

A Study of Motion Tracking Accuracy of Robotic Radiosurgery Using a Novel CCD Camera Based End-to-end Test System

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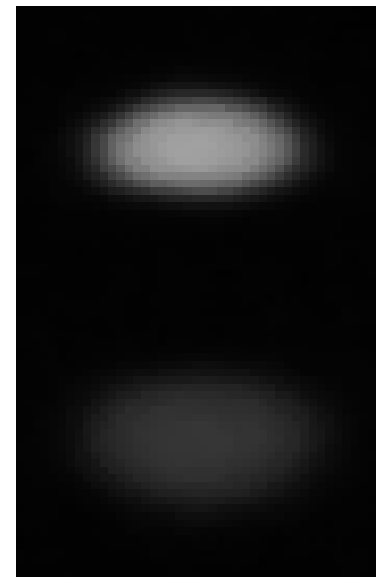
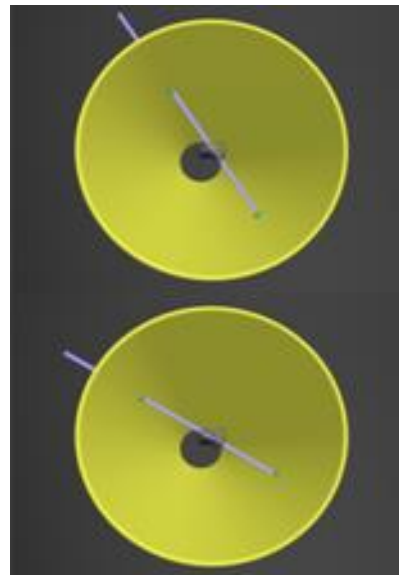
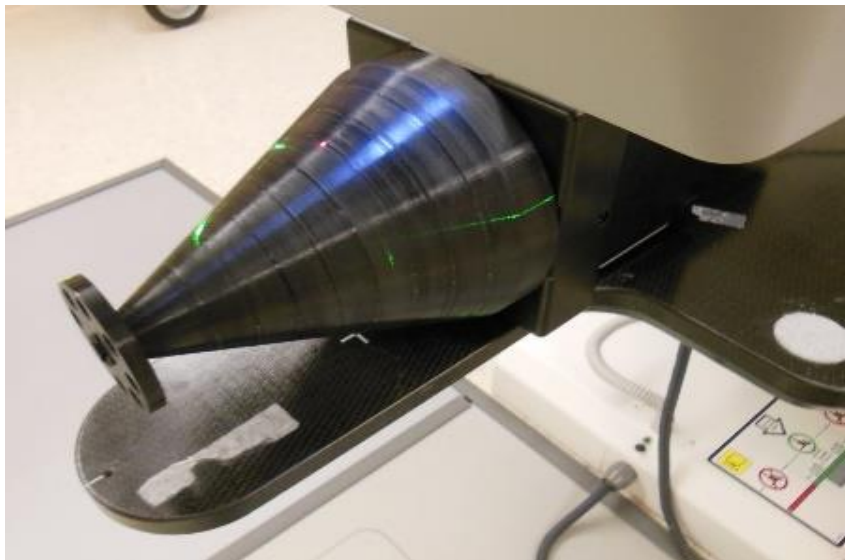
Stanford University

Purpose

To assess the motion tracking (Synchrony) accuracy for CyberKnife using a scintillator/CCD camera based phantom.

A Scintillator/CCD System: XRV124

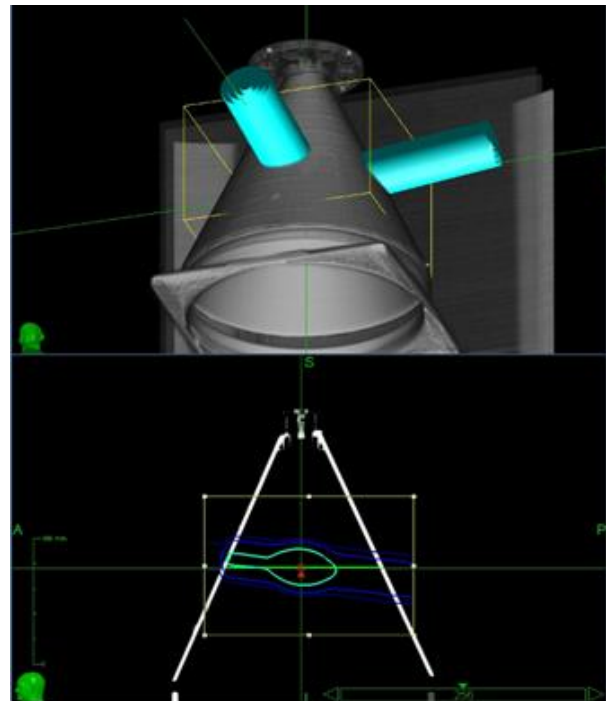
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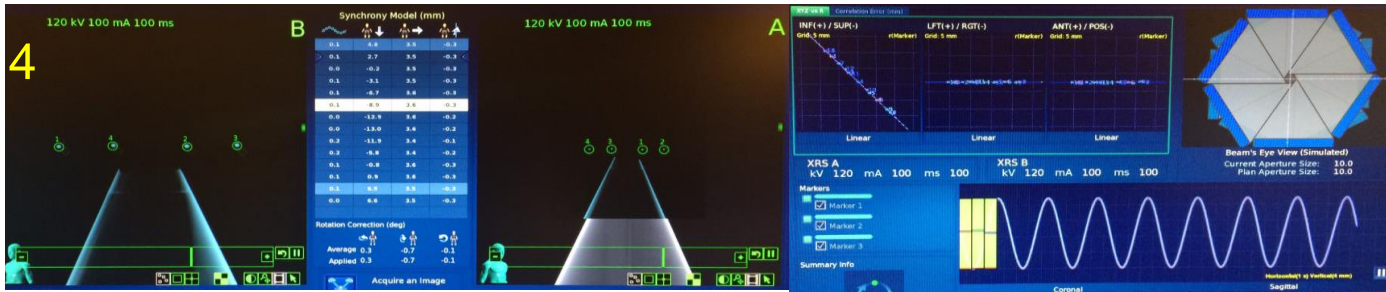
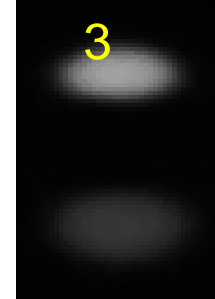
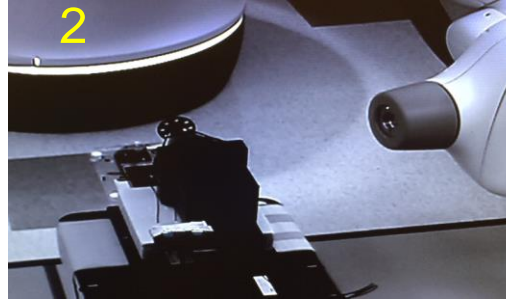
Beam by beam delivery accuracy($\leq 0.3\text{mm}$)
Sensitivity to beam spot size ($< 0.2\text{mm}$)

Material and Method: Treatment Planning

1. XRV124 phantom was first scanned at 1.25 mm slice thickness.
2. The CT was transferred to the treatment planning system (Multiplan v5.3)
3. Two plans were created with Anterior and Lateral beams :
 - Plan #1, 10mm, 20mm, 35mm, 45mm, 200 MU per beam.
 - Plan #2, 10mm ,1000 MU per beam.



Material and Method: Treatment Delivery



1. The phantom was placed on the CIRS motion platform (CIRS 008PL motion platform).
2. The treatment was delivered on a CyberKnife M6 system.
3. The XRV-124 CCD camera recorded the integrated image or video during the delivery (10frame/sec).
4. Fiducial tracking and Synchrony was used.

Material and Method: Two Tests

XRV in integrating mode: tracking stability and reproducibility

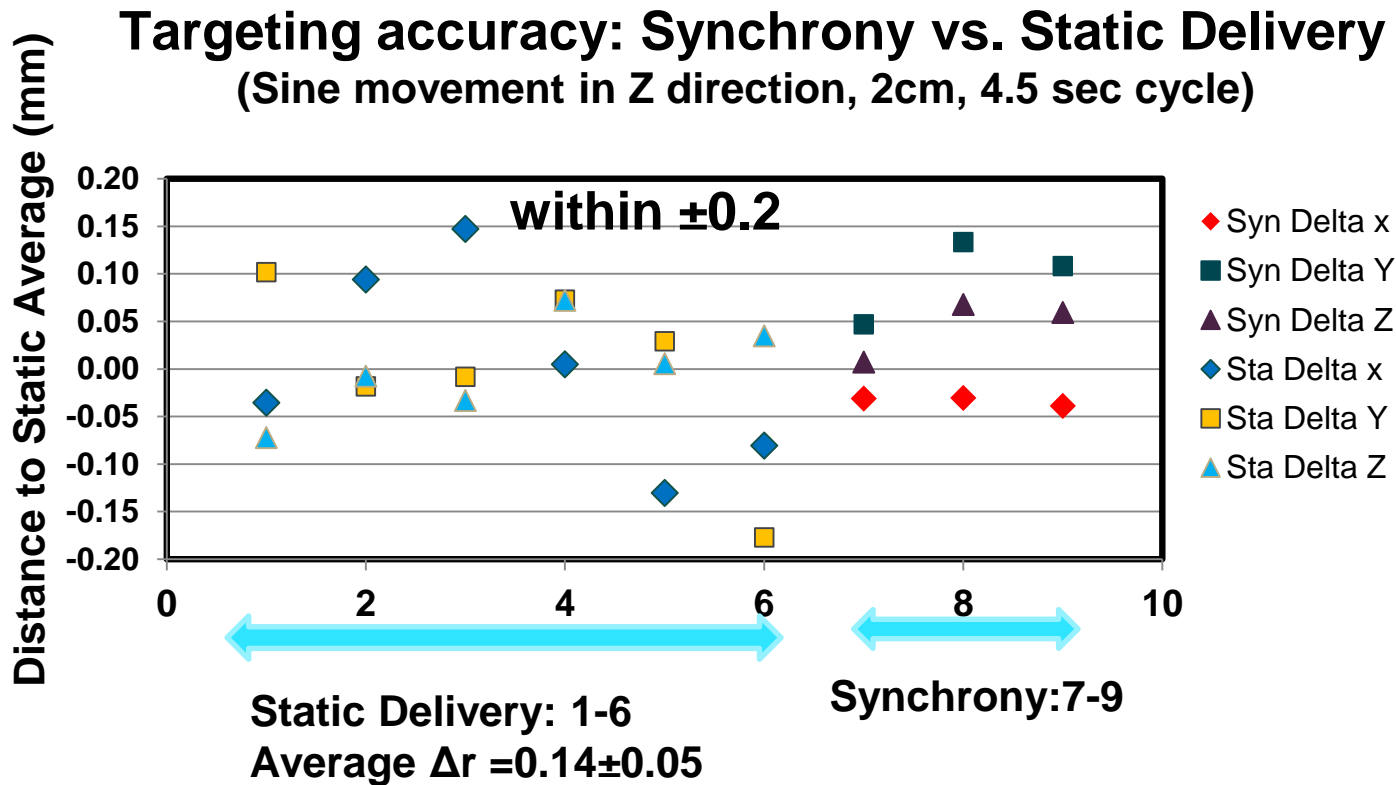
- Plan #1
- Sine wave
- 6 Static delivery, 3 Synchrony delivery.
- Targeting accuracy and beam shape consistency was assessed.

XRV in video mode: tracking accuracy with different motion

- Plan #2
- 1)No motion; 2)a typical patient breathing pattern; 3)a Sine wave; 4) a Sine wave with 15 degree phase shift.
- Log-files were fetched from CyberKnife system for marker motion.
- Measure beam position was aligned with marker motion.

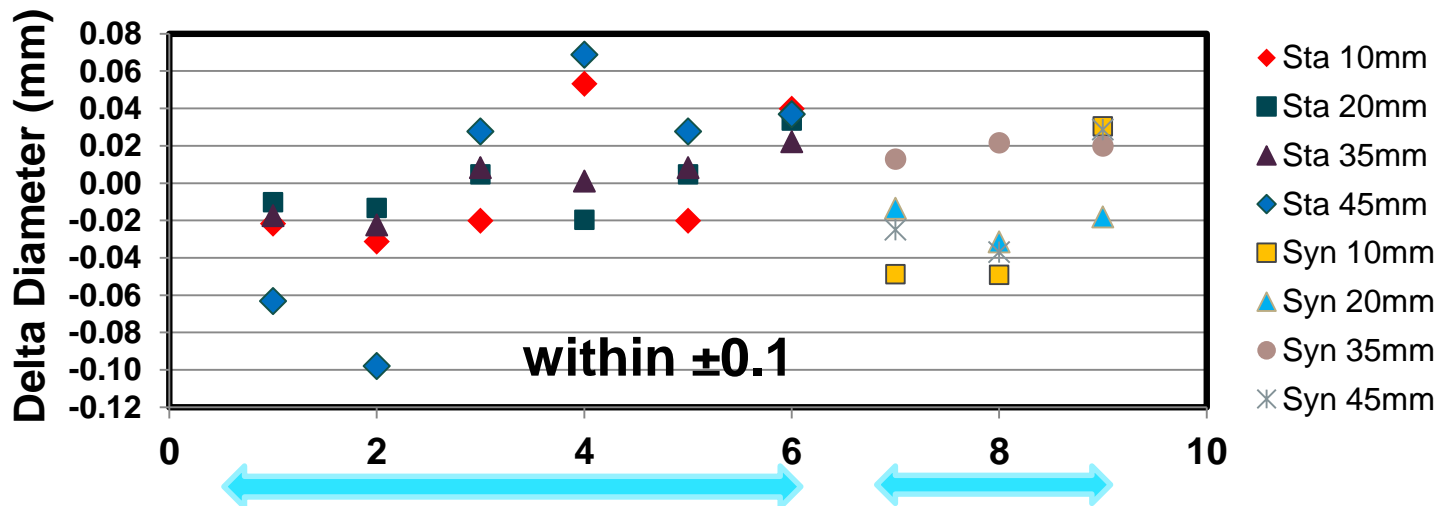
Motion is Sup-Inf only. Amplitude: 2cm, T=4 sec.

Results: Targeting Accuracy (Plan #1)



Results: Beam Diameter Consistency (Plan #1)

Difference of Measured AP Beam Diameter to Static Average
(Sine movement in Z direction, 2cm, 4.0 sec breathing cycle)

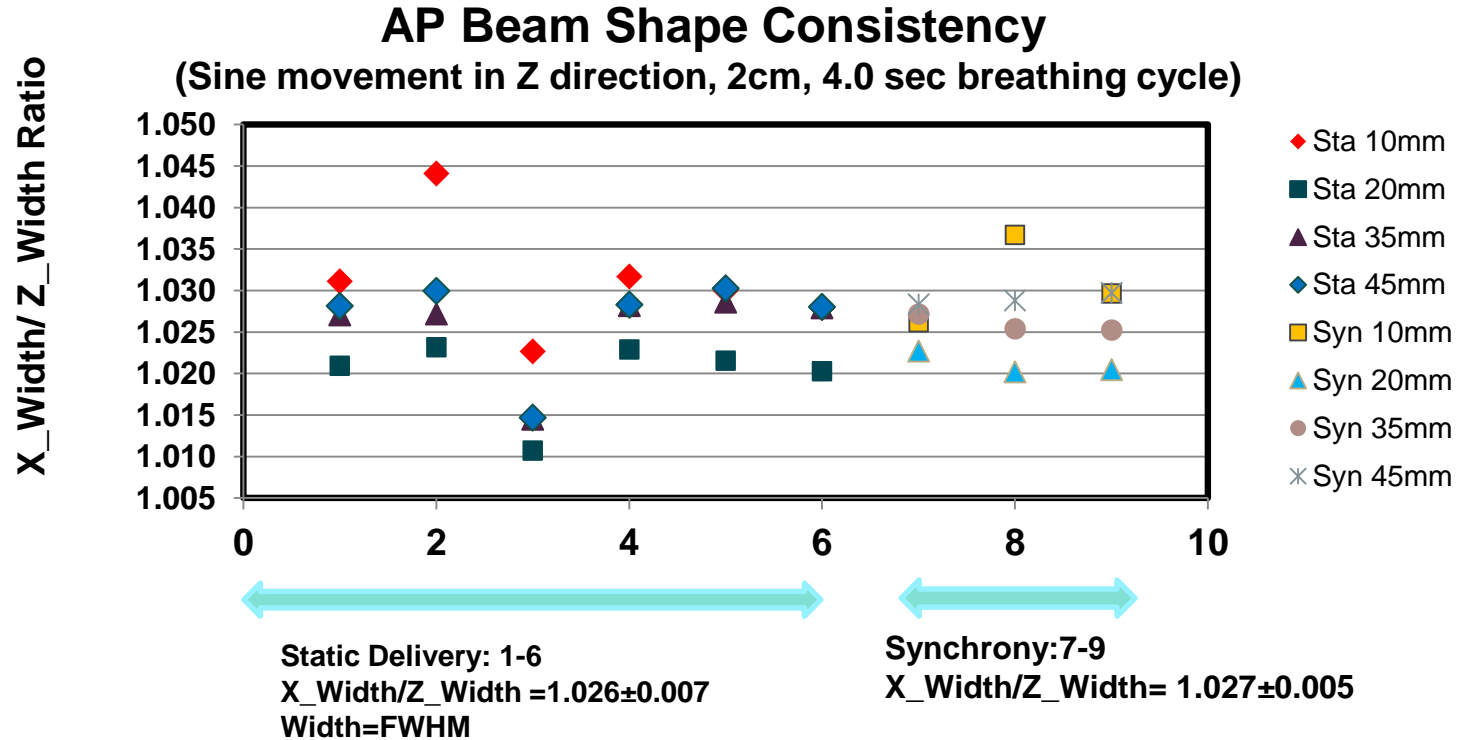


Static Delivery: 1-6
Average $|\Delta d| = 0.03 \pm 0.02$

Synchrony: 7-9
Average $|\Delta d| = 0.03 \pm 0.01$

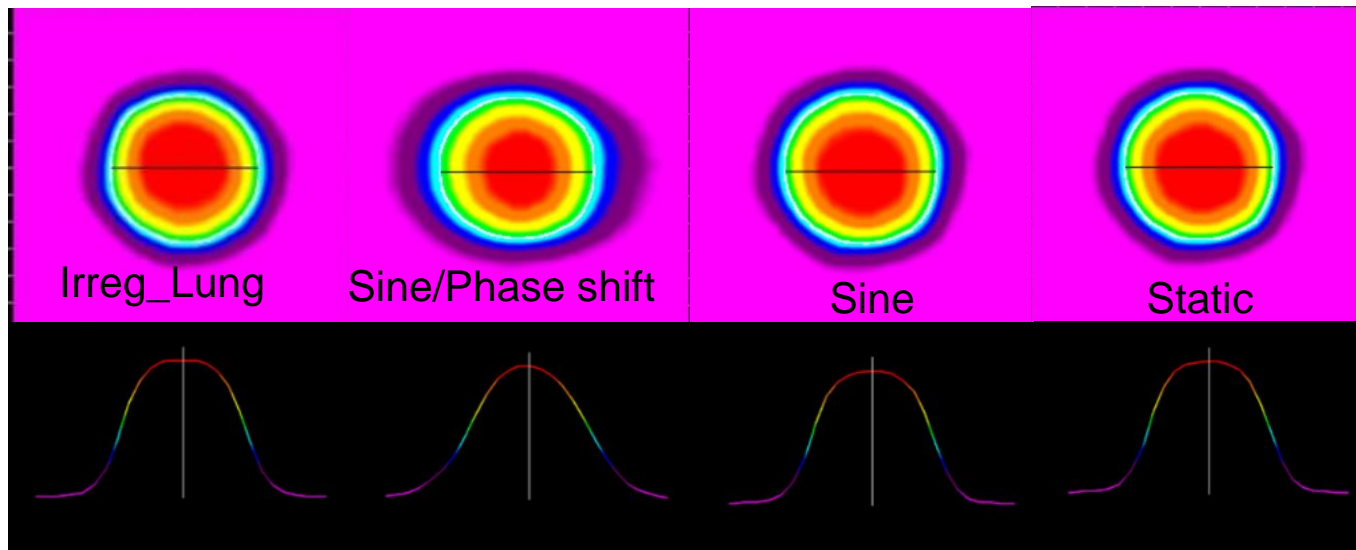
Diameter = FWHM

Results: Beam Shape Consistency (Plan #1)



Results: Dose Integration From Video (AP beam, Plan #2)

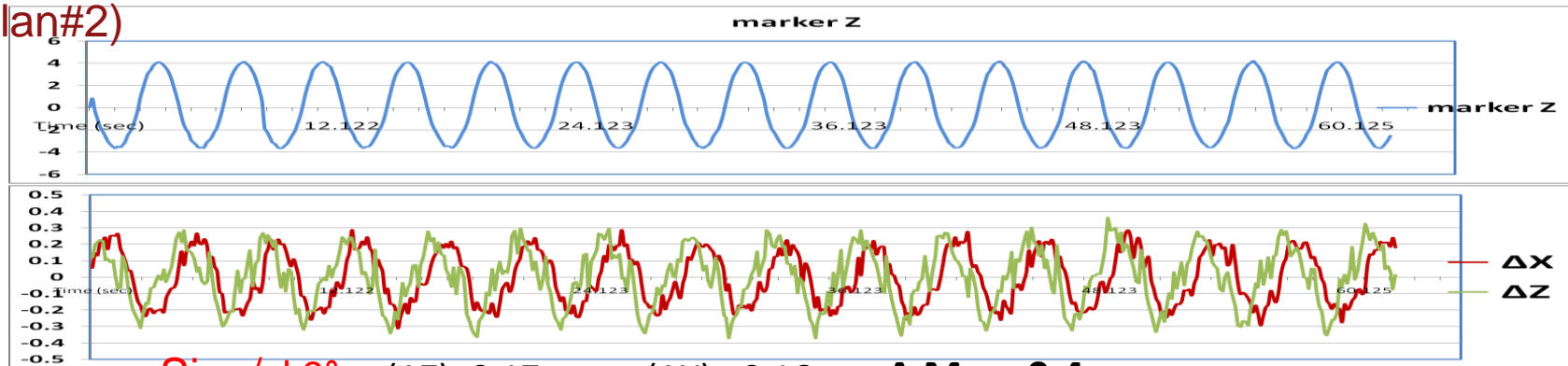
Measured X and Z positions agree within 0.25mm



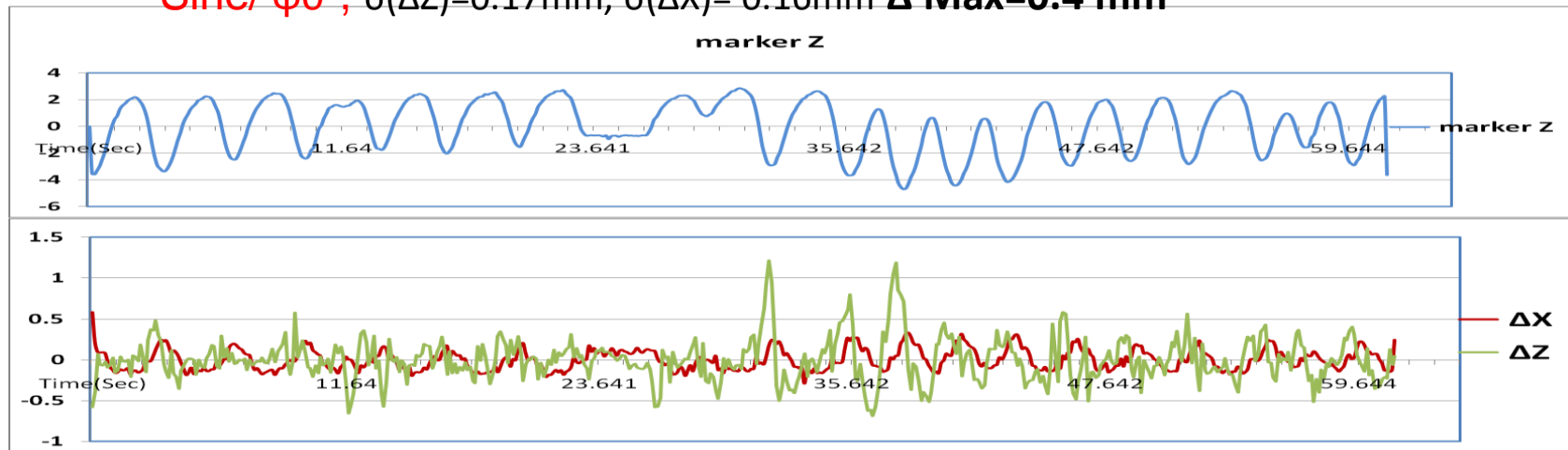
	X Width	Z Width	2D Width	X Width/Z Width
Irreg	11.393	11.189	11.3762	1.018
Sine/15 degree phase shift	10.881	11.520	11.3278	0.944
Sine/no phase shift	11.263	11.077	11.3342	1.017
Static	11.438	11.231	11.4224	1.018

Field width is defined as FWHM of the profile.

Results: Position Deviation (from Average) vs. Time (AP Field) (Plan#2)

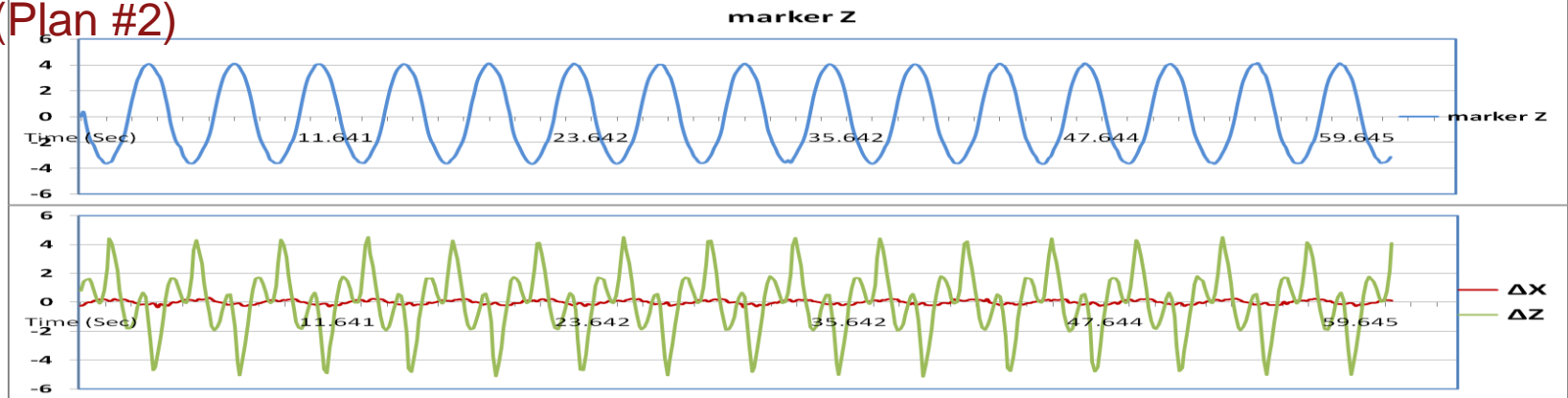


Sine/ $\phi 0^\circ$, $\sigma(\Delta Z)=0.17\text{mm}$, $\sigma(\Delta X)=0.16\text{mm}$ **$\Delta \text{Max}=0.4 \text{ mm}$**

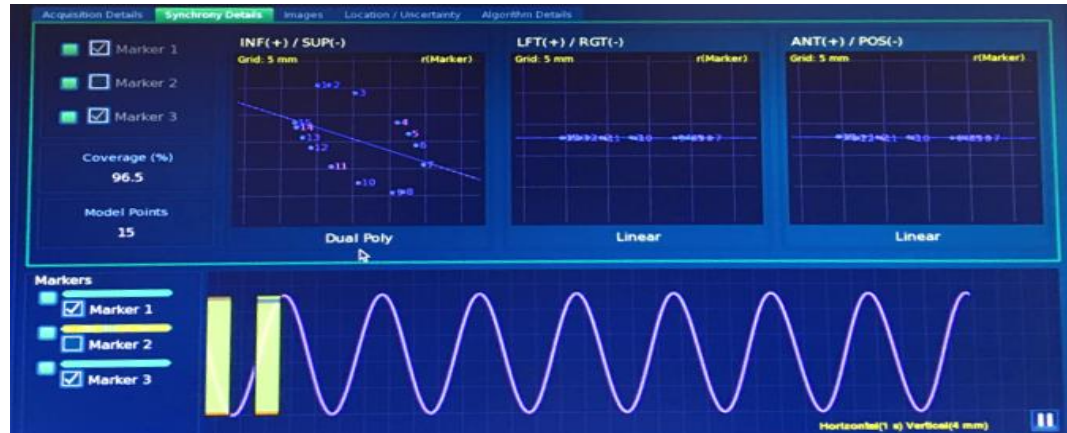


Irregular Lung, $\sigma(\Delta Z)=0.26\text{mm}$, $\sigma(\Delta X)=0.13\text{mm}$ **$\Delta \text{Max}=1.2 \text{ mm}$**

Results: Position Deviation (from Average) vs. Time (AP Field) (Plan #2)

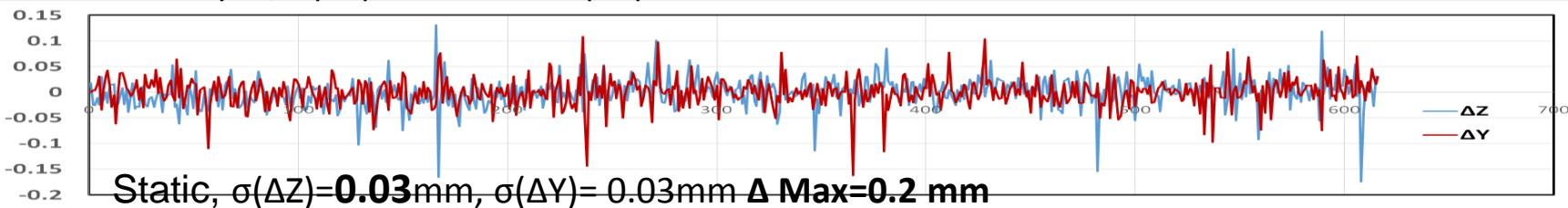
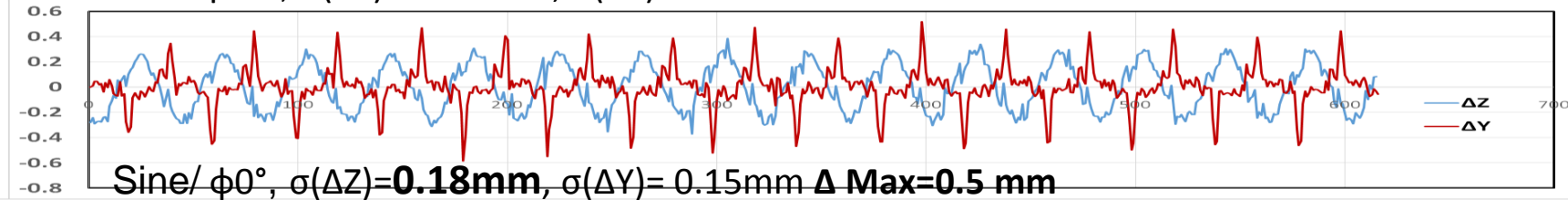
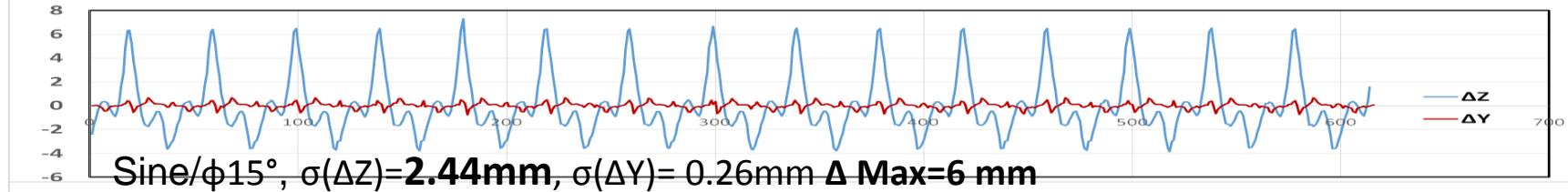
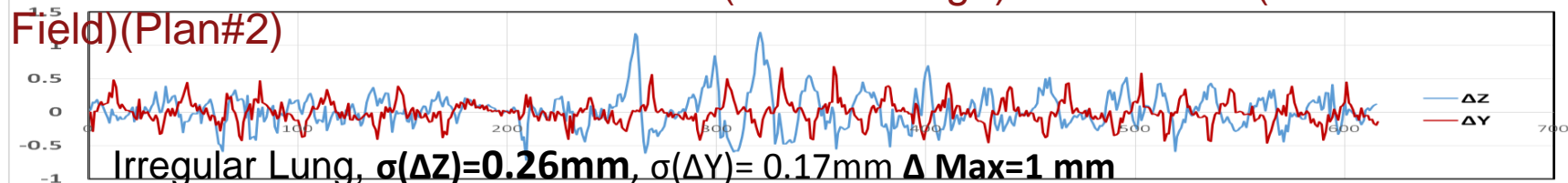


Sine/ $\phi 15^\circ$, $\sigma(\Delta Z)=2.13\text{mm}$, $\sigma(\Delta X)=0.14\text{mm}$ $\Delta \text{Max}=5\text{ mm}$



Dual poly model was used.

Results: Position Deviation (from Average) vs. Time (Lat Field)(Plan#2)



Measured average positions agree within 0.46mm

Conclusion

- The XRV-124 system is able to provide 4D targeting accuracy for Cyberknife delivery with Synchrony.
- The experimental results showed overall sub-millimeter tracking accuracy of Cyberknife Synchrony on a moving phantom with good target to marker correlation (including irregular pattern).
- The tracking error increased significantly when phase shift was introduced.

Thank you!