ScandiDos Delta4 Discover Transmission Detector: A new paradigm for patient safety and QA

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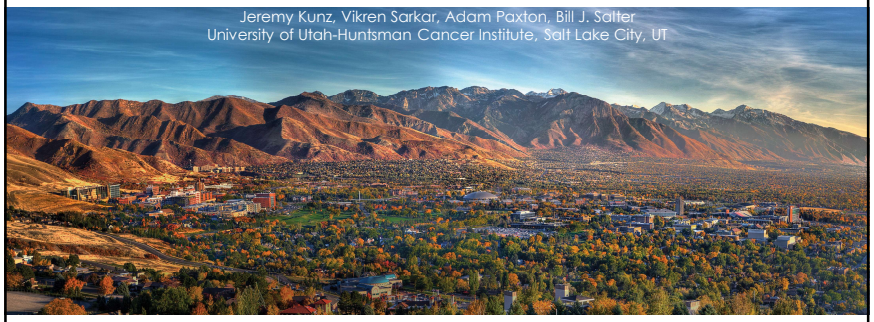

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Disclosures:

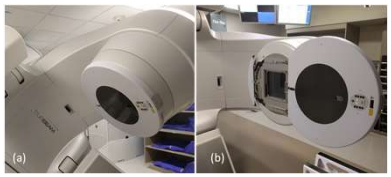
- No conflicts of interest to disclose

Outline

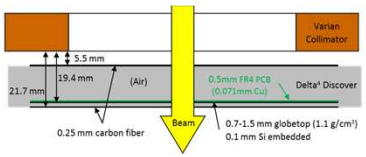
- What is the Delta4 Discover?
- Why use the Discover transmission detector?
- Impacts of Discover on beam characteristics
- Discover's ability to detect plan deviations
- Other Discover potential uses

What is the Delta4 Discover?

- The ScandiDos Delta4 Discover is a novel diode-based transmission detector that analyzes MLC position, gantry angle, and collimator angle.
- Attaches directly to the head of the LINAC.
- Positioned close enough to the collimator that it does not interfere with the LaserGuard (on TrueBeam platform).



Specifications of the Discover



- Consists of 4040 1 mm diameter and 0.05 mm thick p-type diode detectors.
- Detector spacing is 2.5 mm along direction of MLC motion and 5 mm perpendicular to leaf motion (projected at isocenter).
- Detection area of 20 cm x 25 cm (projected at isocenter).
- Uses built-in gyroscope and inclinometer to detect collimator and gantry angles, respectively.
- Can be used alone (express mode)-MLC, Gantry, and Collimator positions.
- Can be used in conjunction with Delta4+ phantom (synthesis mode) to predict dose based on detected fluence.

Why use the Discover transmission detector?

- Potential to independently verify the operation of the LINAC <u>during</u> treatment
- Provides per Fx delivered dosimetric information
- Information available immediately post treatment

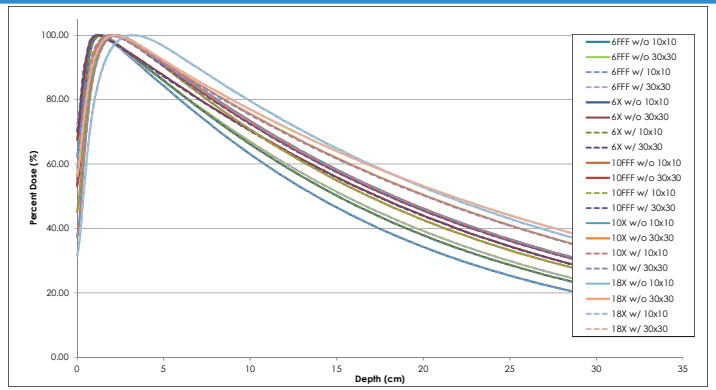
*Picture courtesy of ScandiDos

Discover Transmission/Attenuation

Energy (MV)	(10x10) cm²	(30x30) cm²	Average	Average Attenuation (%)
6	0.987	0.988	0.987	1.3
6FFF	0.984	0.985	0.985	1.5
10	0.989	0.991	0.990	1.0
10FFF	0.988	0.989	0.988	1.2
15	0.990	0.992	0.991	0.9
18	0.991	0.993	0.992	0.8

*Evaluation of the effects of implementing a diode transmission device into the clinical workflow. Paxton AB; Sarkar V; Kunz JN; Szegedi M; Zhao H; Huang YJ; Nelson G; Rassiah P; Su FF; and Salter BJ, Phys Med, Vol 80, pp 335-341, 2020

Discover Effects on PDDs



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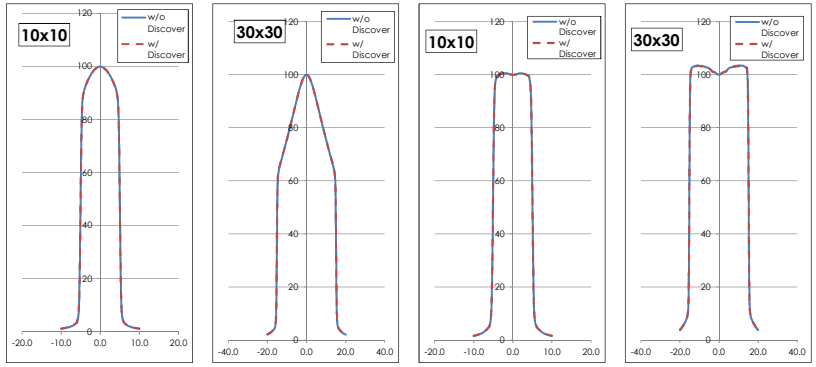
Discover Effects on Profiles



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Discover Effects on MV Imaging

- No significant impact on MV image quality.
- Contrast to noise ratio:
  - 187.4 (6.3)-with
  - 191.6 (4.3)-without
- Spatial frequency (50% MTF):
  - 0.441 (0.003) lp/mm-with
  - 0.439 (0.004) lp/mm-without

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Discover Effects on IMRT Delivery Validation

- Variety of clinical plans delivered to Delta4 Phantom+ (w/ and w/o Discover).
- Gamma analysis performed using 2%/2mm criteria

Plan Site	Beam Energy (MV)	Delivery Technique	Dose (cGy) x Fractions	Superficial Dose Evaluated
Pelvis (Male)	10	3 arc VMAT	180 x 28	X
Head and Neck (SIB)	6	3 arc VMAT	200, 180 x 30	X
Prostate SBRT	10FFF	2 arc VMAT	725 x 5	X
Spine SBRT	6FFF	2 arc VMAT	800 x 3	X
Brainstem	6	9 field IMRT	180 x 30	
Brain	10	4 arc VMAT	180 x 30	
Pelvis (female)	10	9 field IMRT	180 x 25	
Pelvis (male) (SIB)	10	2 arc VMAT	240,180 x 28	X
Pituitary Fossa	6	4 arc VMAT	180 x 24	X
Scalp	6	9 field IMRT	250 x 20	X

FFF - flattening filter free; SIB - simultaneous integrated boost; SBRT - stereotactic body radiation therapy; IMRT - intensity modulated radiation therapy; VMAT - volumetric modulated arc therapy

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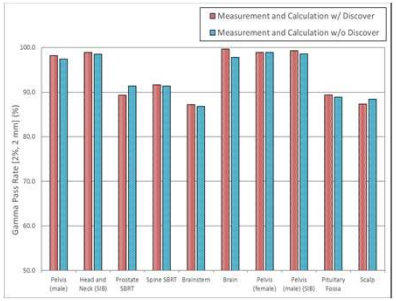
Discover Effects on IMRT Delivery Validation

- Good agreement between gamma pass rates.
- Average difference in pass rates was 0.2% and max difference -2.1% (prostate SBRT)



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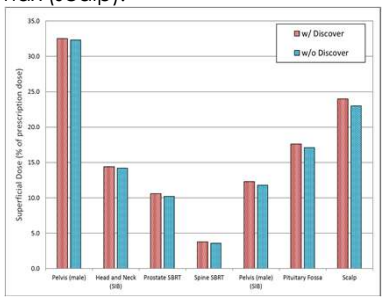
Discover Effects on Superficial Dose

- OSLDs placed on surface of Delta4 Phantom+ during IMRT QA delivery.
- Superficial dose higher for all deliveries with Discover with average of 0.4% higher; 1% max (scalp).



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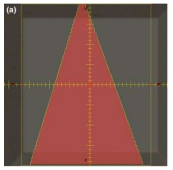
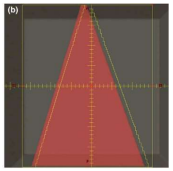
Sensitivity to Plan Deviations: Single Conformal Field

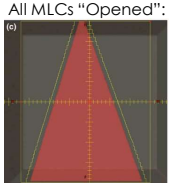
Base:



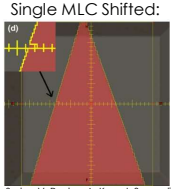
All MLCs Shifted Same Direction:



All MLCs "Opened":



Single MLC Shifted:



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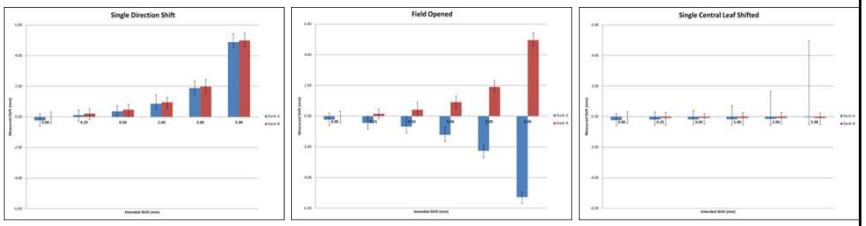
Sensitivity to Plan Deviations: Single Conformal Field



- Average detected leaf deviations within 0.2mm of planned deviations
- Max deviation 0.5mm of planned

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Sensitivity to Plan Deviations: Single Conformal Field

- Additionally, single conformal field was modified to move x-jaw out by 1 cm
- Also delivered the field using three different photon energies (6 MV baseline)
  - 10 MV
  - 6 FFF
  - 10 FFF

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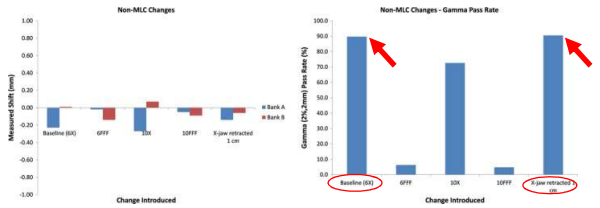

- Correctly detected essentially 0 leaf deviation
- Gamma pass rate decreased significantly with introduction of incorrect energies
- Was unable to detect 1 cm retraction of x-jaw

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Sensitivity to Plan Deviations: Single IMRT Field

- Similarly to 3D conformal plan, IMRT baseline plans (DMLC and SMLC/SS) created in Eclipse.
- The RTPlan was then modified using an in-house script to shift the leaves 0.25, 0.5, 1, 2, and 5 mm.
- Sensitivity to jaw location determined by disabling jaw tracking and delivering plan.
- Sensitivity to energy (DMLC) also tested by delivering with three additional energies other than the planned energy (10 MV, 6 FFF, and 10 FFF).
- All plans were delivered and measured using express and synthesis modes. SMLC plans also delivered to the Delta4+ alone.

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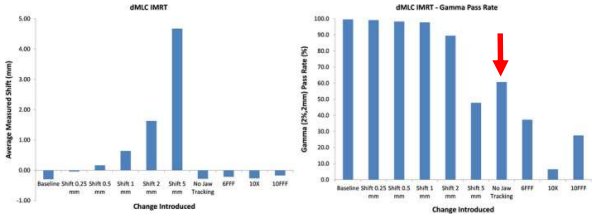

- Correctly detected average leaf deviation introduced (within 0.3 mm)
- Max leaf deviation detected 4.5 mm different from intended value
- Gamma pass rate decreased significantly with introduction of incorrect energies
- Gamma pass rate also significant drop for cases where jaw tracking was disabled

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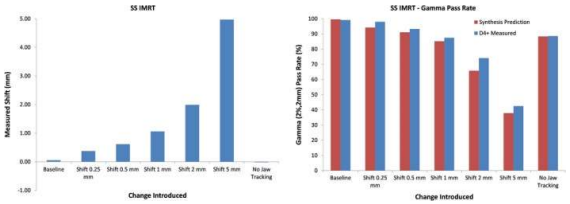

- Correctly detected average leaf deviation introduced (within 0.3 mm)
- Max leaf deviation detected 1.5 mm different from intended value
- Discover-predicted gamma pass rates correctly track with Delta4+ measured gamma pass rates
- Discover-predicted gamma pass rates slightly more sensitive to MLC deviations than Delta4+

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Sensitivity to Plan Deviations: Dynamic Conformal Arc (DCA)

- DCA baseline plan created in Eclipse
- The RTPlan was then modified using an in-house script to shift the leaves 0.25, 0.5, 1, 2, and 5 mm.
- Sensitivity to jaw location determined by disabling jaw tracking.
- Introduced gantry position errors of 1, 2, 5, and 10 degrees.
- Sensitivity to combination of errors tested by shifting MLCs by 1 mm with gantry position shifts of 1 and 2 degrees.
  - Evaluated using 1 mm/1° gamma criteria
- All plans were delivered and measured using express and synthesis modes.

*A systematic evaluation of the error detection abilities of a new diode transmission detector. Sarkar V; Paxton A; Kunz J; Szegedi M; Nelson G; Rassiah-Szegedi P; Zhao H; Huang YJ; Su F; and Salter BJ, J APPL CLIN MED PHYS, Vol 20, Issue 9, pp 122-132, 2019

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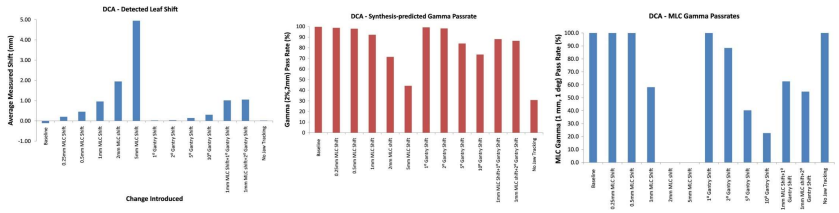

- Correctly detected average leaf deviation introduced (within 0.3 mm)
- Max leaf deviation detected 1.7 mm different from intended value
- Max detected leaf deviations higher than expected when gantry deviations were introduced (6 mm for 10° gantry shift)
- MLC gamma pass rates drop once leaf and gantry errors exceed set tolerances

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Sensitivity to Plan Deviations: Volumetric Modulated Arc Therapy (VMAT)

- The RTPlan was then modified using an in-house script to shift the leaves 0.25, 0.5, 1, 2, and 5 mm.
- Sensitivity to jaw location determined by disabling jaw tracking.
- Introduced gantry position errors of 1, 2, 5, and 10 degrees.
- Introduced collimator position errors of 1, 2, 5, and 10 degrees.
- Sensitivity to combination of errors tested by shifting MLCs by 1 mm with gantry position shifts of 1 and 2 degrees.
  - Evaluated using 1 mm/1° gamma criteria
- Delivered to Discover (synthesis mode) and Delta4+.

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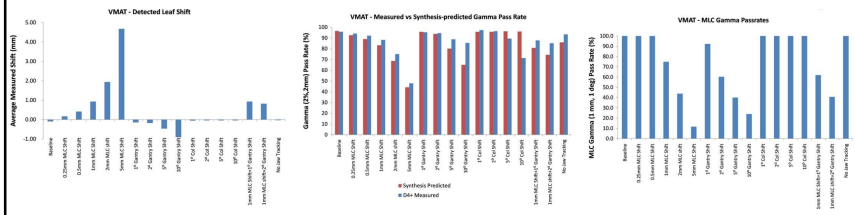

- Correctly detected average leaf deviation introduced (within 0.8 mm)
- Max leaf deviation detected 10 mm different from intended value
- Max detected leaf deviations higher than expected when gantry deviations were introduced (25 mm for 10° gantry shift)
- MLC gamma pass rates drop once leaf and gantry errors exceed set tolerances
- Collimator changes did not affect gamma pass rates

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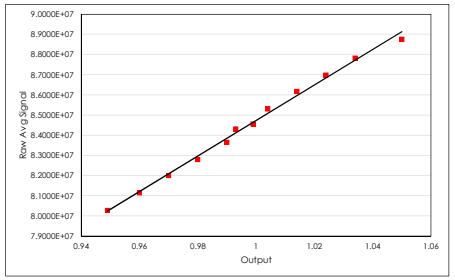
Other Potential Uses: Output

- Made series of output measurements using IC and Discover
- Obtained conversion factor of raw signal from Discover to output



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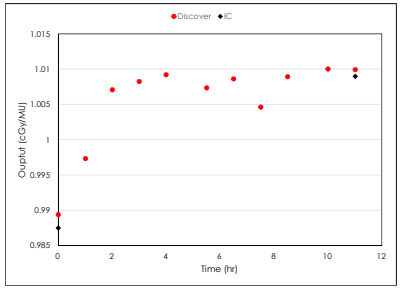

- Using conversion factor, tracked fluctuations in LINAC output through treatment day
- Obtained IC measurements of output at beginning and end of treatment day
- Discover-measured output correlated very well with IC-measured output
- Showed fluctuation of up to 2% from baseline over treatment day

Other Potential Uses: Real-Time Measurements

- Software version allowing for real-time tracking of:
  - MLC position
  - Gantry angle
  - Dose delivered

Summary of Delta4 Discover Transmission Detector

- Very minimal impact on beam characteristics (PDDs, profiles, MV image quality, etc.)
- Able to correctly detect sub-millimeter deviations in MLC positions (static 3DCRT field, DCA, IMRT, & VMAT).
- Generally more sensitive to plan deviations that Delta4+ alone (in Synthesis mode)
- Potential to make other QA on LINAC more efficient
- Real-time software in the works

References:

- Evaluation of the effects of implementing a diode transmission device into the clinical workflow. Paxton AB; Sarkar V; Kunz JN; Szegedi M; Zhao H; Huang YJ; Nelson G; Rassiah P; Su FF; and Salter BJ, *Phys Med*, Vol 80, pp 335-341, 2020.
- A systematic evaluation of the error detection abilities of a new diode transmission detector. Sarkar V; Paxton A; Kunz J; Szegedi M; Nelson G; Rassiah-Szegedi P; Zhao H; Huang YJ; Su F; and Salter BJ, *J APPL CLIN MED PHYS*, Vol 20, Issue 9, pp 122-132, 2019.

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