P13375 : Computer Controlled Hydraulic Nanomanipulator

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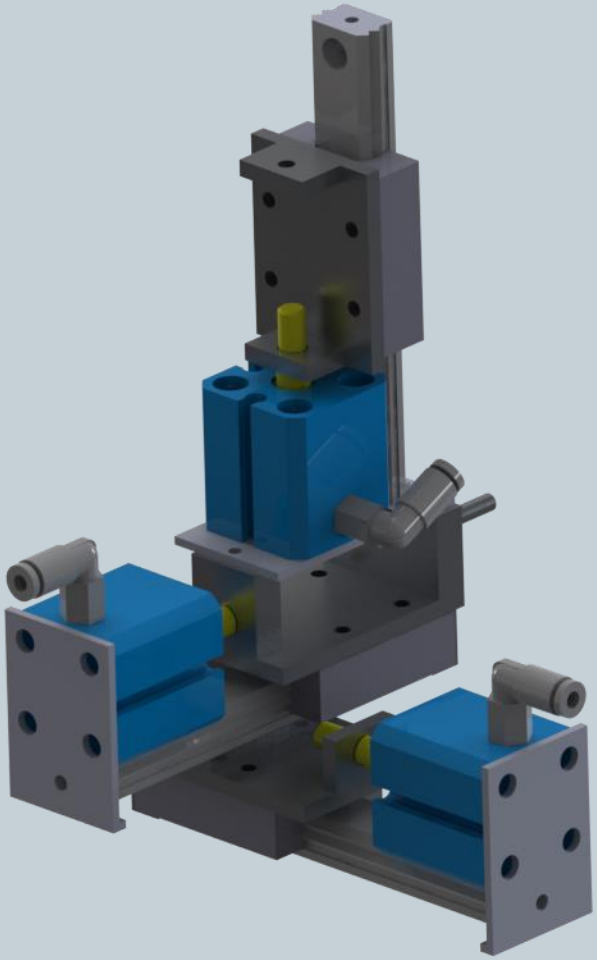
Main Focus of Improvements

- Reduce Backlash
- Increase Speed
- Provide Remote Access Capabilities
- Stop System Leakage Issue

Design Concept (Mechanical) Cont.



Engineering Specifications

#	Specification (metric)	Unit of Measure	Target Value	Theoretical Value	Actual Value	Previous System
S1	Size of manipulator (h x w x l)	cm	8 x 8 x 8	13 x 12 x 12	13 x 12 x 12	13 x 13 x 13
S2	Weight of manipulator	Grams	550	400	400	689
S3	Development cost	$	1,352	1,441.81	1,441.81	2,128
S4	Cost to manufacture after development	$	1000 - 1500	1,413.01	1,413.01	1,470
S5	Limits of travel in each direction	cm	>0.25	0.5	0.5	1.1
S6	Speed of travel	mm/sec	0.5	.088	0.0392	0.04
S7	Observed Resolution	nm	< 100	86.74	1601	Eppendorf 500
	Theory Resolution (From Speed)	nm	<100	86.74	14	56
S8	Sampling Rate	Hz	60	0	60	NA
S9	Level of Difficulty of Use	Binary	Easy	Easy	Easy	Medium

Engineering Specifications Continued

#	Specification (metric)	Unit of Measure	Target Value	Theoretical Value	Actual Value	Previous System
S10	Supported Control Software	Binary	Yes	Yes	Yes	Yes
S11	Visual Feed Sampling Rate	Hz	60	60	60	NA
S12	System is Controlled by a Device (Remotely and Locally)	Binary	Yes	Yes	Yes	Locally
S13	System Provides Additional Feedback	Subjective	Yes	Yes	Yes	No
S14	System Provides Calibration	Binary	Yes	Yes	Yes	No
S15	System Backlash	Revolutions	<3	0	2.27	25
S16	Video Latency	Frames Per Second	>30	30	30	NA
S17	Control Latency	ms	<200	200	~100	NA

Speed Testing

- Find current and desired coordinates based on current position
- Drive the motor in desired direction
- Stop motor so as to approach desired coordinates
- Measure actual end coordinate
- Calculate speed based on time given by Matlab stopwatch function: “tic” and “toc”
  - Functions tic and toc run at start and stop commands; respectively

Speed

Speed (um/s)	CQS Forward	CQS Reverse	Eppendorf Forward	Eppendorf Reverse
X Axis	0.0392	0.0240	2045	
Y Axis	0.0150	0.0197		
Z Axis	0.0060	0.0062		

A stiffer return spring in x would improve reverse speed

Stabilizing system would also improve speed

Also should be noted that backlash does impact speed

Backlash

- Two observers
  - Observer 1: Camera Feed
  - Observer 2: Motor Rotation
- Observer 1 ran the motors until motion was observed and Observer 2 reported number of revolutions

Backlash Summary (rev)	CQS Forward	CQS Reverse	Eppendorf Forward	Eppendorf Reverse
X Axis	0.50	0.75	Negligible Backlash	
Y Axis	3.38	3.58		
Z Axis	2.92	2.50		

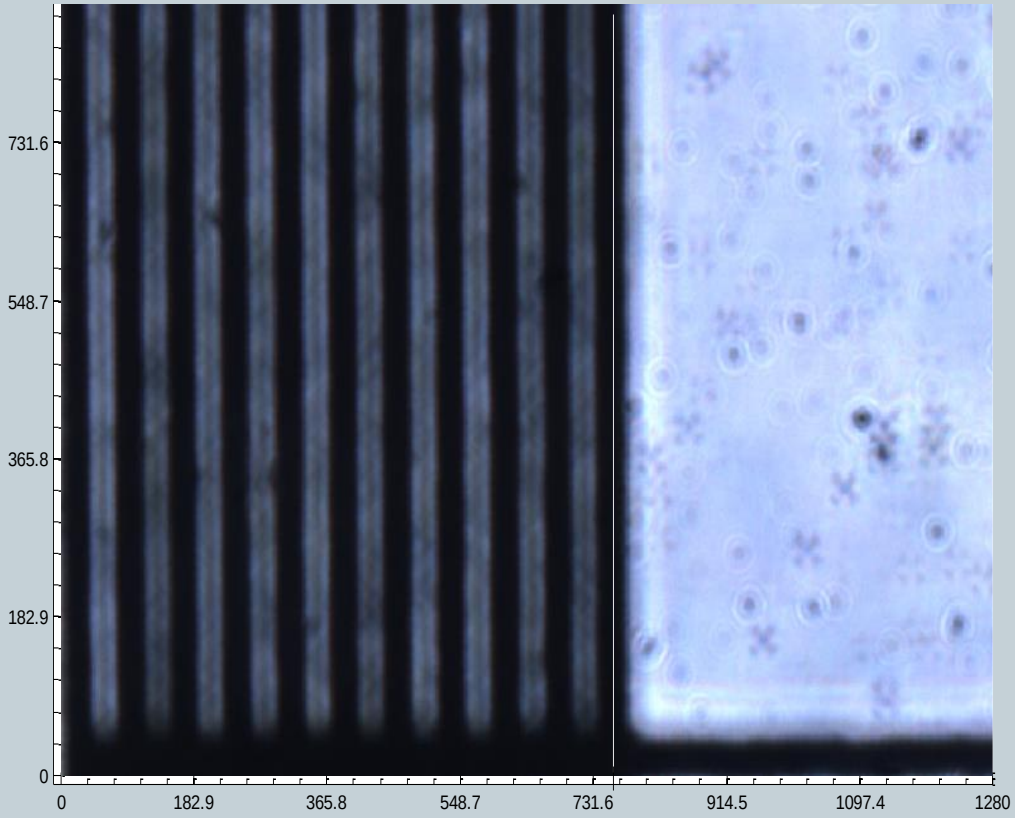
Resolution Testing

- A Matlab function was created to “step” the motors at speed 300/1000 for a period of 3 seconds
- The motors were “stepped” repeatedly until a distinctly different location was observed
- Matlab applied unscaled axes to the image
- Conversion from Matlab Scale to Microscope:
  - Used ruler slide to find the conversion (see next slide)
- Testing done at 40x

Resolution Testing (Scaling)

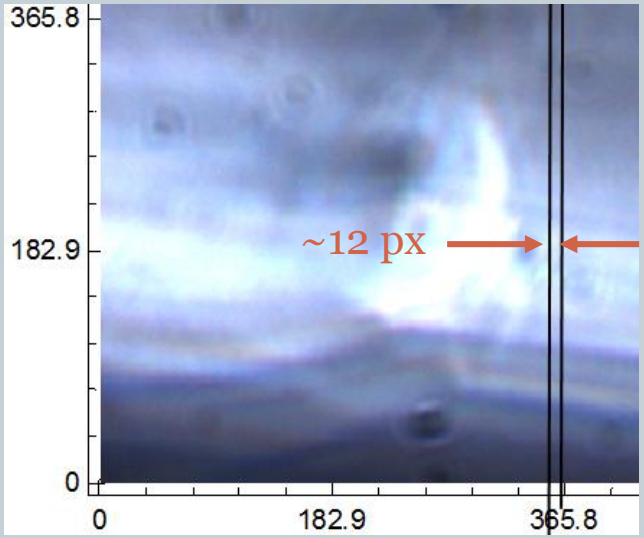
762.18 pixels = 0.1 mm = 100 µm

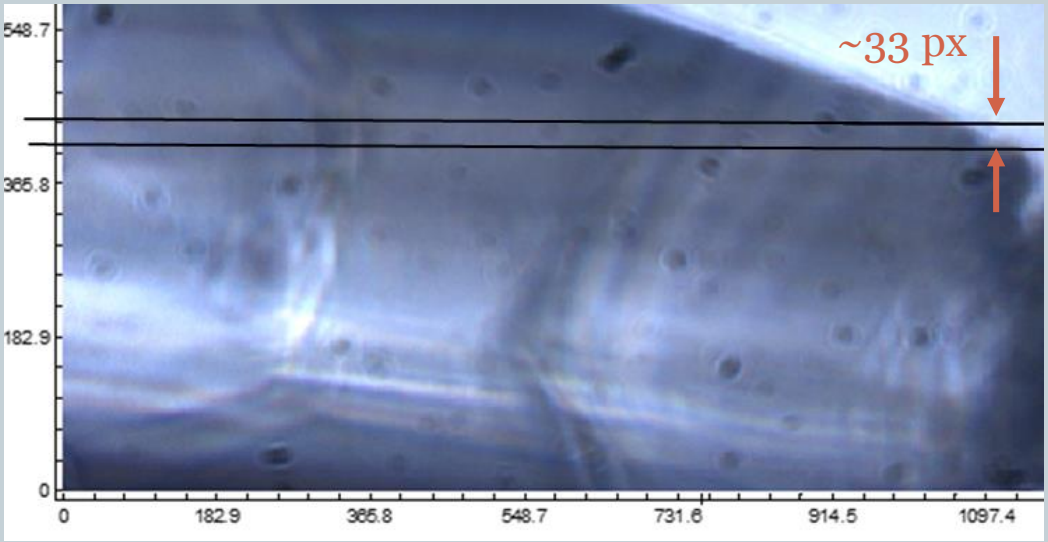
$$\#nm = \#px \times \frac{1\mu m}{7.6218px} \times \frac{1000nm}{1\mu m}$$



Resolution

	CQS	Eppendorf
	Resolution (nm)	Resolution (nm)
X	1601	500
Y	4325	





Items Still in Progress

- User's Manual
- Update Information on Edge

Suggestions for Future Work

- Further improve method of securing nanomanipulator (still using magnetic stand)
- Improve system resolution
- Improve carriage “wobble” – possibly use ball bearing tracks

Eppendorf Software Update

- Eppendorf control implemented
- 2 versions (Eppendorf, Generic)

- Debug, comment and document
- Demonstration or Video?

Eppendorf Future Work

- Merge software forks into 1 package
- Make networked vs. local an option
- Consult with Nick to compare and commit changes

Lessons Learned

- Dealing with Suppliers
  - Discuss items for purchase with the company's engineers, not just sales
  - Communication regarding small quantities can be difficult
    - Give suppliers a sense of the future of your project – can help with discussion regarding quotes
  - ALWAYS follow up on any request for information or product
- Importance of risk management
  - Need to have multiple back up plans
- If not impractical, take time early on to recreate prior results – especially in specs you are seeking to improve
- Machining ALWAYS takes longer than expected

Acknowledgements

The team would like to thank the following individuals for their help and guidance throughout this project.

- Guide: Bill Nowak
- Customer: Dr. Schrlau
- Charlie Tabb
- Nicholas Hensel
- Team P13371
- Team P12371
- Tim Patane of Component Supply

QUESTIONS?