Metal microdetectors test with spatially fractionated gamma-ray beam at the Kyiv Institute of Cancer

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Principle of the spatially fractionated radiation therapy

- Make Irradiation field inhomogeneous:
  Shape it as mini-beams (0.6 mm width and 1.2 mm periodical structure) or micro-beams (50 µm and 100 µm periodical structure)

- Developed for the synchrotron radiation at ESRF (Grenoble)
- Tested at animals – positive effect due to the increased dose in the open area of the collimator.

- Criteria of profit – PVDR (peak to valley dose ratio)

- Measured for the first time in real time in 2011 in Collaboration KINR_ESRF_Medipix(CERN) – spatial dose distribution in agreement with gafchromic films (off-line, time consuming procedure, yet with a perfect position accuracy – few micrometers).

- New idea (IMNC, Yolanda Prezado) – to implement it for the hadron beams (feasibility studies started at HIT – Heidelberg in 2014 (KINR-IMNC-CERN)
Goal

- Study the property of different materials for collimators and dose distribution using different type of collimators

- Archive the best value of PVDR

- Use for shaping and dose measurement of radioactive beam different detector types

- Compare collimator fractionated beam with the pencil beam
Equipment for shaping

Matrix collimators
(holes of 1.5 x 1.5 mm² and c-t-c distance of 4 mm)

Slit Collimators
(1.5 mm width, 2.5 mm c-t-c distance)

Material: aluminum, brass, copper
Equipment for imaging: TimePix

Hybrid pixel detector with the n-Silicon sensor chip and the TimePix electronics chip connected via bump bonds

- 256 x 256 pixels
- 55 µm side length
- Direct X-ray conversion
- positive or negative charge input
- single energy threshold.
- 3 modes: Single particle counting, Time over Threshold or Arrival time mode.
- 13-bit counter per pixel.
- Parallel and serial read-out are realised.
Equipment for imaging. MMD

- High Radiation tolerance (more than 100 MGy)
- Nearly transparent sensor - 1 μm thickness

MMD applications

- Micro-beam Profile Monitoring for Charged Particles and Synchrotron Radiation
- Detectors at the focal plane of mass-spectrometers and electron microscopes
- Imaging sensors for X-ray and charged particle applications
- Precise dose distribution measurements for microbiology, hadron-therapy etc.
- Industrial applications: micro-metallurgy, micro-electronics, etc.
TimePix measuring High intensity X-Ray beams

Measurements at the beamline ID17 ESRF (Grenoble)

The experiment (ESRF, MI1056) was carried out at the beamline ID17 with closed wiggler gap (24.8 mm) in the 16-bunches mode and with 200 mA electron beam current in the storage ring with the electrons energy of 6 GeV. X-rays with peak energy of 150 keV (ranging from 20 to 500 keV) were produced with intensity of \(2,7 \times 10^9\) photons/(c×mm²×mA).

The spatially fractionated mini-beam

Energy: 150 keV
Intensity: \(2,7 \times 10^{11}\) photons/(c•mm²)

Radiation hard detectors are required!

Metal TimePix detector imaging the X-ray beam. Color grade indicates the relative beam intensity.
TimePix imaging X-rays beams at the Bio-medical beamline ID17 (ESRF, Grenoble).

X rays
50 - 600 keV
Intensity:
2.7×10^{11}
photons/(s×mm^2)

Conventional dose measurement (gafchromic films) using microscope technique takes up to 24 hours.

Characterization studies of the TimePix measuring in real time dose distribution at the Mini-beam Radiation Therapy setup (ESRF, Bio-Medical Beamline ID17) were performed.

The results obtained for high intensity synchrotron radiation mini-beams illustrate an excellent performance of the TimePix providing 2D image of the high level dose distribution over many beams in (14 x14) mm^2 area.

Peak-Valley-Ratios measured by TimePix and gafhromic films agree well.
Feasibility studies of the spatially fractionated hadron therapy. HIT (Heidelberg)

2D images of carbon mini-beams shaped by the slit collimator (brass) with five slits (1.5 mm width, 2.5 mm c-t-c distance)

The lateral dose (normalized, a.u.) profiles for carbon ions measured at several depths (13, 33, 53, 73 and 93 mm-depth) in a RW3 solid-water phantom. The irradiation field size was 15×15 mm².

Images of carbon mini-beams shaped by a matrix collimator made out of 40 mm thick brass: 1.5 x1.5 mm² holes with c-t-c distance of 4 mm
Experimental setup for shaping and monitoring mini-beams

X-Ray source

Colimator

Detector

The experimental setup for testing various types of micro-detectors and read-out electronics on charged particles and gamma-rays at the accelerator Clinac-2100 CD "VARIANT"

Beam Energy: 6, 15 MeV
Pulse Width: 5 µs
Pulse Repetition Rate: 20-100 Hz
Beam type: Photon, electron
Positioning and parallel measurements
Positioning and parallel measurements

VARIAN internal collimation
Positioning and parallel measurements
Beam fractionated by brass slit collimator

Brass Slit Collimators
(1.5 mm width, 2.5 mm c-t-c distance)

PVDR: \(~3.45\)
Beam fractionated by brass matrix collimator

Matrix collimators
(holes of 1.5 x 1.5 mm$^2$ and c-t-c distance of 4 mm)

2D dimension distribution

1D dimension distribution

PVDR: ~2.5
Brass Slit Collimators
(1.5 mm width, 2.5 mm c-t-c distance)

PVDR: ~3.5

Beam fractionated by brass slit collimator and MMD detector

2D dimension distribution

1D dimension distribution measured by MMD detector
Summary and Outlook.

• Matrix and slit collimators for such application were designed and produced.

• The whole set of the equipment for shaping and imaging mini-beams has been tested with gamma rays at accelerator Clinac-2100 CD "VARIAN".

• Timepix detectors in a hybrid mode have demonstrated perfect performance for imaging minibeam in real time. Response of MMD was shown. Preliminary results were presented.

• It would be great to perform feasibility studies at CPO (Orsay) with 105 MeV protons in collaboration with LAL and CPO colleagues.

• It would be also nice to test shaping and monitoring equipment built at KINR at ALTO facility with 75 MeV electrons.
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Backup slides
Testing at the Clinac system

а – без фантому,
б – товщина фантому 3 мм,
в - товщина фантому 6 мм,
г - товщина фантому 9 мм,
д - товщина фантому 19 мм.