Small field diode dosimetry

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NCCAAAPM Symposium-October 10, 2013
• Diodes as beam data collection detectors

• Diodes as *in vivo* dosimeters
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• Diodes as *in vivo* dosimeters
Desired detector properties

- High spatial resolution
- High signal, low noise
- Low energy dependence
- Low directional dependence
- Low perturbation
- Dose (rate) linearity
- High stability, robust
- Easy to use in a clinic

Some detectors

- Ionization chamber PTW 31010, 0.125cc
- Ionization chamber PTW 31006, PinPoint, 0.015cc
- Shielded Si-diode Sc.-Wellhöfer PFD Photon, 0.0003cc
- Mini Si-diode Sc.-Wellhöfer SFD stereotactic, 0.000017cc
- Si-MOSFET Thomson & Nielsen TN-502 RD
- Diamond detector PTW 60003, ca. 0.002cc
- microLion Chamber 0.0017cc
PFD (photon field detector) is an energy compensated diode with Tungsten powder mixed with epoxy added behind the chip to differentially absorb low energy scatter.

SFD (stereotactic field diode) is an unshielded diode, has a smaller sensitive area, designed specifically for measurements in stereotactic beams.
... an improper choice of a detector may lower the quality of the collected beam data. .... The variations seem unforgiving for small and large fields.

… inner diameter of the CC04 is larger than CC01… lower values for very small fields with the CC04 chamber are caused by averaging across the beam …

… One would expect that the PFD detector with its larger active areas give smaller measured values … PFD diode has a layer downstream to shield it from low energy photons … its response increases when the contribution of low-energy photons to the fluence decreases as the field size decreases …

• Diodes as beam data collection detectors

• Diodes as *in vivo* dosimeters
  – In IMRT fields
Why *in vivo* dosimetry for IMRT?

- IMRT QA often done on phantom
- Usually, no verification of actual patient plan delivery is performed
  - This is slowly changing
Why *in vivo* dosimetry for IMRT?

- Possible methods to verify dose delivered:
  - Reconstructing the dose from EPID images
  - Reconstructing the dose with the help of a transmission detector mounted on gantry
  - *In vivo* portal dosimetry
  - *In vivo* diode dosimetry
Diodes ...

• Have been extensively studied for static beam delivery
• Used for many years for *in vivo* dosimetry in clinics
• Have limitations and dependence on many factors, i.e. dose rate/SSD, obliquity, field size, etc.
• Provide a measure of the dose at a reference point (often Dose at $d_{max}$ at the CA) extracted from treatment plan or independent MU calculations
Factors affecting diode response

• Dose Rate/SSD
• Energy
• Type (p or n)
• Field Size
• Angle of Incidence
• Temperature
• Multileaf Collimators
• Diode buildup
The effect of MLC

- Introduction of MLCs increases collimator scatter, which is not accounted for in $S_c$ measurements for LINACs with tertiary multileaf collimators
- In static delivery, Jaws conform to MLCs closely (most of the time!)
- In dynamic (IMRT) delivery, multiple MLC-defined segments are found within the larger, jaw-defined field (Varian LINACs, with the exception of TrueBeam with jaw tracking)
The effect of MLC

Comparison of diode’s response in jaw and MLC-defined square fields
(Sun Nuclear QED diodes)
The effect of buildup

Buildup Diode

No-Buildup (Skin) Diode

Detector size: 0.8x0.8 mm

Courtesy: Sun Nuclear
The effect of buildup (static fields)

Comparison of buildup and no-buildup “QED” diodes
The effect of buildup (IMRT fields)

Percentage difference between measured and calculated doses for the two types of diodes: Slight decrease in over-response when no-buildup diode used
Patient study (Eclipse/Helios TPS)

*In vivo* diode dosimetry for routine quality assurance in IMRT

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- Diode measurements performed on 70 IMRT fields (on patient), corrected for SSD-dependence. Results compared to expected doses at $d_{max}$ obtained from treatment plans
- Measurements also performed on hybrid phantom plans using diodes and ion chambers for the same fields
Patient study (Eclipse/Helios TPS)

• Results:
  – Phantom measurements in which diode and ionization chamber measurements are compared show them to generally be in agreement within ±5%. In comparison with plan prediction of dose at $d_{max}$, average percent differences also tend to be within ±5%, but there are some larger discrepancies, in particular for small doses.
Patient study (Eclipse/Helios TPS)

• Results:
  – Clinical data comparison against planned doses show a wider spread, more consistent with a ±10% range, although ratios of diode-to-planned doses, averaged over all fields for a particular patient, were also within ±5%
Patient study (Eclipse/Helios TPS)

Percent differences: diode-to-planned doses (patient measurements)

Courtesy: Patrick Higgins
Diode measurements performed on 295 IMRT fields. Each measurement repeated once if the reading was more than 10% from the expected value. The better of the two measurements selected for analysis.

Measurements also performed on hybrid phantom plans for the same fields.
Patient study (Pinnacle TPS)

- Average difference of fields measured both on phantom and patient (n: 295) is around 3% on phantom and 7% on patient. The additional 4% is due to positioning errors/SSD effects since the same fields were delivered to phantom and patient and all phantom measurements are at a fixed SSD
  - No appreciable difference noted between sites (H&N vs. trunk) for phantom and patient measurements
### Patient Measurements

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<th>Avg.</th>
<th>Std. Dev.</th>
<th>% within 5%</th>
<th>% within 10%</th>
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### Phantom Measurements

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</table>
Patient study (Pinnacle TPS)

- Phantom diode measurements for 47 fields (6 patients) repeated to check for reproducibility and further analysis
- Dose measurements using an ionization chamber were also performed for these fields, with the chamber placed at $d_{\text{max}}$ in the phantom
Comparison of diode and ion chamber measured doses with expected values
Patient study (Pinnacle TPS)

- The analysis of 47 fields plans revealed a correlation between the accuracy of diode results and the percentage of the segments that expose the diodes only partially, i.e. not completely exposed or blocked.
- The higher the percentage of “partially blocked” segments, the larger the discrepancy between measured and expected readings.
Partial blockage of diode with MLCs
Partial blockage of diode with MLCs

Correlation of diode response with partial diode blockage
In vivo dosimetry
A practical approach to modulated radiation therapy

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Department of Radiation Science

Fig. 1. An example of how the EqualDose software displays the lateral energy fluence distribution for an IMRT beam. The white circle shows the position of the in vivo measurement point. It is also possible to zoom in on one part of the beam to better estimate the distance between the point of measurement and large dose gradients.
Fig. 2. Deviations between the actual and the calculated detector reading for all in vivo measurements. If the single measurement showing the largest deviation is excluded for each of the 47 beams, the mean deviation for head and neck treatments was 0.3% with a standard deviation of 1.9% and the mean deviation for prostate treatments was 1.1% with a standard deviation of 1.7%.
Conclusions

• Diodes designed for small field dosimetry the detector of choice for relative dosimetry
  — Caution when using them for large fields

• Diodes as *in vivo* dosimeters for IMRT fields add additional measure for verification of dose delivered but are challenging due to dose gradient and positioning accuracy