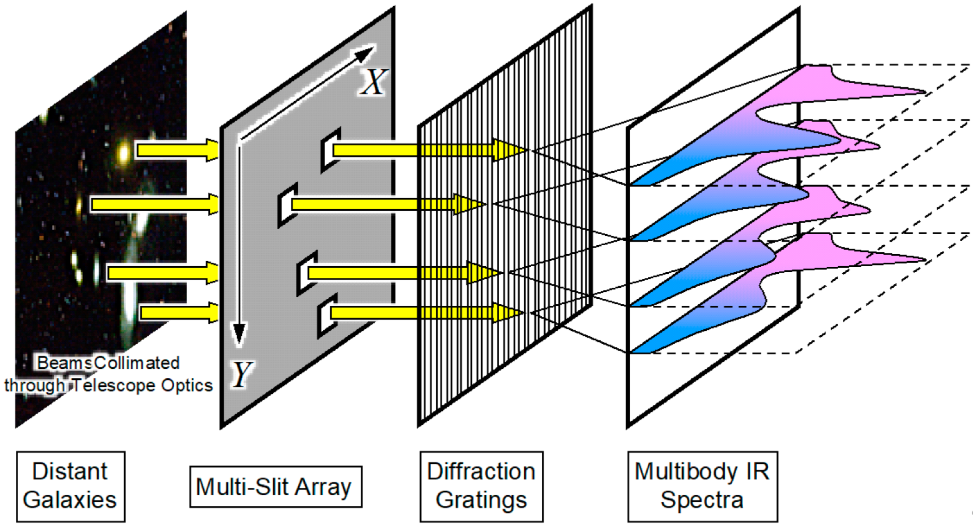
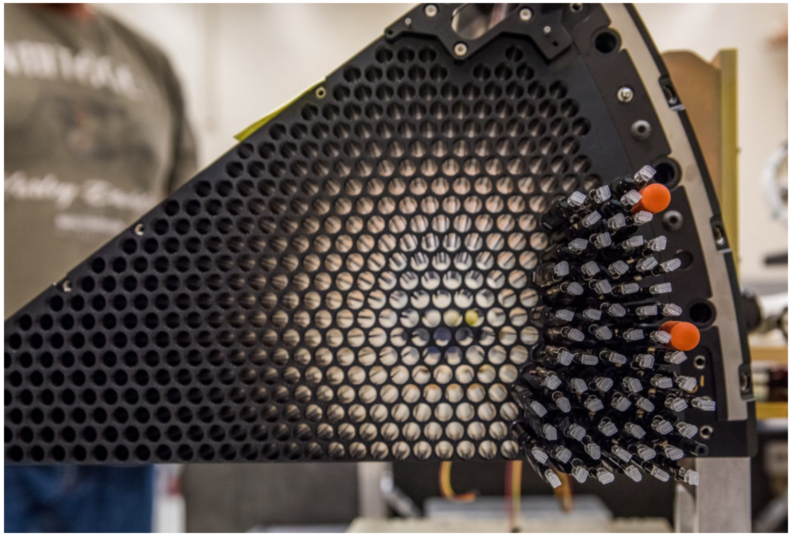
Fiber Positioner for A-SPEC

Ajou University
Advanced Manufacturing Lab.

2022. 2. 14. Mon.

Fiber Positioner System



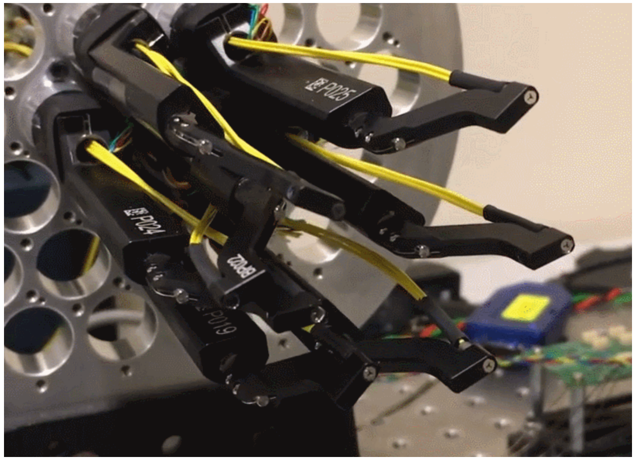


Multi-slit spectrograph **Fiber-fed spectrograph**

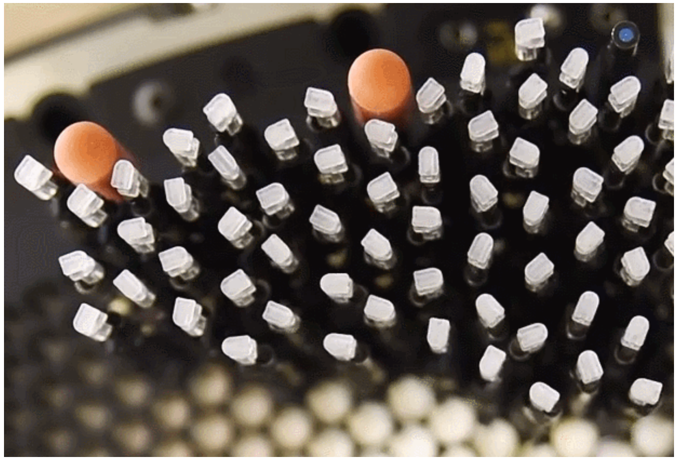
- **Multi-object spectroscopy: Multi-slit spectrograph vs. Fiber-fed spectrograph**
- **Massive Spectroscopy Project → Fiber-fed spectrograph (Object targeting, Spectral range)**
- **SCARA-like robot manipulator(Theta-phi actuator)**
  - **Two Rotary motor(theta-phi)**
  - **Large workspace**
  - **Overlapped coverage**

Theta-Phi? α-β? SCARA?

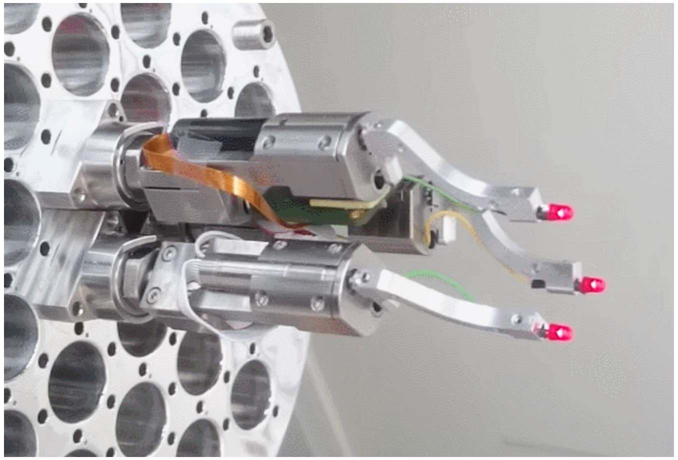
Selective Compliance Assembly Robot Arm (SCARA) By H. Makino (1980)



SDSS-V Fiber positioner

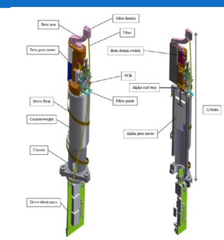
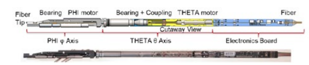
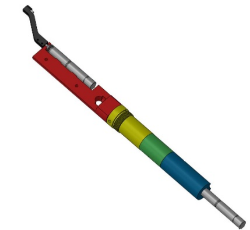


DESI Fiber positioner



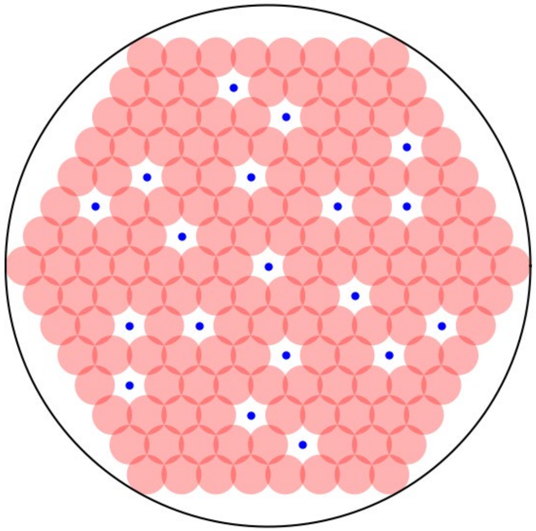
MOONS Fiber positioner

Fiber Positioners

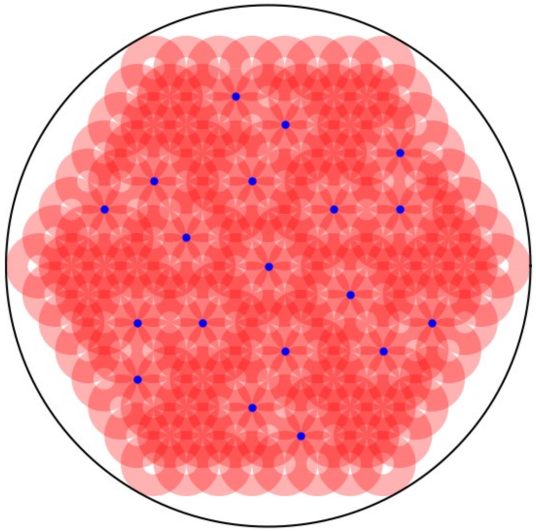
	Cobra[1,2]	MOONS[3]	SDSS-V[4-6]	DESI[7,8]	K-SPEC
Figure					
Range	*Φ* 9.5 mm	*Φ* 50 mm	*Φ* 30 mm	*Φ* 10.4 mm	***Φ* 33.2 mm**
XY Error	≤ 5 μm	≤ 20 μm	10.36 μm (bef. correc.) 1.12 μm (after correc.)	10-13 μm (bef. correc.) 1-2 μm (after correc.)	**≤ 5 μm**
Housing Dimensions	*Φ* 7.7 mm	-	<*Φ* 25 mm	*Φ* 8 mm	***Φ* 16 mm**
Actuation Principle	Piezo motor	Stepper motor (MPS Faulhaber)	BLDC motor (MPS Faulhaber)	BLDC motor (Namiki Precision Jewel Co.)	**BLDC motor (Maxon, Swiss)**
Feedback	NO	YES(IEM3-1024)	Hall sensor	Digital hall sensor	**Magnetic encoder (256 pulse/rev)**
Telescope / Instrument	Subaru / PFS	VLT / MOONS	Apache Point / SDSS-V	Mayall 4m / DESI	**KMTNet /K-SPEC**
Research group	Caltech/ New Scale Technologies	United Kingdom Astronom y Technology Center	École Polytechnique Fédérale de Lausanne	LBNL	**Ajou Univ,/KASI**

1. Fisher C., Braun D., Kaluzny J., Haran T., 2009, IEEE Aerospace Conference
2. Status Report, New Scale Technologies, 2016
3. Proc.SPIE 9908, Ground-based and Airborne Instrumentation for Astronomy VI, 990895 (9 August 2016)
4. High density fiber positioner system for massive spectroscopic surveys, MNRAS **481,** 3070–3082 (2018)
5. INTERNATIONAL JOURNAL OF OPTOMECHATRONICS, 2020, VOL. 14, NO. 1, 53–77
6. An 8-mm diameter Fiber Robot Positioner for Massive Spectroscopy Surveys, MNRAS 450, 794–806 (2015)
7. The DESI experiment part II: Instrument design (2016)

Coverage



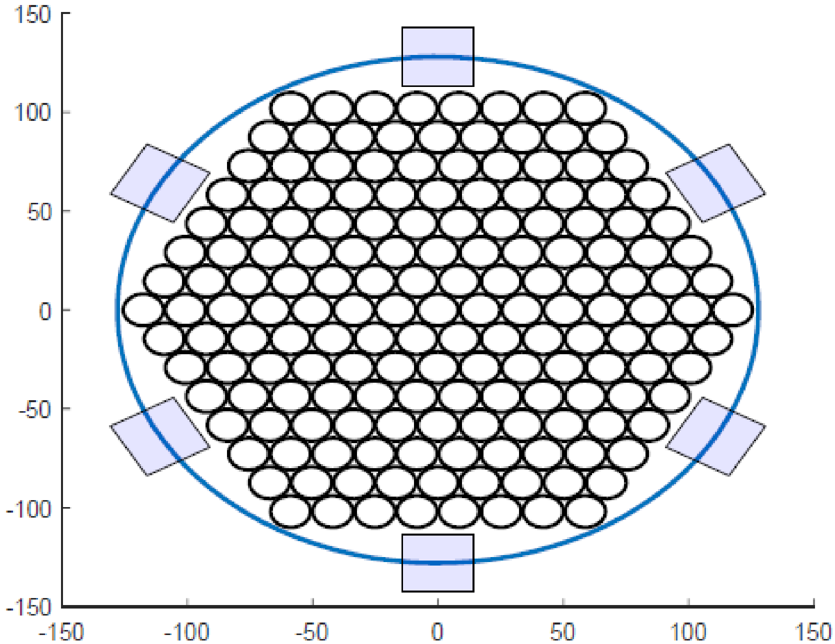
Single coverage



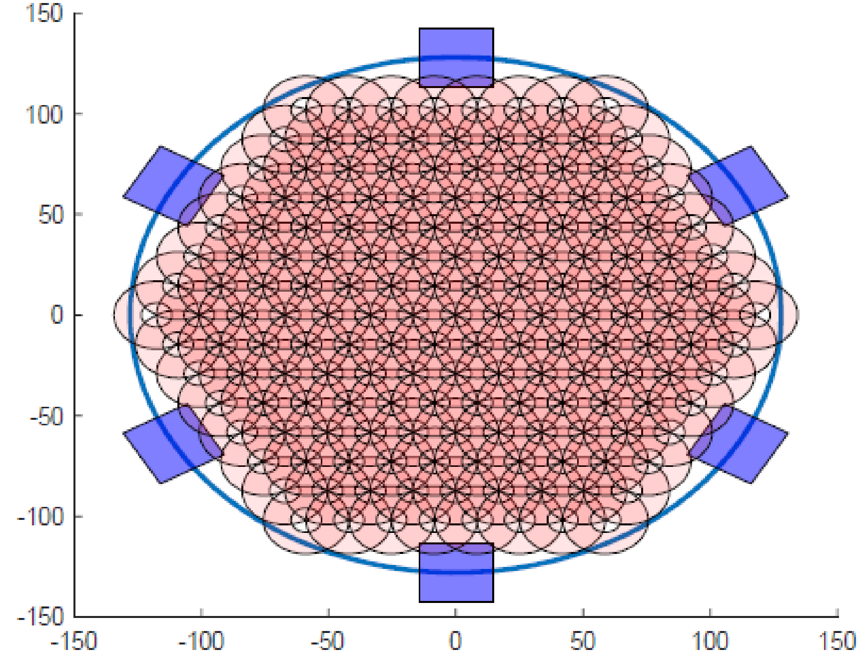
Double coverage

- β-Arm length > α-Arm length: Donut shape workspace (double coverage)
- No coverage loss by fiducial mark
- Coverage loss at the boundary area
- Collision avoidance

Layout of Fiber Positioners



Focal plate layout

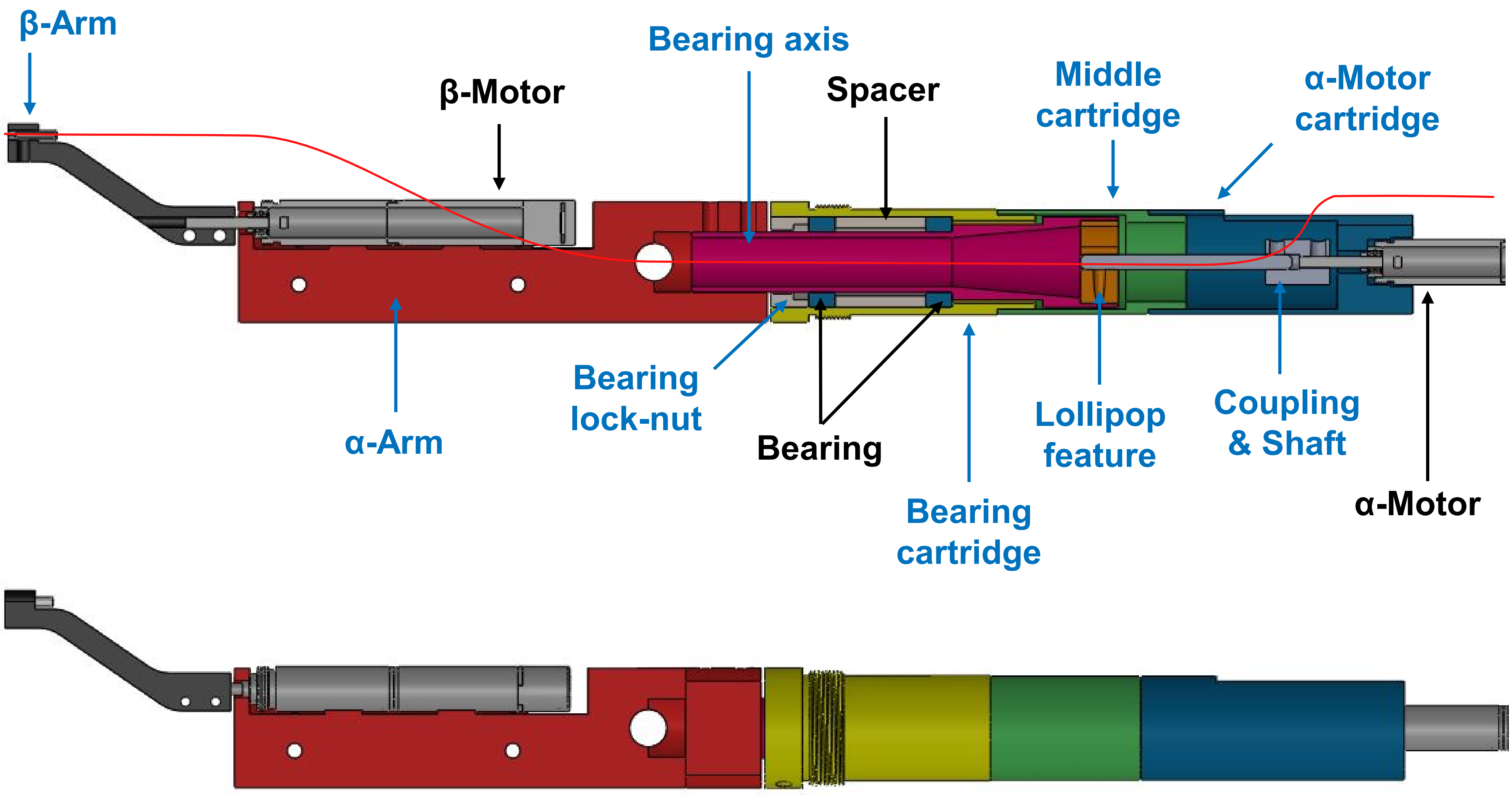


Workspace

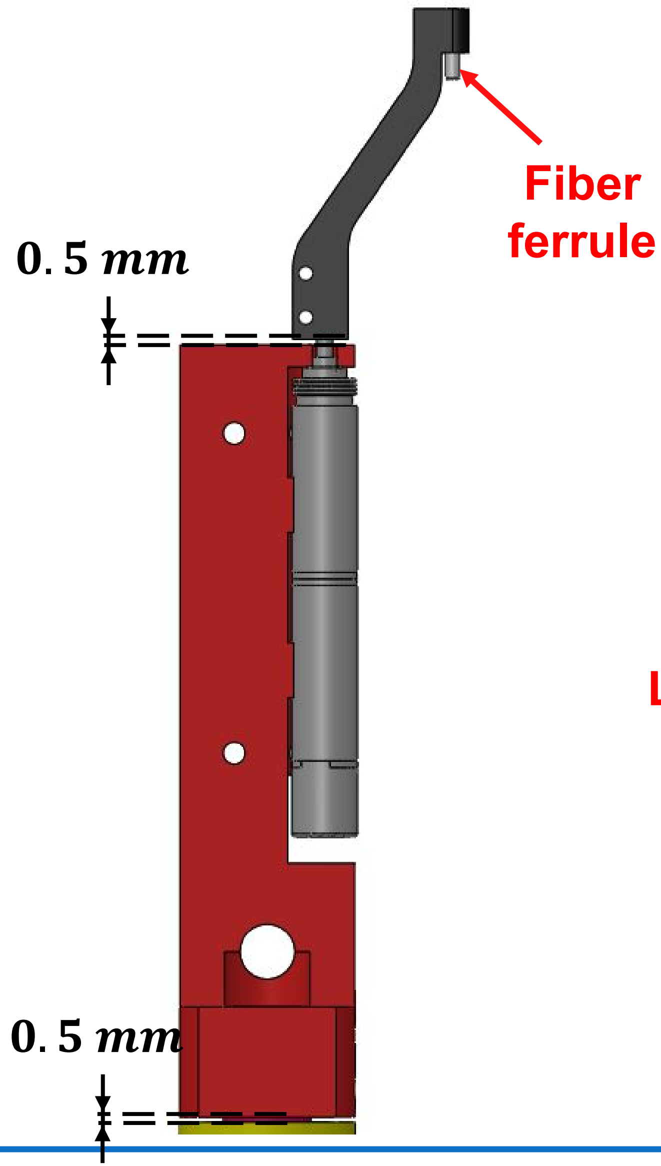
- **150 positioners in focal plate(*Φ* 256 mm) → Pitch 16.8 mm**
- **Fiber positioner diameter 16 mm**
- **Double coverage workspace OD 33.2 mm/ID 12.8 mm**

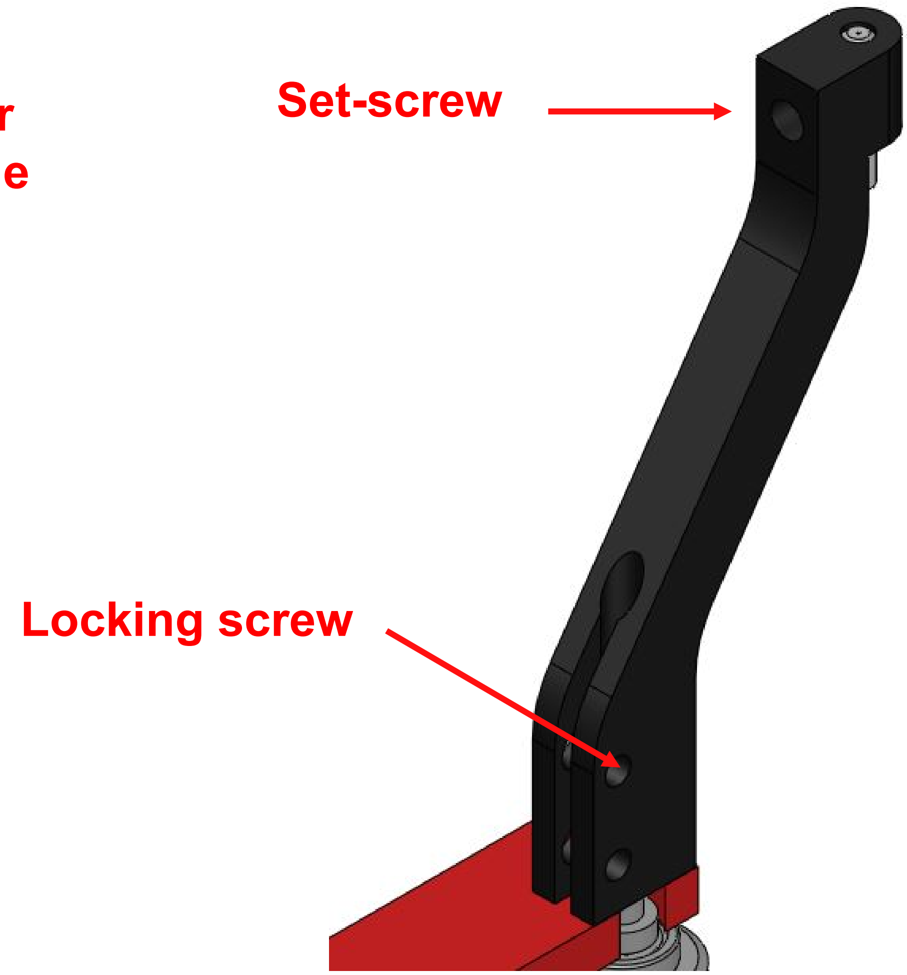
Design of Fiber Positioner

Design of Fiber Positioner

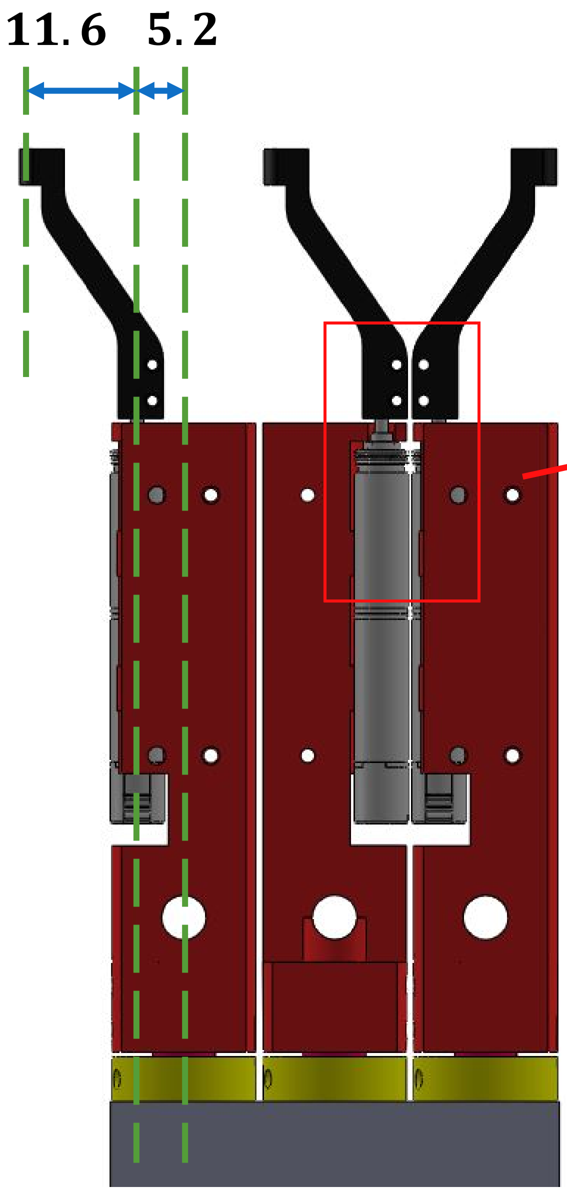


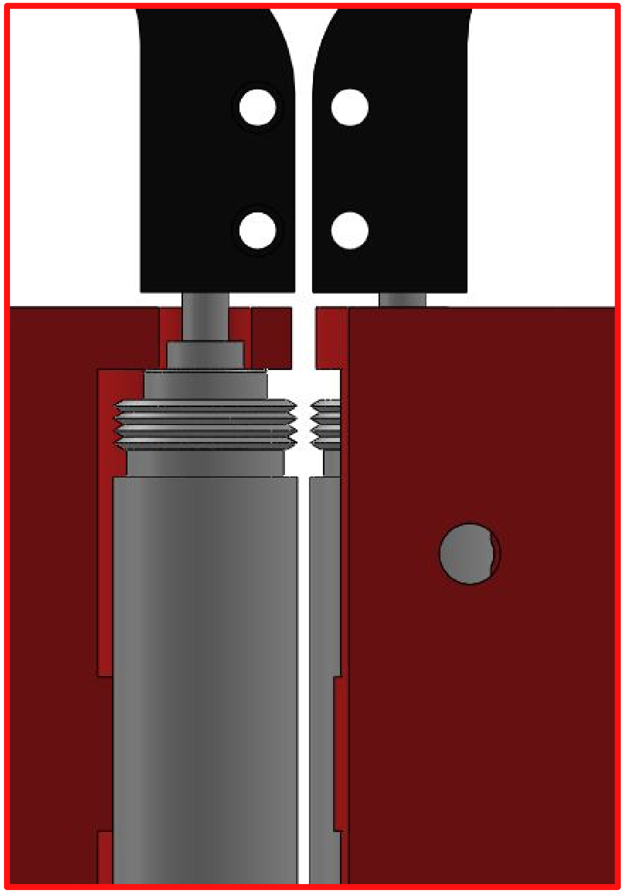
Design of Fiber Positioner : β Arm





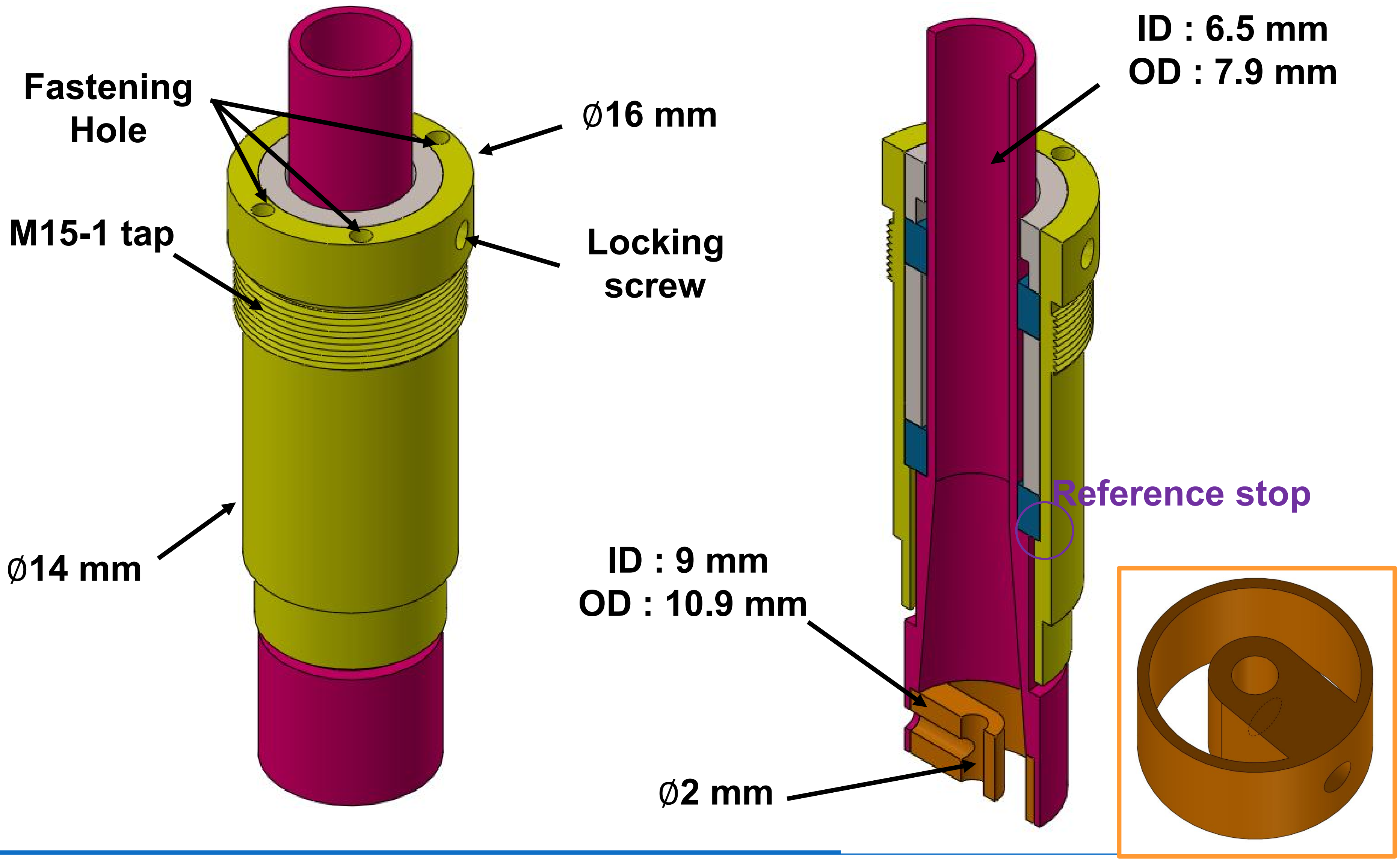
Design of Fiber Positioner : α-Arm



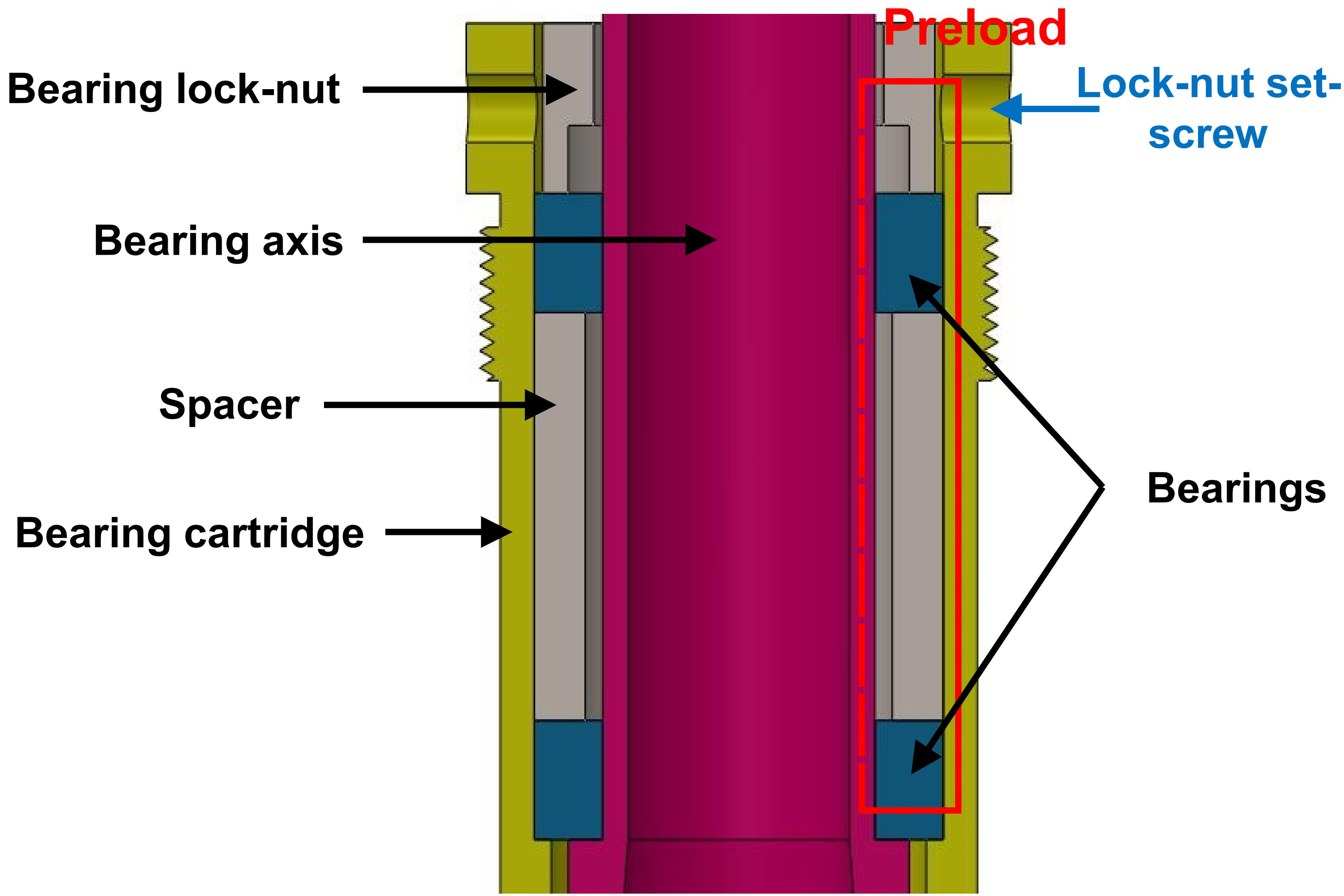


- α-Arm length ≤ $\frac{\text{Pitch}}{2}$ - α-Motor radius
- 5.2 mm

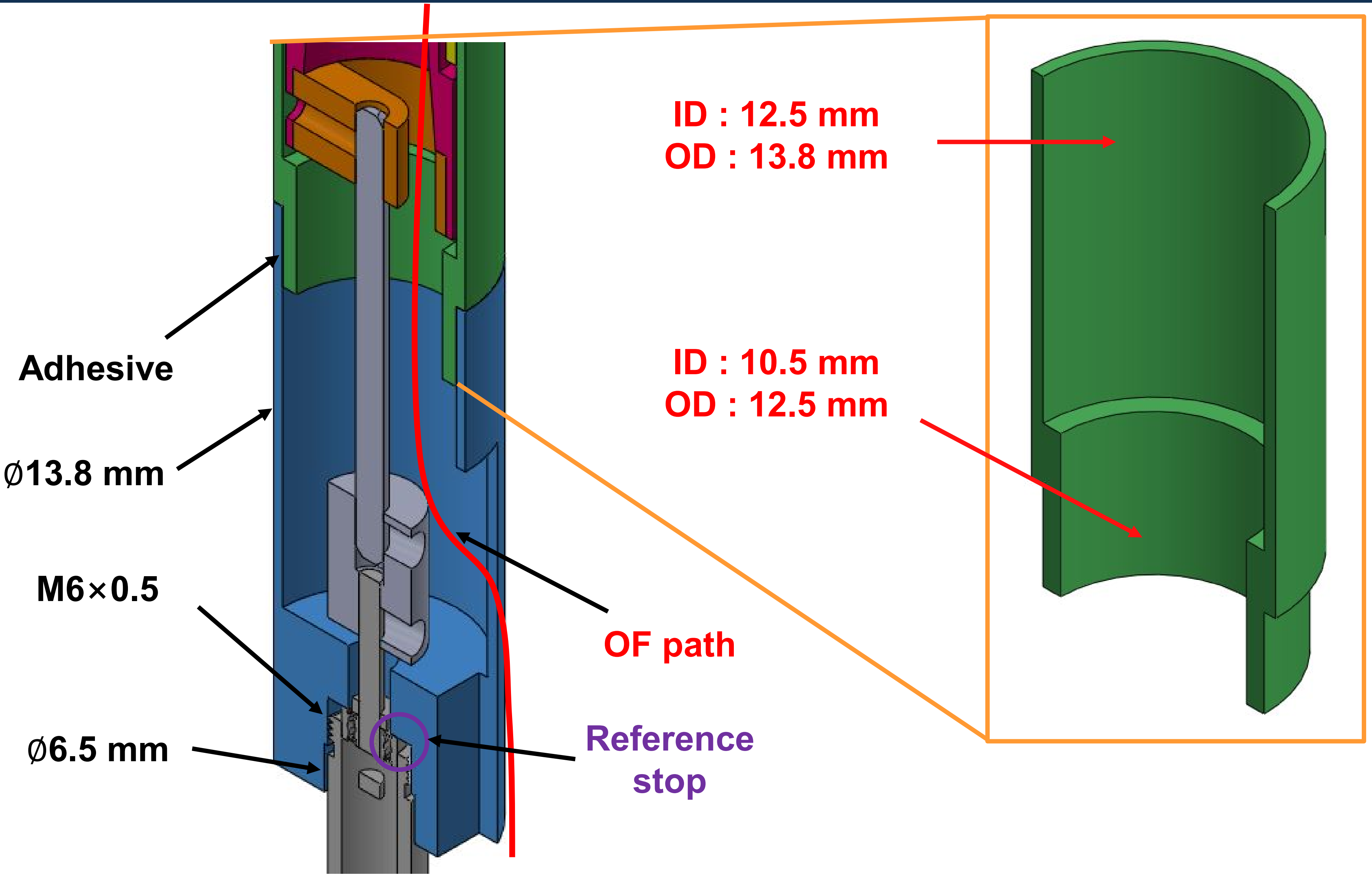
Design of Fiber Positioner : Bearing Cartridge



Design of Fiber Positioner : Bearing Cartridge

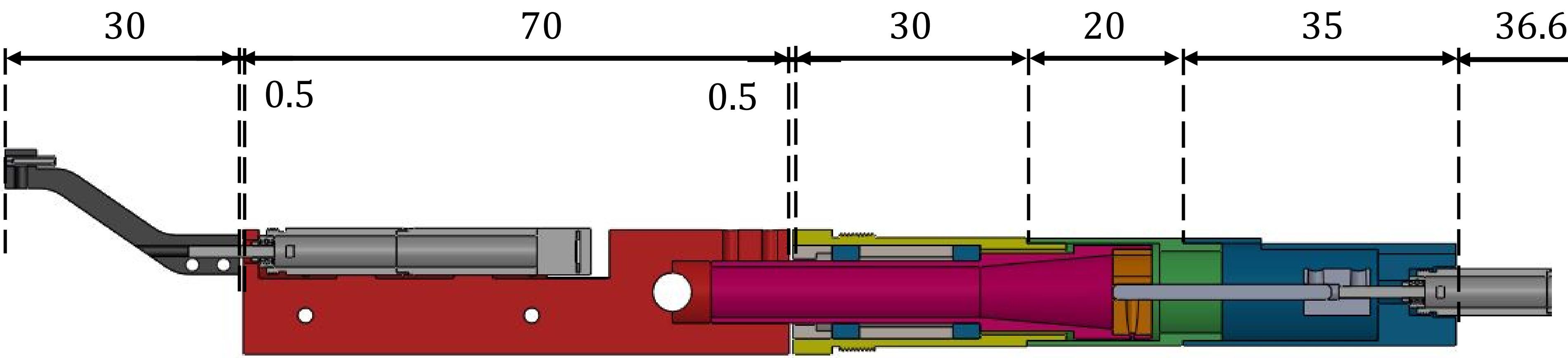


Design of Fiber Positioner : Middle & Motor Cartridge



Design of Fiber Positioner

Length: 222.6 mm / weight: 46.3 g (과제 목표 150 g)

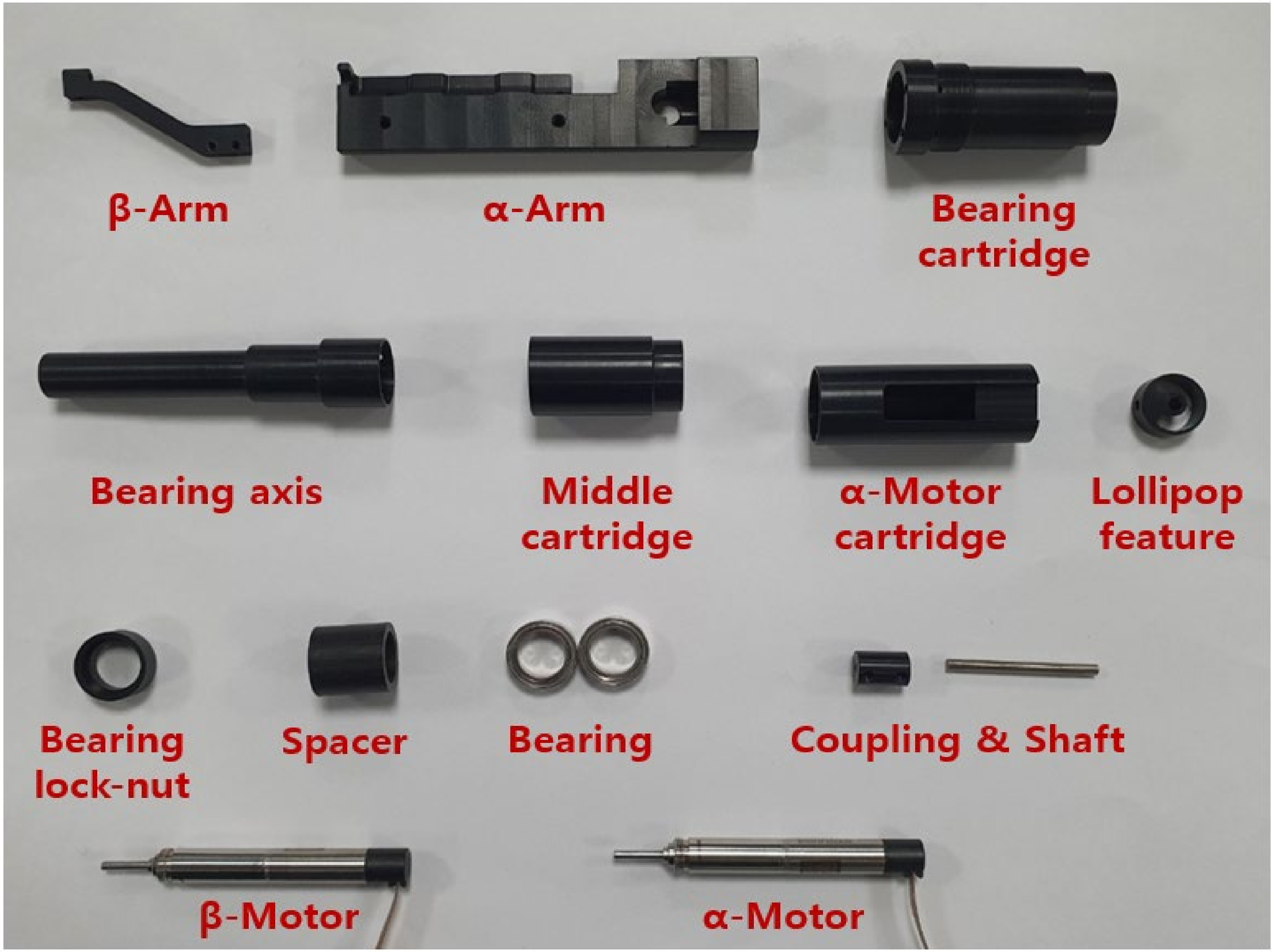


Material : AL6061

Part	α-Arm	β-Arm	Bearing lock-nut	Bearing axis	Bearing cartridge	Lollipop feature	Middle cartridge	α-Motor cartridge
weight [g]	13.2	0.8	0.6	3.8	4.5	0.6	2.1	4.7

Part	Bearing (2Ea)	Spacer	Shaft & Coupling	α-Motor	β-Motor
weight [g]	2.1	0.6	1.8	5.5	5.5

Design of Fiber Positioner



Design of Fiber Positioner: Assembly

Bearing assembly (1)

- Bearing lock-nut
- Bearing
- Spacer
- Bearing cartridge
- Bearing axis

α unit assembly (3)

- Assembly (1)
- Coupling & Shaft
- Middle cartridge
- Motor cartridge
- α -Motor

FPU (5)

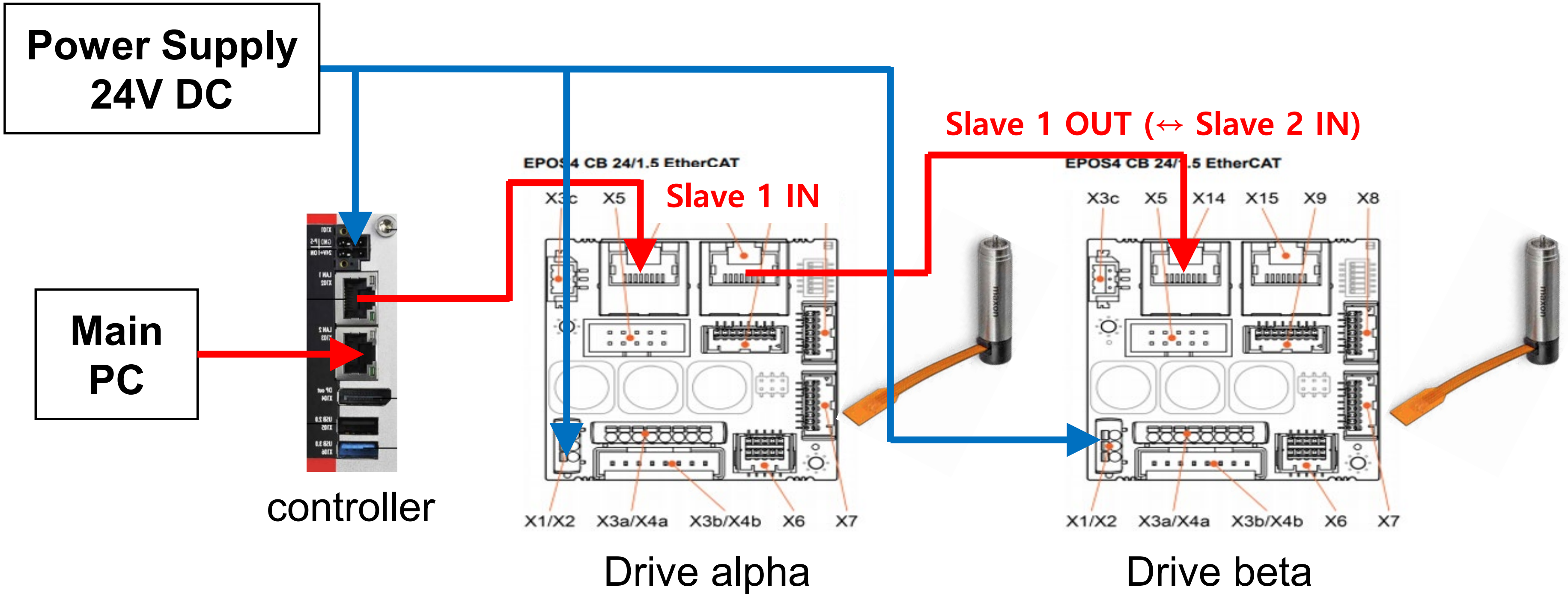
β-Motor assembly (2)

- α-Arm
- β-Motor

α & β arm assembly (4)

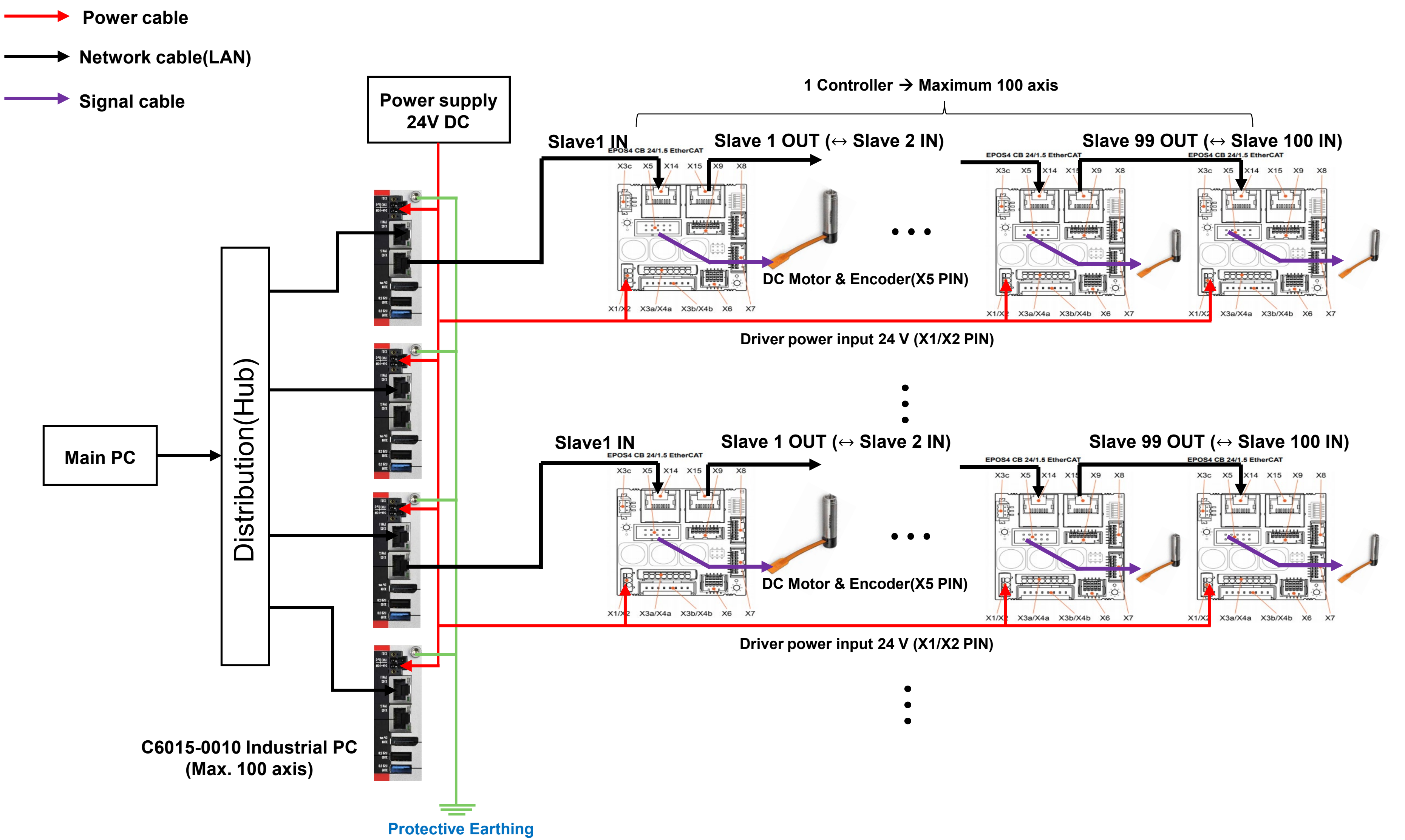
- Assembly (2)
- β-Arm

Design of Fiber Positioner : Communication Scheme



- **Two sets of motor and drive for 1 FPU**
- **150 FPU → 300 motors, 300 drives**
- **EtherCat network (Beckhoff automation) controller**

Design of Fiber Positioner : Communication Scheme



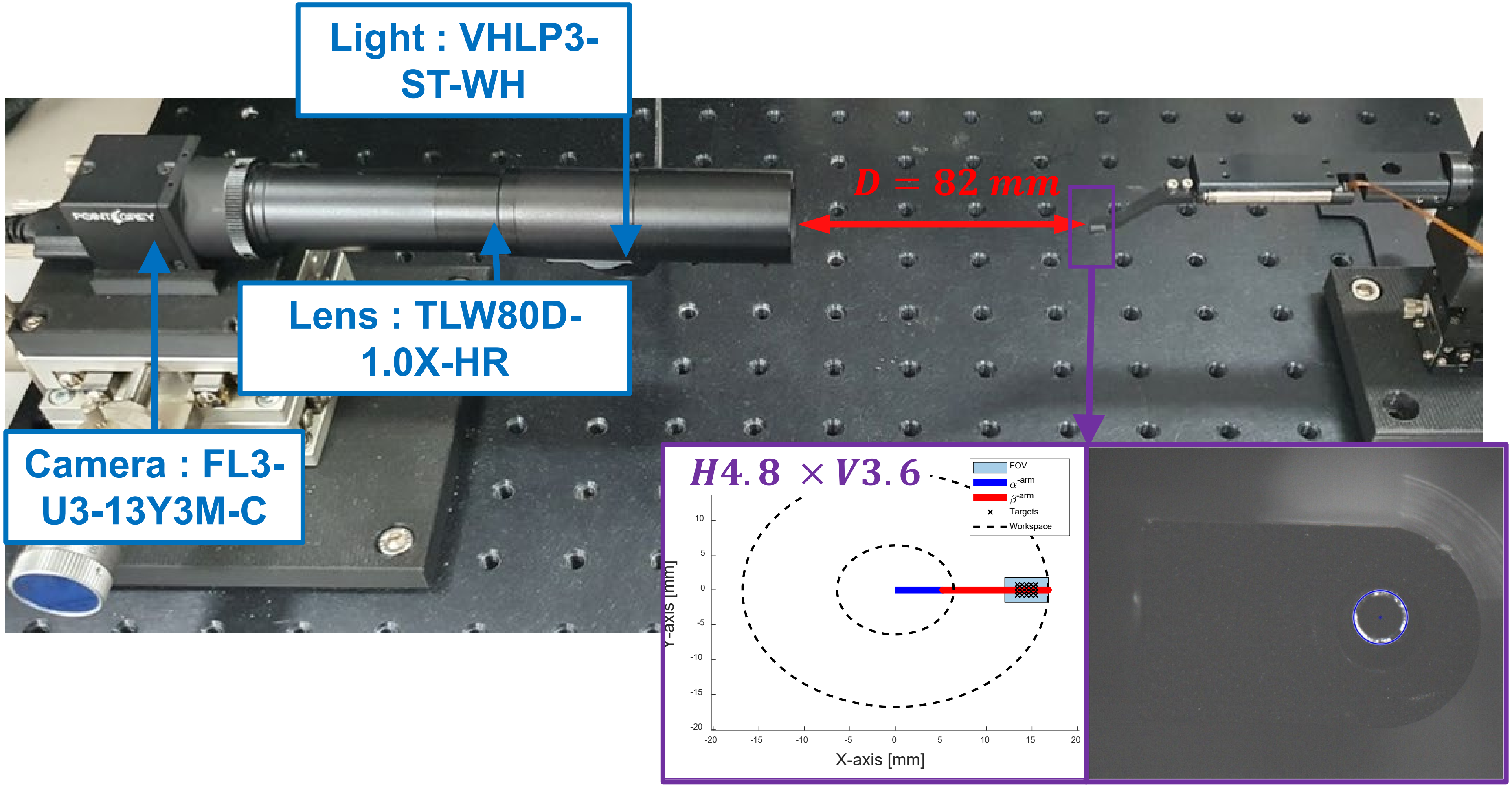
Total 4 Controller : Maximum 400 axis

AML Advanced Mechatronics Laboratory

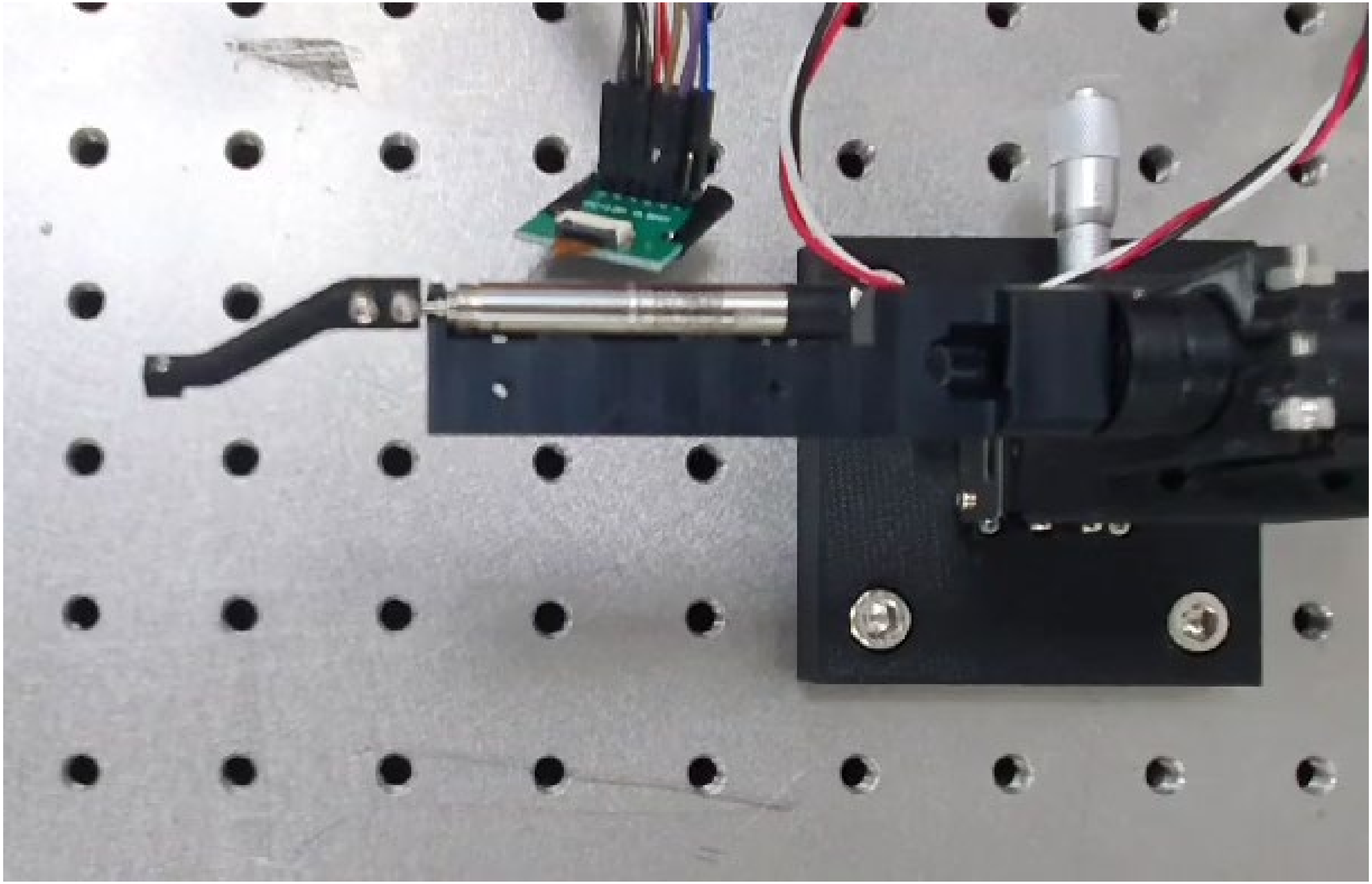
AJOU UNIV. 1973

Test Setup

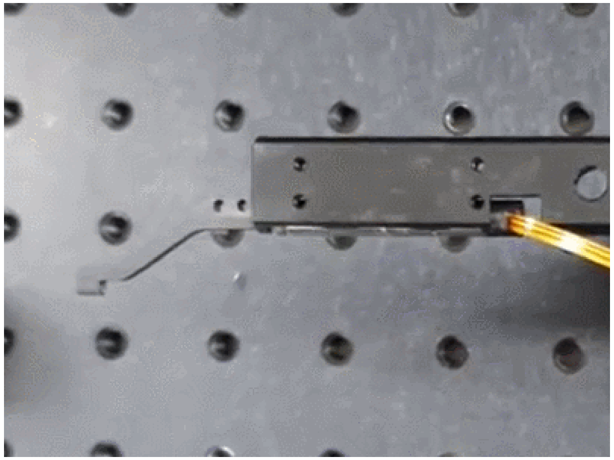
Image : 1024 x 1280
Camera view : 4.6 mm x 6.0 mm
Pixel : 4.7 µm x 4.7 µm

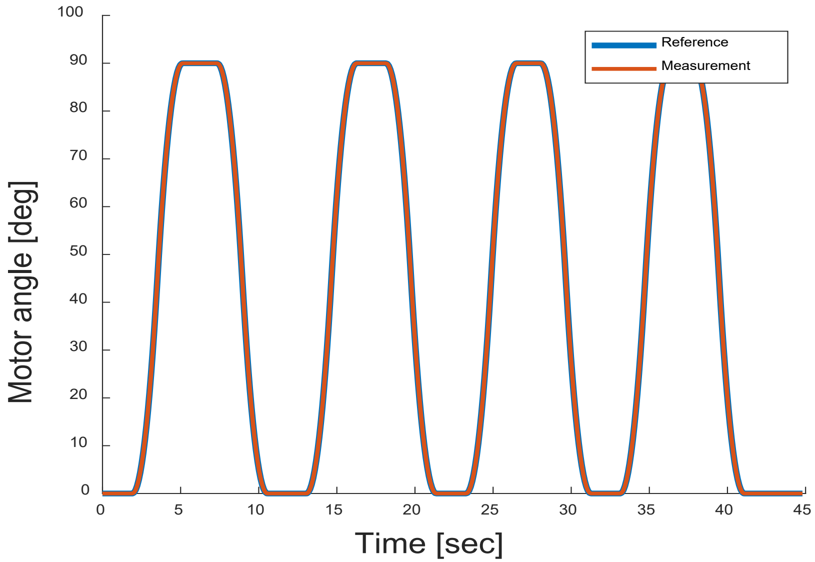


Movies

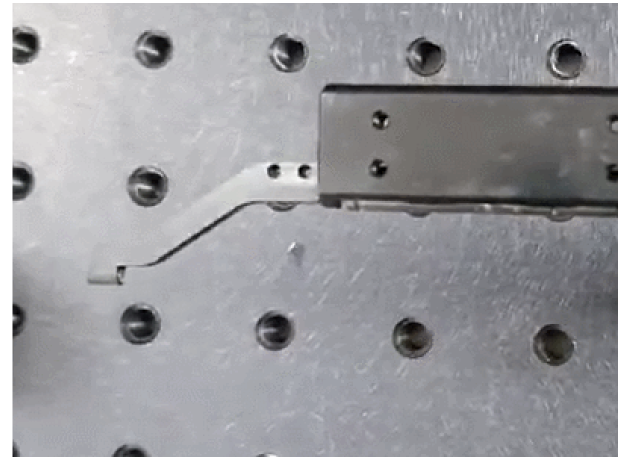


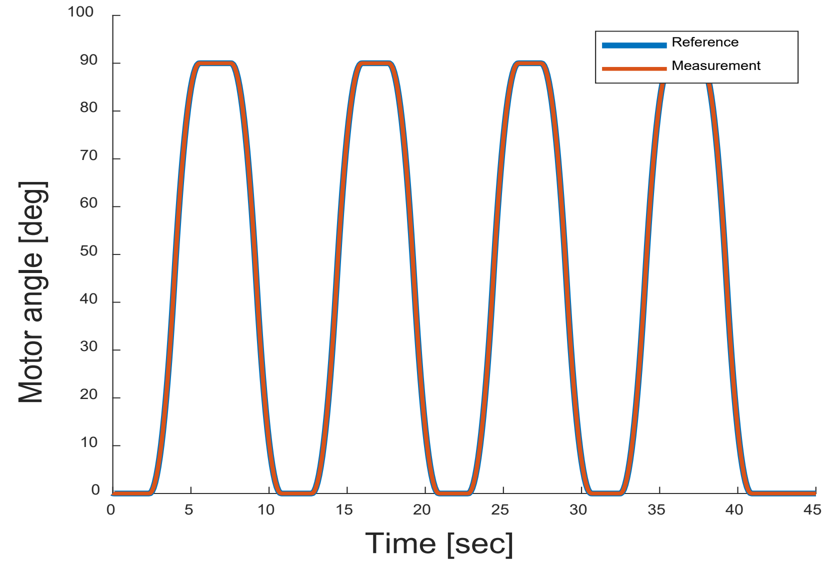
Motion Test





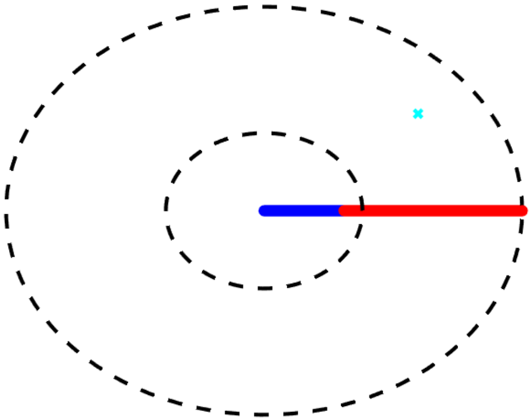
α-Motor





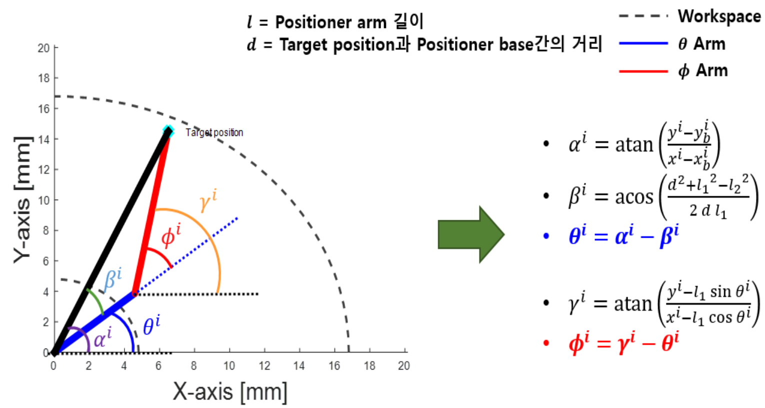
β-Motor

Image : 1024 x 1280
Camera view : 4.8 mm x 6.0 mm
Pixel : 4.7 μm x 4.7 μm



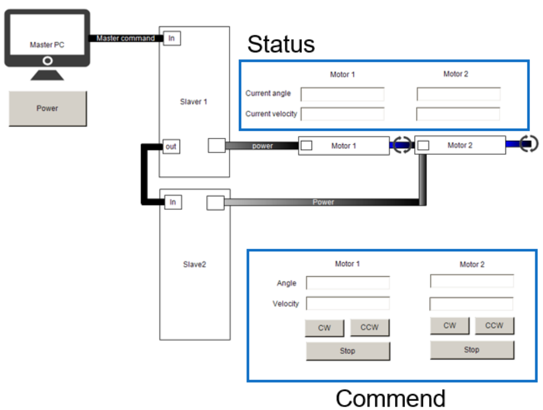
Target assignment

l = Positioner arm 길이
d = Target position과 Positioner base간의 거리

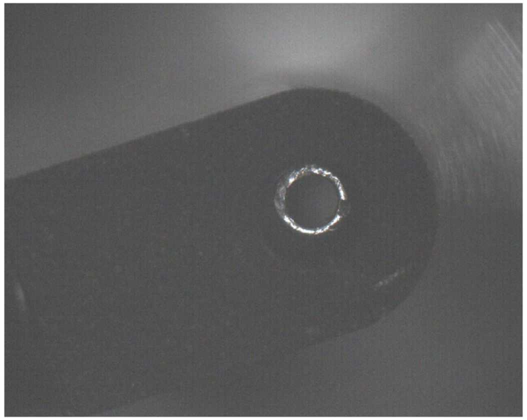


- $\alpha^i = \text{atan}\left(\frac{y^i - y_b^i}{x^i - x_b^i}\right)$
- $\beta^i = \text{acos}\left(\frac{d^2 + {l_1}^2 - {l_2}^2}{2\, d\, l_1}\right)$
- $\boldsymbol{\theta^i = \alpha^i - \beta^i}$
- $\gamma^i = \text{atan}\left(\frac{y^i - l_1 \sin\theta^i}{x^i - l_1 \cos\theta^i}\right)$
- $\boldsymbol{\phi^i = \gamma^i - \theta^i}$

Inverse kinematics & Motion plan



Motion input



Measurements

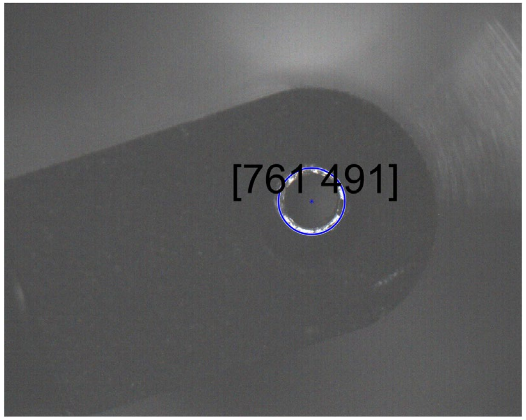
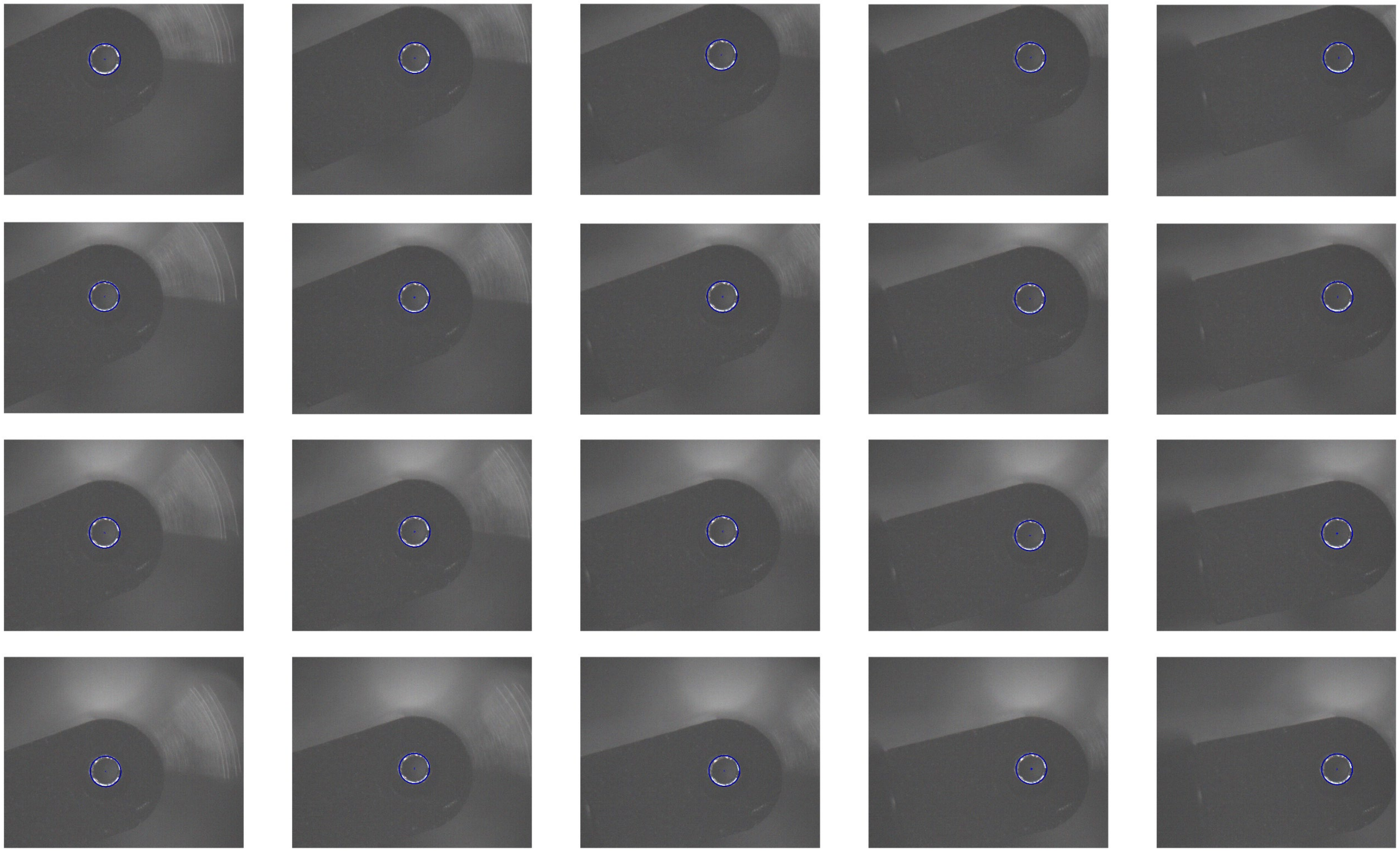


Image processing

Positioning Test

Image : 1024 x 1280
Camera view : 4.6 mm x 6.0 mm
Pixel : 4.7 μm x 4.7 μm



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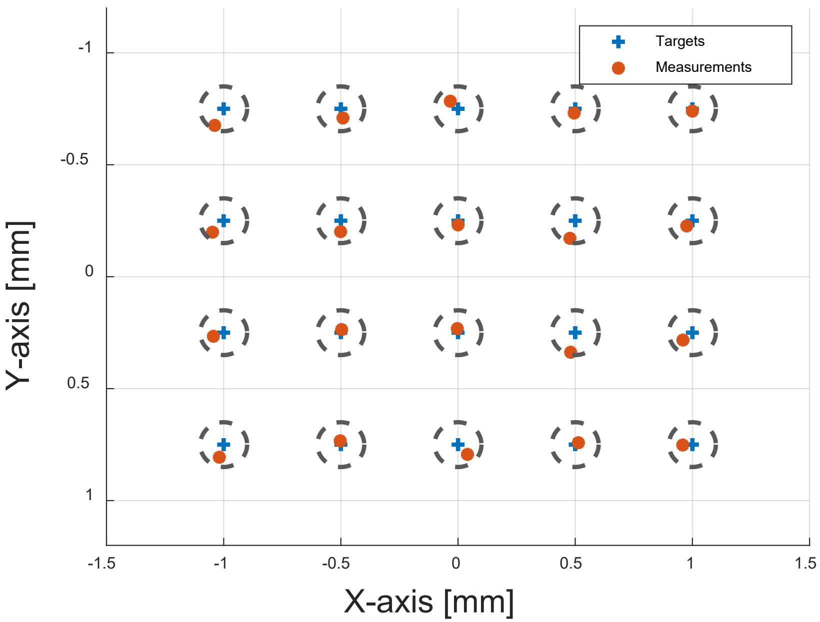

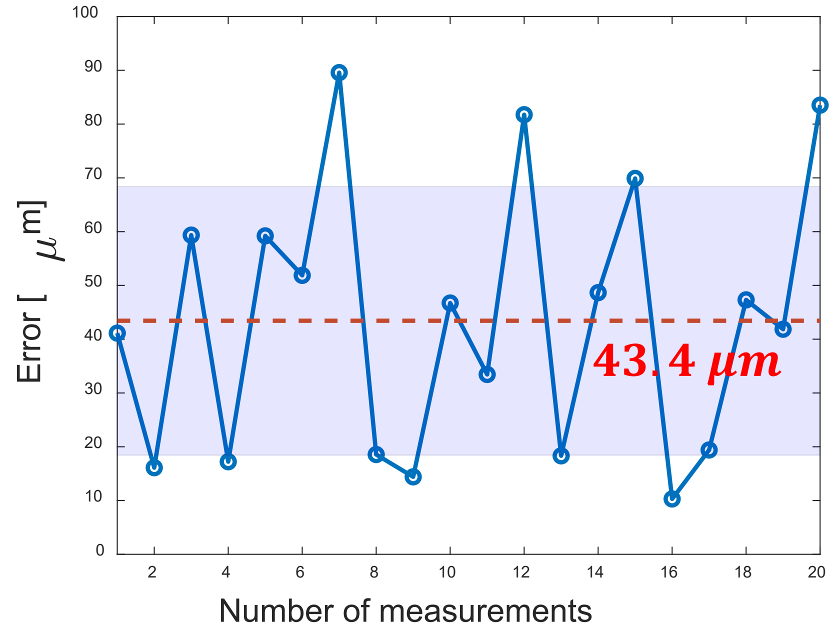

- **20 test points (0.5 mm space)**
- **Position error: 43.4 μm (< 100 μm)**
- **Final goal: 25 μm (after calibration)**

Thank You