Evaluation of a Diode Array for HDR Brachytherapy Quality Assurance

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Overview

- HDR mis-administration continuing in spite of improved QA protocols.
- We decided to evaluate the SNC Mapcheck2 diode array as a new tool for HDR QA.
- Major goals
  - Track the source position during treatment.
  - Dosimetric verification of delivered dose
  - Comparison with treatment plan

Types of Errors in HDR

- Missed target or wrong treatment site (66%):
- Treatment planning errors(16%):
- Source retraction problems (12%);
- Treatment delivery errors (8%):
- Others (8%)

Objectives of the present research.

1. Review recent HDR QA methods
2. Determine accuracy of source dwell position measurements
3. Find source to detector distance (source depth) for each dwell position from changes in FWHM
4. Compare planned dose distribution with estimates calculated from the diode array readings when Mapcheck is calibrated for Ir-192

Current HDR Brachytherapy QA

1. Daily QA on Treatment Day
2. Monthly QA
3. No QA procedure checks
   a) Accuracy of source position with respect to the patient
   b) Measure and verify the actual dose delivered
4. Knowing real time dose and position accuracy can help reduce potential major errors

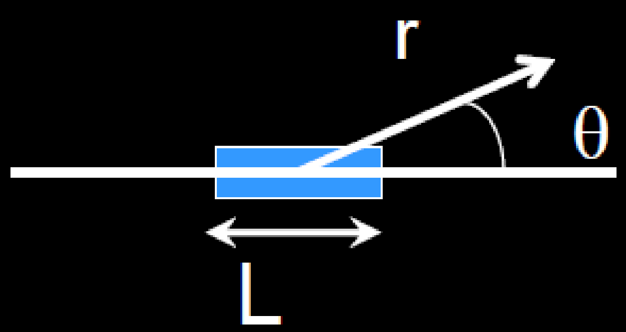
Proposed HDR Brachytherapy QA

An ounce of prevention is worth a pound of cure…

1. Investigate new methods for tracking the source during treatment.

2. Mapcheck2 diode array device used for external beam IMRT QA is implemented to generate real-time dose profiles and find the source dwell locations

Geometry factor



$$G(r,\theta)=\frac{\int_{v}\frac{\rho(\vec{r}')}{|\vec{r}-\vec{r}'|^{2}}dV'}{\int_{V}\rho(\vec{r}')dV'}$$

For line source,

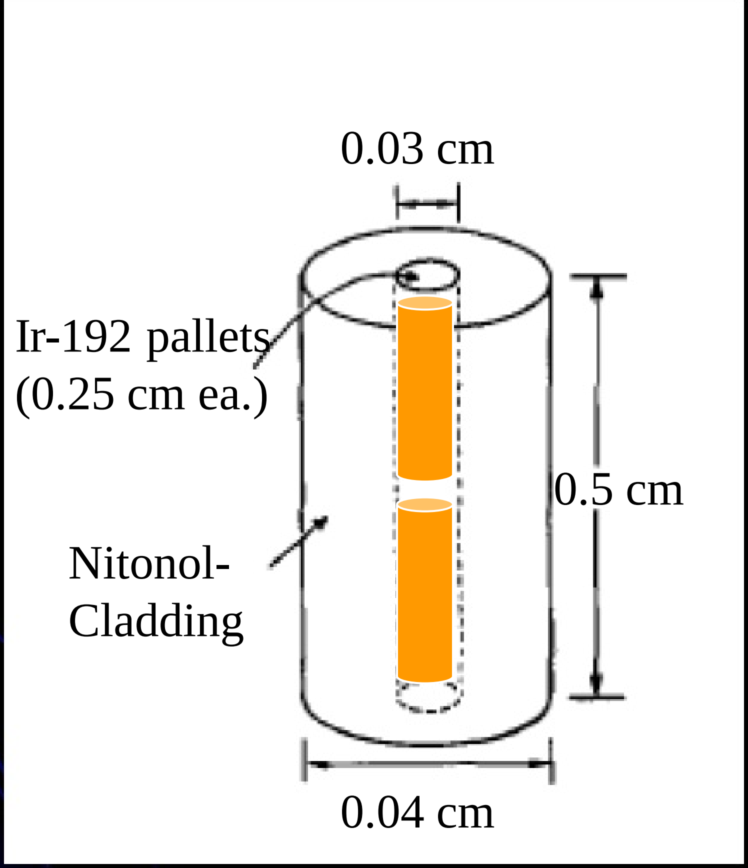
$$G(r,\theta)=\frac{\theta_2-\theta_1}{Lr\sin(\theta)}$$

$$\begin{cases}\tan(\theta_1)=\dfrac{r\cdot\sin(\theta)}{r\cdot\cos(\theta)+L/2}\\ \tan(\theta_2)=\dfrac{r\cdot\sin(\theta)}{r\cdot\cos(\theta)-L/2}\end{cases}$$

For point source,

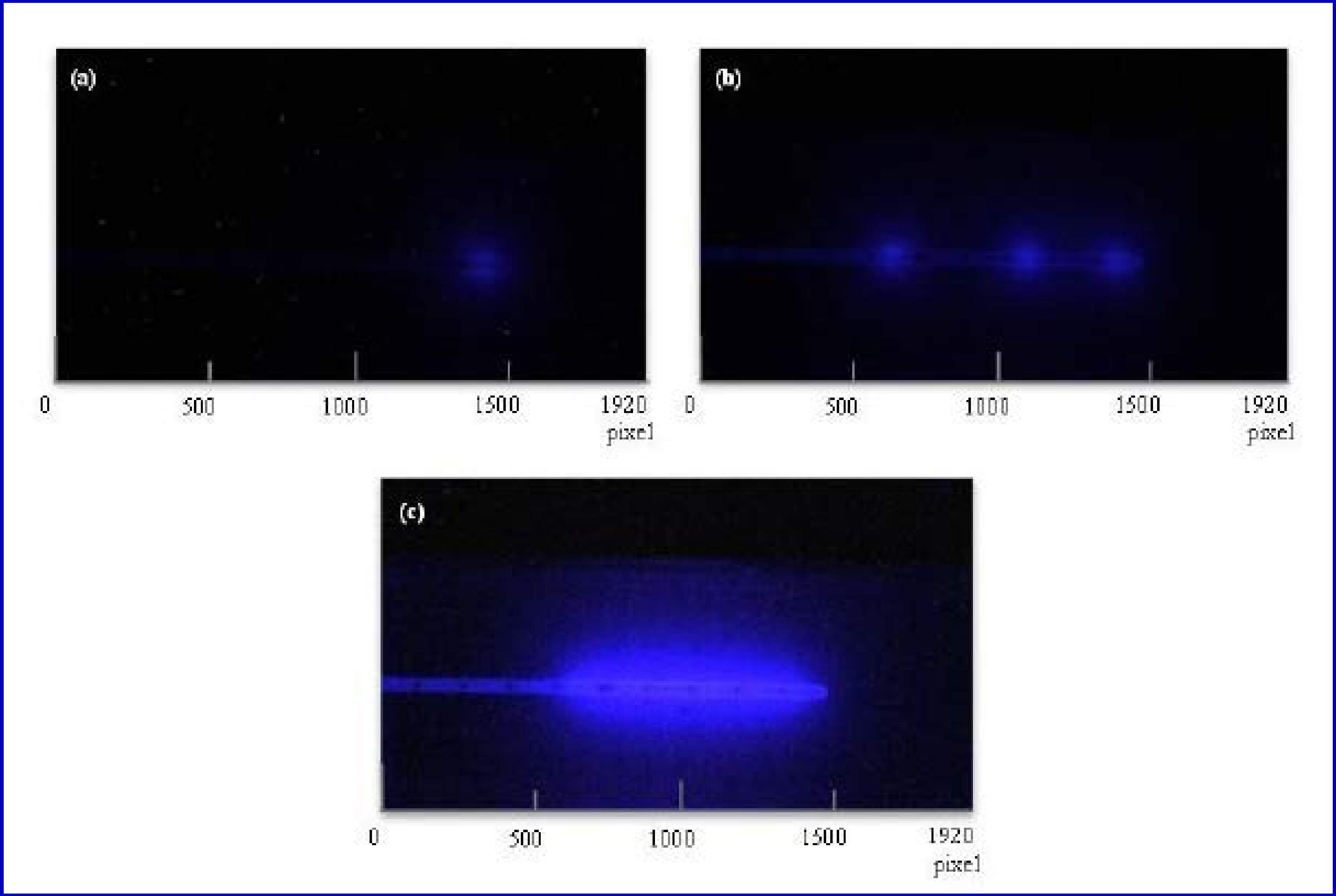
$$G(r,\theta)=\frac{1}{r^{2}}$$

Ir-192 Source Schematic



Scintillator Image Analysis

- Ir-192 scintillation brightness distribution
  - Created by high-speed automatic analysis software developed by Fukushima et al.
  - Source dragged through catheter, stopped at dwell positions
  - Added pixel values in the region of interest (ROI) in every line of the depth direction of the plastic scintillator
  - the source position and time information could then be obtained from the resulting image of scintillation luminescence



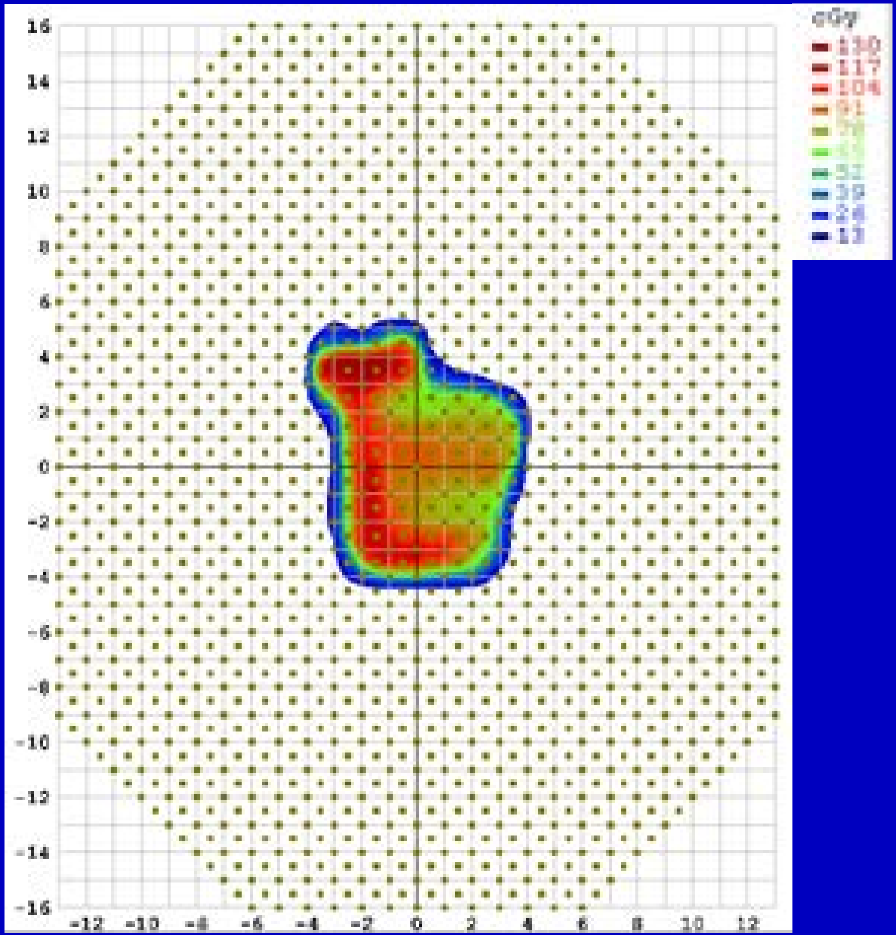
a) Image of 1 frame, source stops at tip of applicator

b) Image of 3 frames, source movement distance set to 5cm (2cm + 3cm) in 3 steps

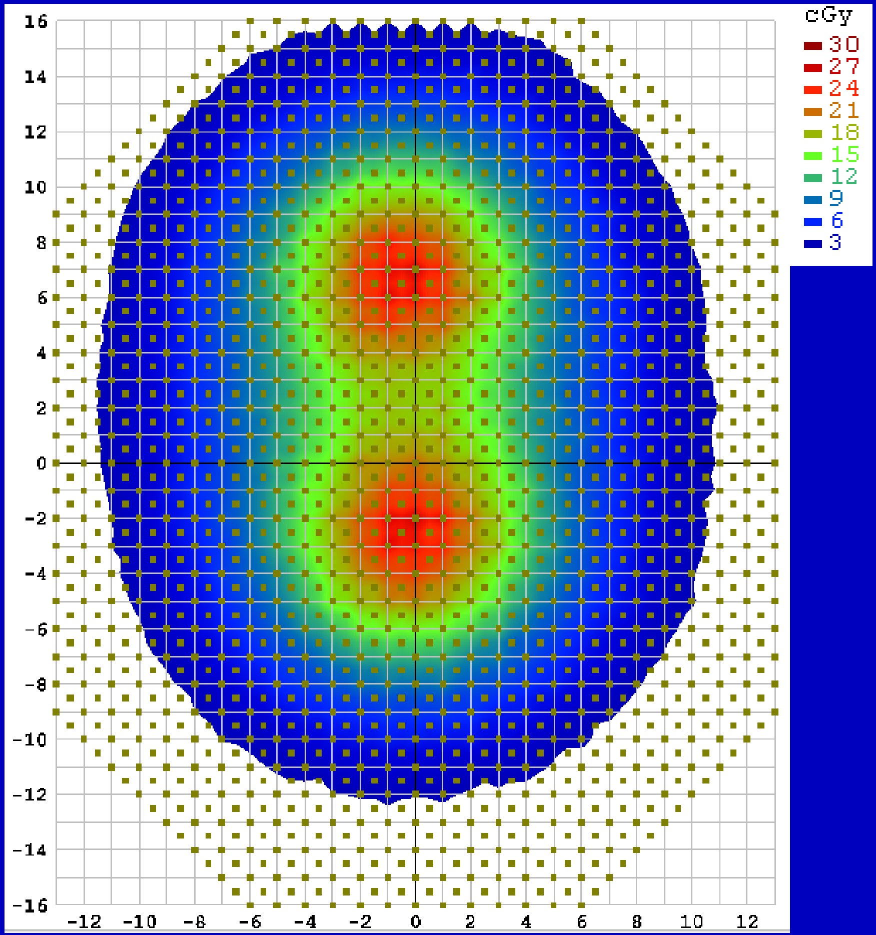
c) Image of 11 frames, source movement distance set to 5cm in 11 steps at 5mm intervals. These 11 frames form a single scintillation luminescence image.

Dose Distributions

IMRT
Patient Specific QA



HDR Brachytherapy
Patient Specific QA

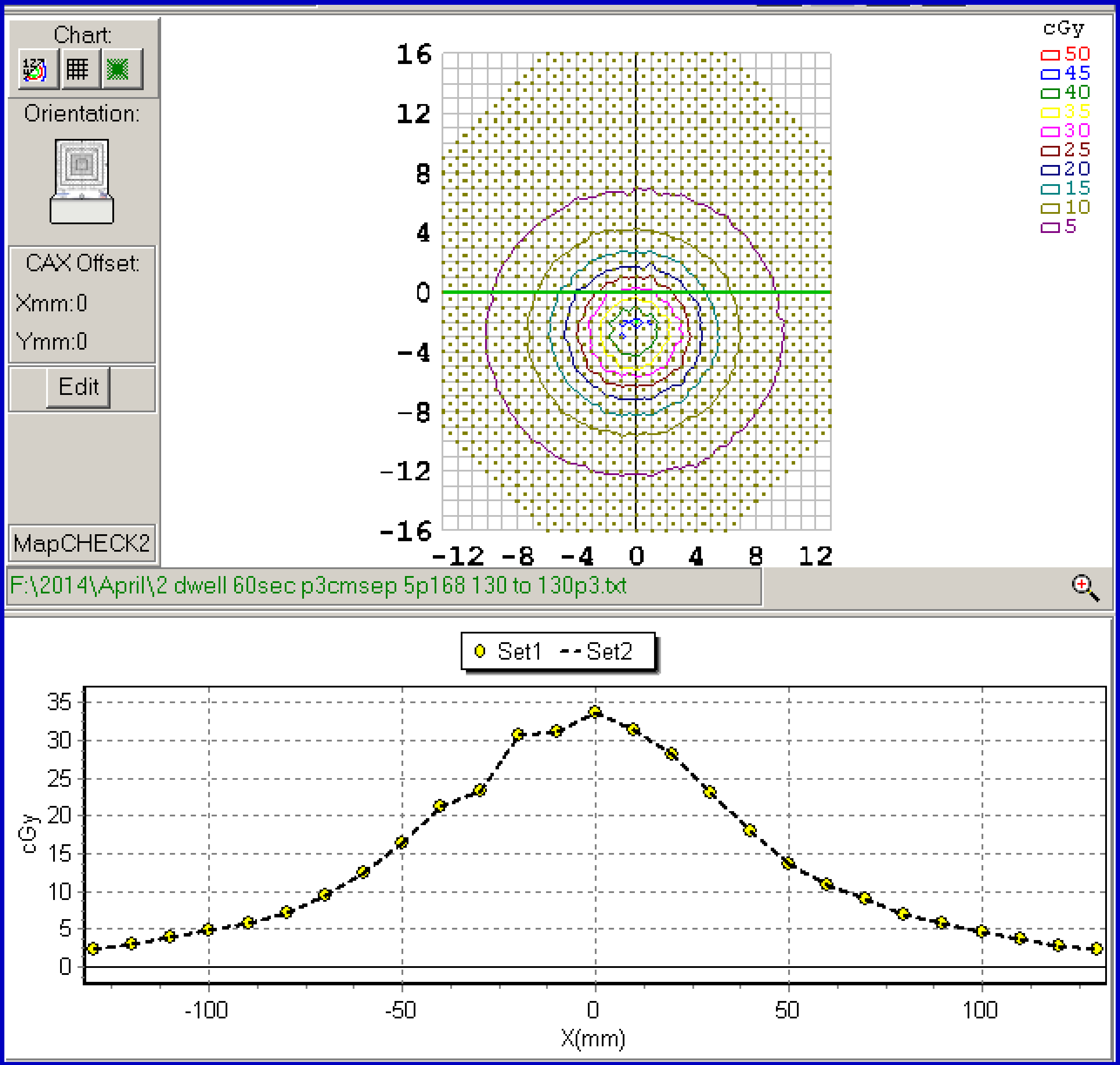


X Profile

STD 5cm

2 dwell pos.

3 cm sep

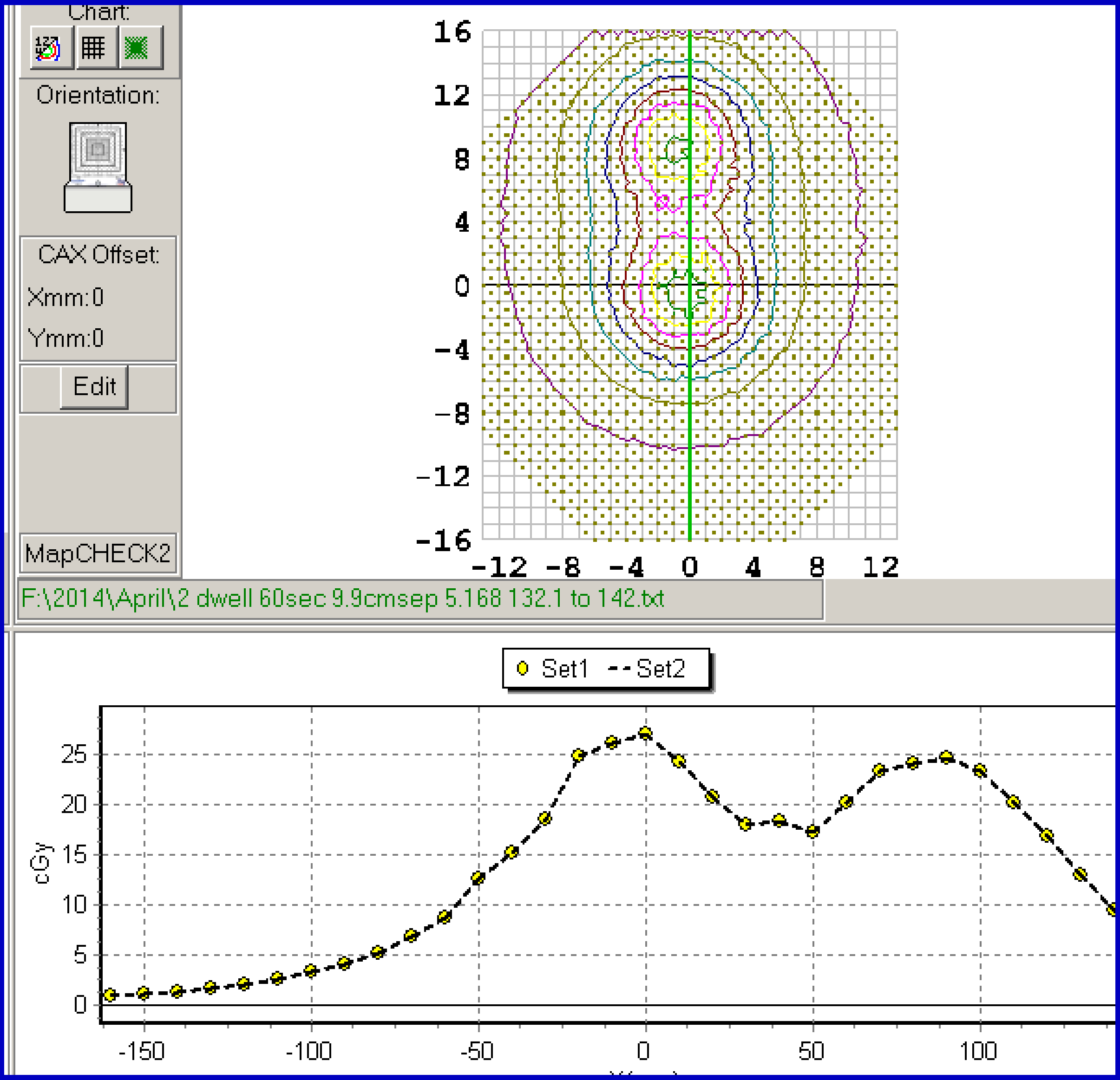


Y -Profile

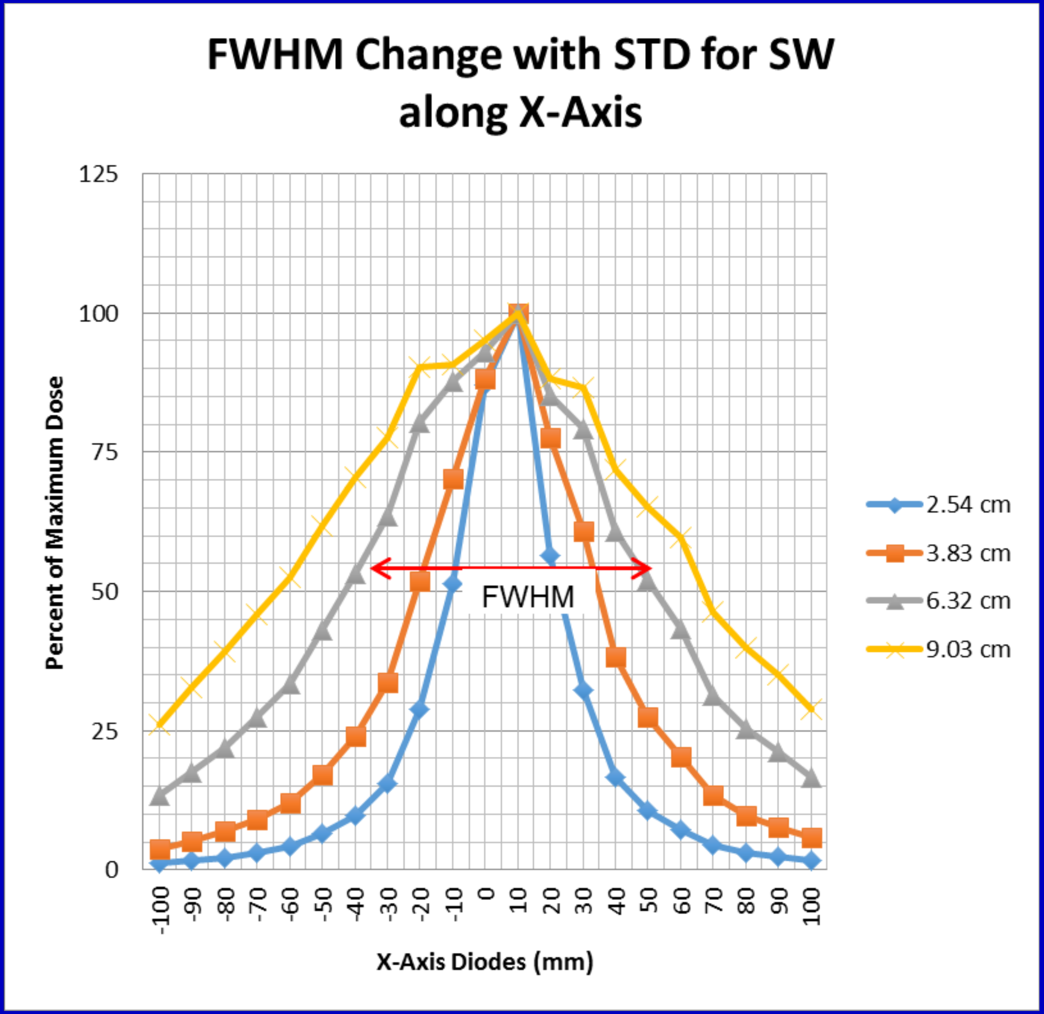
STD 5 cm

10 cm Sep SW

Peaks visible

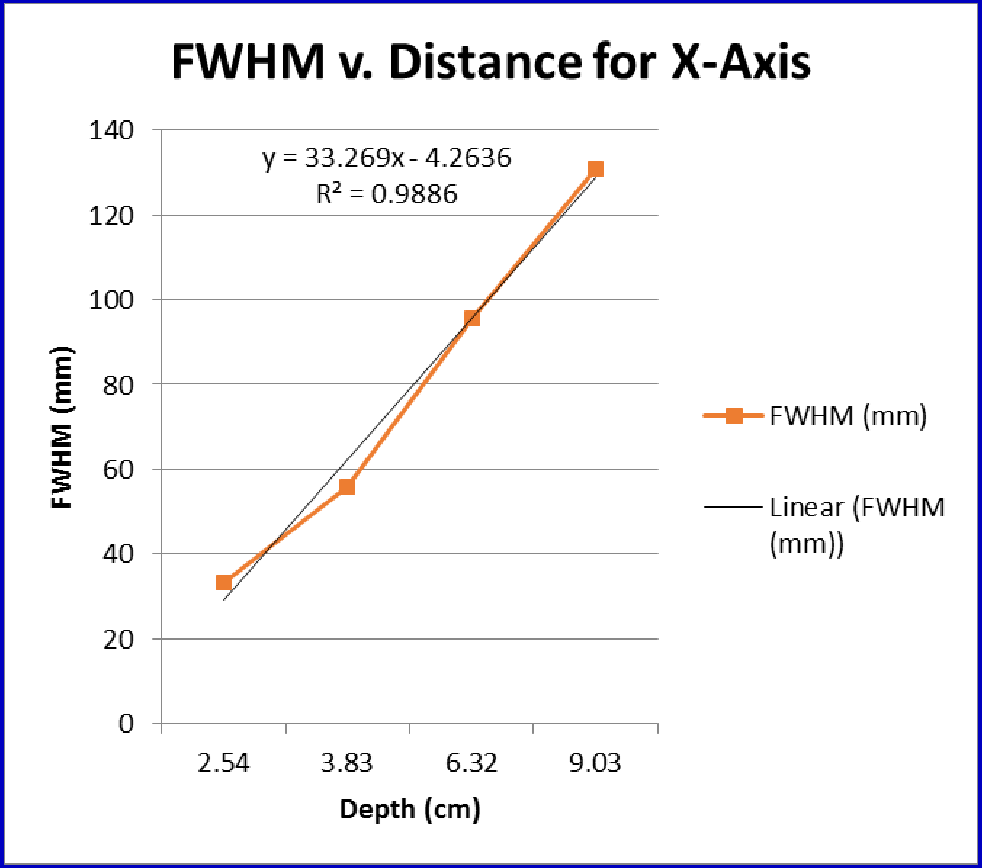


X-Axis Dose Profile



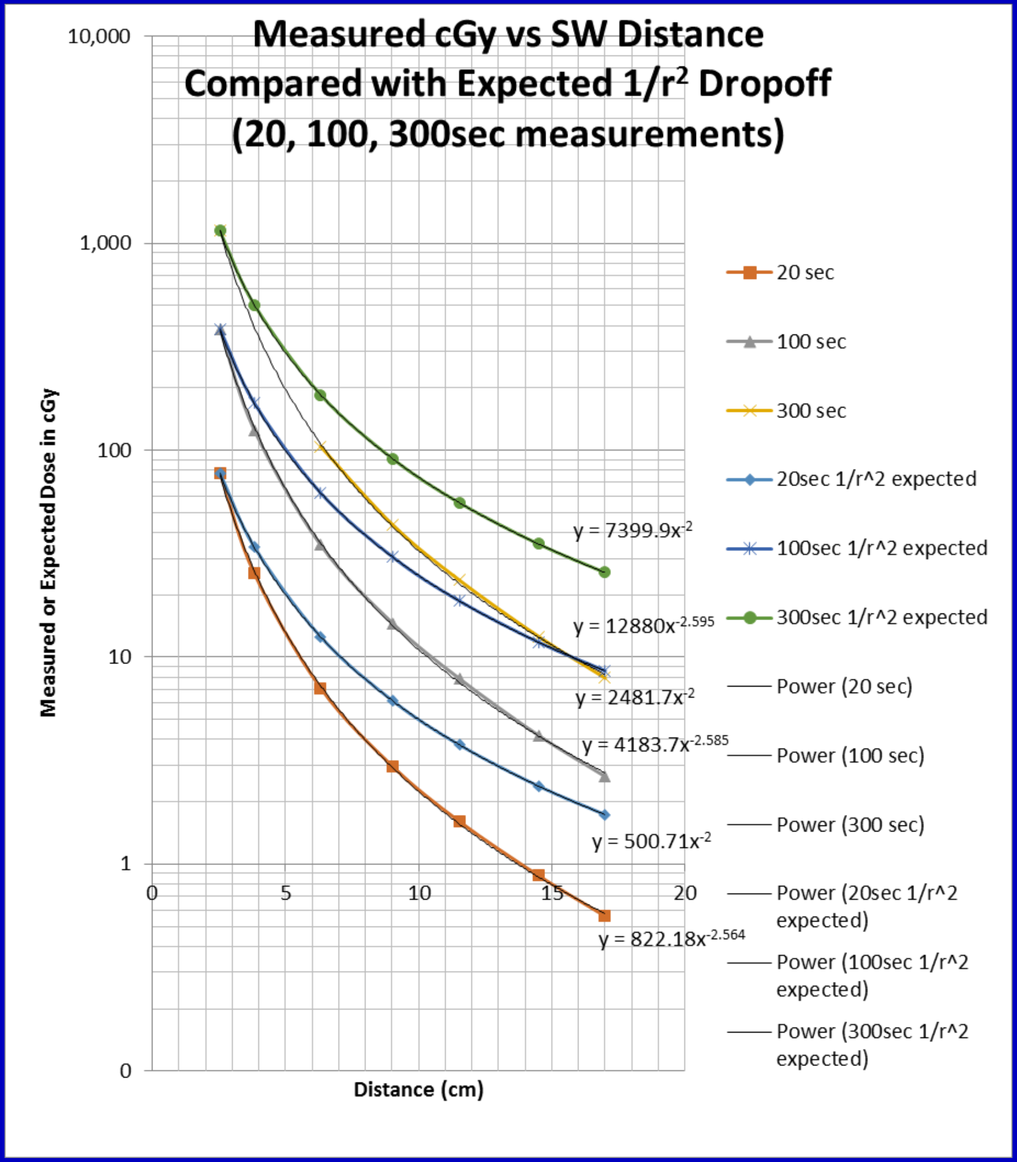
- Peak value is 100 percent.
- Dose profiles are normalized to the maximum-reading diode.
- Peak occurs at (10, 10).
- Assumes a Gaussian Distribution.

FWHM v. Distance for X-Axis



From this equation, we can measure the source to detector distance.

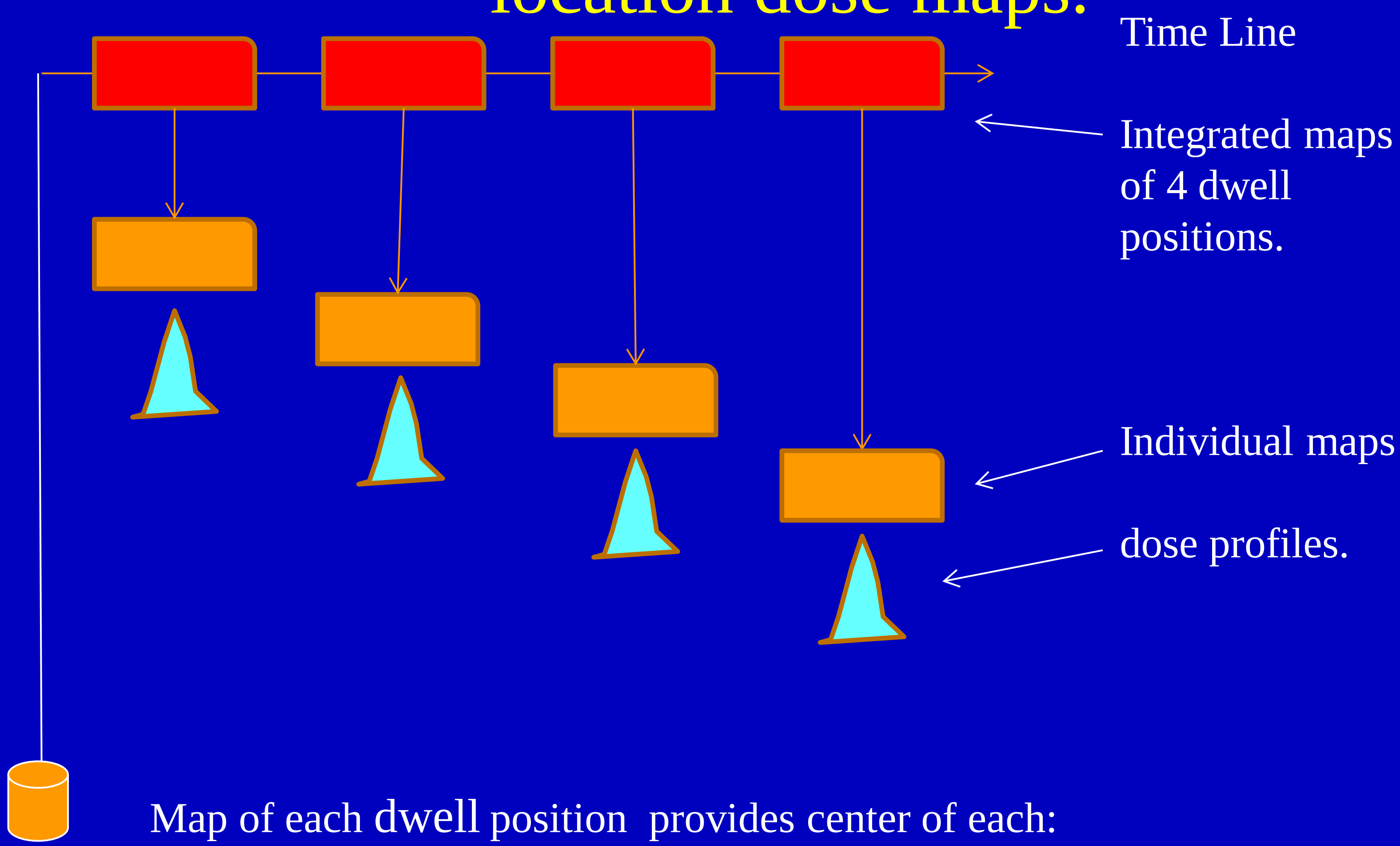
Dose v. Distance



Results:

1. Dose maps acquired with the diode array can verify source dwell locations to an accuracy of about +/-2 mm.
2. The FWHM method can provide source depths to about +/- 5 mm
3. Dose distributions along the length of HDR applicators may be calculated to around +/- 5% with a calibrated diode array.
4. These experiments verify that the inverse square law is applicable for the diode detectors in this size diode array.

Acquisition of integral and individual dwell location dose maps.



Map of each dwell position provides center of each:
dwell position, elapsed time and self dose D(self)

Future Directions and Planned Experiments

- The diode array remains to be calibrated for Ir-192 and Sun Nuclear is verifying the calibration protocol.
- If the images acquired for each dwell position can be acquired as separate frames, it should be possible to view the images acquired in real time on a separate PC.
- Analysis of the individual images will provide verification of each dwell time and provide dose estimates for each dwell location.
- The integral transit time dose can be calculated from the integral image acquired from the difference in dose from the integral and summed individual images.

References

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The feasibility study and characterisation of a two dimensional diode array in "magic phantom" for high dose rate brachytherapy quality assurance.
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Angular Dependence