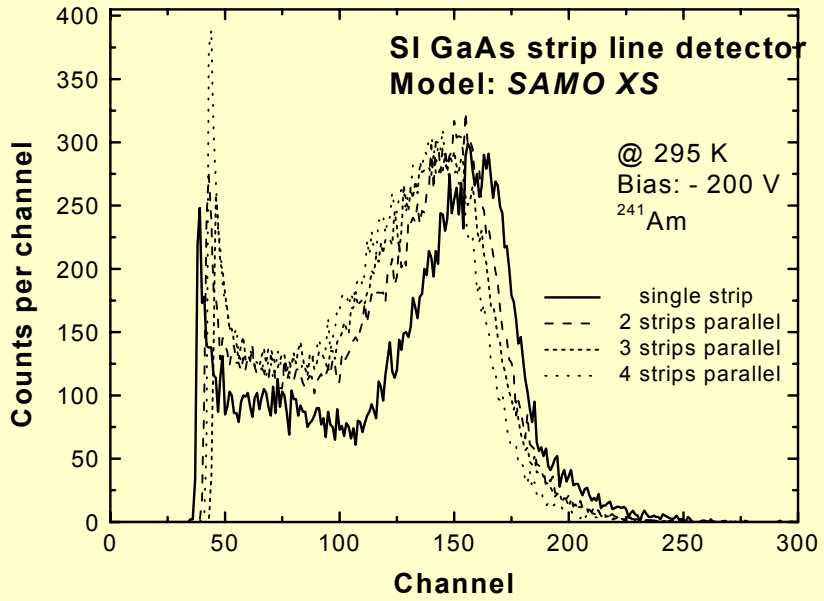


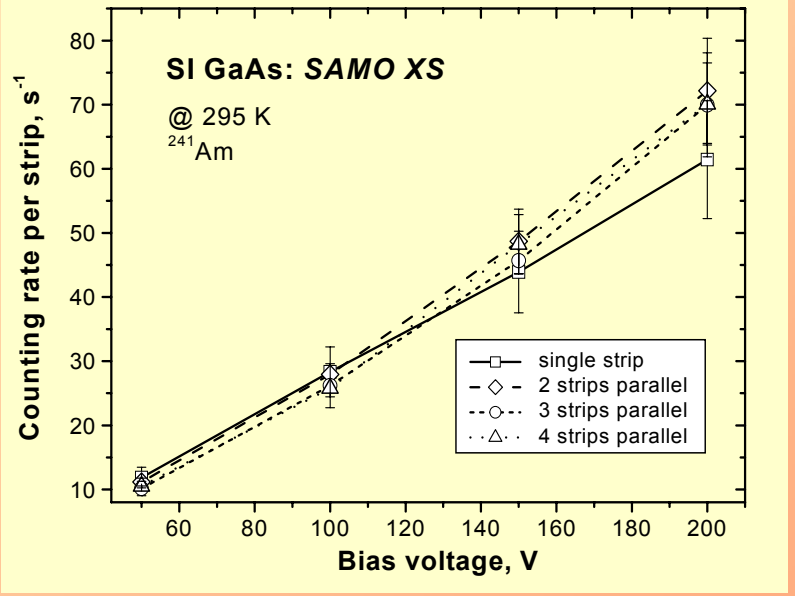




ELECTRIC AND DETECTION PROPERTIES OF PARALLELLY CONNECTED STRIPS



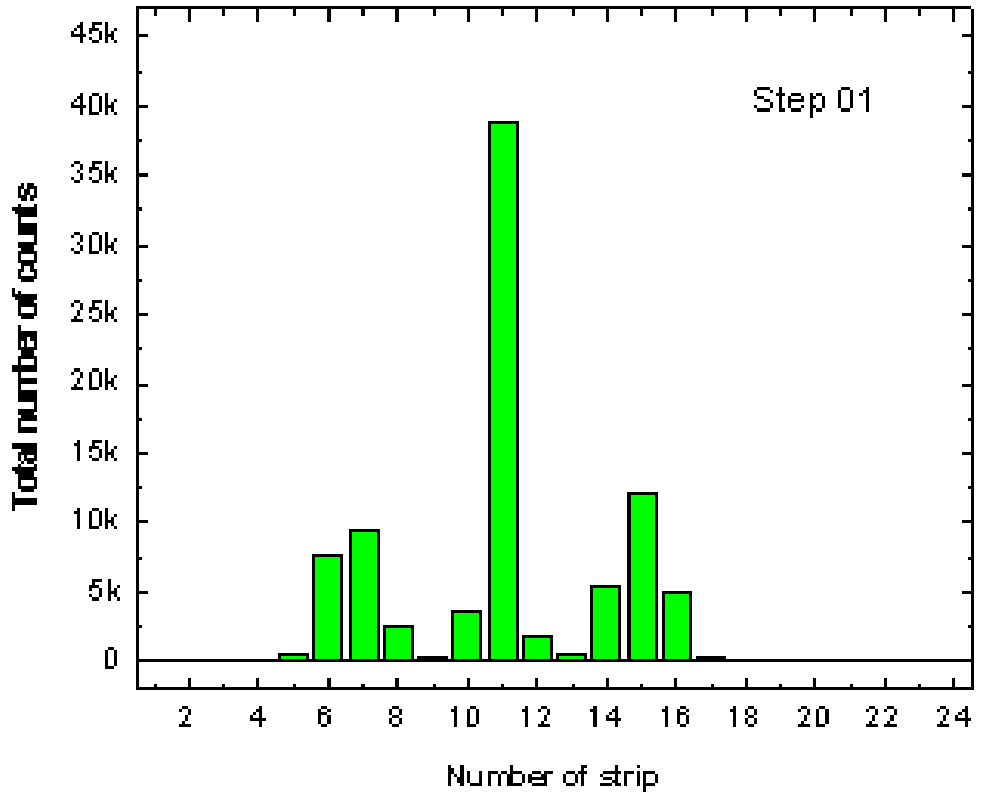




MICROFOCUS BEAM TEST OF CROSS-TALK BETWEEN NEIGHBOURING STRIP LINE DETECTORS

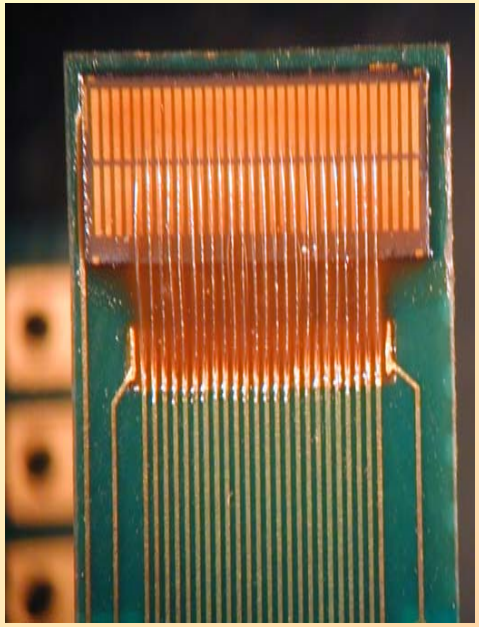
- **X-ray tube: 60 kV, 50 mA**
- **X-ray beam: Ø 250 μm**
- **Step: 25 μm starting from 11th to 13th strip**
- **Time of measurement: 1 s**

RESULT: Negligible cross-talk of strips in line determined

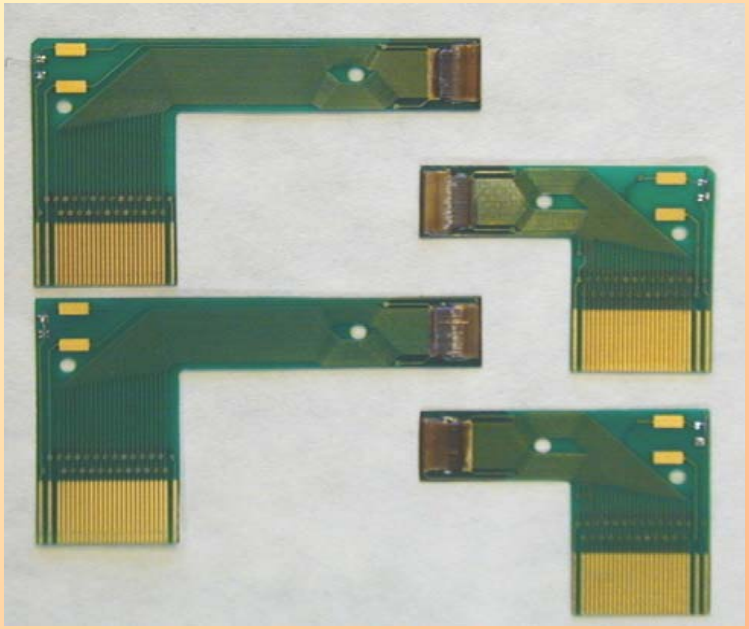


Authors are acknowledged to Fraunhofer Institut für Zerstörungsfreie Prüfverfahren EADQ Dresden for enabling the experiments

SI GaAs STRIP LINE DETECTOR ASSEMBLY



Detail of chip bonded on PCB

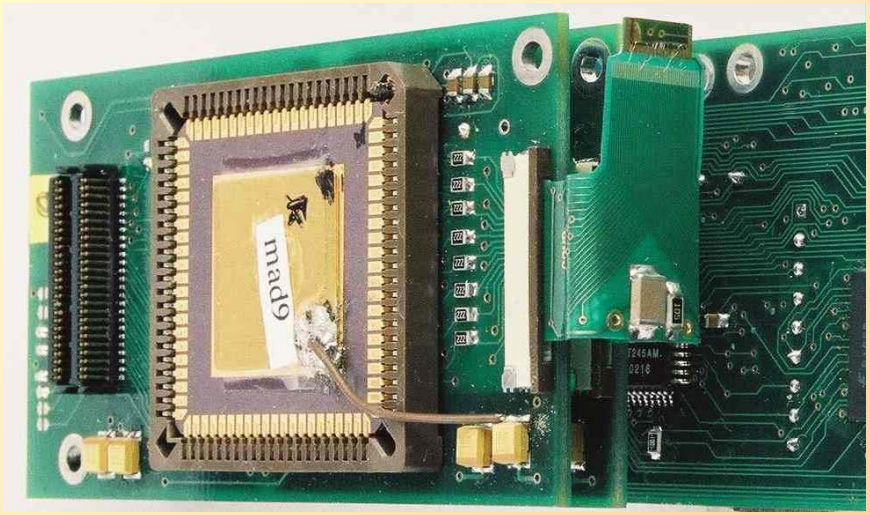


Mounted on 0.25 mm thick PCB holder

Test prototype of detection line

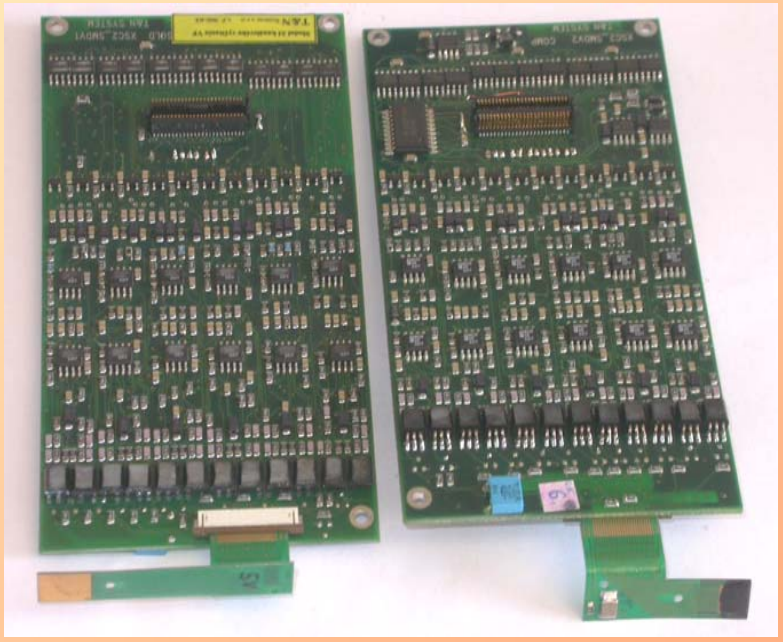
PROGRESS IN READOUT ELECTRONICS

PROTOTYPE CONCEPT:
Based on VLSI readout circuit
(IWORID 2003)



- Prototype series
- Technical problems
- High cost

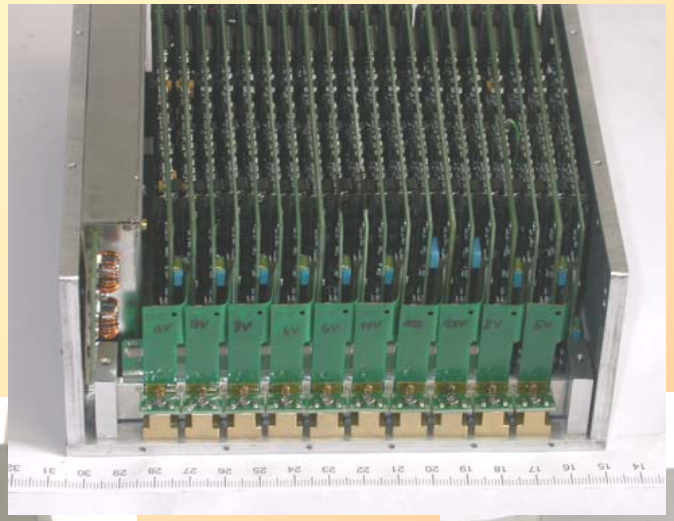
FINAL DESIGN OF F-E READOUT:
SMD assembled PCB



- Low cost per channel
- Simple possibility in modification
- Optimized for used chip holder

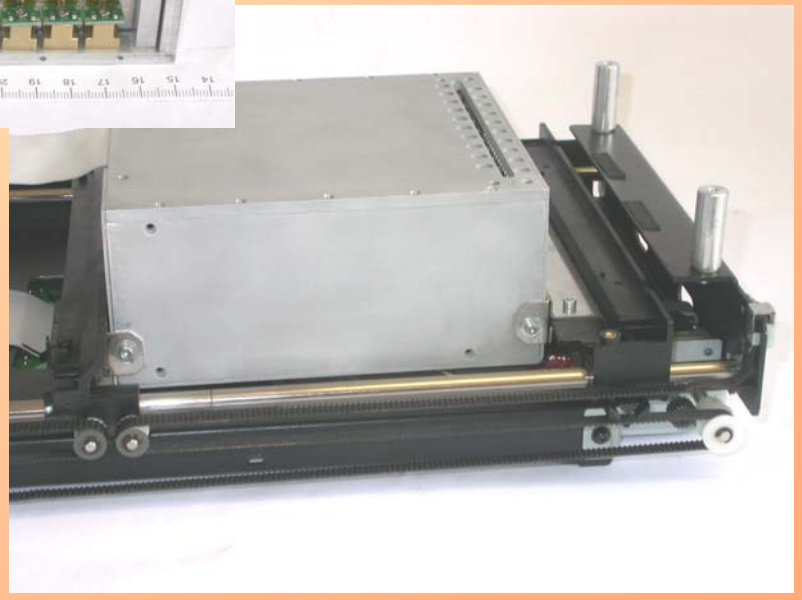
FINAL CONSTRUCTION OF X-ray SCANNER BASED ON *SAMO XS* STRIP LINE DETECTORS

- **480 strip SI GaAs detectors in line 12 cm long (pitch 0.25 mm)**



- **20 readout analogue cards, each with 24 readout channels**

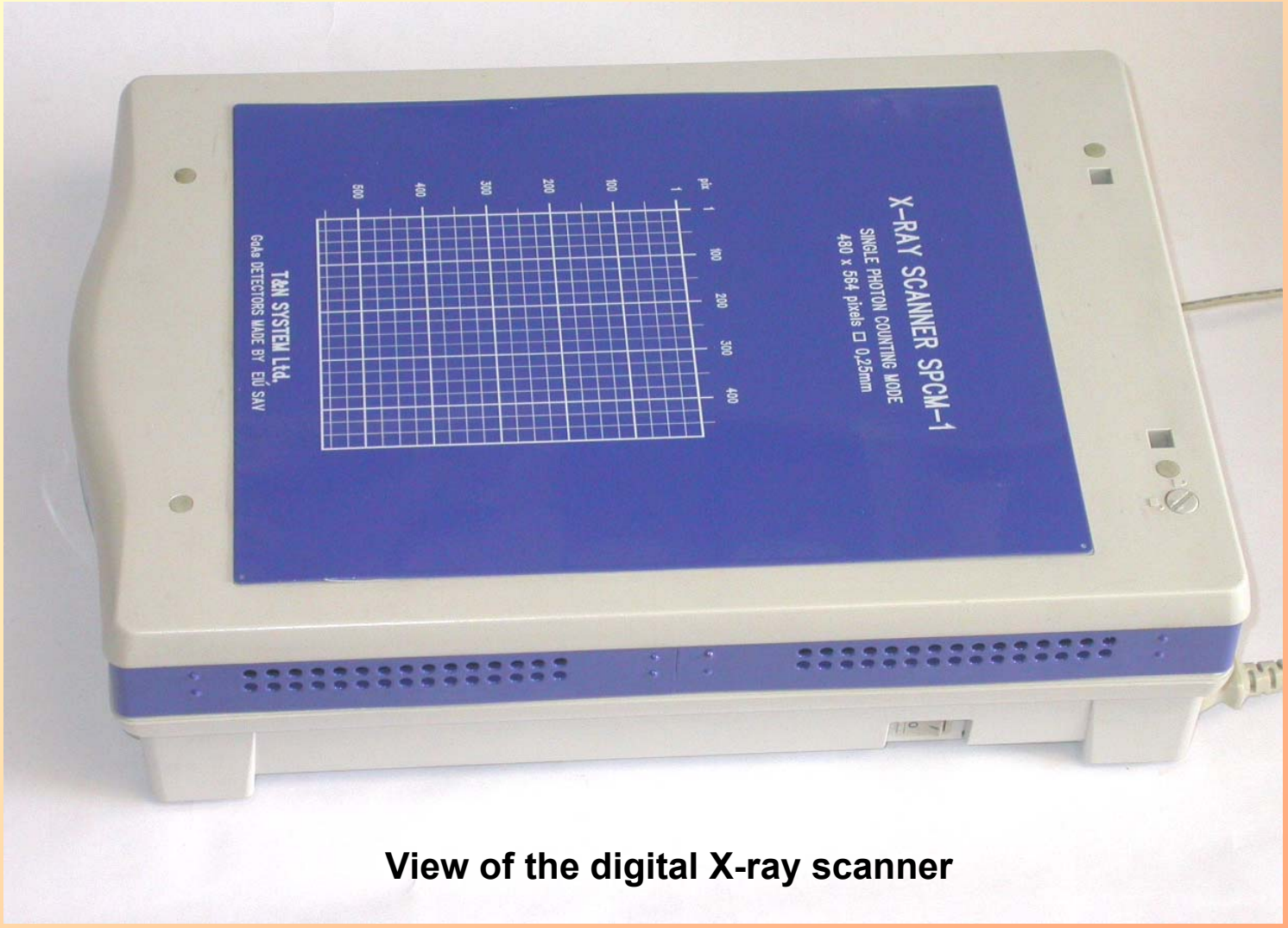
View of opened analog scanner part with cooling system (in front)



Detection unit of scanner in cover with X possitionning motion system up to 14 cm (in 564 (250 μm) or 1650 (85 μm) steps)

THE FIRST DIGITAL X-ray SCANNER

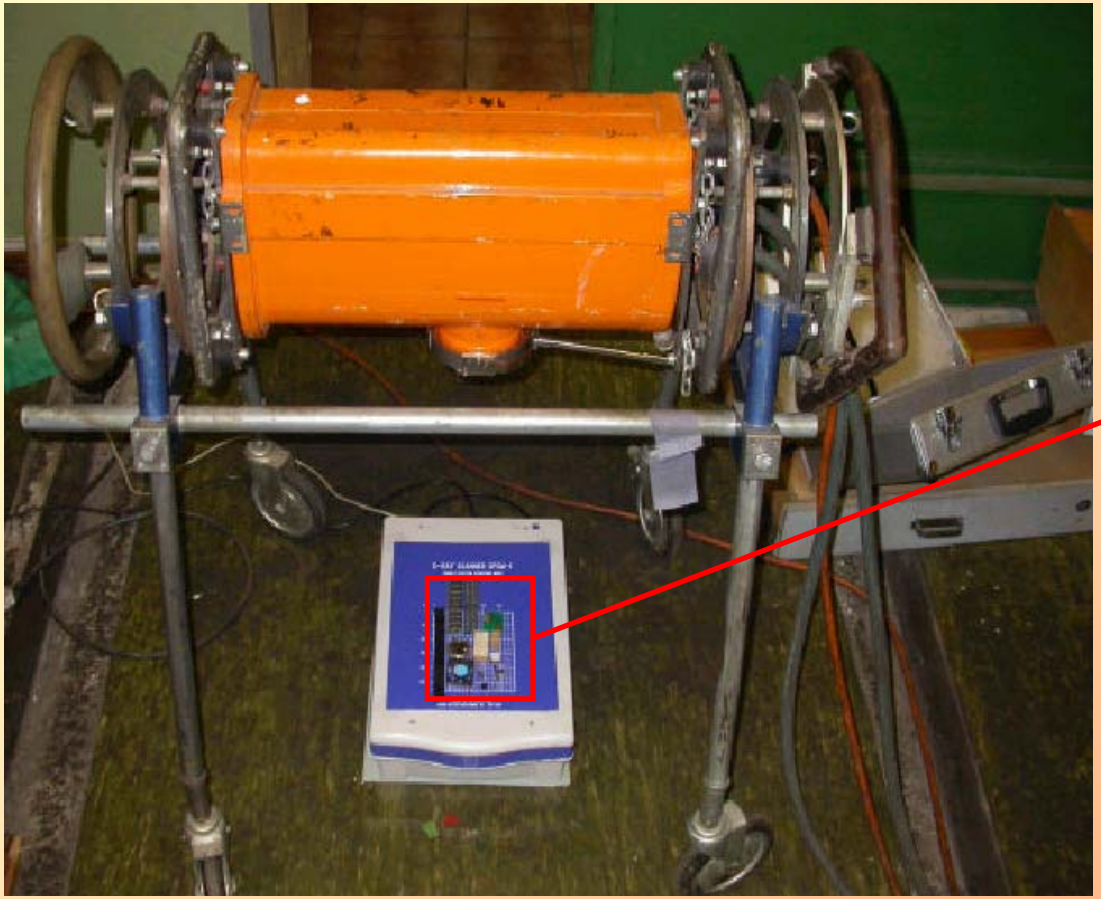
based on bulk SI GaAs radiation detectors working in quantum mode



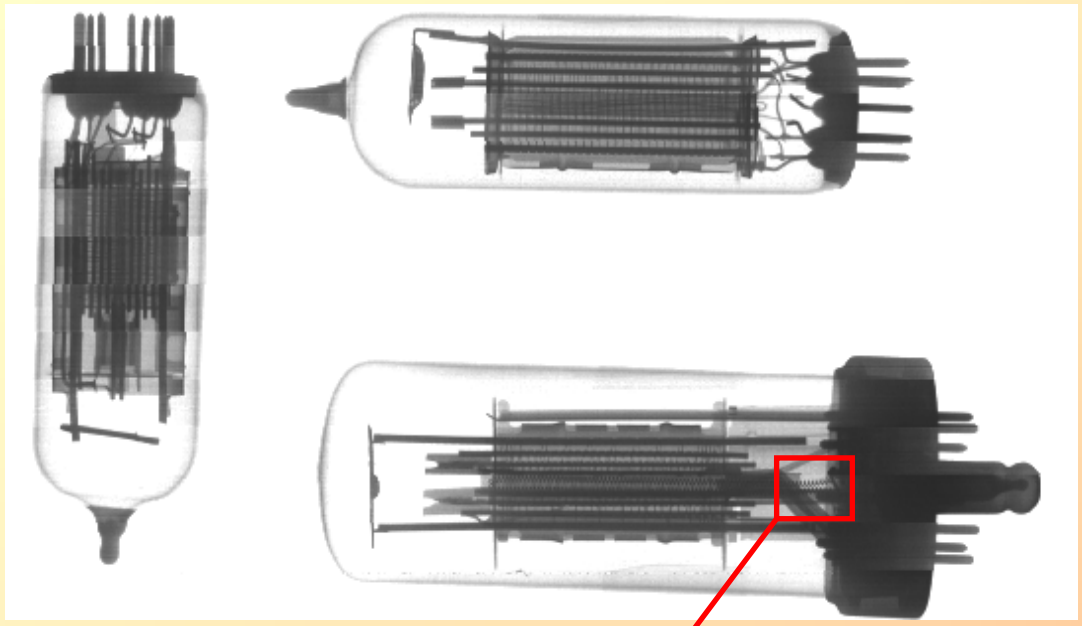
View of the digital X-ray scanner

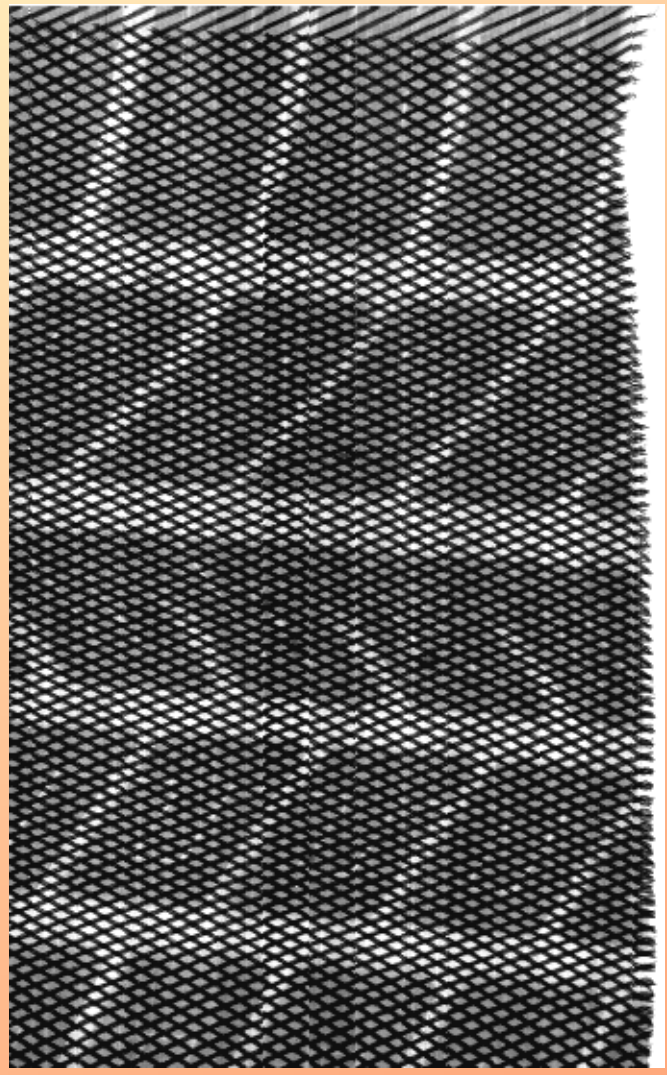
FIRST IMAGES OBTAINED WITH X-RAY SCANNER EXPERIMENT

X-ray tube: 70 kV, 8 mA, 1 s per line



PHOTOS AND X-ray IMAGES





X-ray tube: 70 kV, 8 mA, 0.05 s per line

CONCLUSIONS

- *DETECTOR*

  Succesful realization of line strip detectors based on bulk undoped SI GaAs (CMK Ltd., Žarnovica).

- *CHIP MOUNTING*

  Flexible PCB holders with direct connection through micro-connector.

- *READOUT ELECTRONICS*

  Front-end readout modul fabricated using progressive SMD technology with automatic assembling of electronic devices (24 channels, equivalent noise charge < 400 e^- rms , maximum readout rate 10^5 s^{-1}, memory of each modul, common threshold, USB connection to PC).

- *X-POSSITIONNING MOTION SYSTEM*

  Minimum adjustable step of 0.085 mm.

- *DEVELOPED CONTROLING COMMUNICATION AND IMAGING SOFTWARE*

  3 corrections including:

  - *normalisation of background counting inhomogenities*
  - *compensation of instabilities in X-ray tube flux*
  - *compensation of differencies in collection of even and odd 24 strip chips (due to diverging photons)*

- *FUTURE PLANS*

  - *detail study of imaging performance of the developed X-ray scanner*
  - *improvement of line arrangement*
  - *increasing spatial resolution using finer step of the line*
  - *implementaion of collimated X-ray source in the scanning system...*

GOLDEN AWARD OF 36th FAIR INCHEBA, BRATISLAVA 2004