Testing of Prototype Delta^{4AT} Diode Array for In-Vivo Radiotherapy Dosimetry

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Purpose : The Delta^{4AT}, (ScandiDos, Sweden,) is a head-mounted p-Si diode array detector, that is intended to be used during a patient's treatment. The device currently only exists in prototype form. By introducing MU and MLC errors into radiotherapy plans, the ability of the hardware and software to detect errors was measured. The closest separation of the diodes, (when projected to the isocentre plane,) is 8mm in the prototype, but it is intended to reduce this to 2mm in the final device.

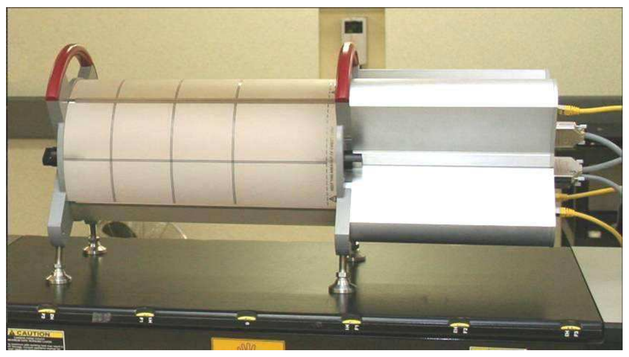

Fig.1 Delta^{4PT}

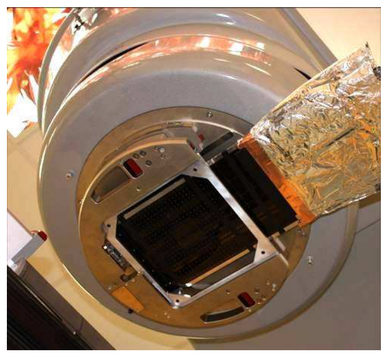

Fig.2 Prototype Delta^{4AT}

Background : The couch mounted Delta^{4PT} phantom is now used in around 200 centers world-wide for pre-treatment verification of complex radiotherapy plans. The new head mounted Delta^{4AT} allows this verification to continue throughout the patient's treatment. The superscripts PT and AT stand for pre-treatment and at treatment.
Recent articles in the New York Times, ref 1, have reminded the radiation therapy community of the continued need to ensure that treatments are as safe as possible. In the United Kingdom, the use of in-vivo dosimetry is nationally recommended for the first fraction for all patients, but in most centres it is used for only a few patients. As the designers of the Delta^{4PT}, ScandiDos have considerable experience in the design of diodes and the associated electronics for radiation measurement. Recent work, ref 2, has demonstrated that the Delta^{4PT} compares favorably to the other available phantoms in the detection of a range of possible errors in radiotherapy plans.

Method : The intentional MU errors were created by modifying the MU in the record and verify system. The intentional MLC errors were created by converting the DICOM plans to text files and using in-house software to re-position the MLCs of each control point before converting back to a deliverable DICOM plan. The Delta^{4AT} is first calibrated for each patient by taking a simultaneous measurement with the Delta^{4PT}. The Delta^{4AT} then reports subsequent measurements of the same plan as predicted doses on the two perpendicular diode arrays within the cylindrical Delta^{4PT} phantom. To test the accuracy of the Delta^{4AT}, the Delta^{4PT} was left on the couch for the subsequent beam deliveries and the predicted doses in the Delta^{4PT} were compared to the actual doses. The Delta^{4AT} was calibrated with known good conformal and RapidArc^{TM} plans, (Varian Medical Systems.). MU errors of -1.5%, -3%, +1.5% and +3% were used and MLC errors of +1.5mm to the X1 bank, +3mm to the X1 bank and +1.5mm and +3mm to an individual MLC.

Results : The TPS planned dose distribution, the Delta^{4PT} measured dose distribution and the dose distribution predicted by the Delta^{4AT} in the Delta^{4PT} phantom were compared using the Gamma Index, ref 3, and the dose deviation. An absolute Gamma test was used with 100% equal to the maximum dose in the planned distribution and diodes receiving < 20% measured dose not included. The comparisons of the TPS and the Delta^{4PT} or Delta^{4AT} show the ability of these detectors to find each of the intentional errors. The comparisons between the Delta^{4PT} and Delta^{4AT} show how effectively the Delta^{4AT} can represent the Delta^{4PT} for every beam of the treatment.

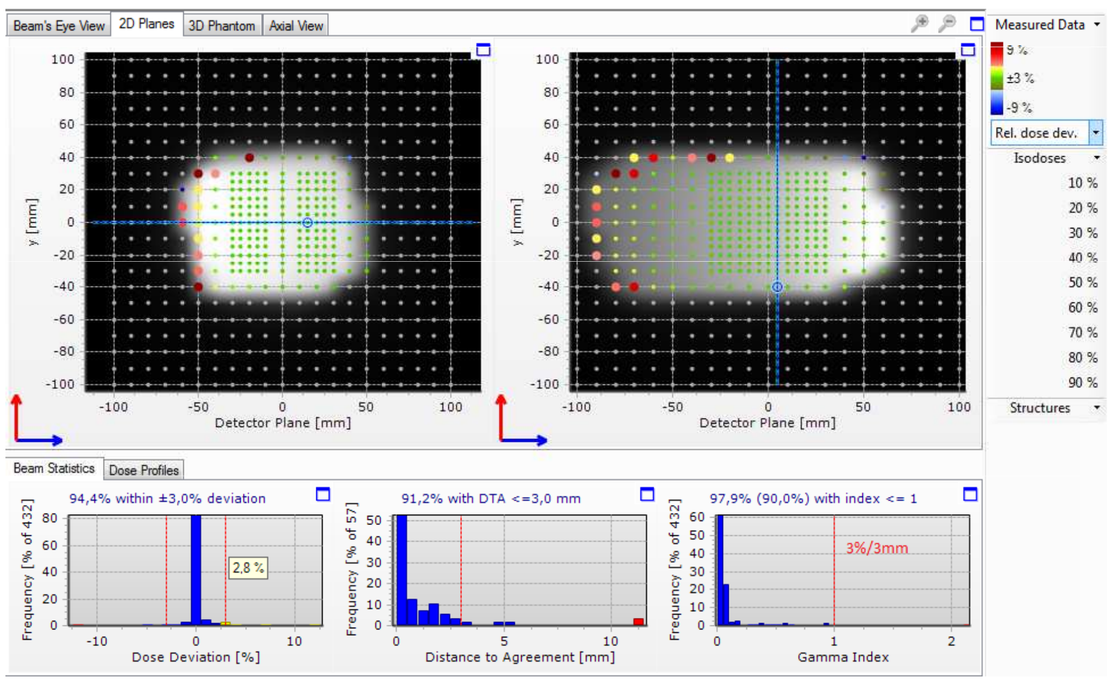

Fig.3 Gamma test comparison of Delta^{4AT} and Delta^{4PT} for a post oblique conformal field with a +3mm deliberate error in the MLCs of the X1 bank

Results Continued : For a RapidArc plan and MU errors, the Delta^{4AT} measurements were within gamma <1 (0.5%/0.5mm) of the Delta^{4PT} for >99% of diodes. For a RapidArc plan and smaller MLC errors (+1.5mm), the Delta^{4AT} measurements were within gamma < 1 for > 95% of diodes at 3%/3mm. For a conformal plan and a +3mm X1 bank error the Delta^{4AT} measurements were within gamma <1 of the Delta^{4PT} for >95% of diodes at 2%/2mm

	3%/3mm			1.5%/1.5mm			0.5%/0.5mm
VMAT Plans	PT vs TPS	AT vs TPS	AT vs PT	PT vs TPS	AT vs TPS	AT vs PT	AT vs PT
	%	%	%	%	%	%	%
Original	100.0	n.a.	n.a.	97.2	n.a.	n.a.	n.a.
-1.5%MU	100.0	100.0	100.0	95.4	95.0	100.0	100.0
-3%MU	98.8	98.5	100.0	80.7	81.0	100.0	100.0
+1.5%MU	100.0	100.0	100.0	95.0	94.5	100.0	100.0
+3%MU	97.6	97.9	100.0	71.2	72.2	100.0	100.0
+1.5mm Shift in bank X1	96.9	97.9	99.9	76.6	79.7	99.4	90.4
+3mm Shift in bank X1	80.0	80.3	99.1	43.2	46.9	96.4	72.2
+3mm error in single MLC leaf	100.0	100.0	100.0	99.1	99.7	99.9	96.3

Table.1 Gamma Test Comparisons of the TPS, Delta^{4PT} and Delta^{4AT}

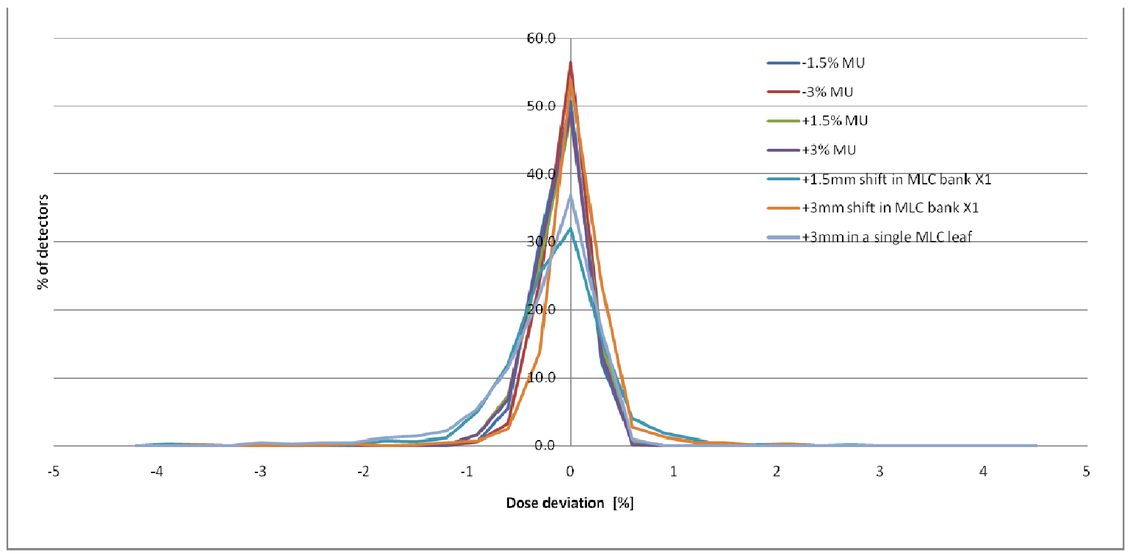

Fig.4 Dose Deviation Between Delta^{4AT} and Delta^{4PT} for Intentional Errors in VMAT Plans

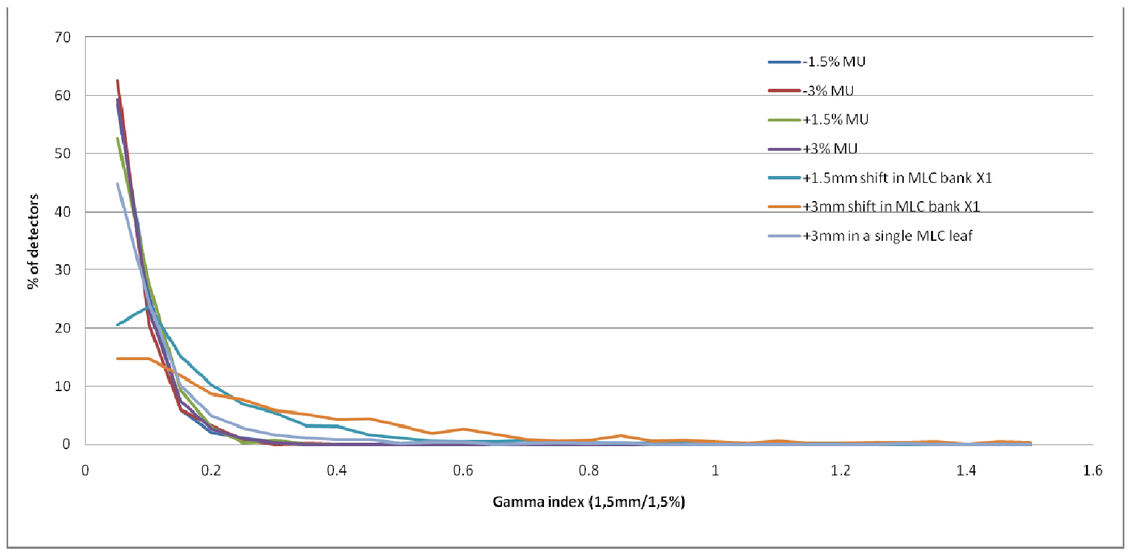

Fig. 5 Gamma Index (1.5%/1mm) Between Delta^{4AT} and Delta^{4PT} for Intentional Errors in VMAT Plans

Conclusion : The prototype Delta^{4AT} has been shown to produce accurate measurements and the measurements from the finished device are likely to be even more comprehensive due to the smaller spacing between the diodes. The Delta^{4AT} will allow in-vivo dosimetry throughout a patient's treatment.

References :

1 Walt Bogdanich, Radiation Offers New Cures, And Ways to Do Harm, New York Times, Jan 23, 2010
2 A.Fredh et al, Comparison of Patient Specific QA Systems for Rotational Therapy, oral presentation ESTRO 2010, abstract in Radiotherapy & Oncology Vol 96 September 2010 Supplement.
3 Low DA, Harms WB, Sasa Mutic, Purdy JA, 1998, A technique for the quantitative evaluation of dose distributions, Med Phys 25, 656 - 661

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