R&D Plan for Demonstrating Elements of a Target Engagement System

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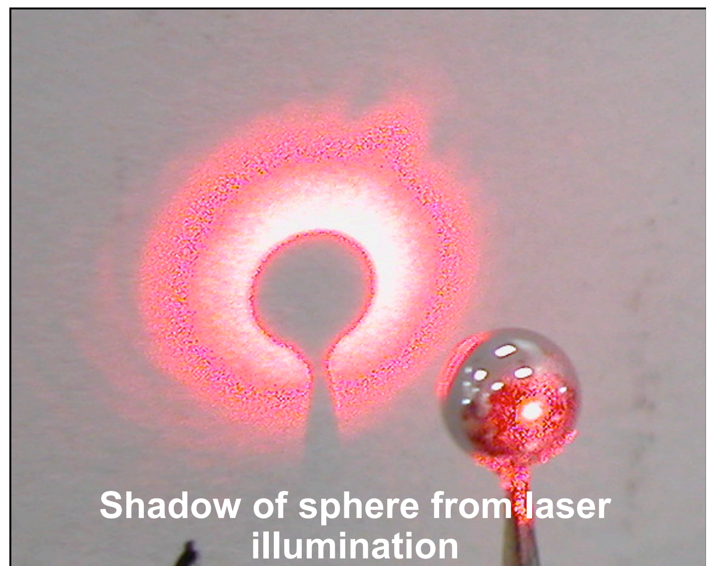
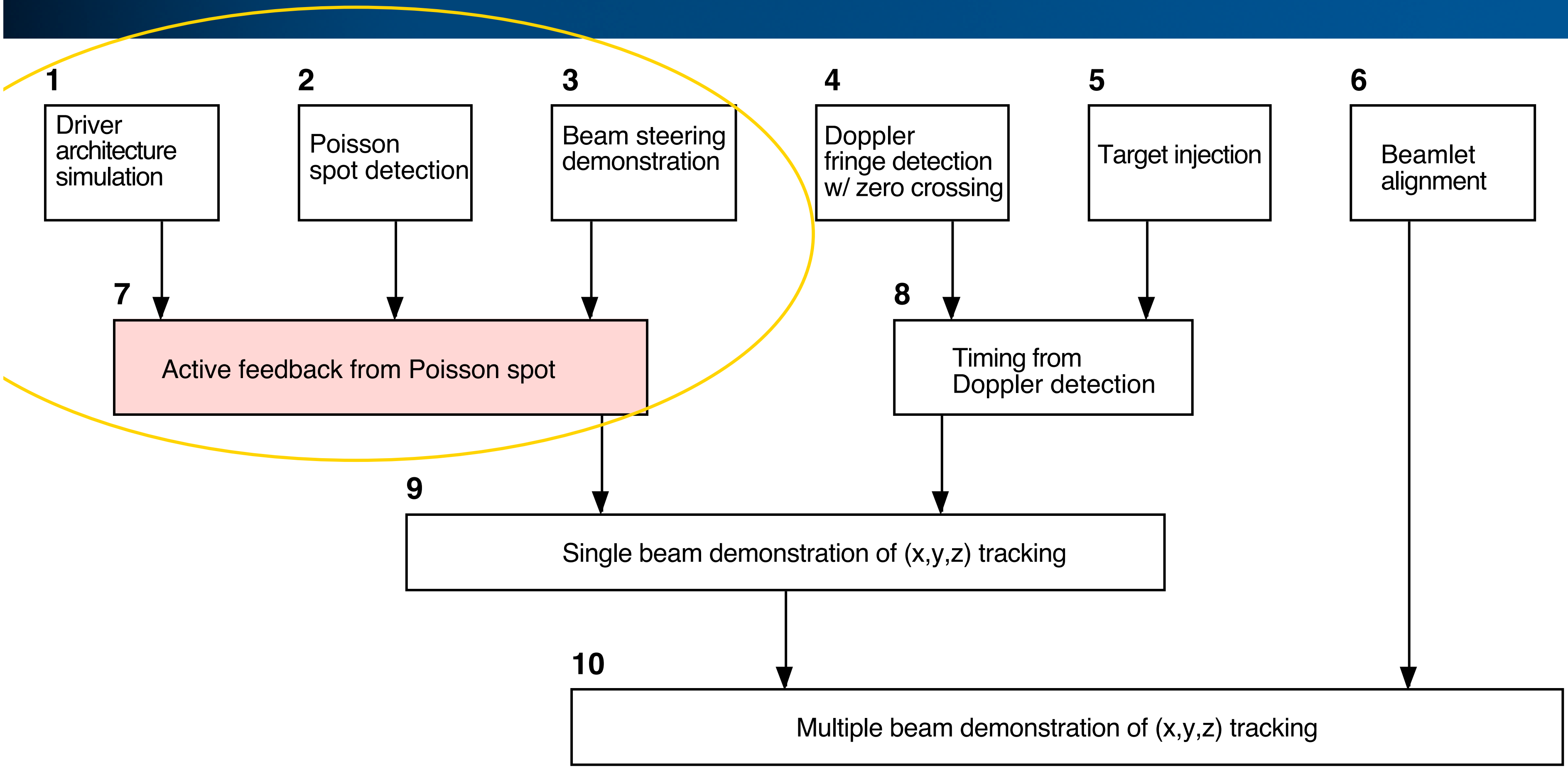
Overview of Flint Engagement Concept

- We have used Graham Flint's engagement concept from HAPL presentation (March 3, 2005) and paper (Sept. 2, 2004) to devise a beam tracking & steering R&D plan.
- This engagement concept can be implemented to utilize either KrF or DPSSL driver beams.
- We have developed a *roadmap* that breaks this system into smaller, prototypical elements.
- We have examined one portion of this system and plan to demonstrate its feasibility: *active feedback and beam steering from Poisson spot position measurements*


Shadow of sphere from laser illumination

R&D Plan



This work will encompass elements 1-3, 7

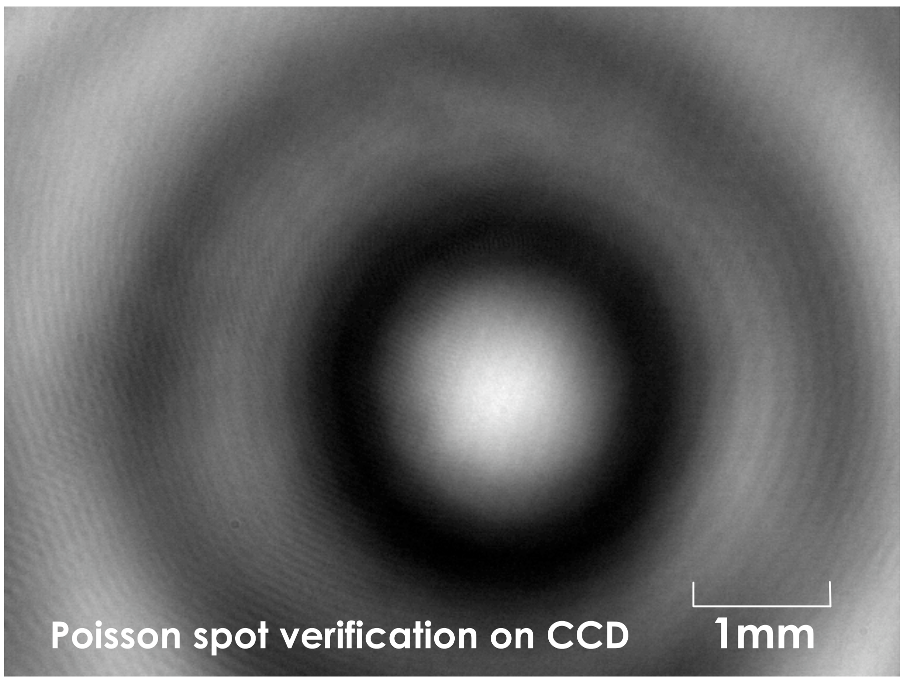
Target Tracking Requirements for IFE Power Plant

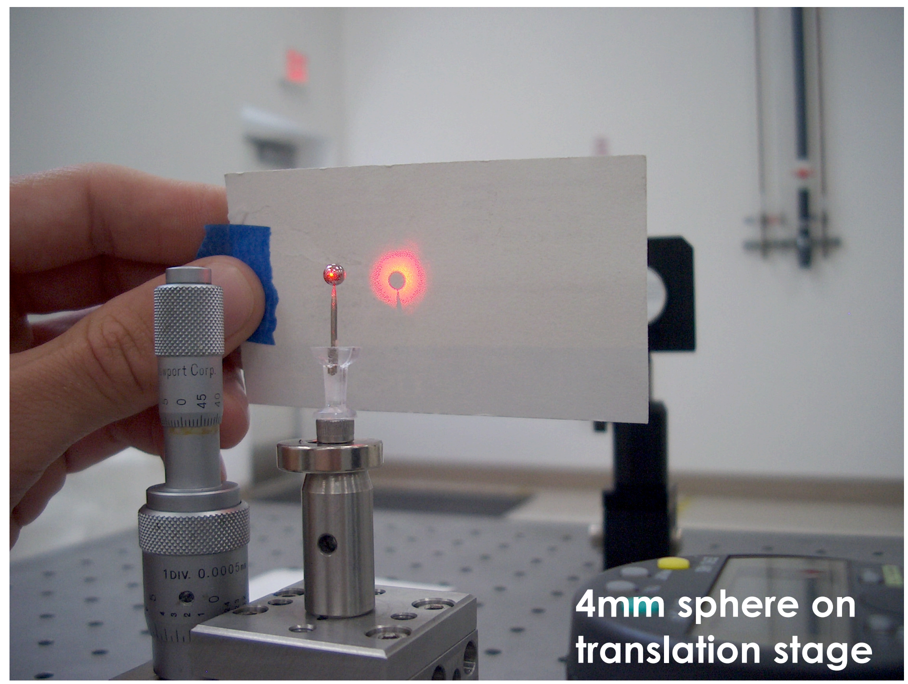
Project Goals:

- ***Tracking accuracy:*** **± 10 μm**
- ***Target illumination accuracy:*** **± 10 μm** $_{rms}$
  (rms for all beamlets)
- ***Final Steering:*** **~ 1-2 ms** @ 100 m/s injection velocity
  - Last target position update before chamber center: ~10-20 cm

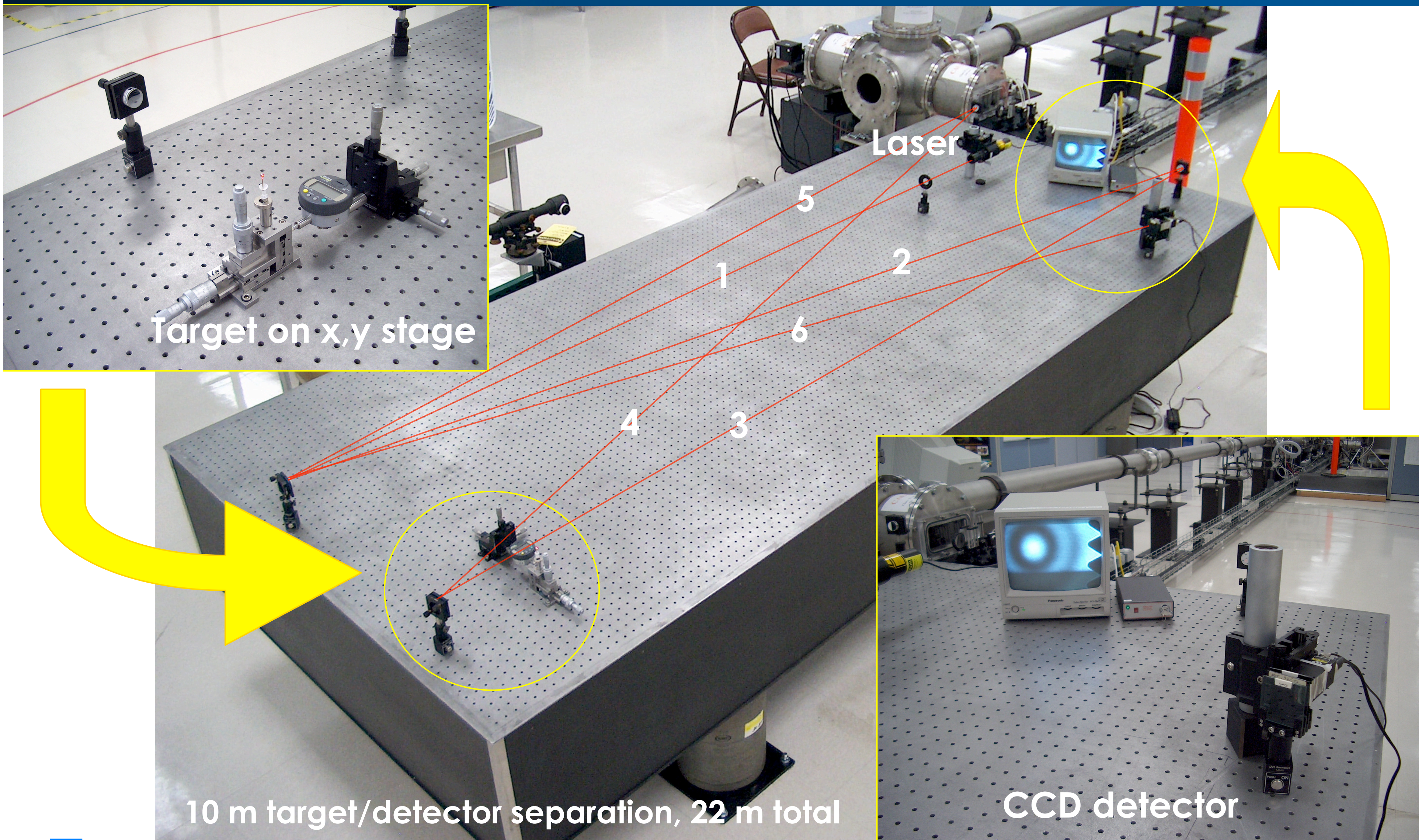
Poisson Spot Tracking Overview

- A *Poisson spot* is an intense diffraction spot that is caused by, and lies on axis with, a circular obstruction.
- We have imaged a Poisson spot from a 4mm steel sphere directly onto a CCD chip.

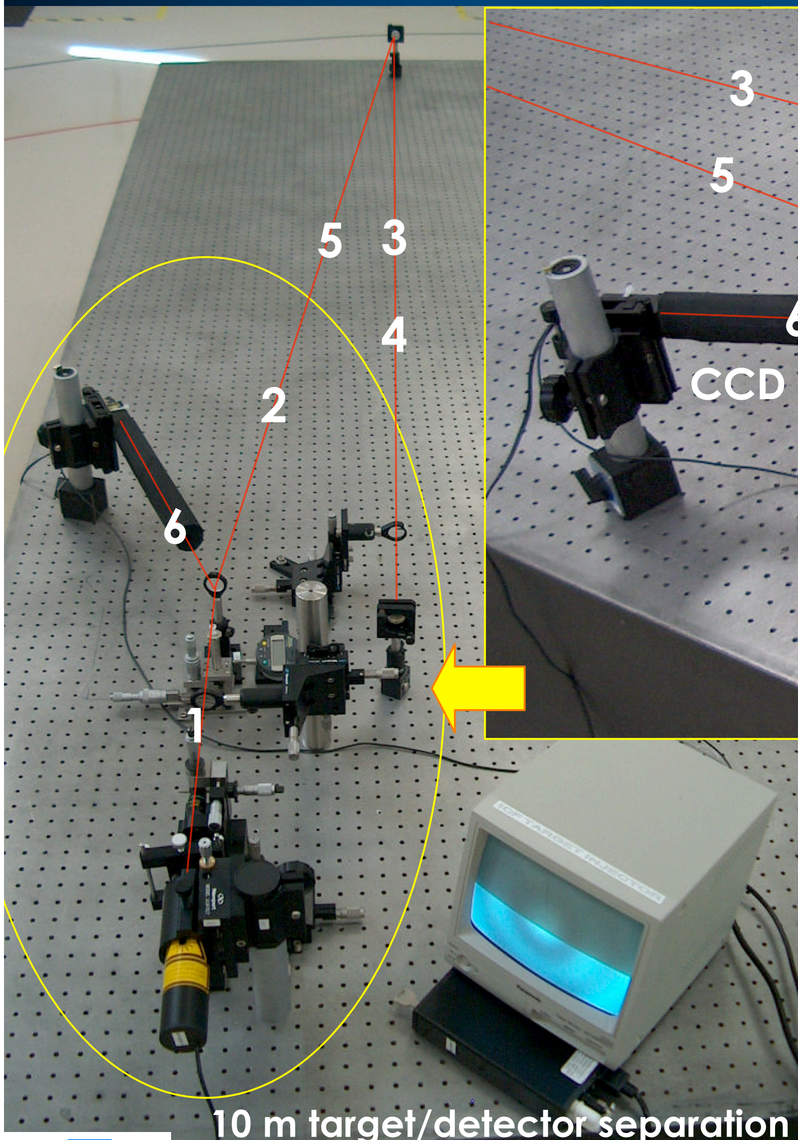


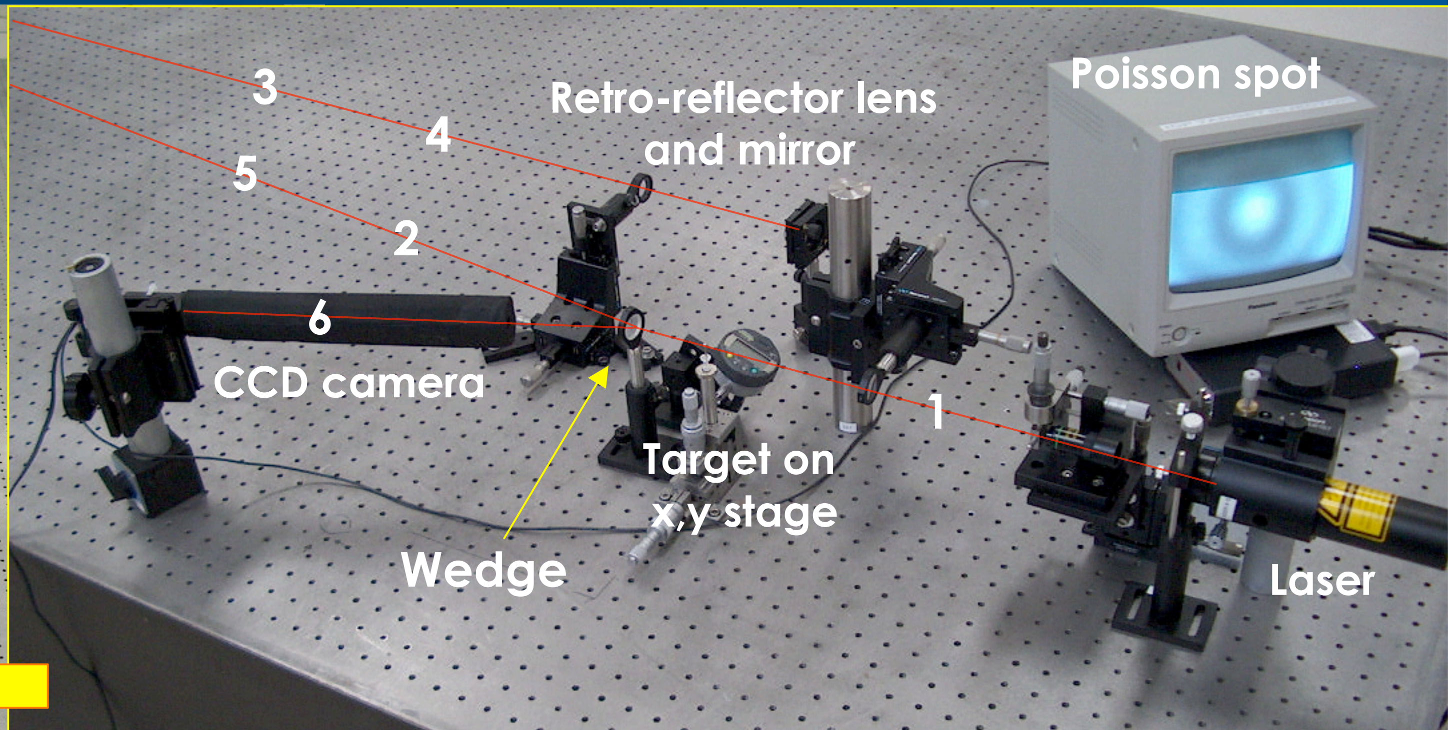


Optical Table Setup #1



Optical Table Setup #2 with retro-reflector

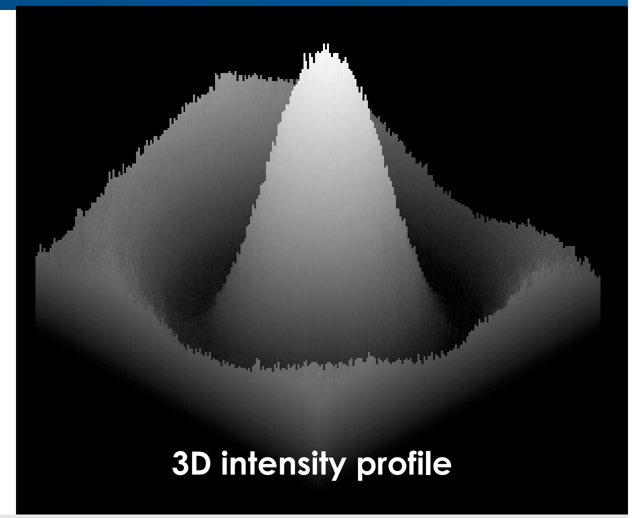


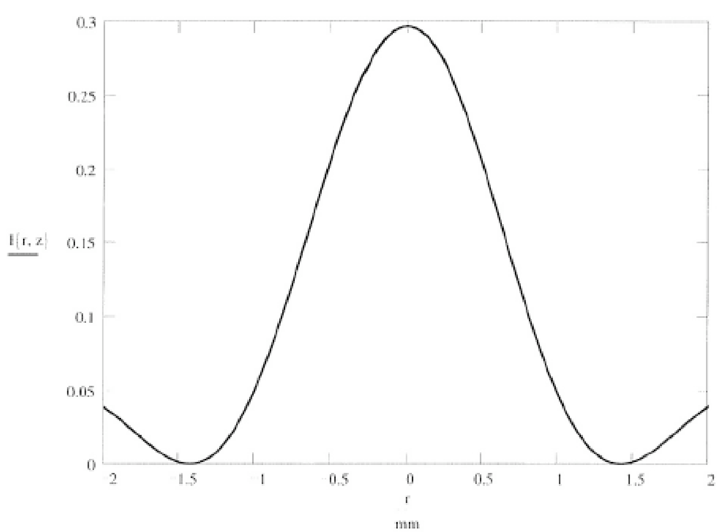


- The retro-reflector folds the beam back upon itself through the same pocket of disturbance to nullify air disturbances and thermal gradients.

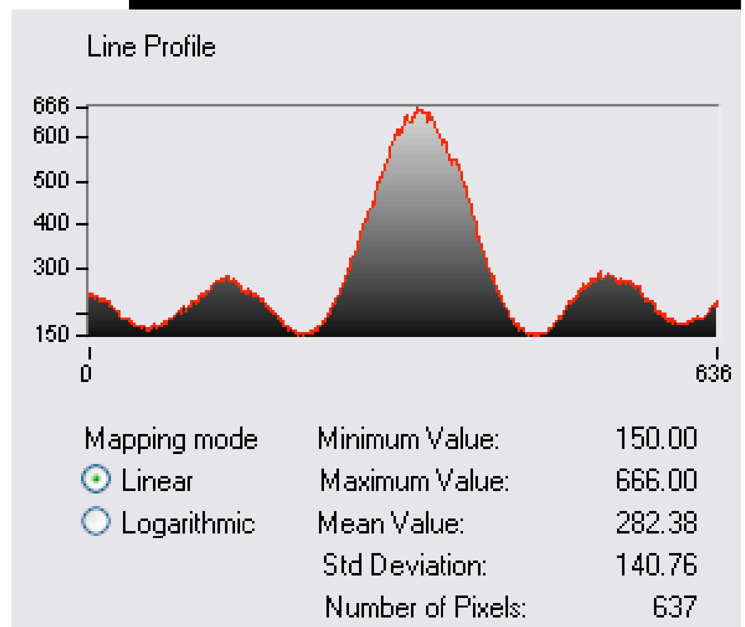
Poisson Spot - Verification of Intensity Calculations

-**We have verified intensity profile calculations with experimental results at a target/detector separation of ~ 10m**


3D intensity profile

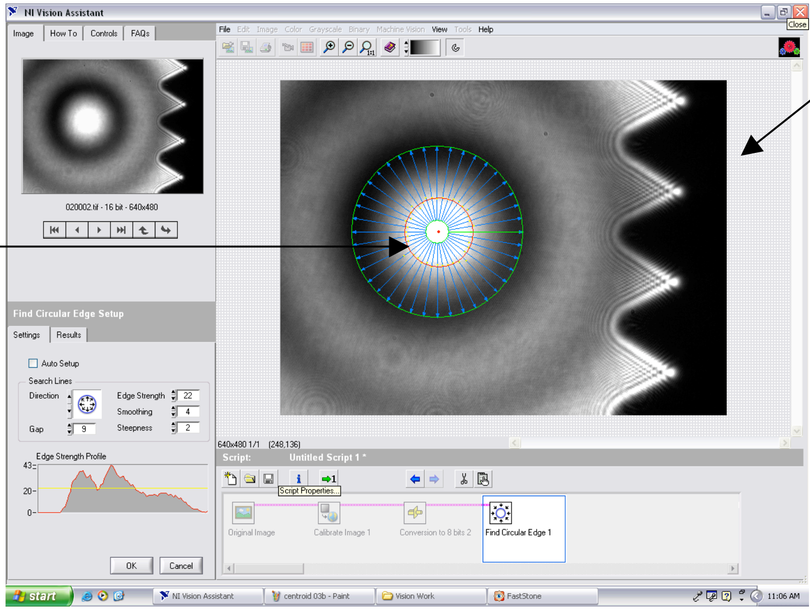


Calculated intensity profile



Poisson Spot - Centroiding using NI Vision Software

- The centroiding algorithm weighs the intensities of pixels on radial spokes within a region of interest, then calculates the centroid.
  - 10 images are taken in rapid succession (60 Hz).
  - The centroid of each is calculated using the same algorithm settings.
  - The standard deviation of the 10 centroids is then computed.
- The centroid has been calculated to within 2.5 μm (single-axis, rms) in ~ 20 ms.
  - 16 to 8 bit conversion: 17-19 ms
  - Circular edge detection: 1-4 ms depending on number of "spokes"

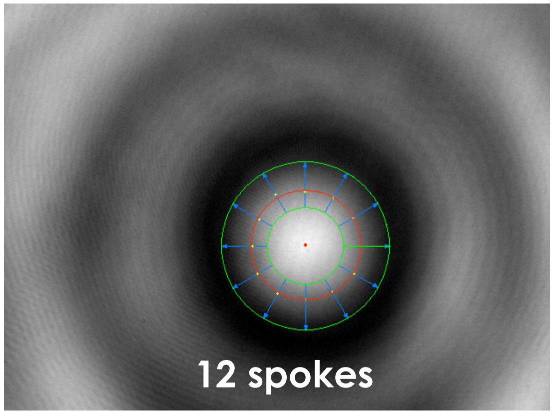


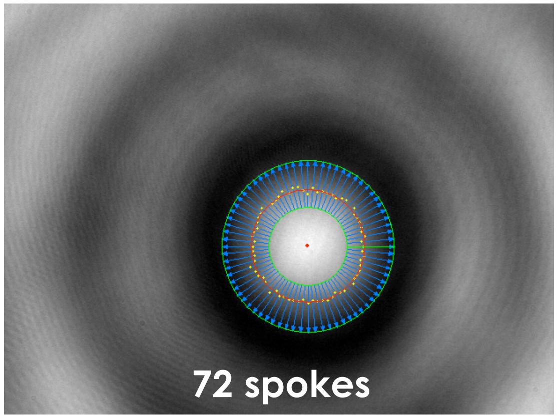
1/4-20 thread shown for scaling

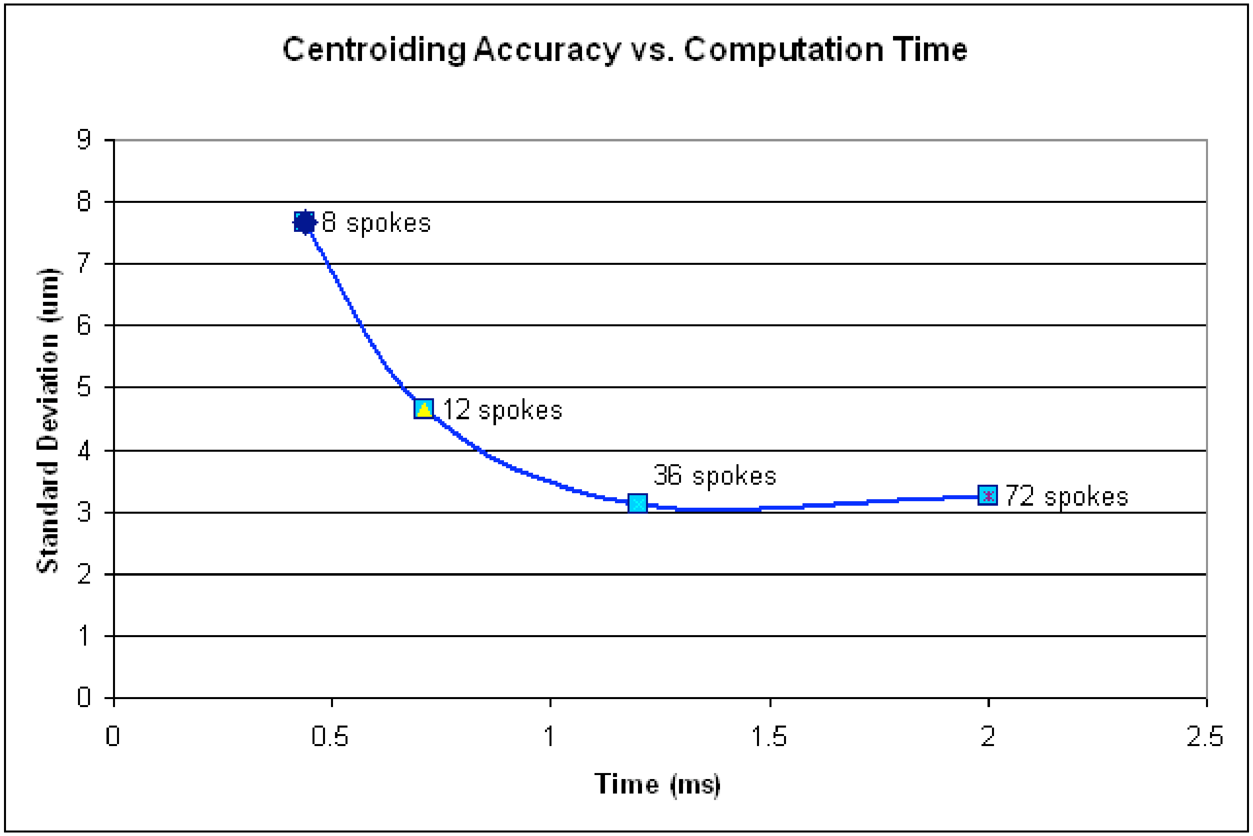
NI Vision centroiding software screenshot

Poisson Spot - Centroiding vs. Computation Time

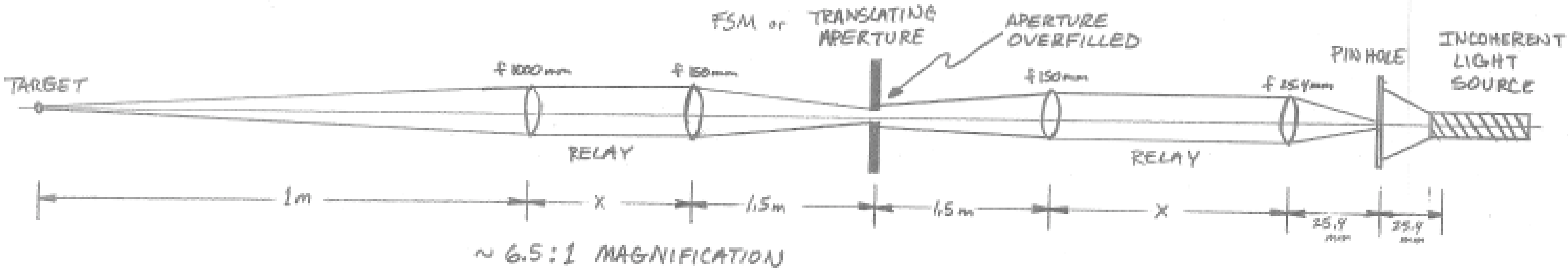
- **Preliminary studies with centroiding software for time and accuracy tradeoffs have resolved a computation time of .71 ms with a 4.6 μm standard deviation by using a 12 spoke algorithm.**







Prototype Driver Architecture

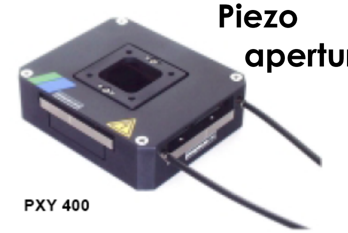


Prototype driver optical layout

- **We have scaled down and simulated the KrF driver beam using an incoherent light source and optical train with 6.5:1 magnification.**
- **A translating aperture or dichoric fast steering mirror can be used to steer the beam.**
  - **The aperture is overfilled to allow full range of aperture movement.**

Feedback to Beam Steering Mirror or Aperture

- **We have assessed different beam steering actuation methods with prototypical emphasis : *voice coils, piezos, & stepper motors.***
- **Processing time for target location includes CCD detection, centroid processing, I/O of all DAQ cards and controllers, computation time, and beam steering movement.**



Piezo aperture

Voice coil

Piezo FSM

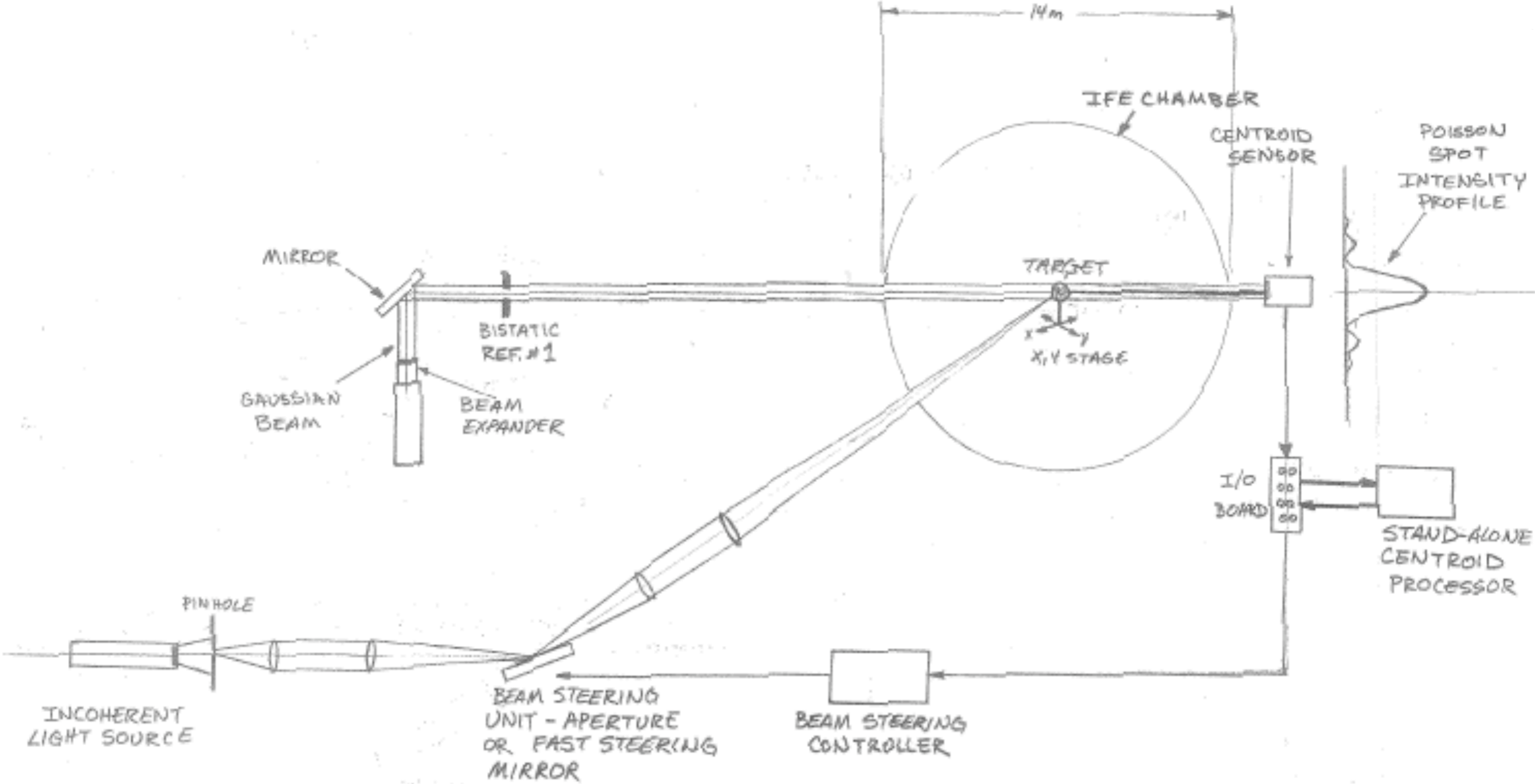
Stepper motor

Driver Assessment	*Response Time*	*Motion (μm)*	*Accuracy (μm)*	*Heat?*	*Hysteresis?*
Piezos	~33 μs at 10 kHz	Up to 400 (with lever arm)	< 1	Low	Yes ~15%
Voice coils	~10 ms	50 μm - 100 mm	~ 10	Yes, at high freq.	No
Stepper motors	500 μm/sec	25 - 100 mm	~ 10	Med.	No, but backlash

Integration of Elements

- **To demonstrate the integration of prototype driver beam, Poisson spot detection, and beam steering, we will:**
  - Shine a HeNe laser on a target to produce a Poisson spot
  - Detect spot at a prototypical distance (~10m)
  - Use software to detect centroid location to within 10μm within a few milliseconds
  - Use centroid information to feedback into aperture actuator or FSM to steer illumination beam onto target
  - Visualize proper target illumination using a video camera

Optical Diagram for R&D Plan



Optical layout for beam tracking and steering system

Future Work

- We plan to continue Poisson spot characterization and confirm accuracy and speed capabilities.
- We will do a final assessment of equipment needed and begin purchasing.
- Additional work will be done on CCD image processing in *real time* and centroiding speed optimization.

- *Final objective* is to demonstrate an active beam tracking and steering system that fulfills speed and accuracy requirements.