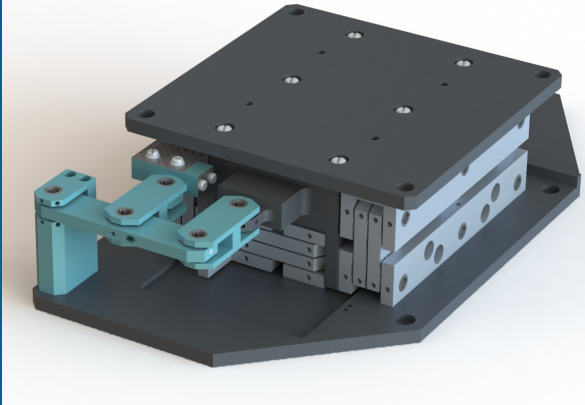
NANOPOSITIONING SUPPORT LAB,

HTTPS://WWW.APS.ANL.GOV/NANOPOSITIONING-SUPPORT-LAB

Argonne NATIONAL LABORATORY

FE MODEL OF A NANOPOSITIONING FLEXURE STAGE FOR DIAGNOSIS OF TRAJECTORY ERRORS

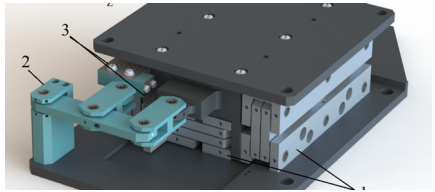


STEVEN KEARNEY AND DEMING SHU
Argonne National Laboratory, Advanced Photon Source, Argonne IL, 60439, U.S.A.

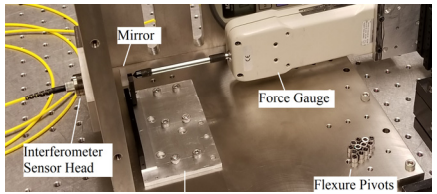
6/27/2018
Paris, France – MEDSI 2018

MEDSI PARIS 2018
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

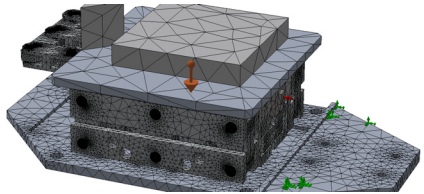
OUTLINE



- Introduction to the deformation compensated flexure stage design



- Validation of the flexure pivot FE model

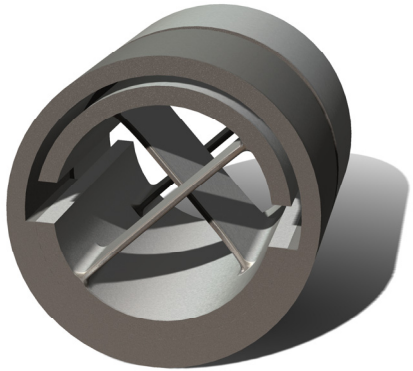


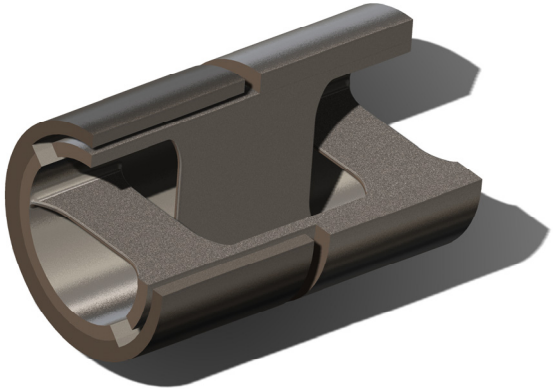
- Results and discussion of complete FE model of stage

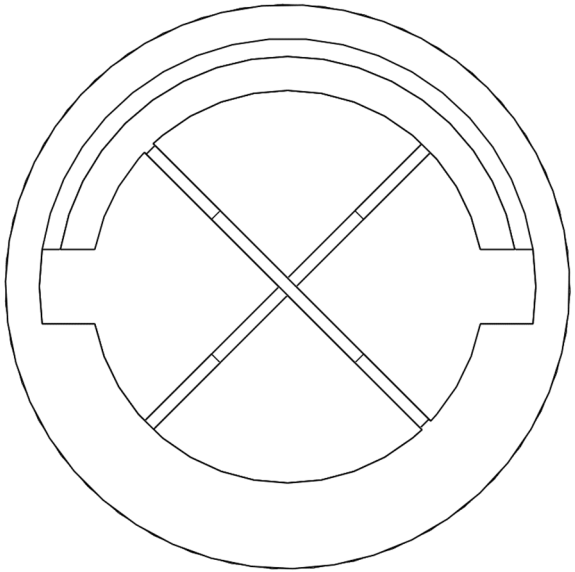
INTRODUCTION TO STAGE DESIGN

INTRODUCTION TO STAGE DESIGN

The Flexure Pivot – Fundamental Element in Design

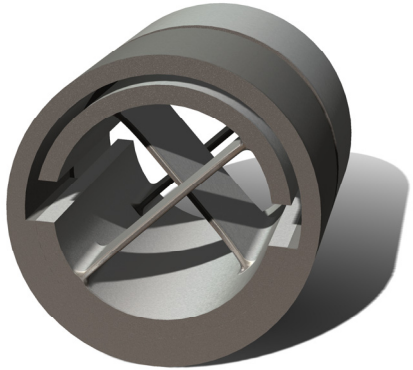


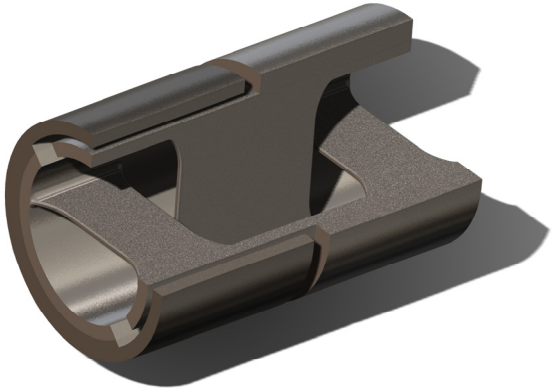


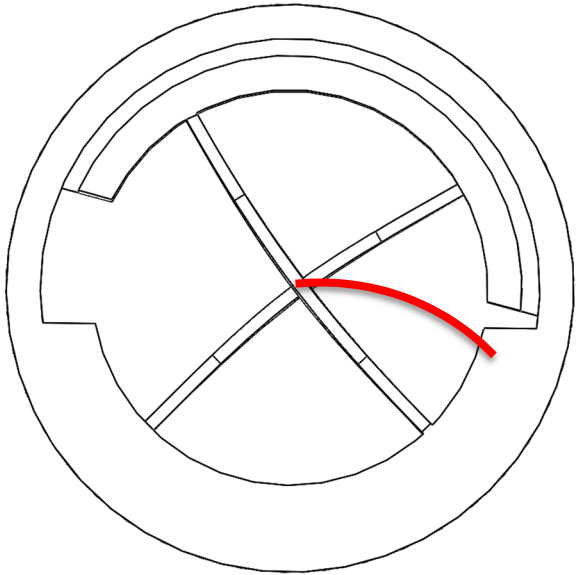


INTRODUCTION TO STAGE DESIGN

The Flexure Pivot – Fundamental Element in Design







INTRODUCTION TO STAGE DESIGN

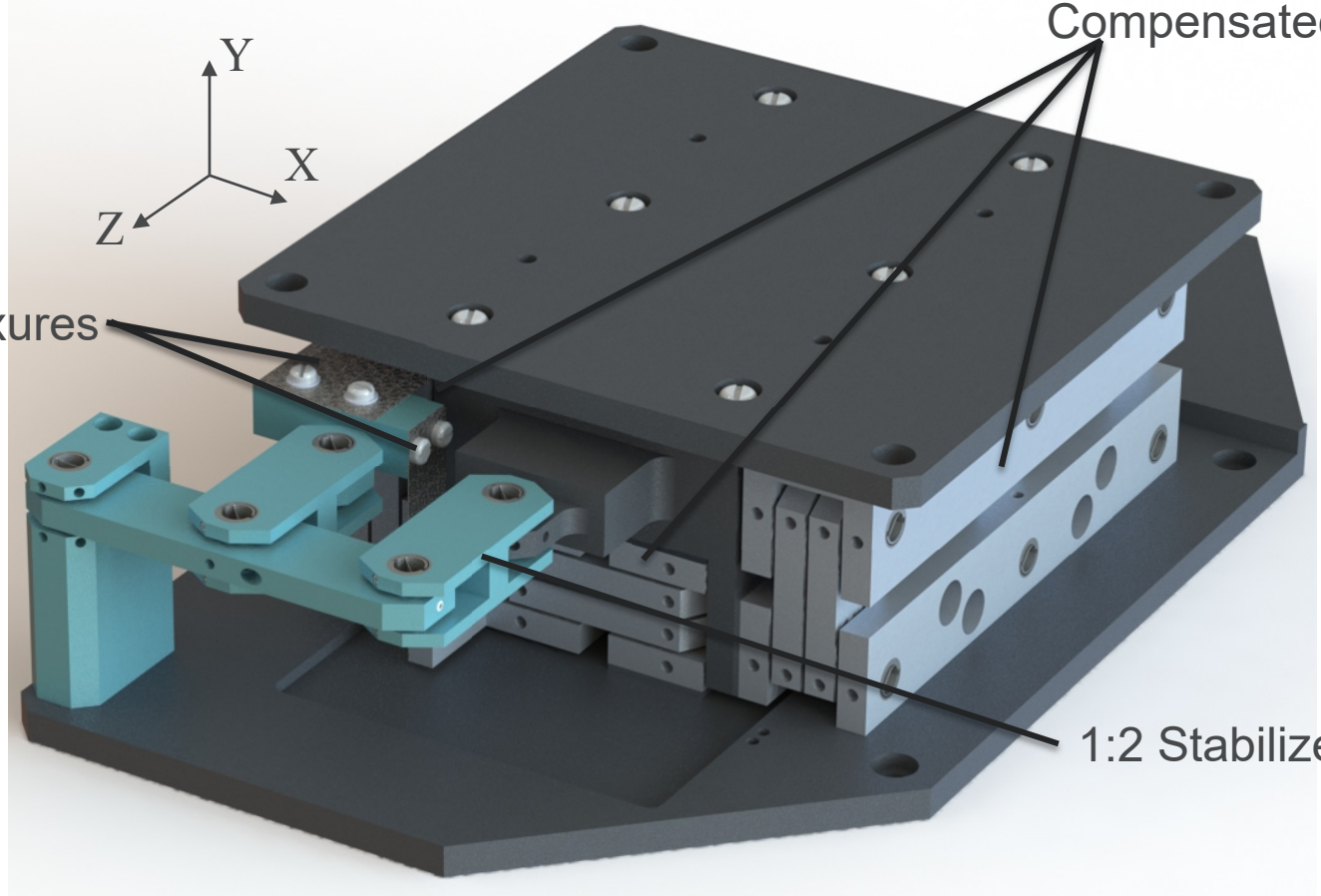
Deformation Compensated Four-Bar Mechanism

INTRODUCTION TO STAGE DESIGN

Double Deformation Compensated Mechanism

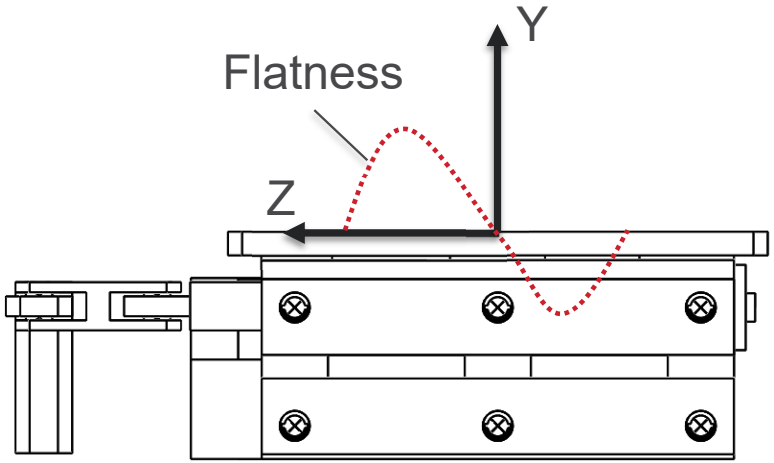
INTRODUCTION TO STAGE DESIGN

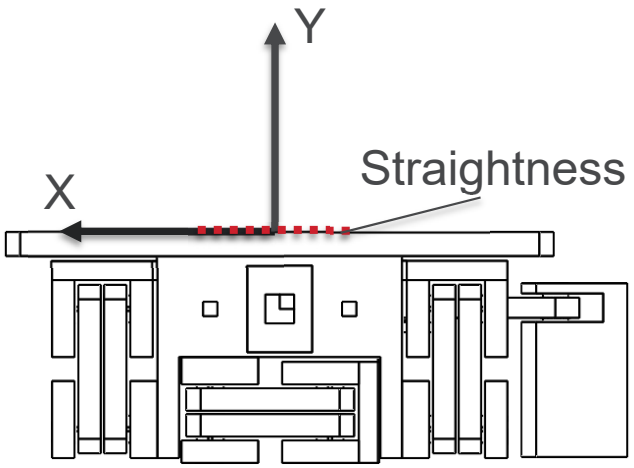
The Complete Flexure Stage



INTRODUCTION TO STAGE DESIGN

Trajectory Errors



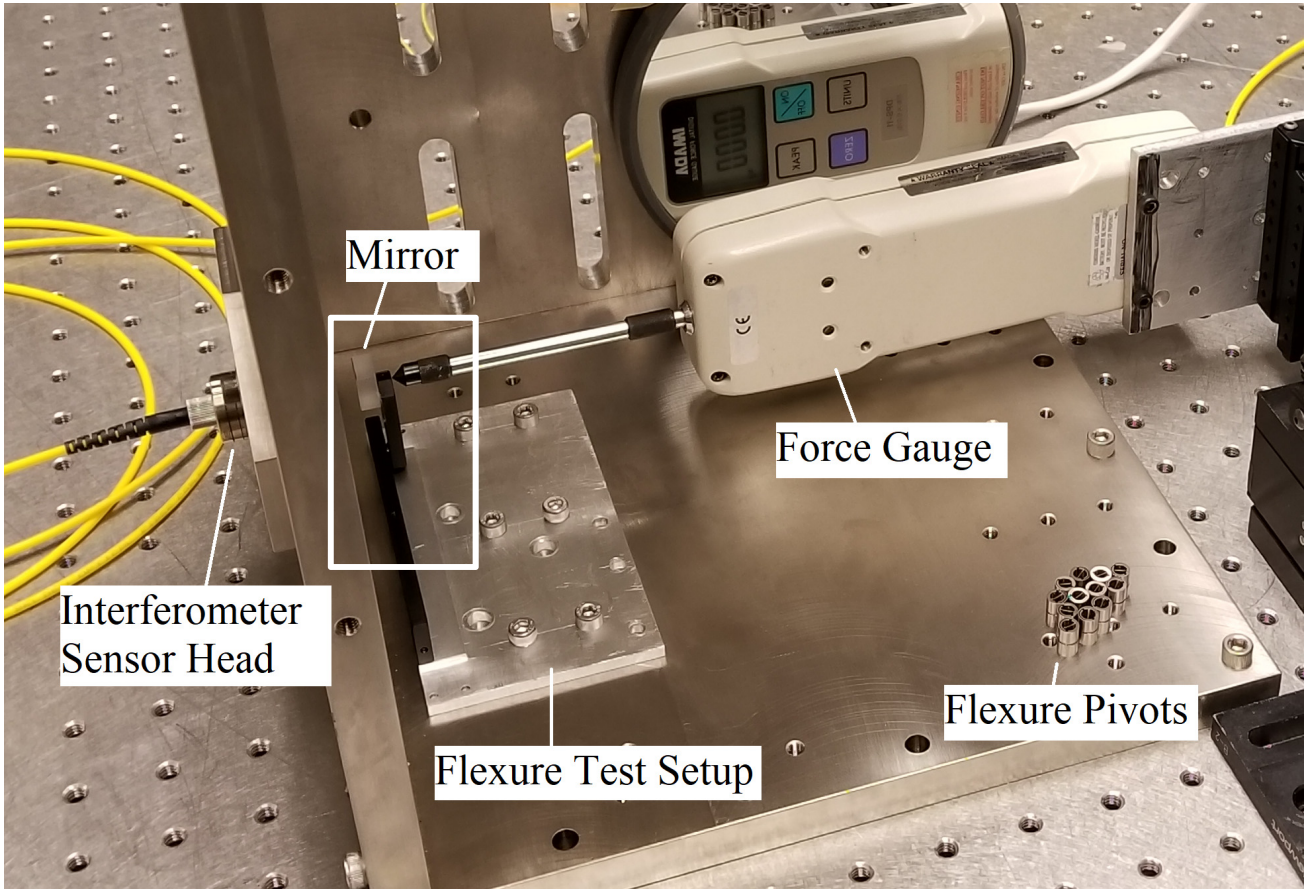


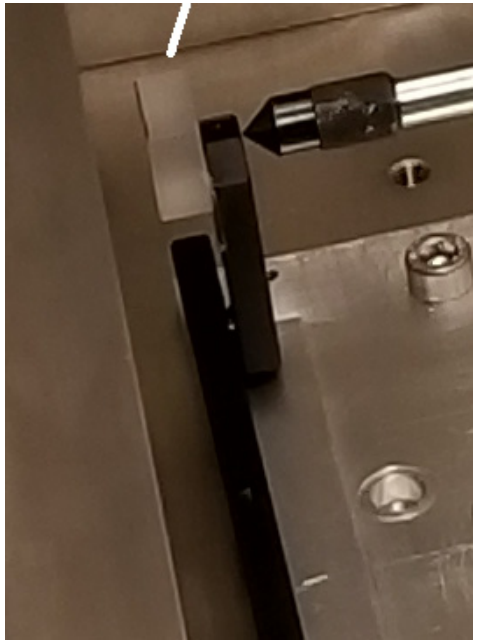
Rotation about Z = Roll Error
Rotation about Y = Yaw Error
Rotation about X = Pitch Error

VALIDATION OF FLEXURE PIVOT FE MODEL

VALIDATION OF FLEXURE PIVOT FE MODEL

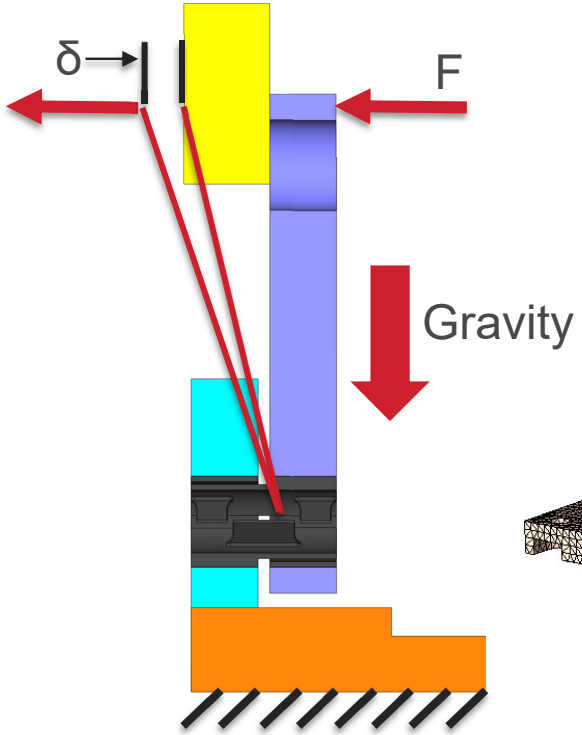
Experimental Setup

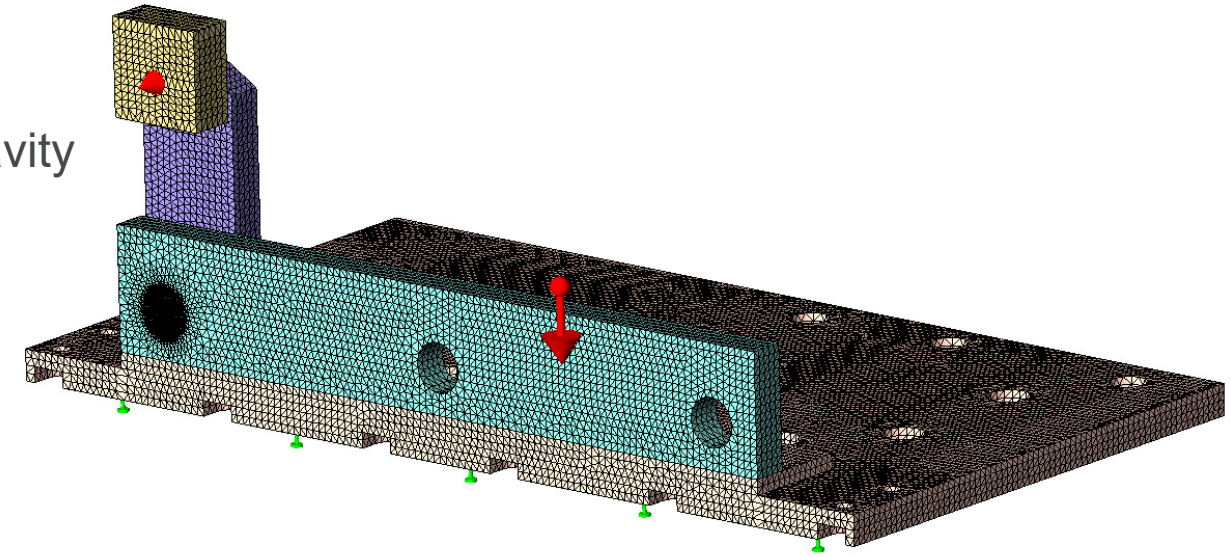




VALIDATION OF FLEXURE PIVOT FE MODEL

FEA Model 1





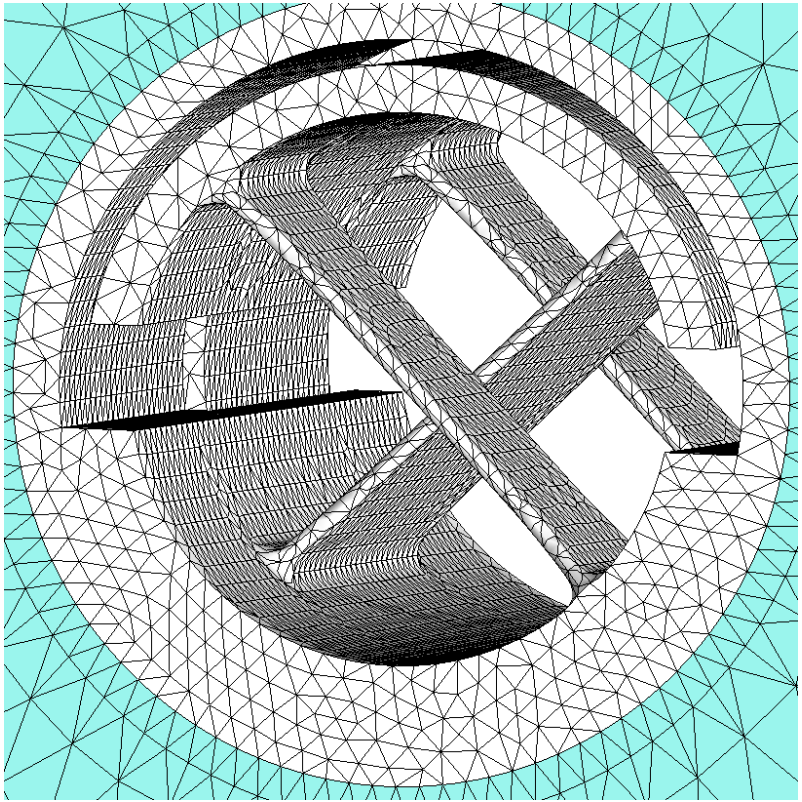
VALIDATION OF FLEXURE PIVOT FE MODEL

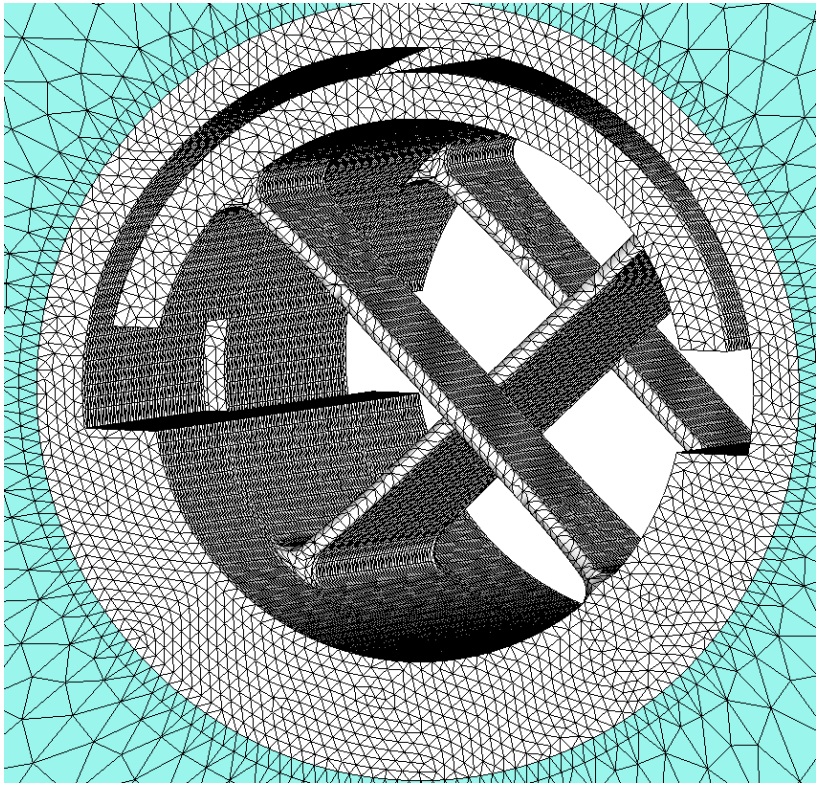
FEA Results Model 1

Exp. Results	K (N/μm)	σ	COV
Flexure Pivots	0.0317	0.0013	4.0 %
FEA Results	K (N/μm)	Error	
Model 1	**0.0368**	**16.0%**	
Model 2			
Model 3			
Model 4			

VALIDATION OF FLEXURE PIVOT FE MODEL

FEA Model 2





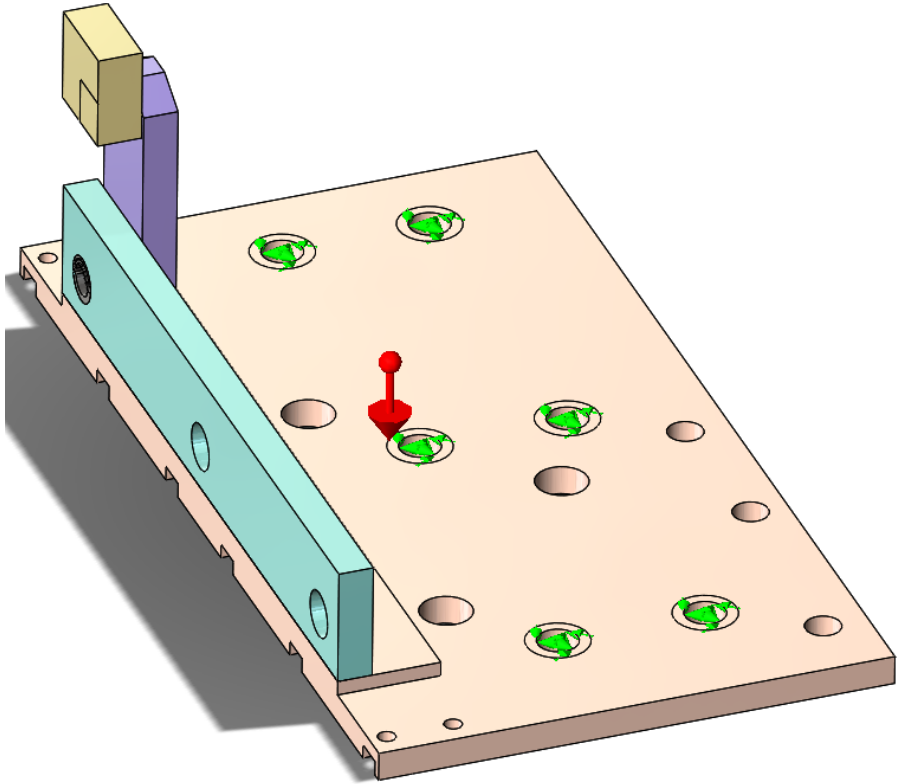
VALIDATION OF FLEXURE PIVOT FE MODEL

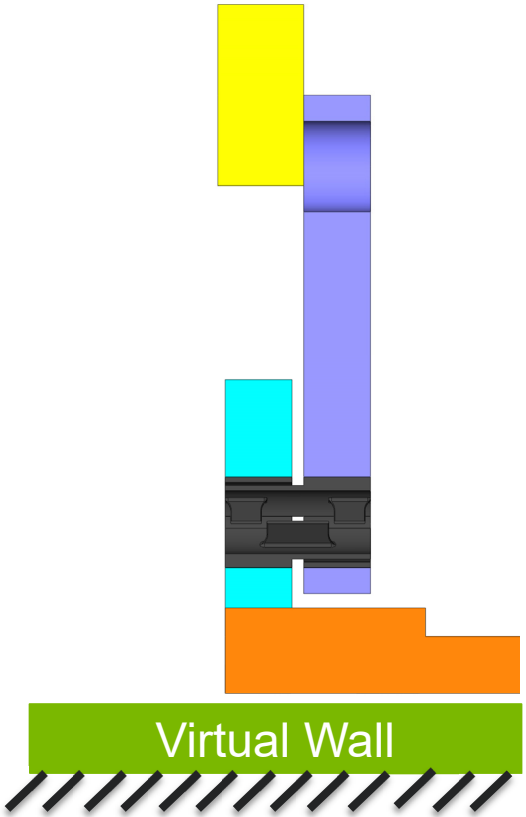
FEA Results Model 2

Exp. Results	K (N/μm)	σ	COV
Flexure Pivots	0.0317	0.0013	4.0 %
FEA Results	K (N/μm)	Error	
Model 1	0.0368	16.0%	
Model 2	**0.0367**	**15.8%**	
Model 3			
Model 4			

VALIDATION OF FLEXURE PIVOT FE MODEL

FEA Model 3





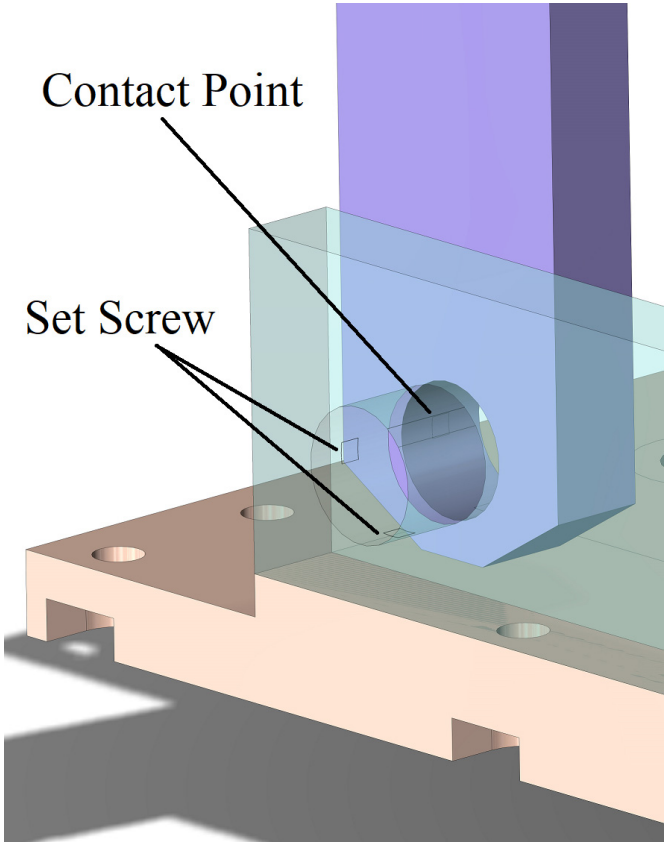
VALIDATION OF FLEXURE PIVOT FE MODEL

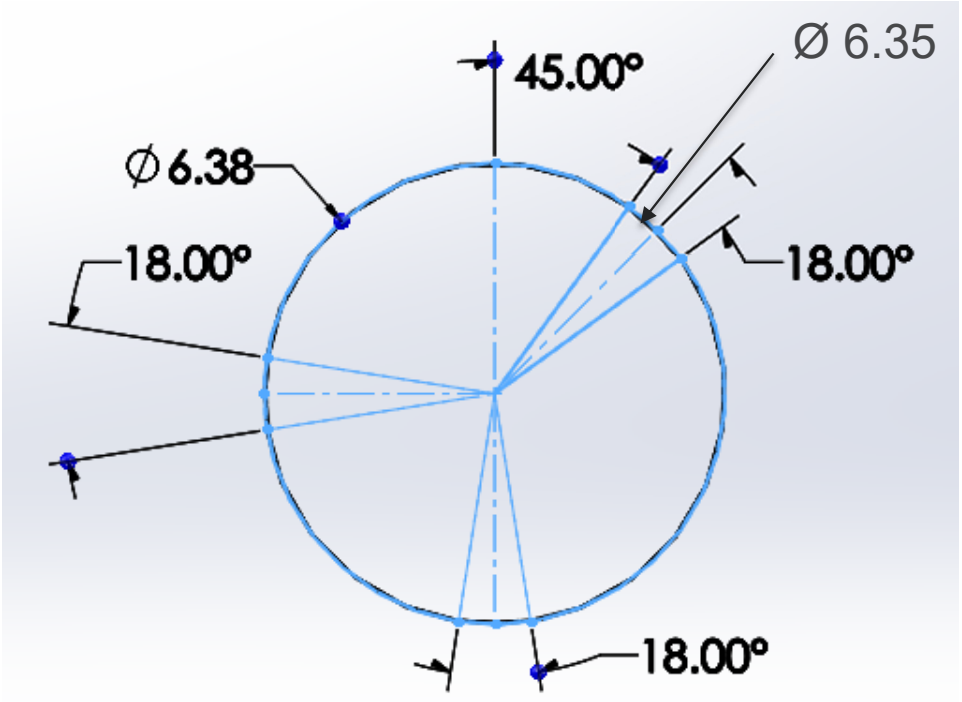
FEA Results Model 3

Exp. Results	K (N/μm)	σ	COV
Flexure Pivots	0.0317	0.0013	4.0 %
FEA Results	K (N/μm)	Error	
Model 1	0.0368	16.0%	
Model 2	0.0367	15.8%	
Model 3	**0.0365**	**15.3%**	
Model 4			

VALIDATION OF FLEXURE PIVOT FE MODEL

FEA Model 4





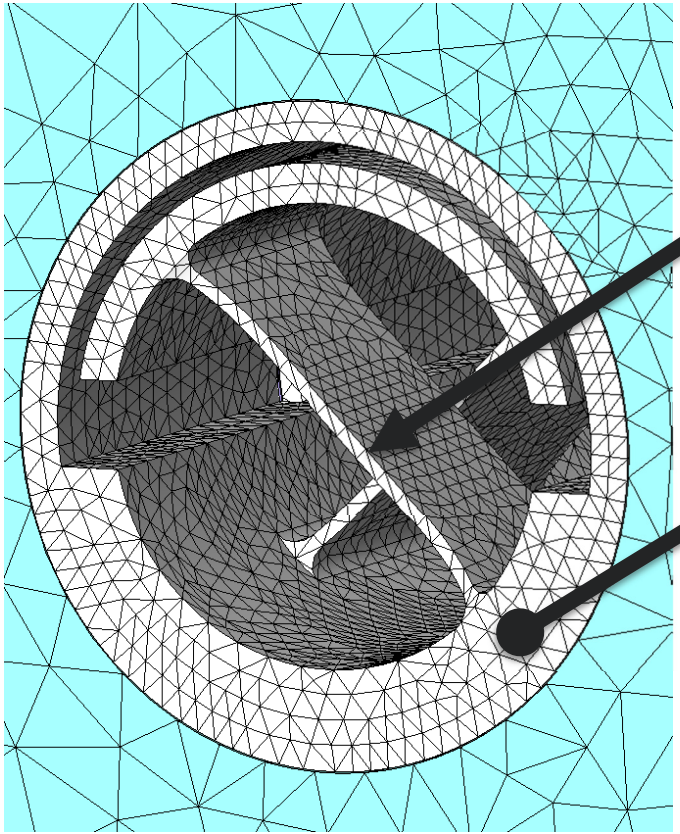
VALIDATION OF FLEXURE PIVOT FE MODEL

FEA Results Model 4

Exp. Results	K (N/μm)	σ	COV
Flexure Pivots	0.0317	0.0013	4.0 %
FEA Results	K (N/μm)	Error	
Model 1	0.0368	16.0%	
Model 2	0.0367	15.8%	
Model 3	0.0365	15.3%	
Model 4	**0.0309**	**-2.42%**	

VALIDATION OF FLEXURE PIVOT FE MODEL

Use Model 4 to Optimize Mesh



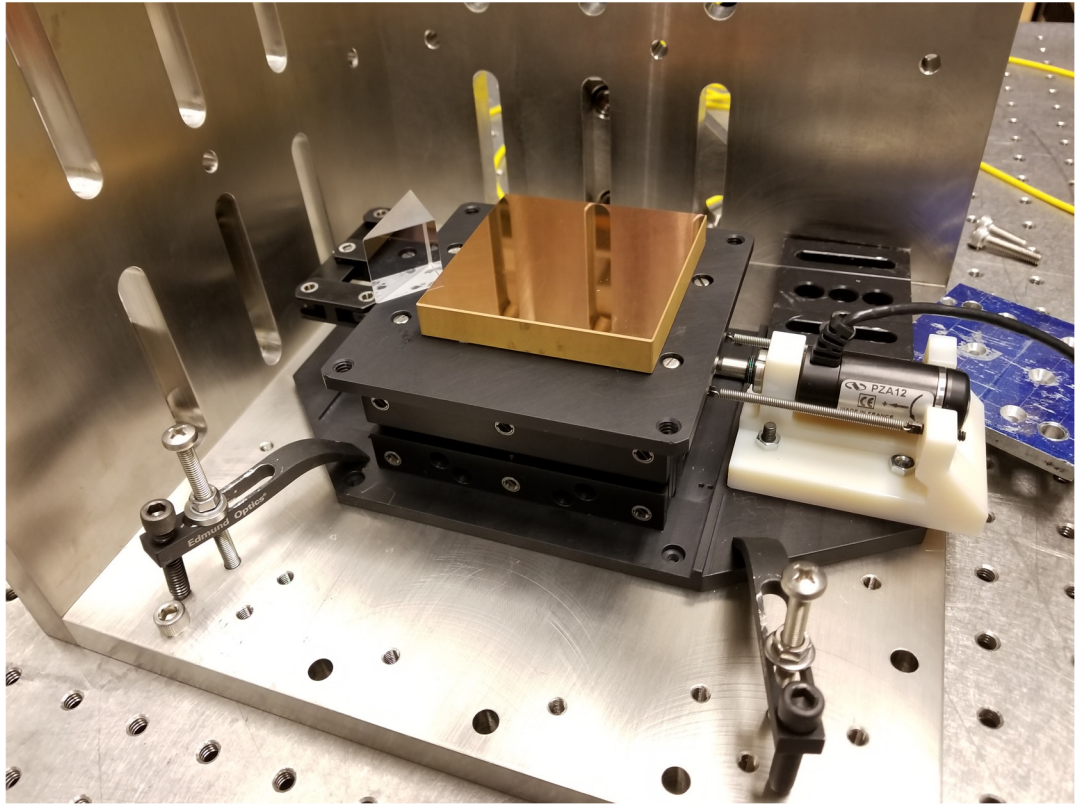
Round on edge removed

Curvature based mesh

RESULTS AND DISCUSSION OF COMPLETE FE MODEL OF STAGE

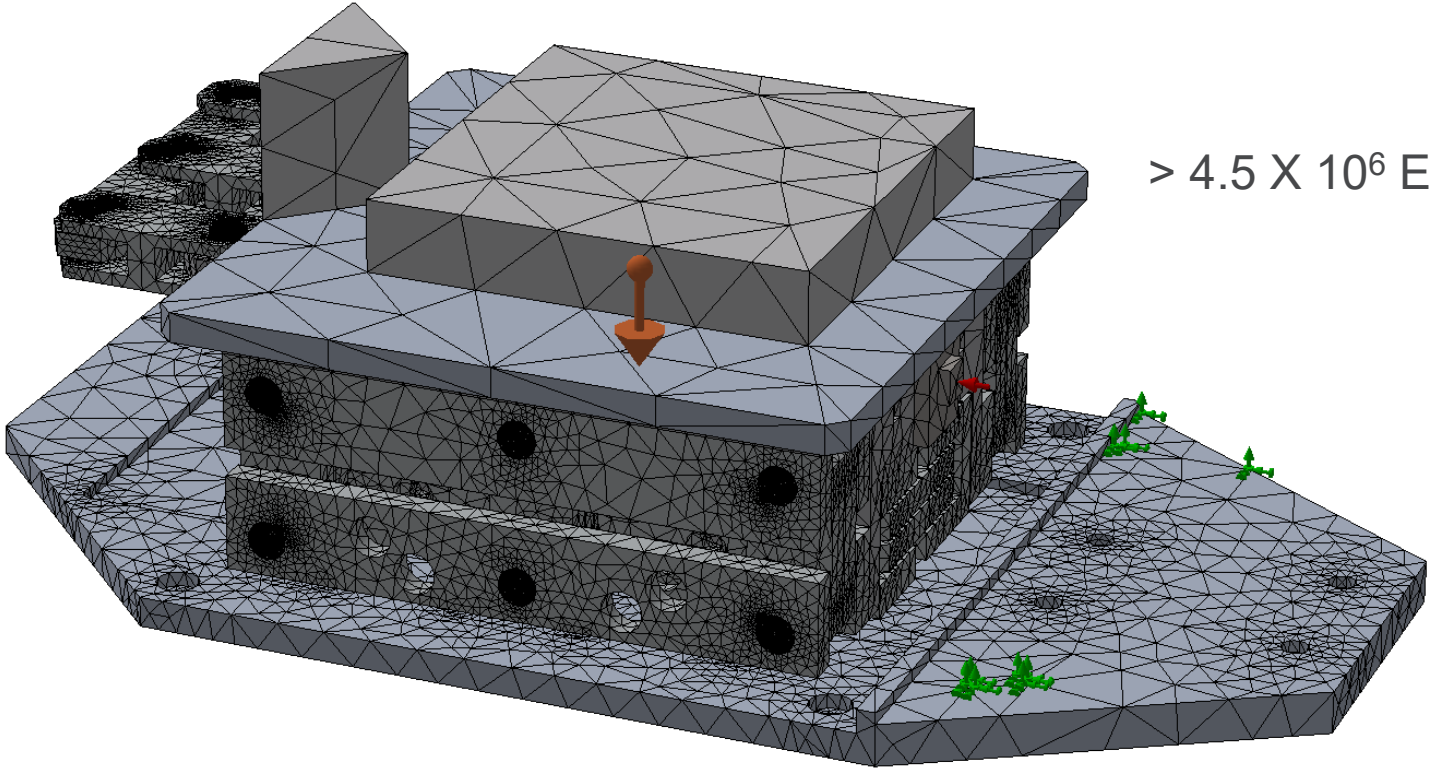
COMPLETE FE MODEL RESULTS & DISCUSSION

Experimental Setup



COMPLETE FE MODEL RESULTS & DISCUSSION

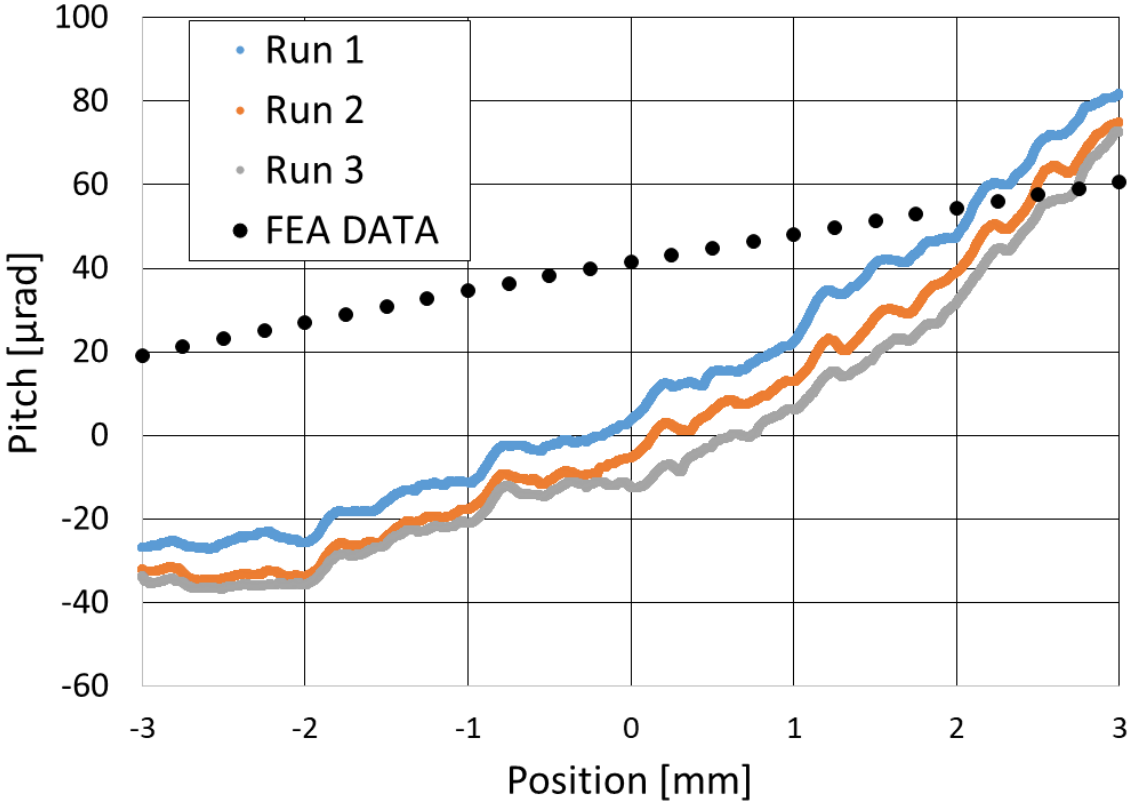
Complete FE Model



> 4.5 X 10^6 Elements

COMPLETE FE MODEL RESULTS & DISCUSSION

Results & Discussion



- Theory does not match exp., but both upward trend.
- Exp. results are at least 2nd order curves, while theory is 1st order.
- Shift in exp. data is from temperature drift in mirror to moving table interface.

CONCLUSION

- Simulated mounting conditions of flexure pivot are required.
- Complete FE model does not yet match theory
- Future improvements to test in model include:
  - Geometric tolerance from manufacturing
  - Set screw holding torques
  - Set screw tightening order
  - Assembly errors
  - Flexure pivot stiffness variance
  - All component interfaces

THANK YOU! QUESTIONS?