Cyclotron Centre in Poland and 2D thermoluminescence dosimetry

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Presentation plan

Two chapters

Cyclotron facility
- Institute of Nuclear Physics
- Existing facility
- Incoming CCB facility
- Status of CCB project

2D dosimetry system
- Thermoluminescence
- 2D thermoluminescence dosimetry system (2D TLD)
  - elements
  - properties
- Applications
Kraków – Heidelberg

by car: 1050 km
by walking: 930 km
Institute of Nuclear Physics in Kraków

- Est. 1960
- Area 8 ha
- ~500 res.
  - 41 full prof.
  - 30 ass prof.
  - 147 PhD
  - ~100 stud.
- 5 divisions
Institute of Nuclear Physics in Kraków
Existing cyclotron facility

BEAM DELIVERY SYSTEM OF AIC-144 ISOCYRONOUS CYCLOTRON

- **M1, M2, M3** - bending magnets
- **R1** - isotope position

System of environmental dosimetry:
- Gamma detector FH2 621 GL-10
- Neutron detector FHT 751
- Wide energy neutron detector FHT 782 WENDI-2
- Wide energy gamma detector FHT 191N N/TL
Existing cyclotron facility

Cyclotron AIC-144
(60 MeV protons)

- 15 patients till Match
- Waiting for financing
- Regular treatment planned from Jan 2013
National Centre for Hadron Radiotherapy

Grounded in Sep. 2006

- Institute of Nuclear Physics – coordinator
- University of Science and Technology
- Warsaw University of Technology
- University of Silesia
- Universitas Varsoviensis
- Medical University, Warszawa,
- Center of Oncology, Warszawa
- Center of Oncology, Kraków
- Holycross Center of Oncology, Kielce
- Institute of Nuclear Problems, Warszawa

contract for Bronowice Cyclotron Centre
contract for gantry

June 2009
December 2010

\(~45 \text{ M€}~\)
Bronowice Cyclotron Centre - Kraków

Foundation act signing ceremony 17.03.2011

Prof. dr hab. Marek Jeżabek
Prof. dr hab. Paweł Olko

signing the contract 2.08.2010
building permission 10.02.2011
start of the construction 17.03.2011
installation of the C-235 cyclotron 05.2012
acceptance tests 11.2012
medical building 04.2013
installation of gantry 07.2013
first beam in the gantry 09.2013
end of the contract 06.2014
Bronowice Cyclotron Centre

March 2011
Bronowice Cyclotron Centre

March 2011

May 2012
Bronowice Cyclotron Centre

November 2012
Bronowice Cyclotron Centre

November 2012

April 2013
CCB – cyclotron

Cyclotron Proteus C-235

- IBA, Belgium
- diameter 4.34 m
- magnet 3.1 T scanning

- Particle: protons
- energy 70-230 MeV
- $6 \cdot 10^8 - 4 \cdot 10^{12}$ part/s
- FWHM 3-9 mm (scanning gantry)
CCB – beam time

The proton beam will be shared between 3 lines:

1) Experimental room – main user from Jan. 2013
2) Eye therapy room – tests of the new eyeline 2013-2014
3) Gantry – end of acceptance tests May 2013

- From September 2013 to June 2014 the priority will be given to the gantry.

- During the regular patient treatment the patient irradiation time takes about 10% of the total time for one patient. The rest of the beam time can be used for other purposes.
CCB – beam QA

Different tools for beam QA

Radiographic films

Gafchromic® films

2-D arrays of ionization chambers

Flat-panel detectors

2D TLD

Scintillator + camera

multi-wire proportional chamber

Single/multi photodiodes
TL Phenomena – outline

Irradiation

- conduction band
- free electrons
- electron trapping
- electron detrapping
- ionization
- hole trapping
- valence band
- free holes

Readout

- conduction band
- electron detrapping
- electron retrapping
- luminescence
- heating
- valence band

Different thermoluminescence materials
Different trap structures
Different luminescence light
TL Phenomena

**Thermoluminescence** is an emission of light by certain materials during their heating after previous irradiation.

\[ \text{Amount of light} \propto \text{absorbed dose} \]
The principle of 2D TL Dosimetry

1. Preparation of foil
2. Irradiation
3. Heating
4. Collection of emitted light
5. Data analysis
Dosimetric system – TLD foils

TL foil = TL powder + polymer

1. The mixture needs to be uniformly distributed.

2. The detector is formed in a press.

3. The mixture is welded in high temperature.
Dosimetric system – TLD foils

Two types of TL:
- LiF:Mg,Cu,P (MCP-2D)
- CaSO$_4$ :Dy

- Water resistance and flexibility
- Up to 20 x 20 cm$^2$
- Reusability
- Resolution below 0.1 mm$^2$
- Linearity of dose response: 0.05-20 Gy

\[ Z_{\text{eff}} \]

\begin{array}{|c|c|}
\hline
\text{MCP-2D} & \text{CaSO}_4 \\
8.1 & 13.4 \\
\hline
\end{array}
Dosimetric system – hardware

Laboratory Reader:
• detector size $50 \times 50 \text{ mm}^2$
• resolution $640 \times 480 \text{ px}^2$
• fully adjustable

Clinical Reader:
• detector size $200 \times 200 \text{ mm}^2$
• resolution $1024 \times 1024 \text{ px}^2$
• easy and safe to use
Dosimetric system – readouts
Dosimetric properties – uniformity

After corrections the uniformity of readouts is around 2%
Dosimetric properties – reproducibility

More than 20 equivalent irradiations and readouts

Repeatability was found below 2%
Dosimetric properties – dose response

Linearity Index \( \frac{f(D)}{D} \) is constant within ±5% for protons (older reader) and ±2% for Co-60 (newer reader)
2D TLD - summary

Advantages of 2-D dosimetry:

- reusability
- water resistance and flexibility
- direct image readout
- spatial resolution (<0.5 mm) adequate for clinical applications

Disadvantages:

- difficulties of obtaining uniform sensitive foils
- energy and LET dependencies
Irradiations have been performed with 60 MeV proton beam at IFJ PAN in Kraków (AIC-144 cyclotron)
Applications – X-ray microbeam

Microbeam Radiation Therapy (MRT) at European Synchrotron Radiation Facility (ESRF)

The aim is to check the applicability of the 2-D system for measuring complicated radiation fields.

Peak-to-peak: 400 μm
FWHM: 50 μm

1 px ≈ 20x20 μm²
Applications – Static/dynamic exposure

The goal is to prepare the system to distinguish between static and dynamic exposure.
LET-painting with TL foils

Set of two foils: MCP-2D + CaSO$_4$:Dy

The idea

Difference in relative efficiency
Thank You for Your attention