AAPM
Practical Medical Physics Course
Radiochromic Film Dosimetry Update

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Session: TU-F-201
2:45 pm – 3:45 pm
Tuesday, July 14, 2015

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Radiochromic Film Dosimetry Update
Outline

- General Aspects of RCF Dosimetry
- Applications of RCF in SRS, SBRT, IMRT, VMAT, and kV Imaging
- Applications of RCF in Brachytherapy
- Applications of RCF in Small Fields and Proton Beams

Members of AAPM Task Group 235
An Update to TG 55 (1998)

Charges of TG-235
(An Update to TG-55)

- To review the literature on recent radiochromic films and dosimetry of RCFs since TG-55,
- To assess the densitometers/scanners used for digitizing RCF since TG-55,
- To outline the procedures for accurate dosimetry and to evaluate measurement uncertainties, and
- To provide guidelines on recent RCF dosimetry for clinical radiotherapy applications.

Ref: Radiochromic Film Dosimetry (TG-55), The AAPM Report No. 63 Medical Physics, Vol. 25, Issue 11, 2093-2115, 1998

Radiochromic Film Dosimetry Update
General Aspects of
Radiochromic Film Dosimetry

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For Azam Niroomand-Rad, PhD, FAAPM, FIOMP
Emeritus Professor, Georgetown University, Washington DC

Session: TU-F-201-1
AAPM Practical Medical Physics Course
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Film Dosimetry

- Permanent Record of 2D Dose Distribution
- Dynamic Dose Range
- Darker Color (Grey) with Higher Dose
- Fine Spatial Resolution (5 μm)
- Steep Dose Gradient Region
- Cut to Size, Bend to Shape
- Irradiate at any Angle of Incidence
- Two Categories of Films for Radiation Dosimetry
  - Radiographic Film (19th Century)
    - AAPM TG69 (2007)
  - Radiochromic Film (Mid 20th Century)
    - AAPM TG55 (1998), TG235 (In Progress)

Radiochromic Film

- Polymer-based (Z~7)
- Nearly Tissue Equivalent
- NOT Sensitive to Light
- Handle in Room Light
  - But Store in Dark
- Easy to Position Accurately
- Self Developing
- Instant Color Change
- Water Resistant
- Weak Energy Response (Model Dependent)

Radiographic Film

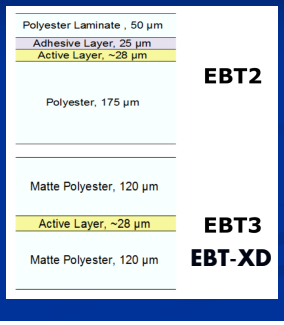
- AgBr-based (Z >>7)
- NOT Tissue Equivalent
- Very Sensitive to Light
- Require Dark Room
  - Always
- Not Easy to Position Accurately
- Require Processing
- Grey Shades Develop with Processing
- Strong Energy Response

Radiochromic Films for Dosimetry and QA for Radiotherapy and Radiology

- Radiotherapy (MV and kV photons, electrons, protons, HDR and LDR brachytherapy)
  - EBT2, EBT3, EBT-XD – 0.01 Gy to >40 Gy
  - MD-V3 – 2 Gy to 100 Gy
  - HD-V2 – 10 Gy to 400 Gy
  - RTQA2 – 0.02 Gy to 8 Gy

- Radiology (kV photons)
  - XR-RV3 – 5 cGy to 1500 cGy
  - XRQA2 – 0.1 cGy to 20 cGy
  - XRCT2 – 0.1 cGy to 20 cGy
  - XRM2 – 0.1 cGy to 20 cGy

Radiochromic Film Configuration
EBT2, EBT3 and EBT-XD

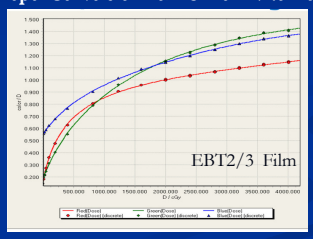


Information Analysis from Irradiated RCFs

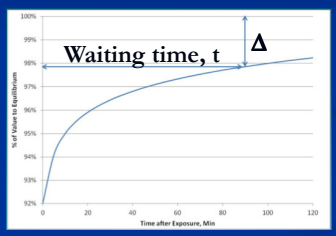
- The signal information is obtained from a light transmission measurement when compared with the incident light intensity:
  Transmission (T) = I_t / I_o
  Transmission and delivered dose is inversely proportional and non-linear
- Absorbance / Optical Density (OD) is defined as inverse log of T
  $OD = \log_{10} (1/T) = \log_{10} (I_o / I_t)$
- OD is expressed in Absorption Units (AU) such as:
  OD = 1 10% transmission
  OD = 2 1% transmission
- OD is a function of the wavelength at which T is measured.

➔ Measured OD and delivered dose can be considered unique for the film and delivered dose only if sampled by spectrometer of a known wavelength, or by an optical densitometer with monochromic light source.

Dose Response Curves, Non-Linear
Crucial to do
Proper Conversion from OD or PV to Dose



Radiochromic Film
Post Exposure Density Growth



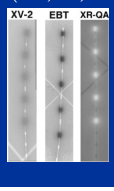
t	Δ
1 hr	2%
24 hr	<0.1%

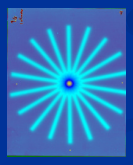
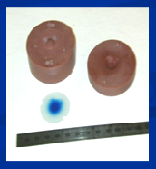
One Scan Protocol to be described later

Some Example of Exposed RCFs
for Radiotherapy (hν, e, p, HDR), QA

- EBT film (IMRT, H&N, Coronal, Phantom) with fiducial marks at crosshair and lot label
- EBT film (2.6 mm from inner surface of a CCX eye plaque)
- HDR source positioning QA measurements (XV-2, EBT, XR-QA)





Radiochromic Film Dosimetry Update
Applications of RCF in SRS, SBRT, IMRT, VMAT, and kV Imaging

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Session: TU-F-201-2
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Outline

- Commissioning
- Beam Data Acquisition
- Machine QA
  - Picket Fence Test
  - Winston-Lutz Test
- Patient-Specific QA
- Skin Dose Evaluation
- kV Imaging Dose Measurement

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Radiochromic Film dosimetry
SRS/SRT/SBRT/IMRT/VMAT

Major Advantages

- High Spatial Resolution (Sub-millimeter)
- No Angular Dependence of Film Response
- Dynamic Dose Range
- Steep Dose Gradient

- SRS/SRT/SBRT
- Single or Hypo Fraction
- EBT2, EBT3, MD-V3, EBT-XD

- IMRT/VMAT
- Conventional Fraction
- EBT2, EBT3

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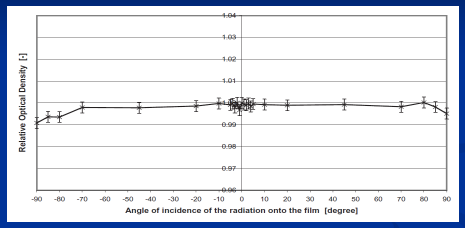
No Angular Dependence of Radiochromic Film Response



EBT Film, Epson 1680 Scanner

van Battum, Med. Phys. 2008; 35: 704-716.

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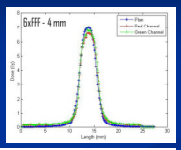
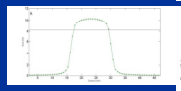
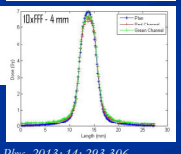
Linac Commissioning Validation
6, 10 MV Photon FFF beam, EBT3 Film

- Varian TrueBeam STx, BrainLab Cone
- 6 and 10 MV Photon FFF Beams
- EBT3 Film, Lot #A09231103
- Epson 10000XL Scanner
- Red and Green Channel Data

Wiant, J. Appl. Clin. Med. Phys. 2013; 14: 293-306.

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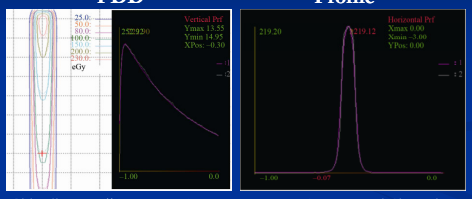
Varian Trilogy Linac, SRS, EBT2 Film

6 MV Photon, 1 cm x 1 cm (MLC), 2 cmx 2 cm Jaw

PDD Profile



EBT2 Film, Lot #A09031001A, Epson 10000XL Scanner, Red Channel Data Verification of the iPlan Beam Commissioning Data Provided by BrainLab.

Chan, Int. J. Med. Phys. Clin. Eng. Rad. Onc. 2012; 1: 1-7.

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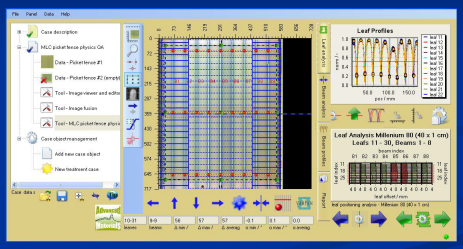
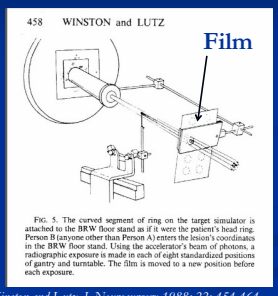
Picket Fence Analysis for MLC QA



GafChromic ASHLAND

Winston-Lutz Test
Target Position Alignment



Winston and Lutz, J. Neurosurgery 1988; 22: 454-464.

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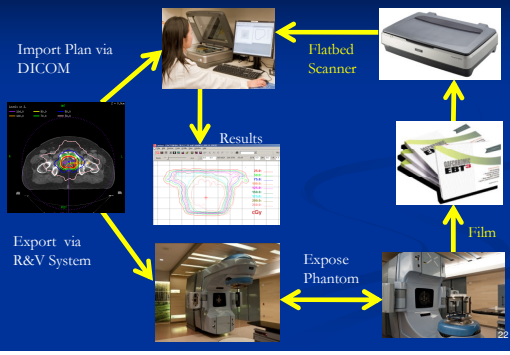
Patient-Specific QA Procedure, EBT2/3 Film



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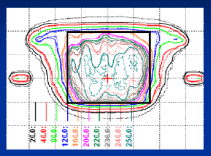
Planar Dose: Gamma Index



Solid: TPS
Dotted: EBT2 Film

Gamma Index: $\Gamma(\vec{r}_e,\vec{r}_r)=\sqrt{\frac{r^2(\vec{r}_e,\vec{r}_r)}{\Delta d^2}+\frac{\delta^2(\vec{r}_e,\vec{r}_r)}{\Delta D^2}}$

Distance Difference: $r(\vec{r}_e,\vec{r}_r)=|\vec{r}_e-\vec{r}_r|$ DTA Criterion: Δd

Dose Difference: $\delta(\vec{r}_e,\vec{r}_r)=D_e(\vec{r}_e)-D_r(\vec{r}_r)$ Dose Diff Criterion: ΔD

Low, Med. Phys. 2003; 30: 2455-2464.

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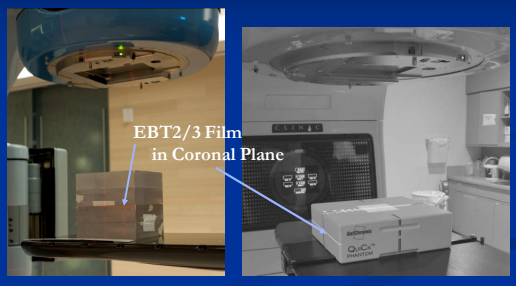
EBT2/3 Film in Phantom on Couch



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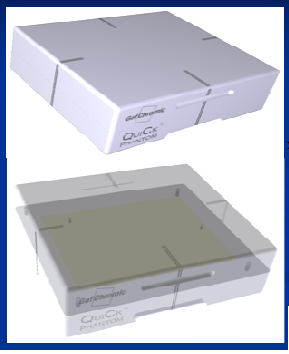
New GafChromic QuiCk Phantom

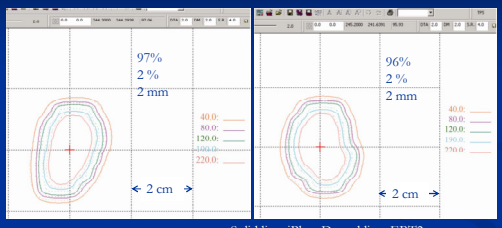


29 cm x 32 cm
Two Slabs
5 cm each

GafChromic

ASHLAND

Brain SRS QA, EBT2 Film



Solid line: iPlan, Dotted line: EBT2

Chan, Int. J. Med. Phys. Clin. Eng. Rad. Onc. 2012; 1: 1-7.

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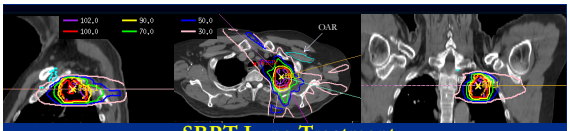
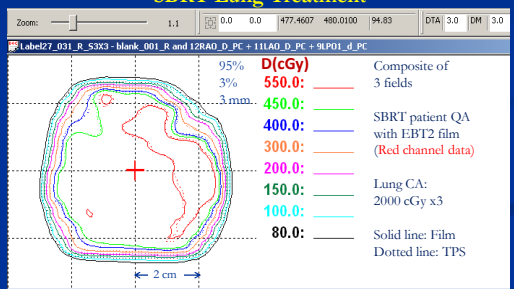


SBRT Lung Treatment



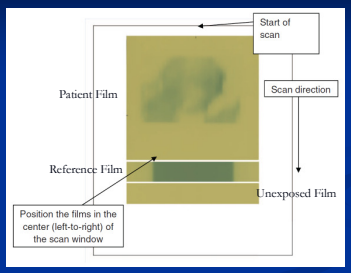
Composite of 3 fields

SBRT patient QA with EBT2 film (Red channel data)

Lung CA: 2000 cGy x3

Solid line: Film
Dotted line: TPS

One Scan Protocol



Lewis, Med. Phys. 2012; 39: 6339-9350.

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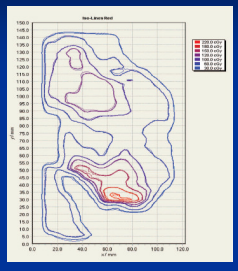
Isodose Curves w/One Scan Protocol
EBT3 Film



Scan Patient/Reference/Unexposed Films Together After Exposure
Thick Line: 0.5 hr
Thin Line: 72 hr

Scan Calibration Films After Exposure
2 hr

Gamma Passing Rate
> 98%
For R, G, B Channels

Lewis, Med. Phys. 2012; 39: 6339-9350.

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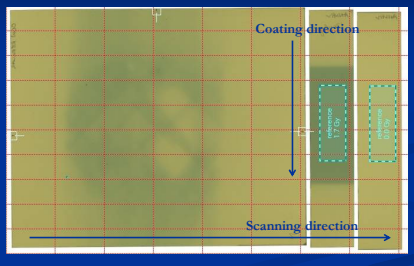
VMAT, Double Arc, EBT3 Film
Scanned Image, Portrait Orientation



Application Film

1.7 Gy 0 Gy
Reference Films

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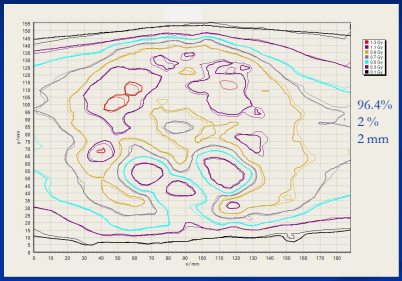
VMAT, Double Arc, EBT3 Film Isodose Curve comparison



Thick line: TPS, Thin line: EBT3 Film

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Skin Dose Elevation

- Skin Reaction is a Major Concern in RT
- Single or Hypofractionated Treatment
- Beams Delivered Through the Support/Immobilization Devices
- Bolus Effect – Lack of Skin Sparing
- Treatment Plan Comparison
  - Correction of the Bolus Effect (with Approx. Effective Bolus Thickness)
  - Without Correction

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Grade-4 Skin Necrosis

Fig. 1. Patient who developed Grade 4 skin necrosis from stereotactic body radiation therapy.

Hoppe, Int. J. Rad. Onc. Biol .Phys. 2008; 72: 1283-1286.

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Treatment Plan Comparison

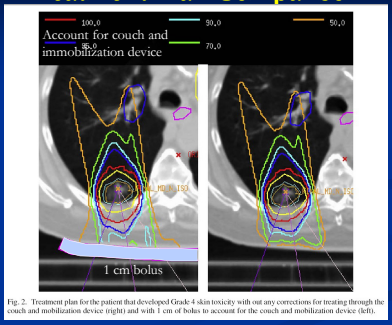

Fig. 2. Treatment plan for the patient that developed Grade 4 skin toxicity with out any corrections for treating through the couch and mobilization device (right) and with 1 cm of bolus to account for the couch and mobilization device (left).

Hoppe, Int. J. Rad. Onc. Biol .Phys. 2008; 72: 1283-1286.

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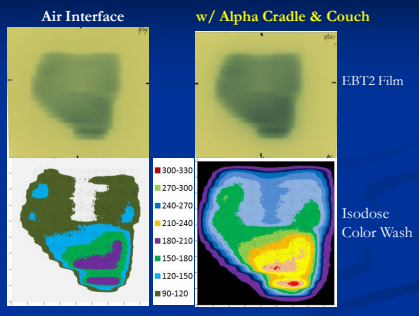
6 MVX IMRT Field, Dose at d = 2 mm



Chan, Technology in Cancer Research & Treatment 2012; 11: 571-581.

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Radiochromic Film dosimetry

Useful for Patient-Specific QA in SRS/SRT/SBRT/IMRT/VMAT

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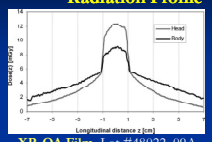
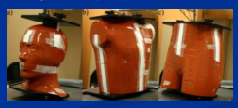
kV Imaging in IGRT, CT Scan Dosimetry

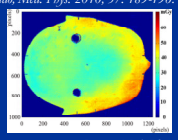
Radiation Profile

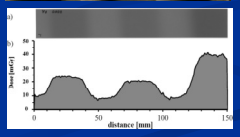


XR-QA Film, Lot #48022–09A
Rampado, Med. Phys. 2010; 37: 189-196.

XR-QA Film, Lot #A12090904B







Boivin, Med. Phys. 2011; 38: 5119-5129.

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Thank You

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