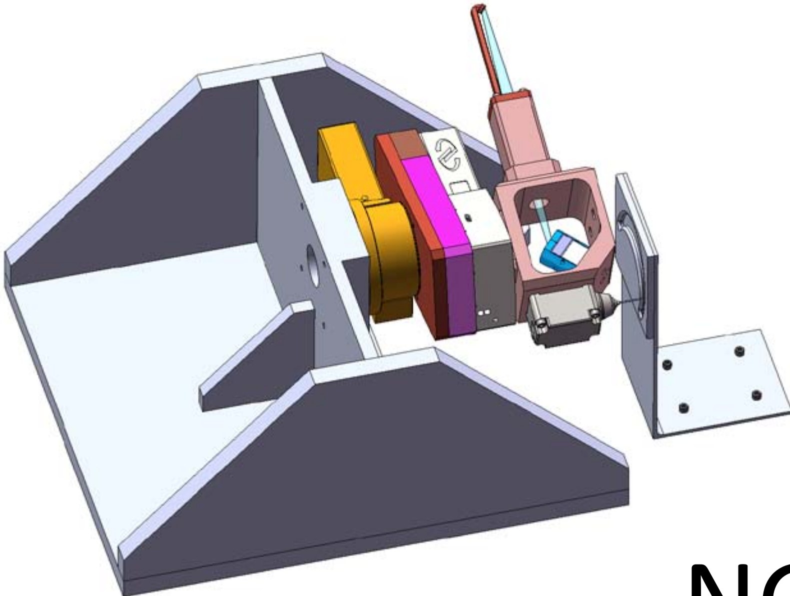


NGAO OSM

Design Study

Alex Delacroix
09/15/2009
Version 16

1. Conceptual design and operation

Three probes cover the entire Ø 120” (87.24 mm) Field of View.

Each probe is mounted on a 2 degrees of freedom articulated arm composed of a crank arm and a lever arm, driven by 2 corresponding rotation motors: The crank and lever motors. (See Fig. 2)

Any position in the OSM field of view can be acquired by calculating appropriate values for theta and phi, noting that two possible solutions could be found due to symmetry.

The crank motor is secured to the Sensor and rotates the crank arm, precisely about the rotation axis of the crank motor referred to as the theta axis. The lever arm motor provides the necessary second degree of freedom by rotating the lever arm and all associated optics, about the phi axis.

Each probes are a at a different distance from the Focal plane, 15mm apart, with the closest probe 5 mm upstream from the focal plane. This design allow each probe to freely roam the entire field without risk of colliding into an other probe. (See Fig. 1)

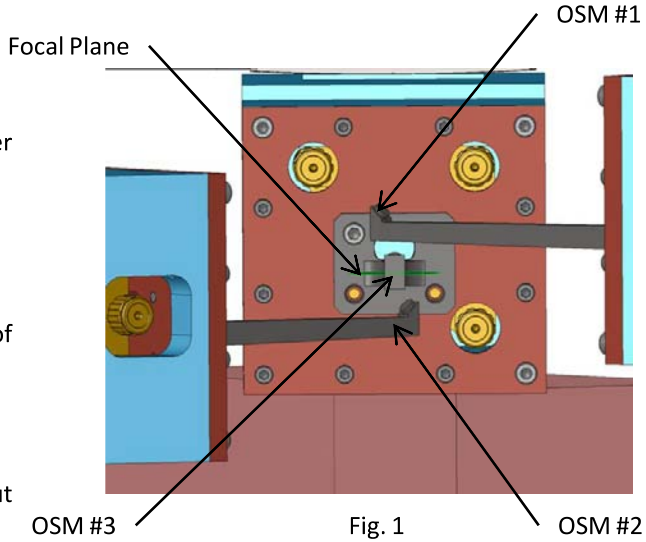


Fig. 1

1.2 Field of View:

The Field of View at the Focal Plane is Ø 5” (3.635mm)

The Field of View at the probe is defined by it’s distance from the Focal Plane / f# (See Fig. 2)

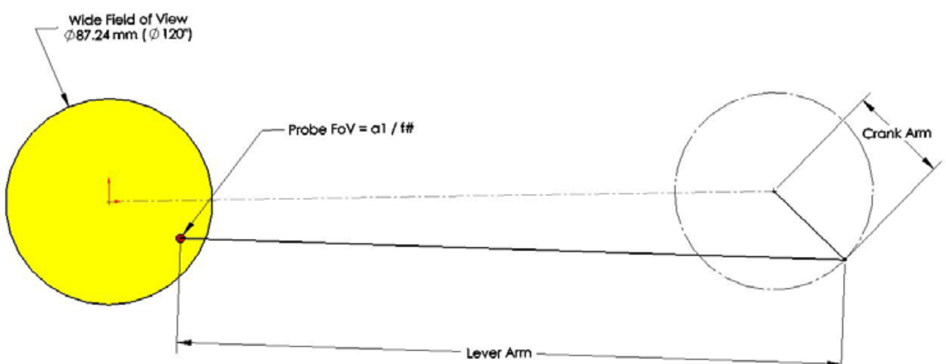


Fig. 2

Position Accuracy

Total Position Accuracy of 30µm at 300 mm arm extended length requires a crank and Lever rotation accuracy of:
$\sin \alpha$ = 30µm / 300 mm = .03 / 300 = .0001 ➔ α = 0.0057° = .0057 π / 180 = .0001 rad
The 250 mm lever arm motor is 86 % longer than the 40mm Crank arm
Crank motor rotation accuracy: 0.0057° x 86% = 0.0049°
Lever motor rotation accuracy: 0.0057° x 14% = 0.0008°

1.1 Basic Design requirements:

Mechanism Type: ϕ/θ

Patrolled Field: Ø 120” (87.24mm)

Focal Plane FoV : Ø 5” (3.635mm)

Acquisition accuracy: 40 mas (30µm)

Stability: 5 mas / 3600s (1 µm)

Position knowledge: < 1 µm (TBC)

Minimum Incremental motion: TBD

Operating Temperature: -10°C +/- 0.3

2. Optical Equation

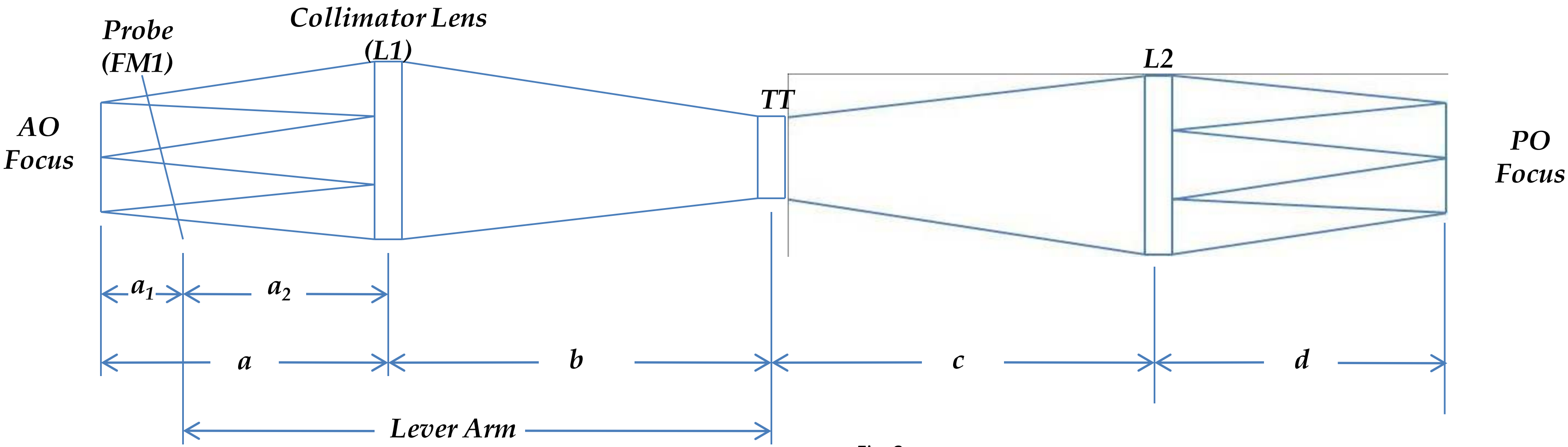


Fig. 3

Optical Layout (Fig. 3) is optimized when the following equations are verified:

2.1) $a = b$ & $c = d$

2.2) $a + b = x\ (c + d)$
Keeping the AO Focus away from the Probe mirror (FM1) gives:

2.3) $a = a_1 + a_2$
Keeping each Lever arms on a different plane to avoid collision between each other gives a different value of a1 for each OSM
The Lever Arm Length previously determined gives:

2.4) Lever Arm length = $b + a_2$
Replacing 3.3 & 3.4 in 3.1 gives: $a = b$ ➔ $a_1 + a_2$ = Lever Arm length - a_2
Solving for a_2 ➔ $2a_2$ = Lever Arm length - a_1 ➔ **a_2 = (Lever Arm length - a_1)/2**

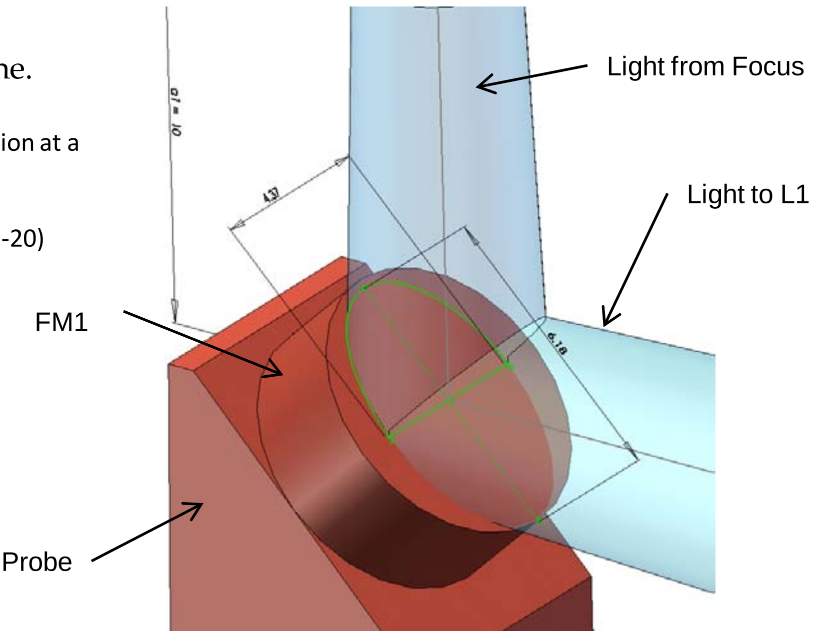
2.5) With $a = b = 120$

OSM#	a_1	$a_2 = a - a_1$	$a = b = a_1 + a_2$	Arm = $b + a_2$
I	10	110	120	230
II	-5	125	120	245
III	-20	140	120	260

3) Sizing the Probe

3.1) Probe FoV size depends directly from it's distance from the Focal plane.

The probe Fold Mirror intercept the light beam at a 45 degree angle creating an elliptical projection at a distance a1 from the Focal plane.
The minimum diameter of the mirror needs to be larger than the Ellipse Major Diameter.
The Larger Fold mirror will be at the furthest distance from the Focal plane OSM #1 (a1 = -20)



Each Probe FoV is a potential vignetting of an other probe.

3.1.1) Largest FoV at the Fold Mirror #1 (FM1) is at OSM #1 (a1 = -20) Probe

Ellipse Minor Diameter:
d = d at Focus Plan + (a1 / f#)
= 5 X 0.727 + (20 / 13.66)
= 3.635 + 1.464
d = 5.10 mm

Ellipse Major Diameter:
D = d√2= 5.1√2
D = 7.21 mm

3.1.2) Smallest FoV at the Fold Mirror #1 (FM1) is at OSM #2 (a1 = -5) Probe

Ellipse Minor Diameter:
d = d at Focus Plan + (a1 / f#)
= 5 X 0.727 + (5 / 13.66)
= 3.635 + .366
d = 4.00 mm

Ellipse Major Diameter:
D = d√2= 4√2
D = 5.66 mm

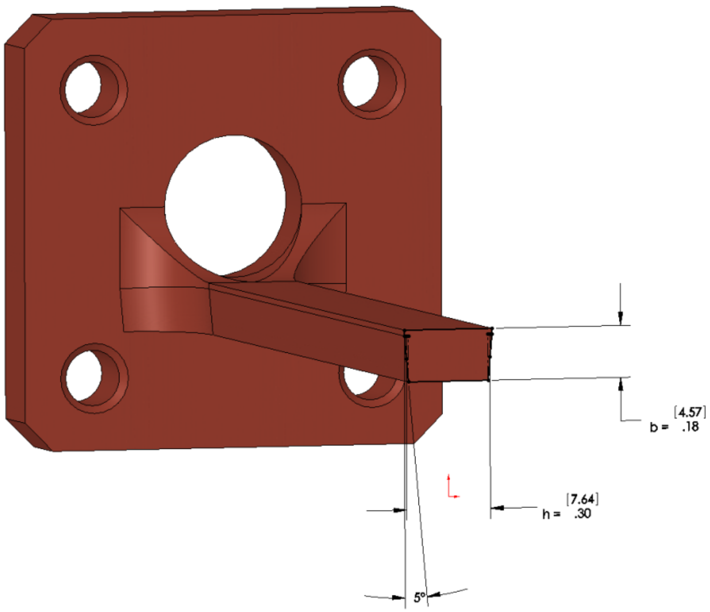
3.1.3) Medium FoV at the Fold Mirror #1 (FM1) is at OSM #3 (a1 = 10) Probe

Ellipse Minor Diameter:
d = d at Focus Plan + (a1 / f#)
= 5 X 0.727 + (10 / 13.66)
= 3.635 + .732
d = 4.37 mm

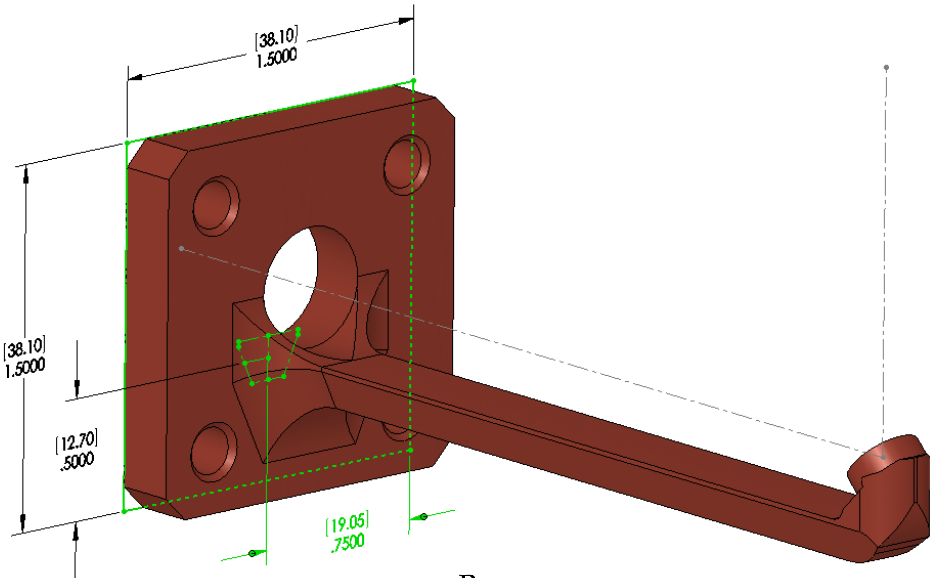
Ellipse Major Diameter:
D = d√2= 4.37√2
D = 6.18 mm

4) Probe Analysis

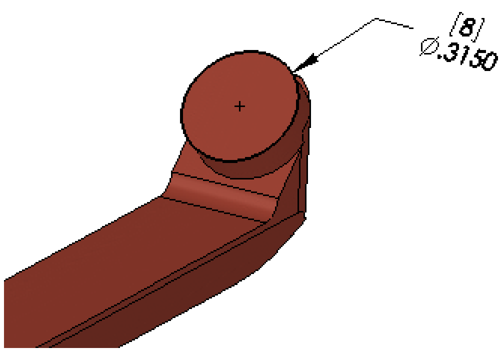
4.1) Design Features Common to all Probes



- Probe Cross Section



- Base



- Fold Mirror

4.2) Frequency Analysis

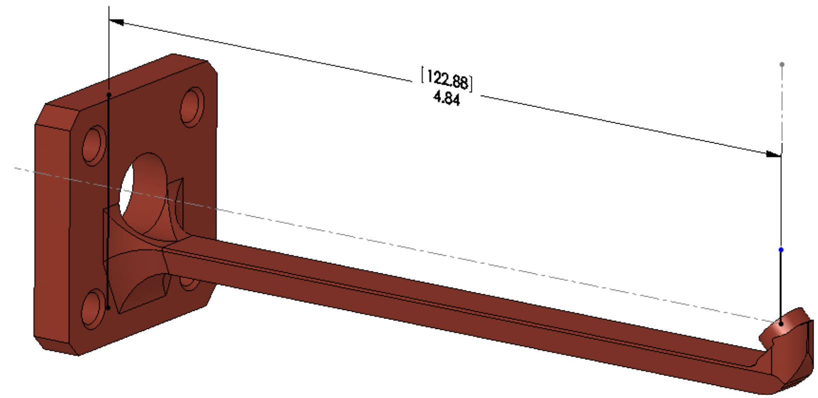
OSM #1

List Modes

Study name: Frequency

Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	1480.3	235.59	0.0042446
2	2512	399.79	0.0025013
3	9407	1497.2	0.00066792
4	15592	2481.6	0.00040296
5	25594	4073.5	0.00024549

Close Save Help



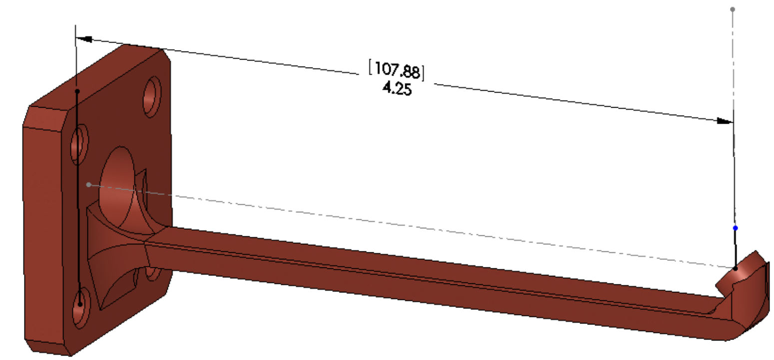
OSM #2

List Modes

Study name: Frequency

Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	1911.6	304.24	0.0032869
2	3246.5	516.7	0.0019354
3	12159	1935.1	0.00051677
4	19832	3156.3	0.00031683
5	29325	4667.2	0.00021426

Close Save Help



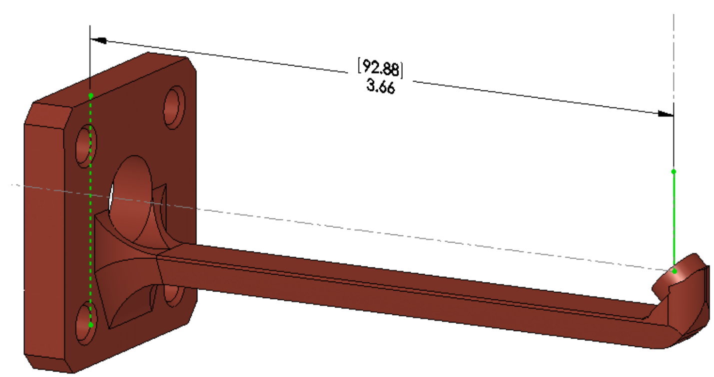
OSM #3

List Modes

Study name: Frequency

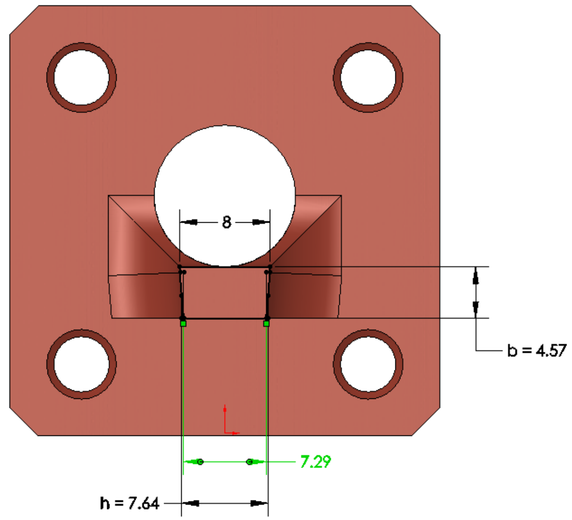
Mode No.	Frequency(Rad/sec)	Frequency(Hertz)	Period(Seconds)
1	2514.5	400.2	0.0024987
2	3706.5	589.9	0.0016952
3	16237	2584.2	0.00038696
4	22491	3579.5	0.00027937
5	32890	5234.6	0.00019103

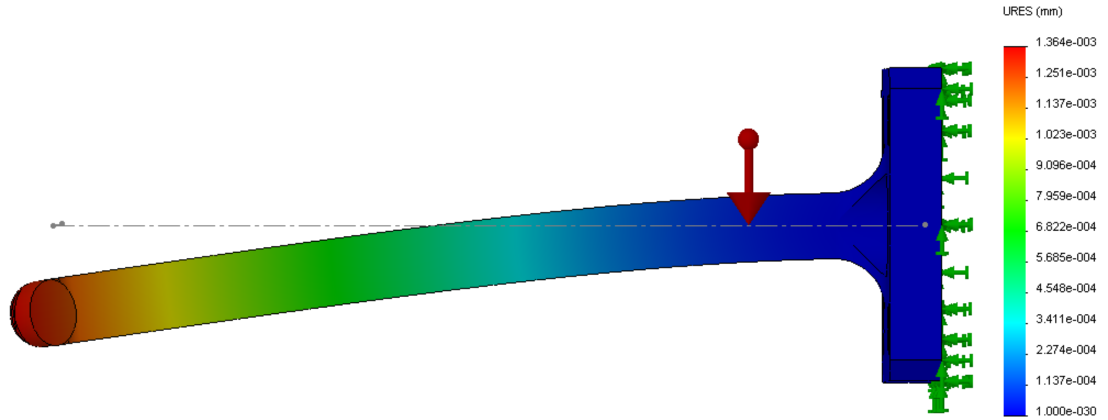
Close Save Help



4.3) Probe Deflection, at rest, under it's own weight:

- Deflection analyzed on the longest Inclined probe (OSM #2)





Probe Deflection

-Mass of the probe w = mg = 0.01 Kg x 9.81 ms^{-2} = 0.098N

-Moment of Inertia: I = $bh^3/12 = 4.57 \times 7.64^3/12 = 169.8\ mm^4$

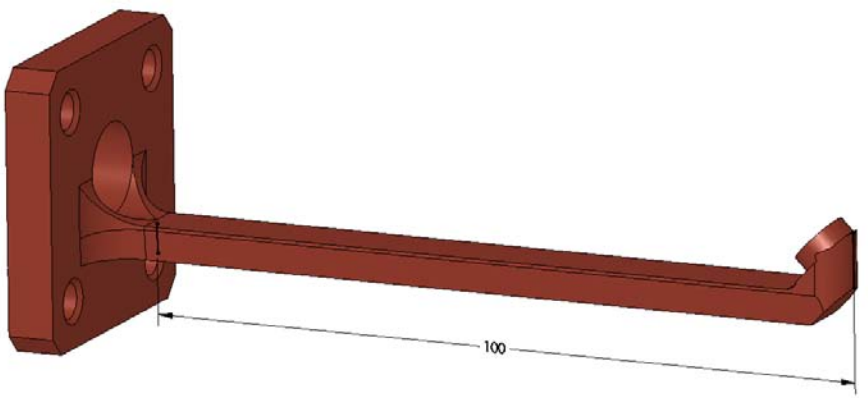
-6061-T6 Module of Elasticity: E = 68,800 N/mm^2

-Max Deflection: v = $wL^3 / 8EI$

v =0.098 X 100^3 / (8 X 68,800 X 169.8)

v = 98000/ 93457920

v = 0.001mm

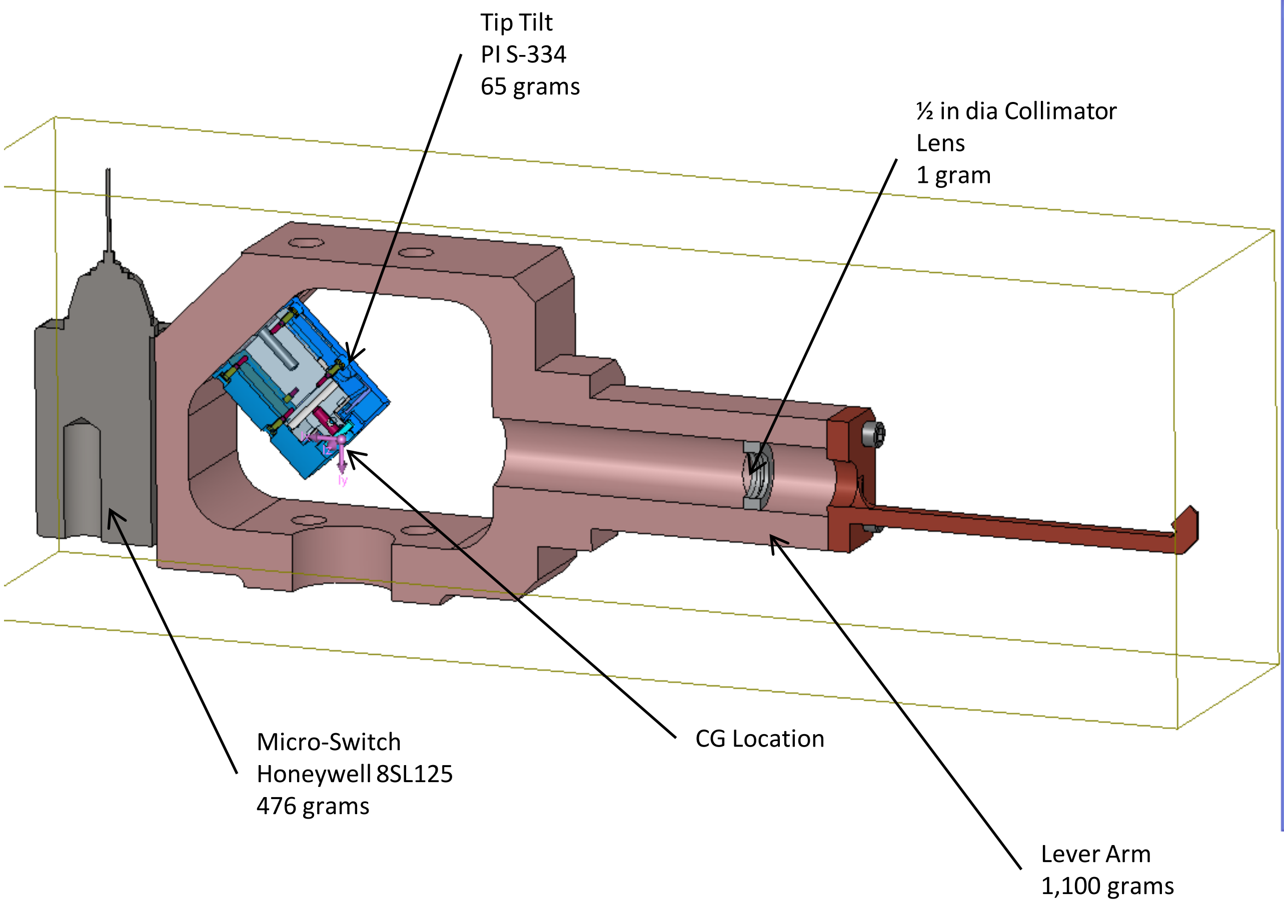


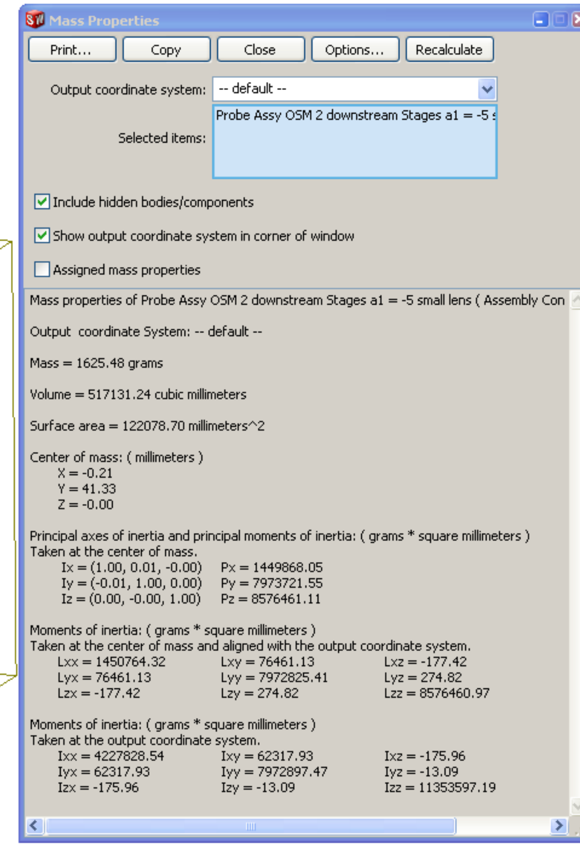
Probe Length

5) Mass and CG

5.1) Lever Arm Assembly

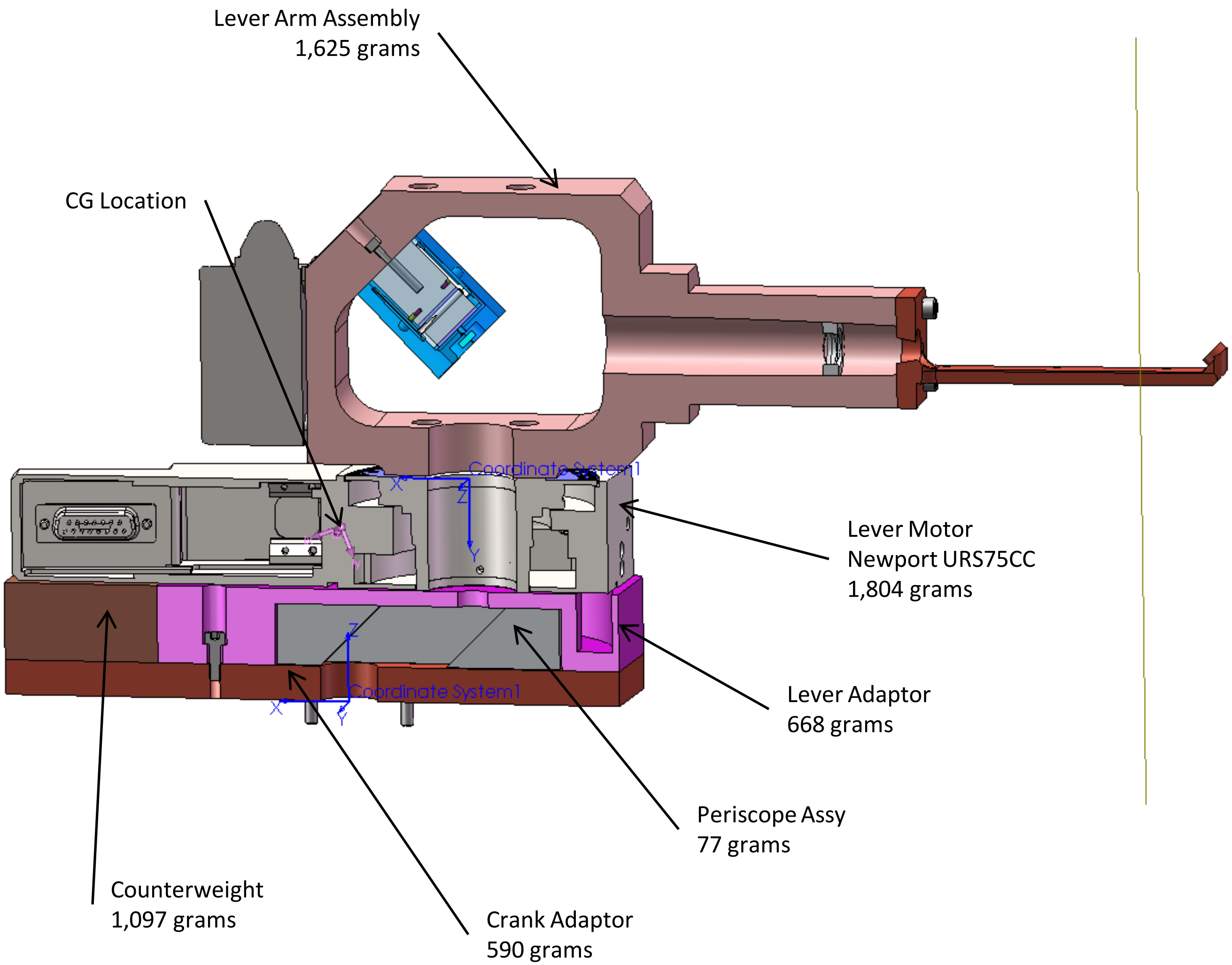
Total Mass: 1,625 grams, CG located at the Axis of rotation, 41 mm above the Lever motor Interface.

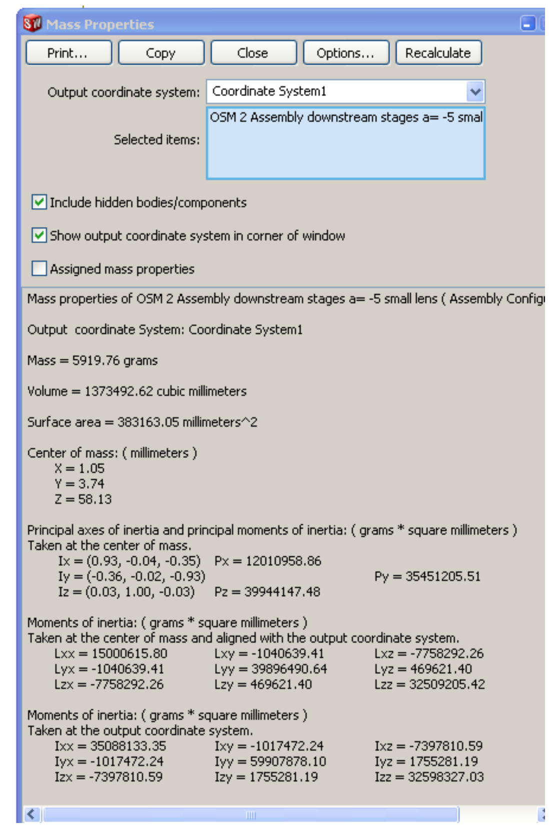




5.2) OSM #1 Assembly

Total Mass: 5,920 grams, CG located at the Crank Axis of rotation, 58 mm above the Lever motor Interface.





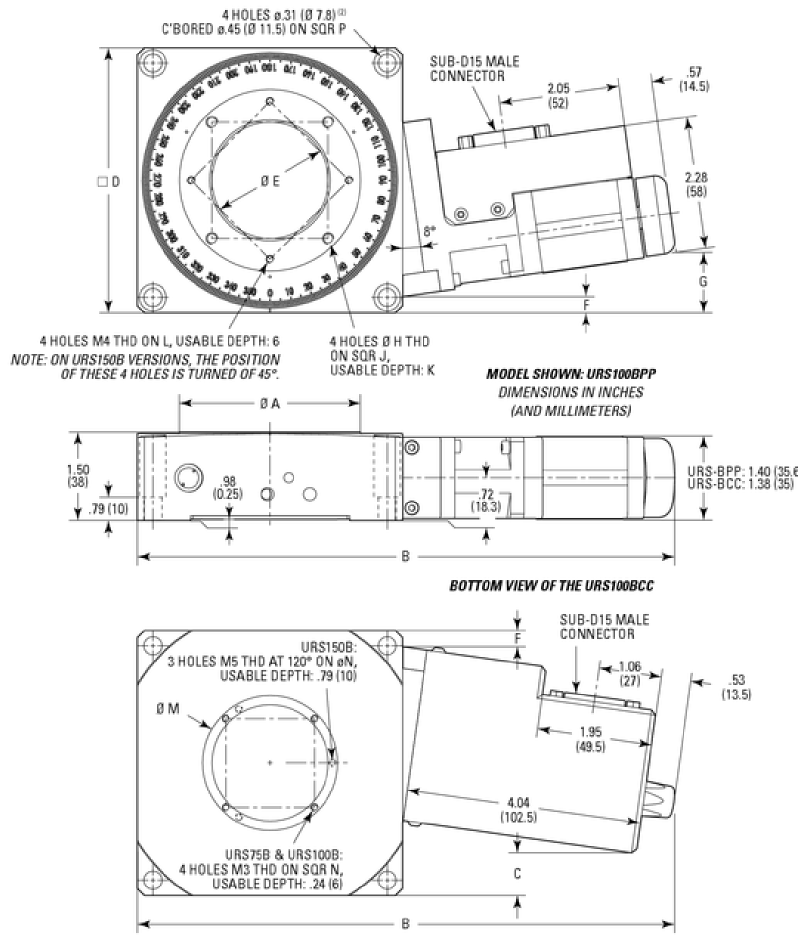
6) Lever Motor: Newport Stage URS75

Newport URS Series Precision Rotation Stages

Dimensions

Dimensions in inches (millimeters)

MODEL URS100B



	A	B	C	D	E	F	G	H	J	K	L	M	N	P
URS75B	1.97 (50)	8.19 (208)	-.20 [1] (-5) [1]	3.54 (90)	1.18 +.0051/0 (30 +.013/0)	.08 (2)	.83 (21)	M3	1.26 (32)	.24 (6)	–	1.50 (38)	1.34 (34)	2.98 (75.6)
URS100B	3.07 (78)	9.13 (232)	.71 (18)	4.49 (114)	1.97 +.0063/0 (50 +.016/0)	.26 (6.5)	1.02 (26)	M6	1.97 (50)	.24 (6)	SQR 1.89 (SQR 48)	2.28 (58)	2.13 (54)	3.97 (100.8)
URS150B	5.18 (131.5)	11.14 (283)	2.56 (65)	6.50 (165)	3.54 +.0087/0 (90 +.022/0)	.41 (10.5)	1.14 (29)	M6	2.95 (75)	.31 (8)	ø4.92 (Ø 125)	4.13 (105)	3.86 (98)	5.91 and 6 [2] (150 and 152.4) [2]

Notes:

[1] The drive box of the URS75BCC exceeds .20 in. (5 mm) from the body.

[2] URS150B: 4 slots counterbored.

Design Details

Base Material	Hardened steel with aluminum body
Bearings	
Drive Mechanism	Ground worm gear with self-compensating preload. Additional 1:2.75 drive belt with URS-CC versions (no belt on URS-PP versions)
Worm Gear Ratio	1:90
Feedback	CC: Worm mounted rotary encoder, 8,000 cts/rev, index pulse. PP: None
Limit Switches	Two independently adjustable optical limit switches
Origin	Optical, fixed at position 0°. Typical 0.0005° repeatability for URS-CC and 0.04° repeatability for URS-PP
Manual Adjustment	Via allen wrench at the end of the worm screw. Allen wrench is included.
Motor	CC: UE34CC DC servo motor PP: UE34PP Two phase stepper motor, 1 full step = 0.02°
Cable	

Specifications

	PP		CC	
	Typical	**Guaranteed**	**Typical**	**Guaranteed**
Travel Range (°)	360 continuous(1)			
Resolution (°)	0.0002(2)		0.0005	
Minimum Incremental Motion (°)	0.0002		0.002	
Uni-directional Repeatability (°)	0.001	0.002	0.001	0.002
Reversal Value (Hysteresis) (°)	0.006	0.01	0.002	0.004
Absolute Accuracy (°)	0.016	0.030	0.012	0.023
Maximum Speed (°/s)	40		80	
Wobble (µrad)	20	50	20	50
Eccentricity (µm)		3		3
MTBF	20,000 h at 25% load and with a 30% duty cycle			

1) With disabled limit switches

2) Equal to 1/100 of a full step

See the Motion Control Metrology Primer section (see Motion Control Metrology Primer) for more information on typical and guara

Absolute Probe Position Accuracy on Field: 250 X tan 0.023 = 0.1 mm

6.1) Load (Qh):

Qh = 1.625 Kg = 15.9N

6.2) Cantilever Torque:

Distance between Lever Motor and center of Mass: D = 41mm

Cantilever Torque at Lever motor: 0.041m X 15.9 = 0.65 Nm

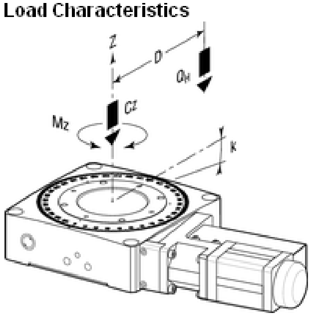
Off Center Load Requirement: Q < 200 / 2/(1 + 41/25) = 38 N ➔ 16N < 38N

$$\boxed{16N < 38N \rightarrow FS = 2.4}$$

Tip deflection angle K (urad) = 30 X 0.65 = 19.6 urad:

Component	Manufacturer	P/N	Weight (Kg)	Mass (N)
TT Mirror	PI	S-334	0.065	
Lens Holder	Newport	LPV-1	0.001	
Microswitch	Honeywell	8SL125	0.476	
Lever Arm	Caltech	XXX	1.083	
Lever Arm Assy			1.625	
Total Mass			1.625	15.94
D (mm)	41			
Cz (N)	200			
a (mm)	25			
Max Off center load (N)				76
K(urad/Nm)	30			
Torque (Nm)	0.65			
Deflection (urad) (rad)	19.61	1.96077E-05		
Proj Dist (mm)	112			
Twisting of the tip (mm)	0.0022			
Tip Horiz disp (mm)	0.0022			
Tip Vert disp (mm)	0.0000			

Load Characteristics



	URS75	URS100	URS150
Cz, Normal centered load capacity (N)	200	300	300
a, Construction parameter (mm)	25	35	55
kα, Transversal compliance (µrad/Nm)	30	10	5
Mz, Nominal Torque (Nm)	+/- 0.5	+/- 1	+/- 2
Q, Off-center load	Q ≤ Cz / (1 + D/a)		
D, Cantilever distance in mm			
Weight [lb (kg)]	3.7 (1.7)	4.4 (2)	7.5 (3.4)

7) Crank Motor: Newport Stage RV Series

Specifications

Travel Range (°)	360 continuous	With disabled limits, except HAT & HAHLT
	±170	HAT & HAHLT versions
Resolution (°)	0.001	Except RVS80, HAT & HAHLT versions
	0.00025	RVS80CC
	0.0001	RVS80PP, equals 1/100 of a full step
	0.0001	RV120HAT & HAHLT
	0.00075	RV160HAT & HAHLT
	0.0005	RV240HAT & HAHLT
	0.00035	RV350HAT & HAHLT
Minimum Incremental Motion (°)	0.001	Except RVS80, HAT & HAHLT versions
	0.00025	RVS80CC
	0.0002	RVS80PP
	0.0001	HAT & HAHLT versions
Uni-directional Repeatability (°)	0.001 typical, 0.002 guaranteed	Except RVS80CC, HAT & HAHLT versions
	0.001 guaranteed	RVS80CC
	0.002 guaranteed	RVS80PP
	0.00011 typical, 0.0002 guaranteed	HAT & HAHLT versions
Reversal Value (Hysteresis) (°)	0.001 typical, 0.002 guaranteed	Except RVS80PP, HAT & HAHLT versions
	0.005 guaranteed	RVS80PP
	0.0006 typical, 0.001 guaranteed	HAT & HAHLT versions
Absolute Accuracy (°)	0.007 typical, 0.01 guaranteed	Except RVS80, HAT & HAHLT versions
	0.015 guaranteed	RVS80CC
	0.02 guaranteed	RVS80PP
	0.003 typical, 0.005 guaranteed	HAT & HAHLT versions
Maximum Speed (°/s)	80	CC & HAT motor option, except RVS80CC
	40	RVS80CC
	20	PP motor option
	16	CCHL & HAHLT motor option
	2	PE motor option
Wobble (µrad)	40 guaranteed	RVS80
	10 typical, 20 guaranteed	RV120 & RV160
	8 typical, 16 guaranteed	RV 240 & RV350
Eccentricity (µm)	1.4 typical, 4 guaranteed	
MTBF (h)	20,000	

Absolute Probe Position Accuracy on Field:

RVS80PP: 290 X tan 0.02 = 0.101 mm ($ 3983)

RVS80CC: 290 X tan 0.015 = 0.076 mm ($ 4454)

RVS120HAT: 290 X tan 0.005 = 0.025 mm ($ 8920)

7.1) RVS80 Load Qv = 5.920Kg = 59.2N

Distance between Crank Motor and center of Mass: D = 58 + 32 = 90 mm

Cantilever Torque at Crank motor: 0.090m X 59N = 5.3 Nm

Max Off Center Load: 900/2 / (1 + 90/30) = 112 N

$\boxed{59N < 112N \rightarrow FS = 1.9}$

Load Characteristics

	RVS80	RV120	RV160	RV240	RV350
Cz, normal centered load capacity (N)	900	1800	2700	4000	6500
a, construction parameter (mm)	30	40	50	70	100
b*, (mm) except HAT & HAHLT	39	53	57	59	73
b*, (mm) for HAT & HAHLT		71	75	77	91
k, radial compliance (µrad/Nm)	3.5	1.5	0.6	0.3	0.1
Q_H, Off-center load, vertical rotation axis			Q_H Cz / (1+D/a)		
Q_V, Off-center load, horizontal rotation axis			Q_V Cz / 2 / (1+D/a)		

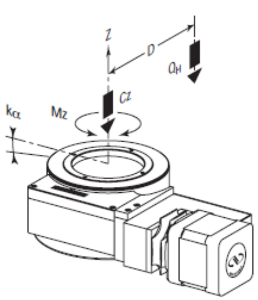
* Construction parameter = Distance between the top surface of the RV stage and the bearing center.

Example:

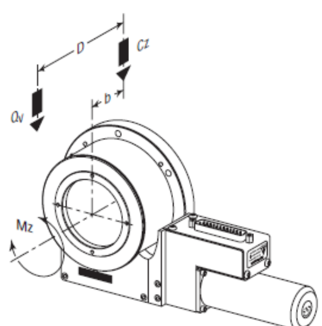
Q_V at a distance of 80 mm from the top surface for a RV160HAT rotation stage, D = 80 mm + 75 mm = 155 mm:

Q_V = 2700 N / 2 / (1 + 155 mm / 50 mm) = 329 N

Load Rotation Axes



Vertical Axis



Horizontal Axis

Component	Manufacturer	P/N	Weight (Kg)	Mass (N)
TT Mirror	PI	S-334	0.065	
Lens Holder	Newport	LPV-1	0.001	
Microswitch	Honeywell	8SL125	0.476	
Lever Arm	Caltech	XXX	1.083	
Lever Arm Assy			1.625	
Rotation Stage	Newport	RVS80	1.804	
Lever Adaptor	Caltech	XXX	0.668	
Periscope Assy	Caltech	XXX	0.136	
Crank Adaptor	Caltech	XXX	0.59	
Counterweight	Caltech	XXX	1.097	
Total Mass			5.92	58.08
D	90			
Cz	900			
a	30			
Max Off center load				225
K(urad/Nm)	3.5			
Torque (Nm)	5.2			
Deflection (urad) (rad)	18.29	1.82937E-05		
Proj Distance (mm)	130			
Deflection at tip (mm)	0.0024			
Tip Horiz disp (mm)	0.0024			
Tip Vert disp (mm)	0.0000			

6) *Absolute Probe Position Accuracy on Field*

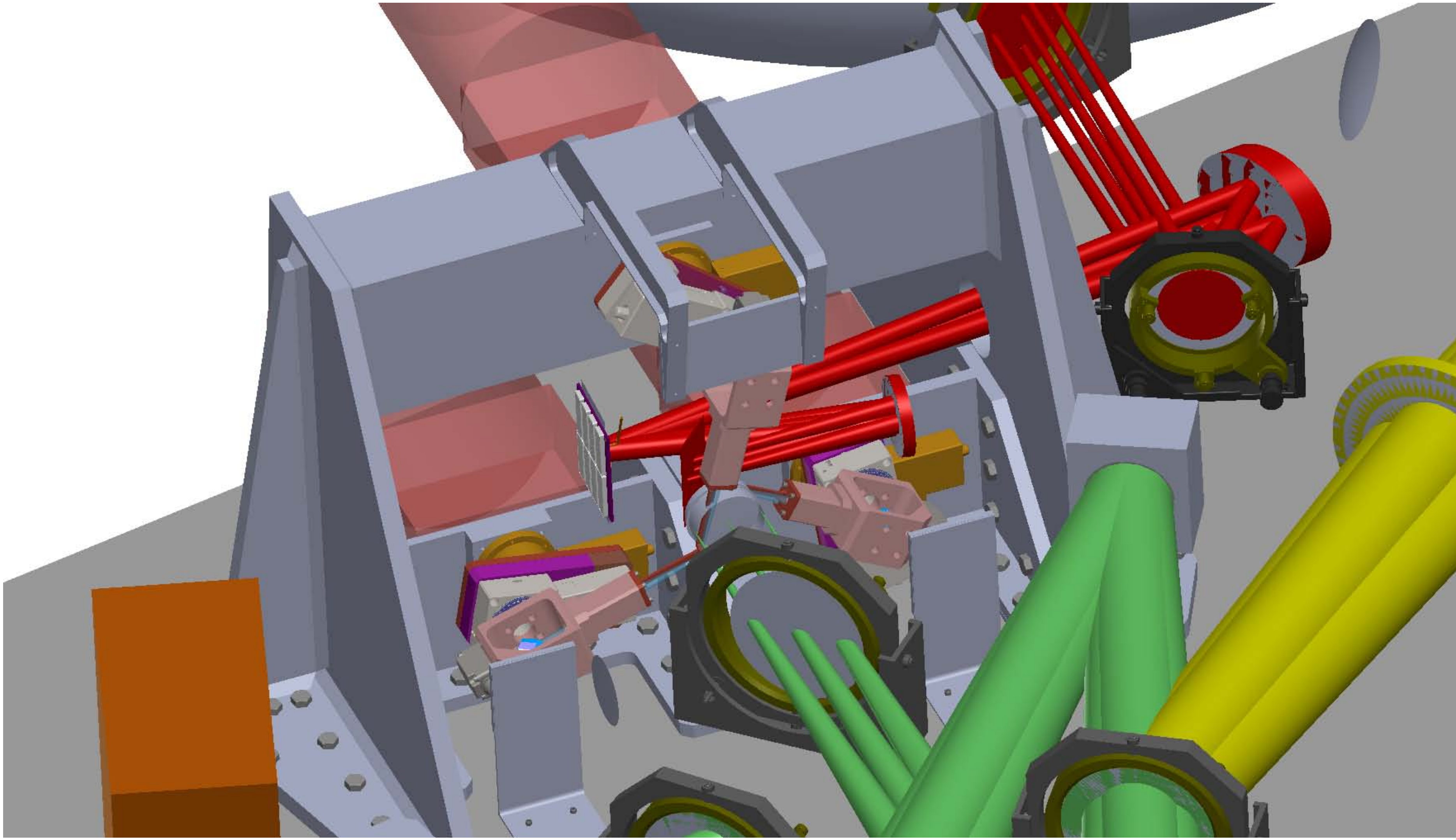
- Lever Motor Newport Stage URS75: 250 X tan 0.023 = 0.1 mm

- Crank Motor Newport Stage RVS80PP: 290 X tan 0.02 = 0.101 mm

- Crank Motor Newport Stage RVS80CC: 290 X tan 0.015 = 0.076 mm

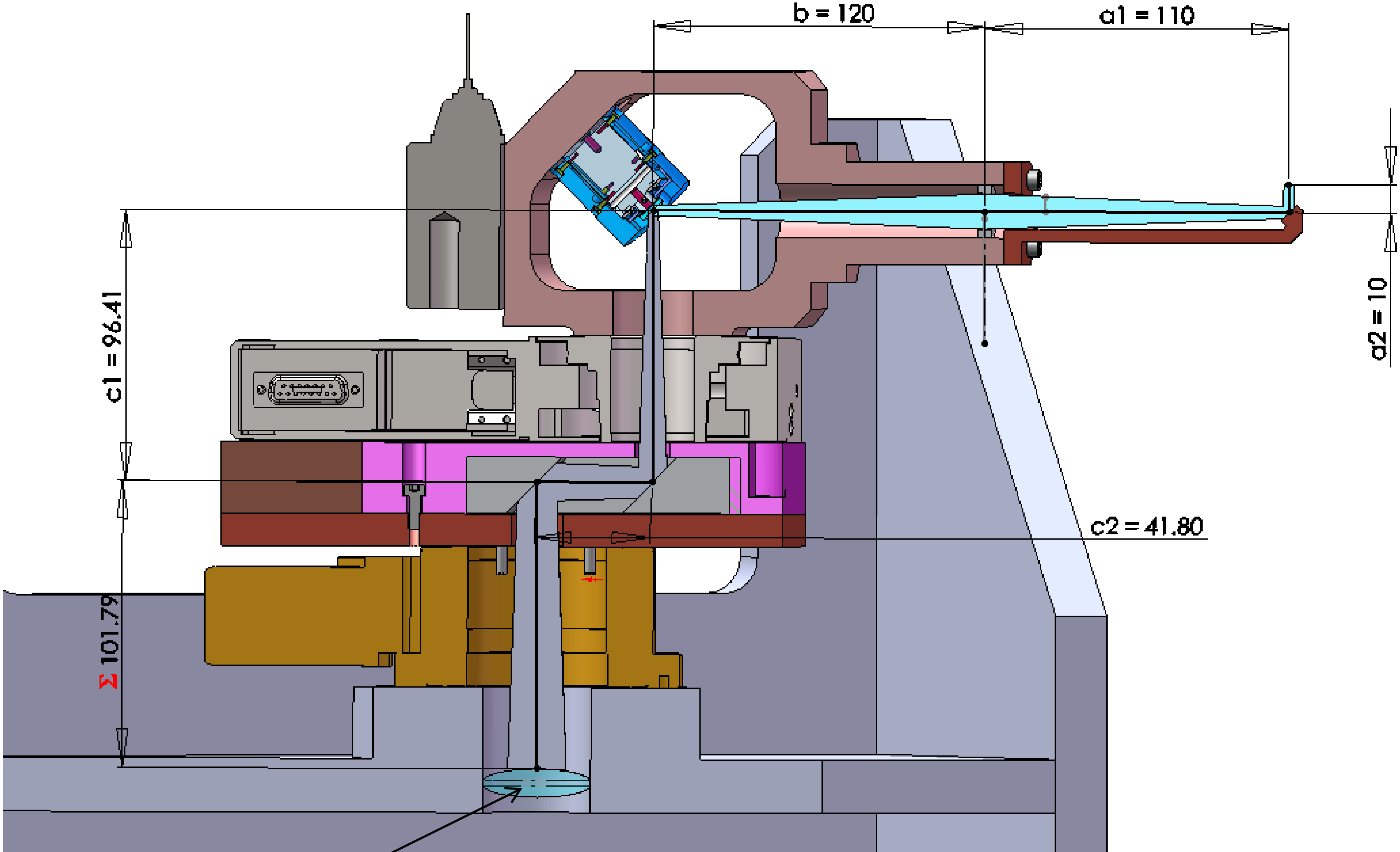
- Crank Motor Newport Stage RVS120HAT: 290 X tan 0.005 = 0.025 mm

NGAO VIEW



OPTICAL PATH

a = b = 120mm & c = d = 240mm

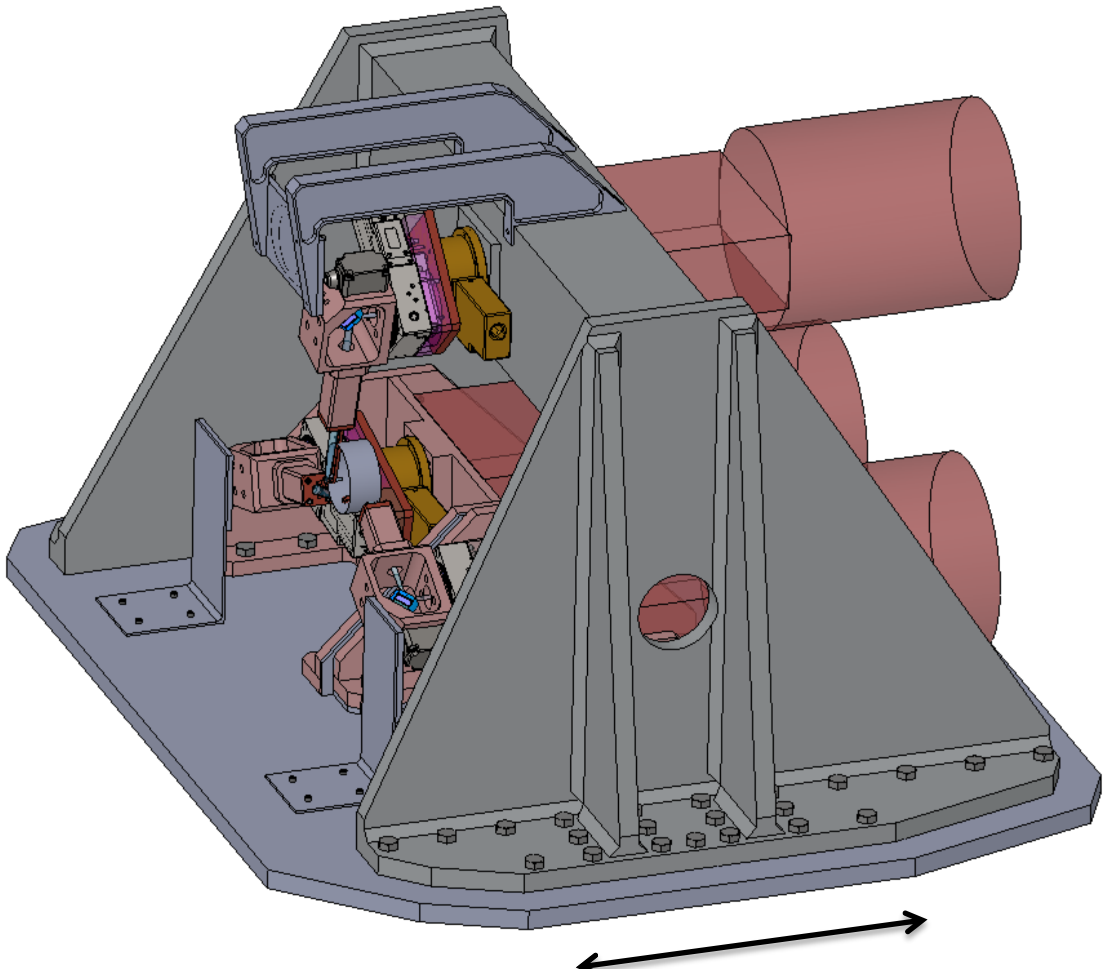


1 in dia Lens

OPEN ISSUES

1) The entire 200Kg LOWFS OSM should be installed on linear stages to provide the 5mm focus adjustment necessary to compensate for the Dichroic pickoff motion. (Accuracy TBD)

2) The 1mm sag caused by the curved focus around the Probes FM1 is not solved yet.



NGAO VIEW