Details count! Micrometric air gaps between phantom slabs influence film dosimetry when micro-fractionated X-ray beams are used

P. PELLICIOLI [1, 2, 3], M. DONZELLI [1, 4], R. HUGTENBURG [3], F. ESTÈVE [2], E. BRÄUER-KRISCH [1] and M. KRISCH [1, 2]

1. ESRF – the European Synchrotron Radiation Facility, ID17 Biomedical beamline, Grenoble, France. 2. STROBE – Synchrotron Radiation for Biomedicine, Grenoble, France
3. Swansea University Medical School, Singleton Park, Swansea, United Kingdom 4. ICR – The Institute of Cancer Research, London, United Kingdom

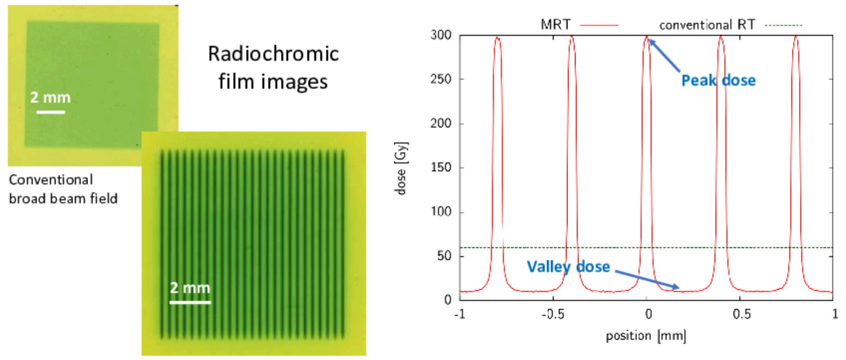
JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

Radiation Therapy (RT) is one of the most frequently used techniques to fight cancer with ionizing radiation.

Microbeam Radiation Therapy (MRT)

spatially micro-fractionated, low energy (≈100 keV), X-ray beams



Array of 50 µm wide microbeams , 400 µm beam spacing

MRT dose distribution feature:
- Micrometric spatial scale
- Steep gradients
- High peak-to-valley dose ratio

Broadening of the therapeutic window using MRT

MRT specific effects:
- Vascular system response
- Rapid healthy tissue repair
- Immune system response
- Preservation of neuron connections

Microbeams best generated at 3rd generation synchrotron sources

ESRF – ID17 Biomedical beamline
- Ultra-high dose rate: up to 14 000 Gy/s
- Low divergent beam: ≈ 3.3 mrad horiz.
- Orthovoltage photons: ≈ 100 keV mean energy

AIM

- Dosimetry in MRT is still a challenge due to the extreme condition used during irradiation

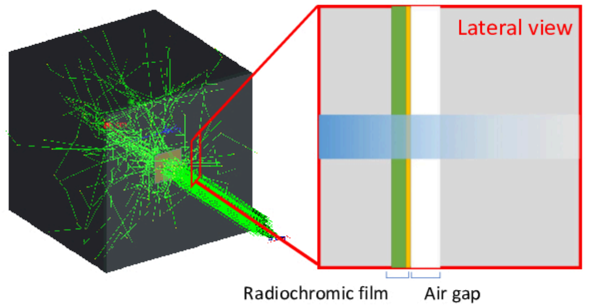
✗ Non-satisfactory agreement still occurs between simulated and experimental MRT dosimetry

- Investigation of experimental setup to define critical points during the irradiation:

⇨ Influence of micrometric **air gaps** between phantom slabs and radiochromic film during irradiation

METHODS

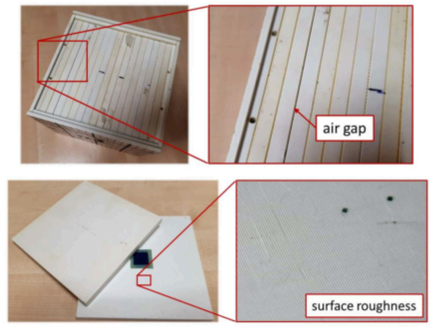
Monte Carlo simulations were performed to estimate the **relative dose variation** at detector position when increasing an **airgap in contact with the radiochromic film active layer**



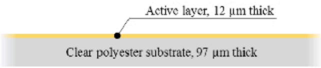
Phantom made by slabs of water equivalent plastic

× Possible presence of air gaps between the slabs

➢ Surface roughness characterization of the plastic



GAFChromic® HD-V2 radiochromic film used for high dose measurements



➢ Surface roughness characterization of the active layer exposed to air

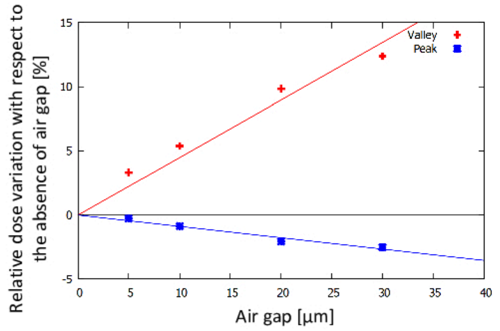
RESULTS

Simulation of the dose deposition at film position varying the size of the air gap

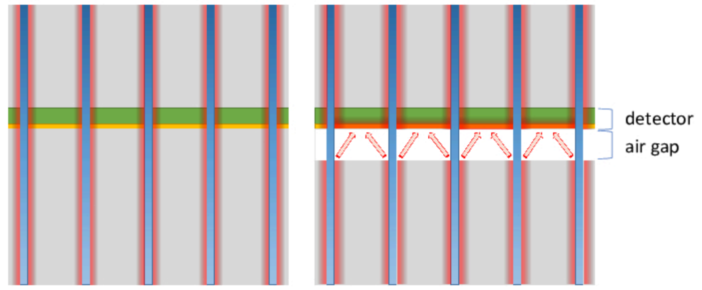
Increasing the size of the air gap:

➢ Dose delivered in the peaks decreases;

➢ Scattered dose reaching the valley increase

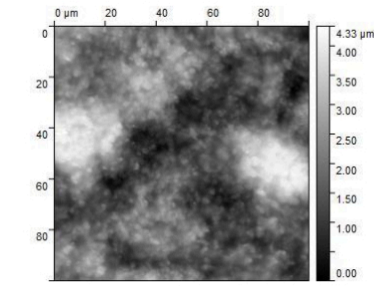


The **secondary electrons**, produced inside the phantom in proximity to the air gap, can **travel along the air gap and reach the center of the valley** region before being absorbed.

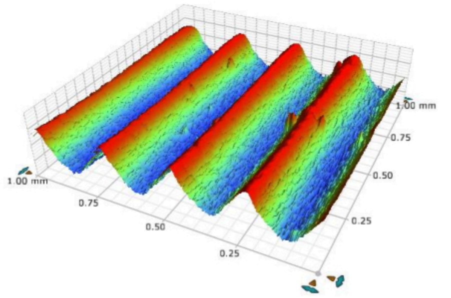


Phantom and film roughness characterization

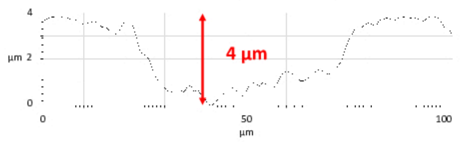
Atomic Force Microscope (AFM) evaluation of the film surface roughness



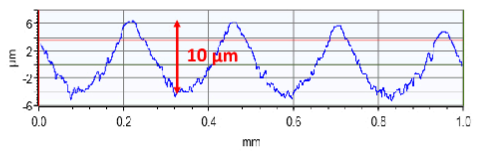
Phantom surface roughness evaluation with stylus profilometer



Film surface topography profile



Phantom surface topography profile

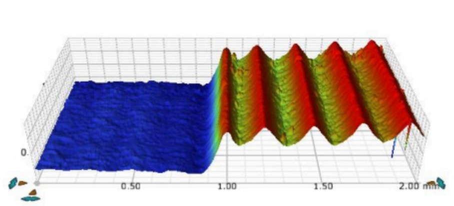


up to **14 µm wide air gap** due to material roughness

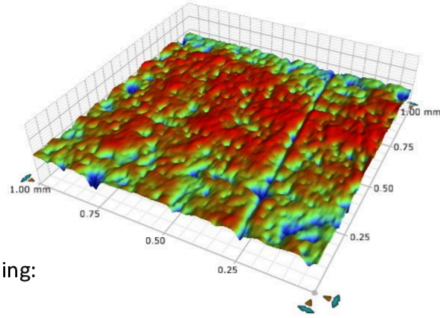
Plastic phantom machining

One plastic slab was milled with ESRF in-house developed instrument.

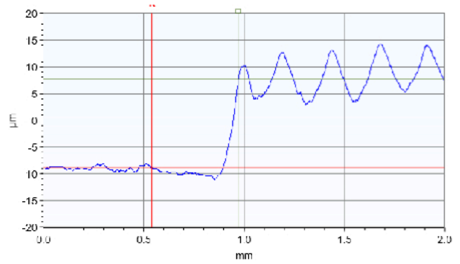
After & pre-machining plastic surface



Plastic roughness after machining



Phantom surface topography profile after and pre-machining: from 10 µm wide gap to ~2 µm wide gap



Preliminary experimental data collected before and after the phantom machining show **8.75% in relative valley dose reduction**, in agreement with simulation prediction

CONCLUSIONS

When dosimetry on the micrometric scale is performed with plastic slab phantoms and radiochromic films, the presence of micrometric air gaps in contact with the film can significantly affect the dose distribution.

For this reason, it is mandatory to pay attention to the level of the roughness of the surfaces and to any setup imperfections that can create air gaps.

REFERENCES

1. Bräuer-Krisch, E. et al. Medical physics aspects of the synchrotron radiation therapies: Microbeam radiation therapy (MRT) and synchrotron stereotactic radiotherapy (SSRT). Phys. Medica 31, 568–583 (2015).
2. Pellicioli, P. et al. High resolution radiochromic film dosimetry: Comparison of a microdensitometer and an optical microscope. Phys. Medica 65, 106–113 (2019).
3. Bartzsch, S. et al. Technical advances in x-ray microbeam radiation therapy. Phys. Med. Biol. 65, (2020).

CONTACT INFORMATION

PAOLO PELLICIOLI, PHD
CONTACT: PAOLO.PELLICIOLI@ESRF.FR

ID17 BIOMEDICAL BEAMLINE
WWW.ESRF.EU/USERSANDSCIENCE/EXPERIMENTS/CBS/ID17

ESRF – EUROPEAN SYNCHROTRON RADIATION FACILITY
WWW.ESRF.EU

ESRF The European Synchrotron

STROBE

Prifysgol Abertawe Swansea University