Development and Characterization of Optical Follower Servo for Photon Calibrator

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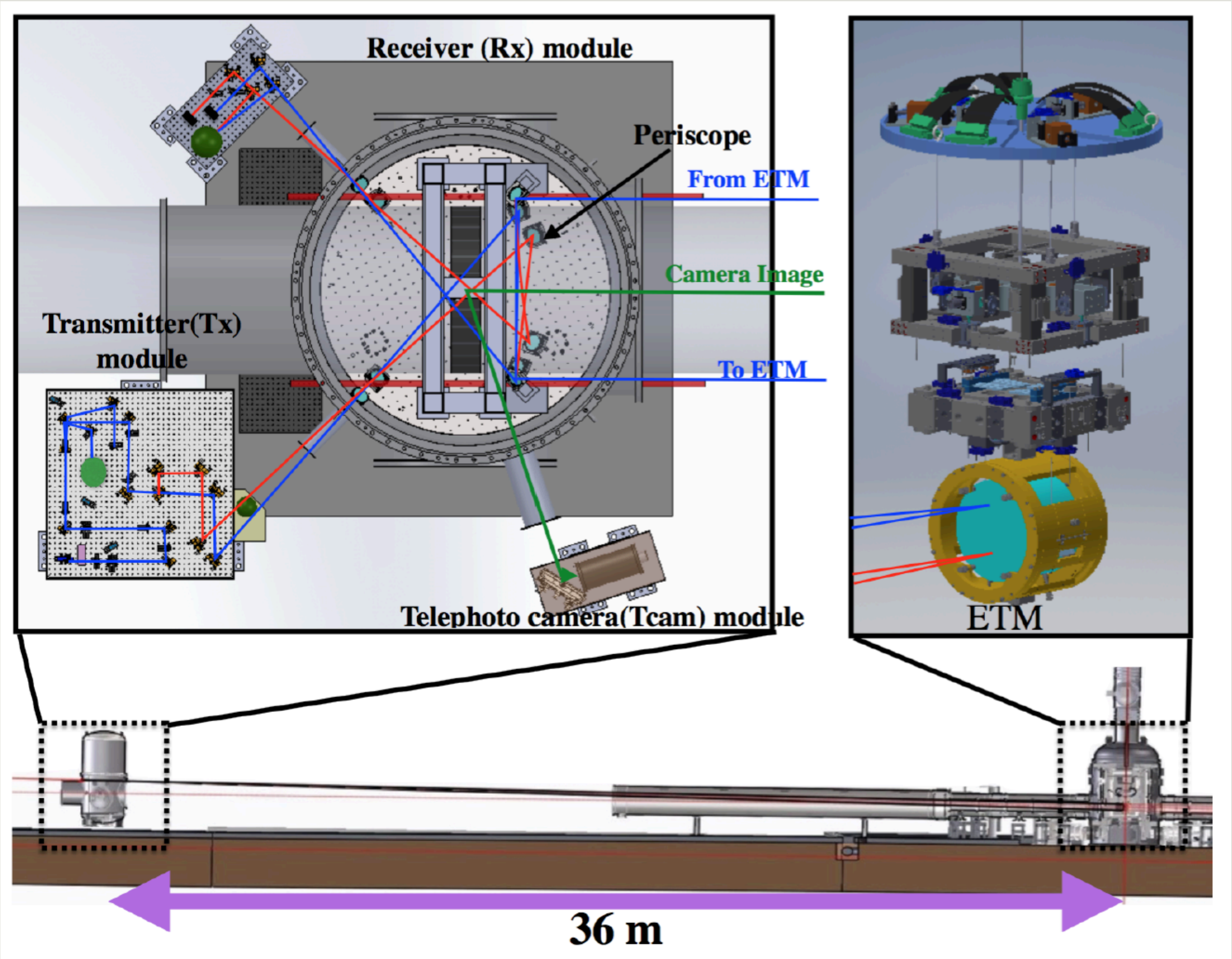
Outline

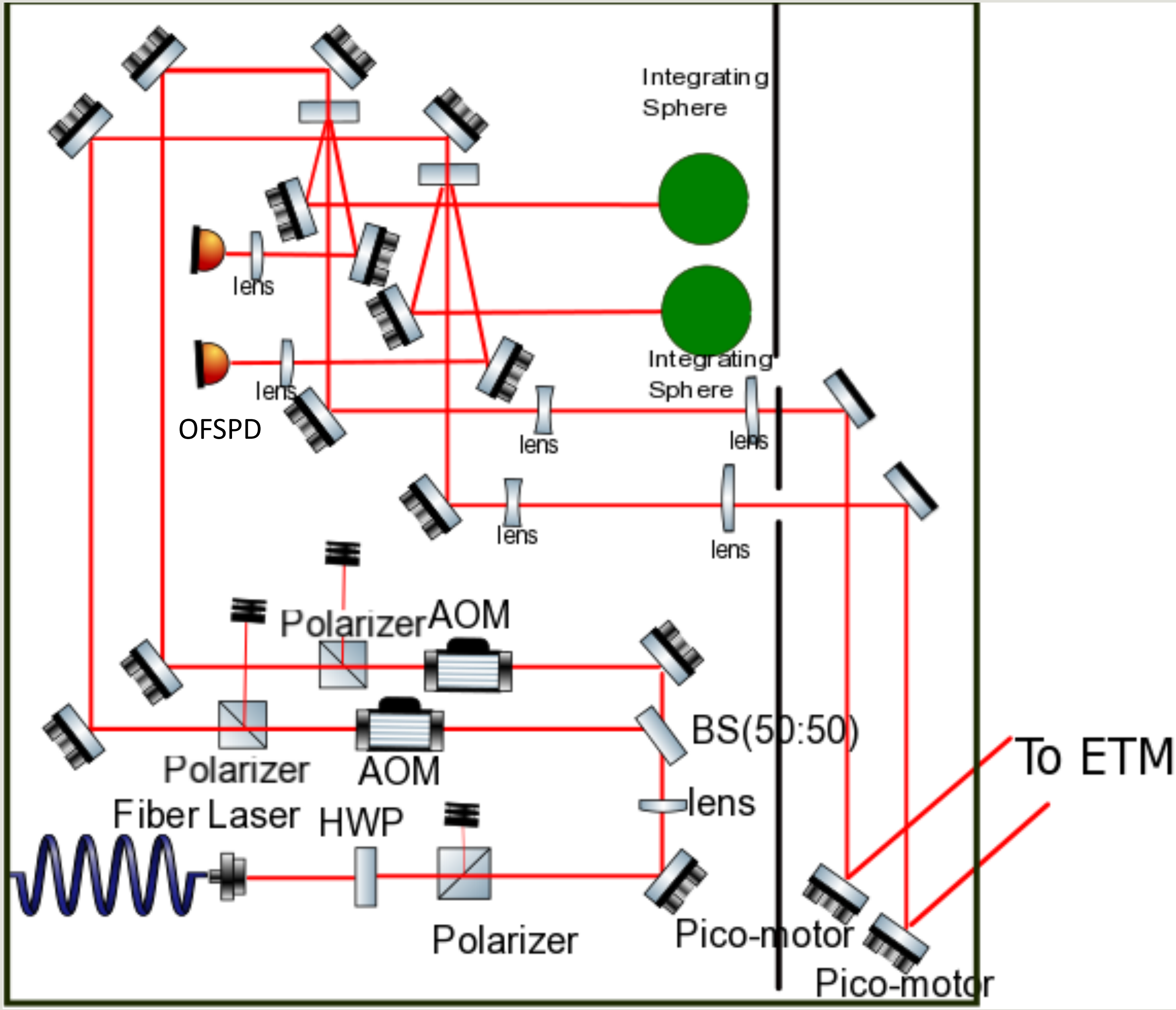
- Introduction
- Beam Waist Measurement
- Mode Matching
- AOM Modulation
- Optical Follower Servo
- Future Work & Summary

Photon Calibrator



Transmitter Module

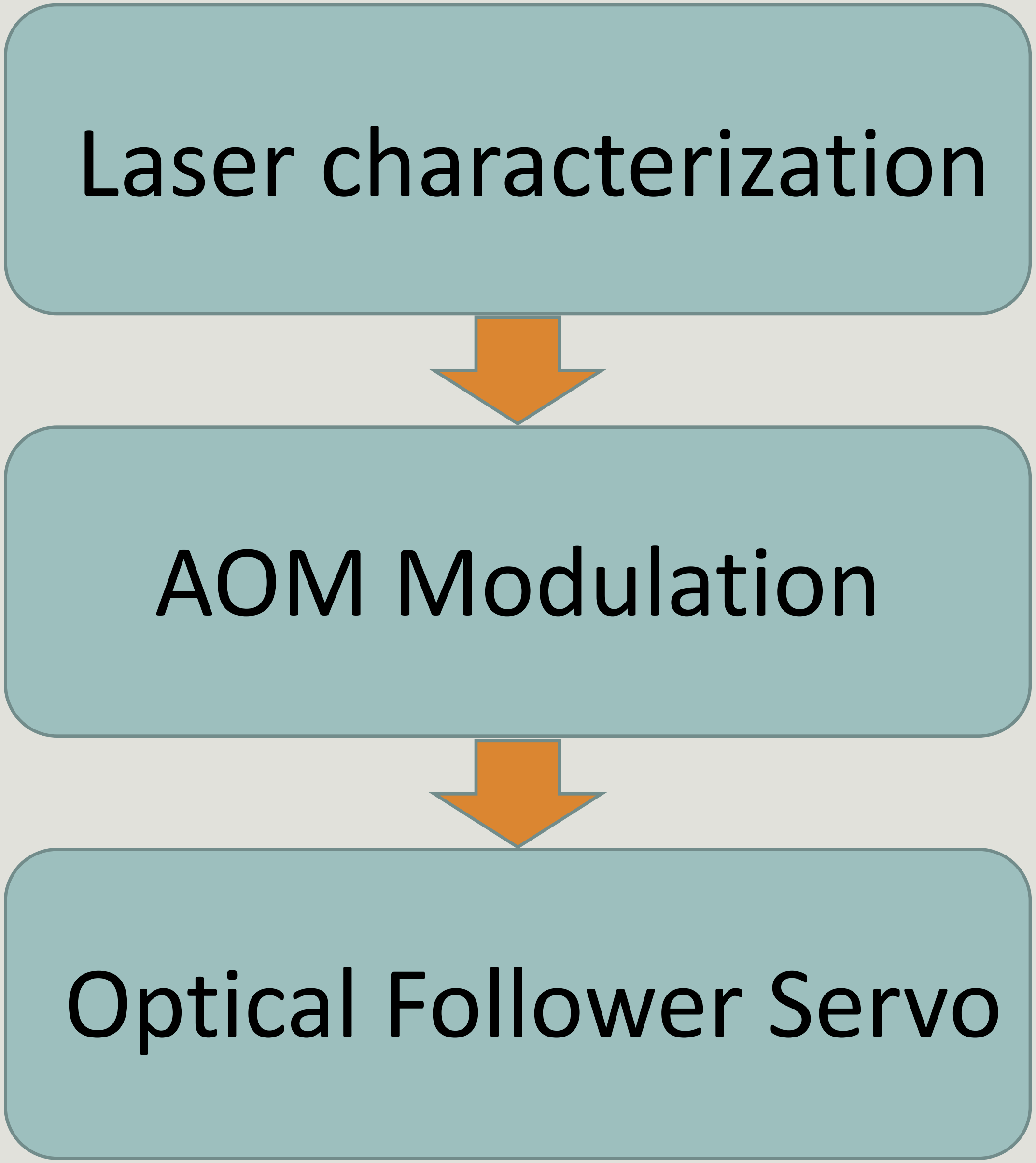
Laser Power: 20W



Motivation of using High Power Laser

For the same mirror displacement, we need high power laser to modulate mirror in high frequency

1. To reconstruct h(t) signal at high frequency
2. Gravitational waveform injection test


Laser characterization
AOM Modulation
Optical Follower Servo

Beam Waist Measurement

The beam width requirement of AOM is 250 μm, so we need to measure the beam spot size of our laser and calculate the beam waist.

We used the Gaussian beam spot size equation to fit the data.

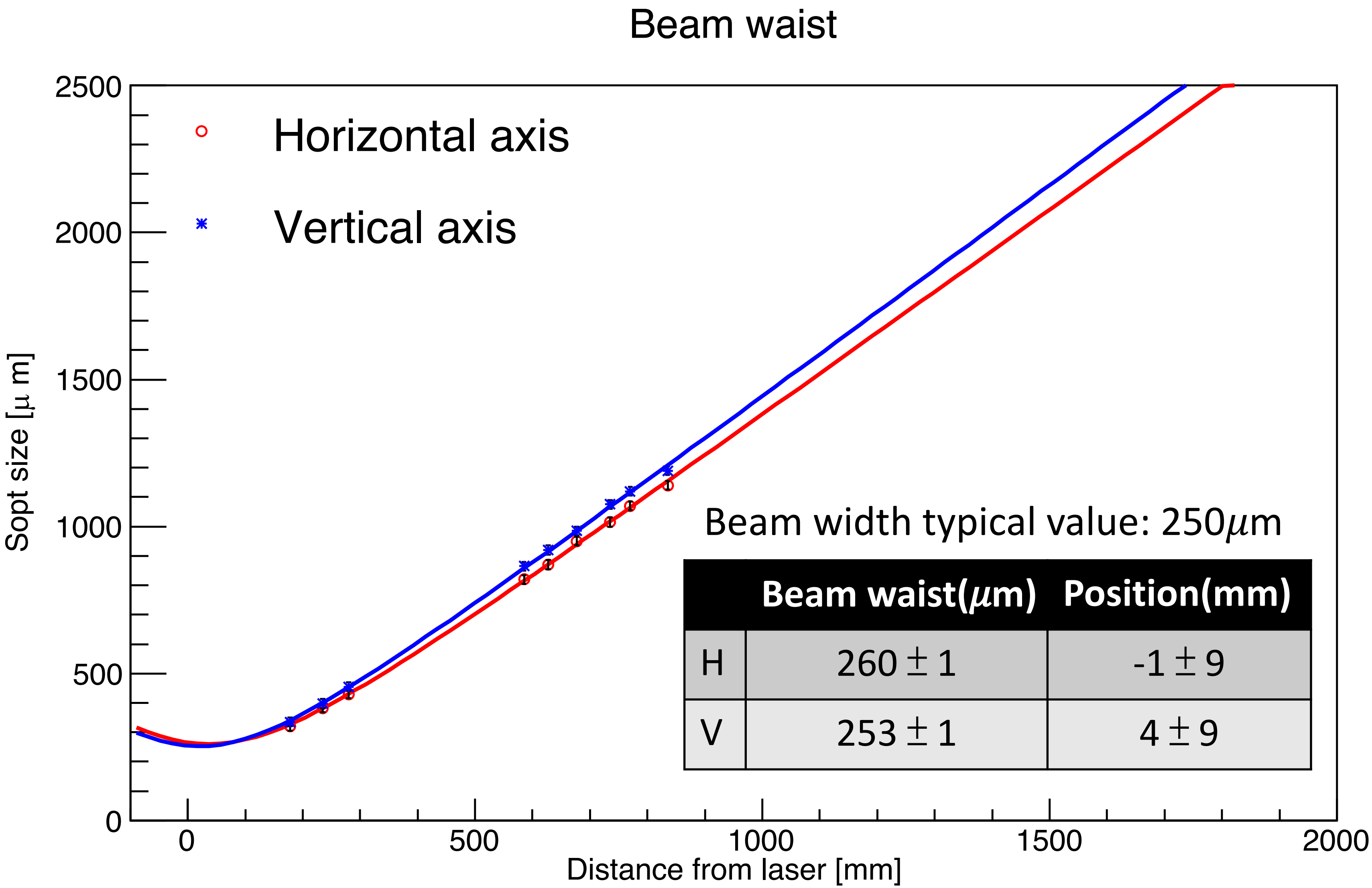
$$\omega(z) = \omega_0 \sqrt{1 + \left(\frac{\lambda z}{\pi \omega_0^2}\right)^2}$$

z: Distance from the laser

ω_0: Beam waist

λ: Beam wavelength

Beam Waist Measurement



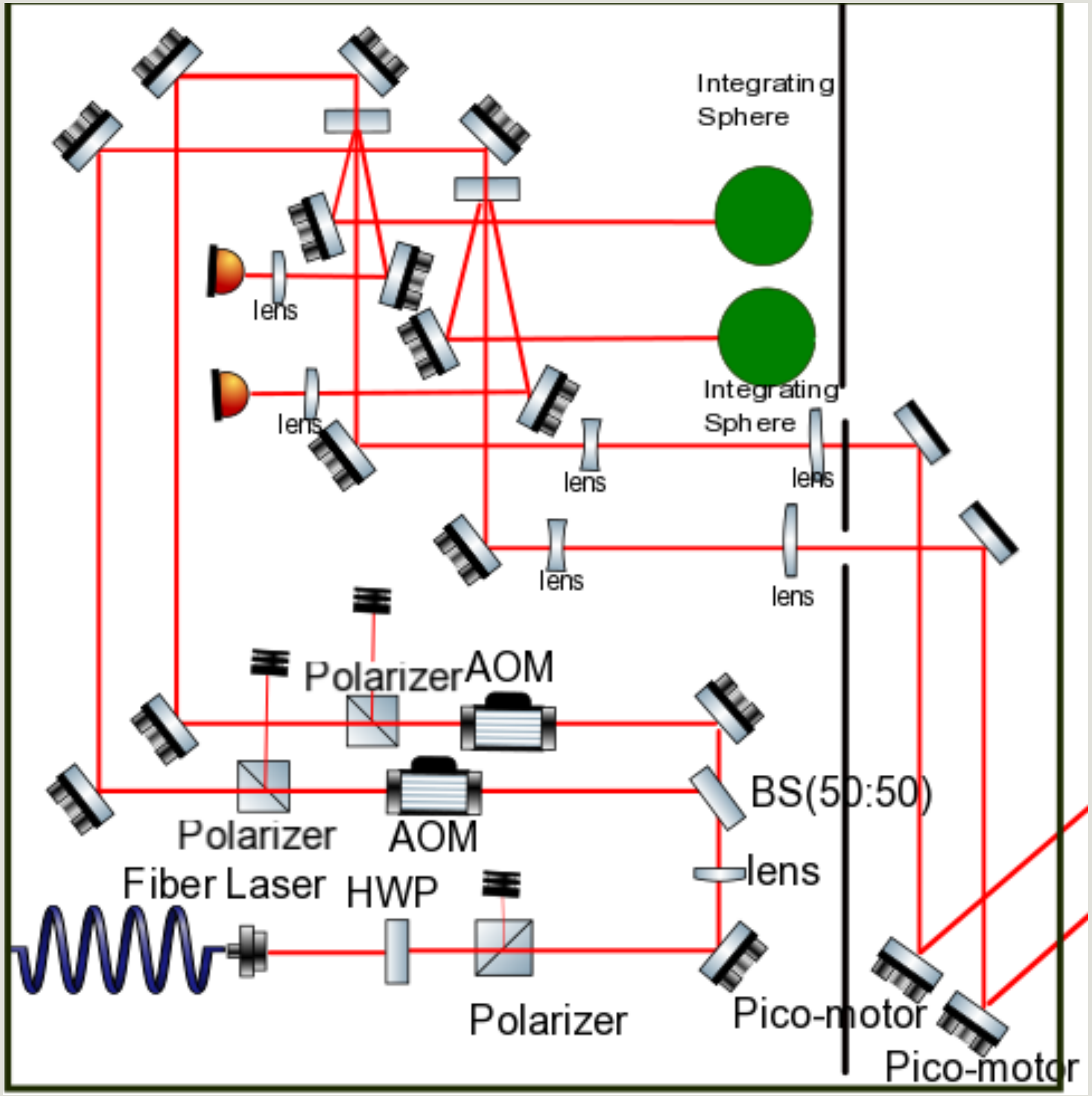
Beam width typical value: 250μm

	Beam waist(μm)	Position(mm)
H	260 ± 1	-1 ± 9
V	253 ± 1	4 ± 9

Mode Matching

- Beam waist Requirements
  - AOM:250 μm
  - Sapphire Mirror:~3500 μm

- Need to decide the position of lenses and AOM



Mode Matching

1st Mode Matching (AOM)

1 positive lens

Requirements:

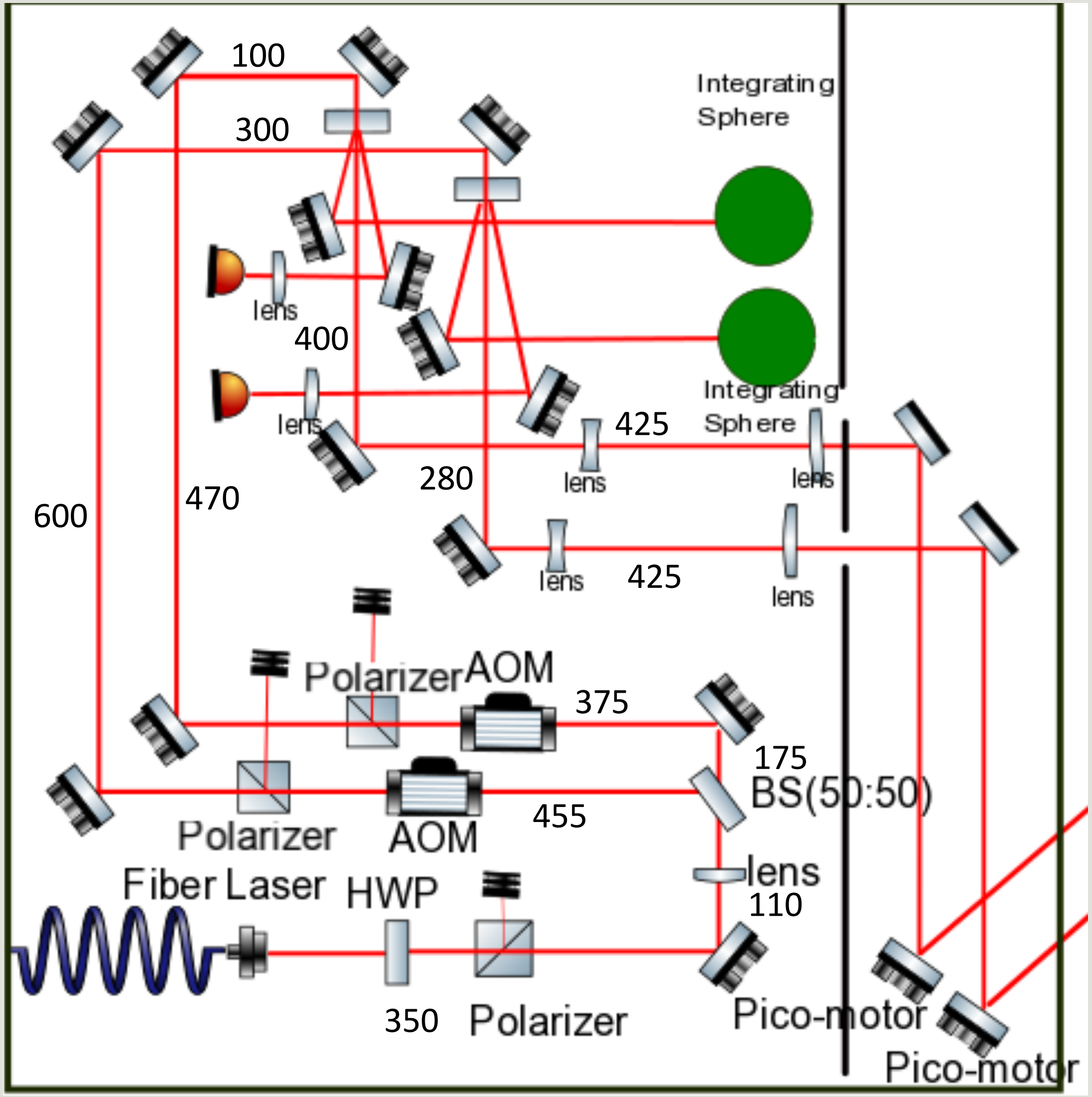
- W_0 (beam spot size)= 250 μm
- Z_0 (position)= 635~ 915mm
- Lens Shifting Range= 150~400mm

2nd Mode Matching (ETM Mirror)

1 positive and 1 negative lens

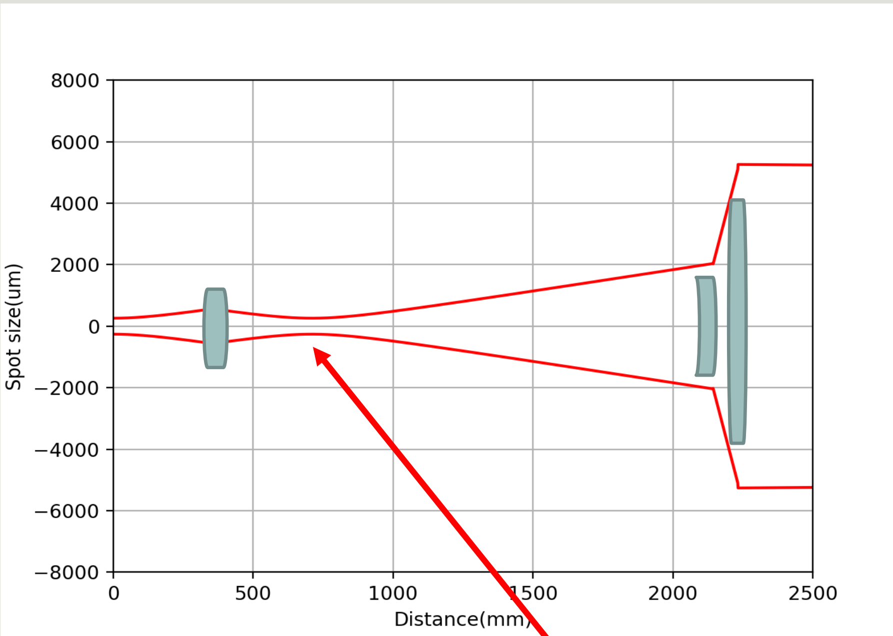
Requirements:

- W_0 = 3500 μm
- Z_0 = 36~40 m
- Shifting Range=2095~2405mm



Mode Matching

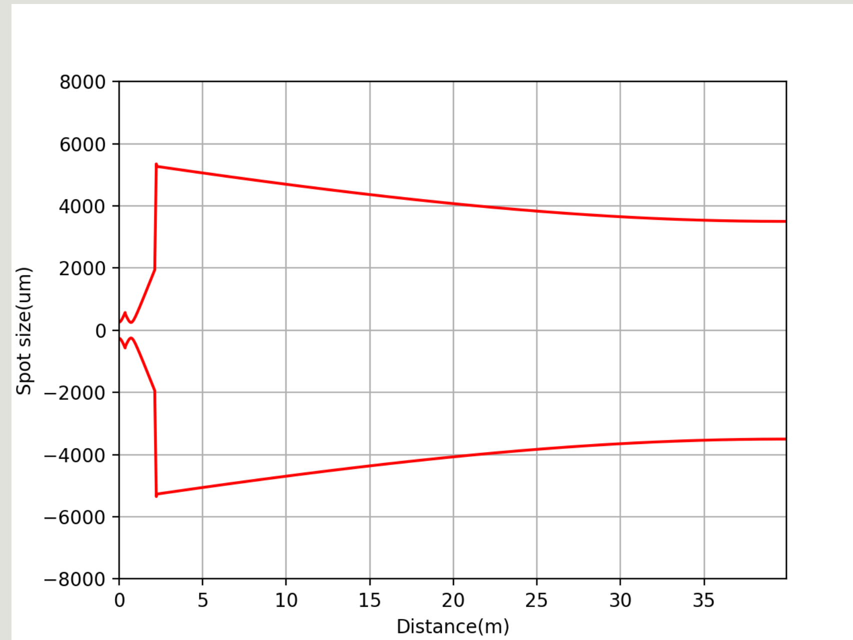
1st Mode Matching (AOM)



Positive Lens
f= 286.46mm
z=361mm

$W_0 = 250\ \mu m$
$Z_0 = 710$ mm

2nd Mode Matching (Mirror)

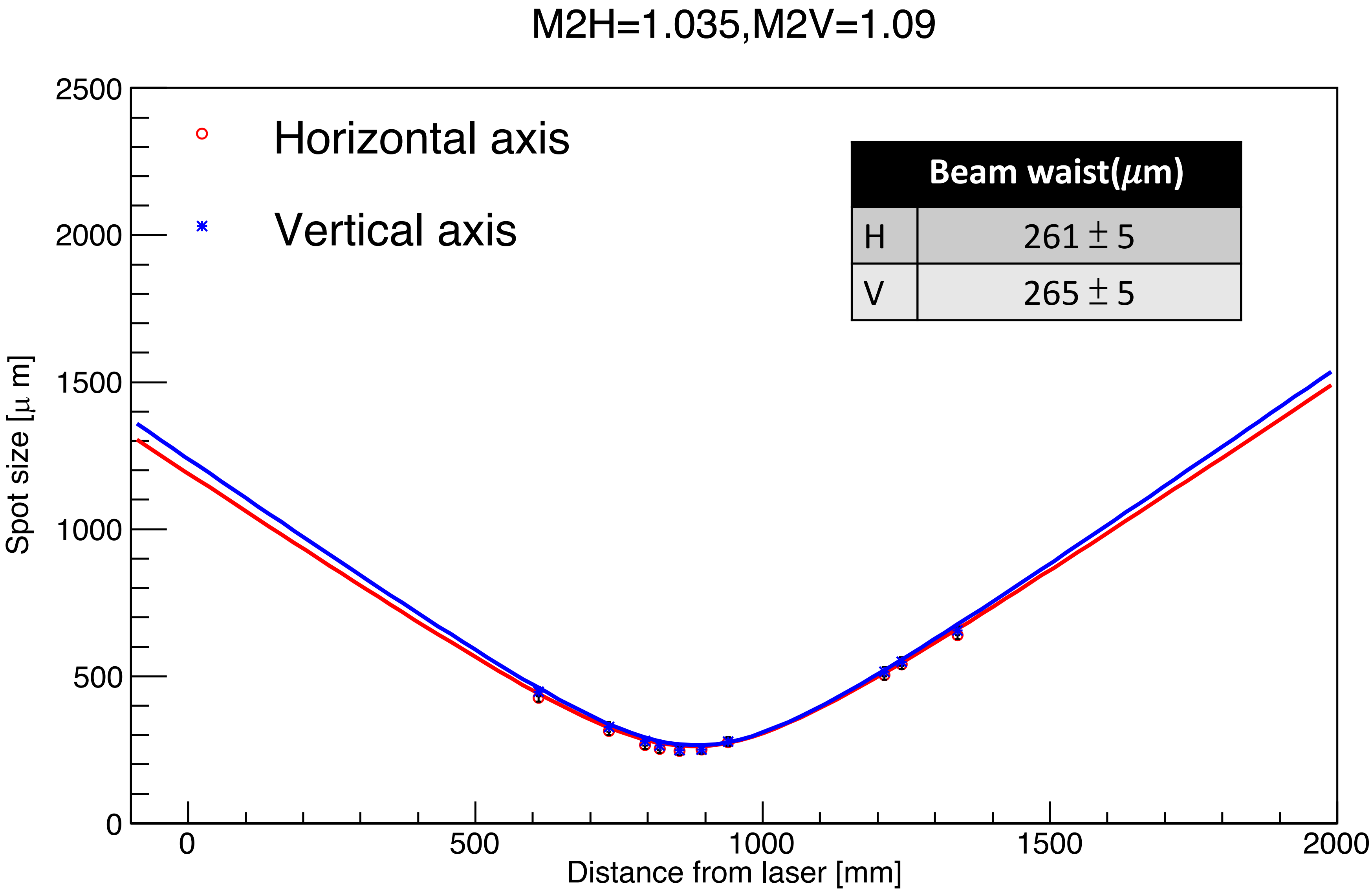


Negative Lens
f= -57.38mm
z=2136mm

Positive Lens
f= 143.22mm
z=2226mm

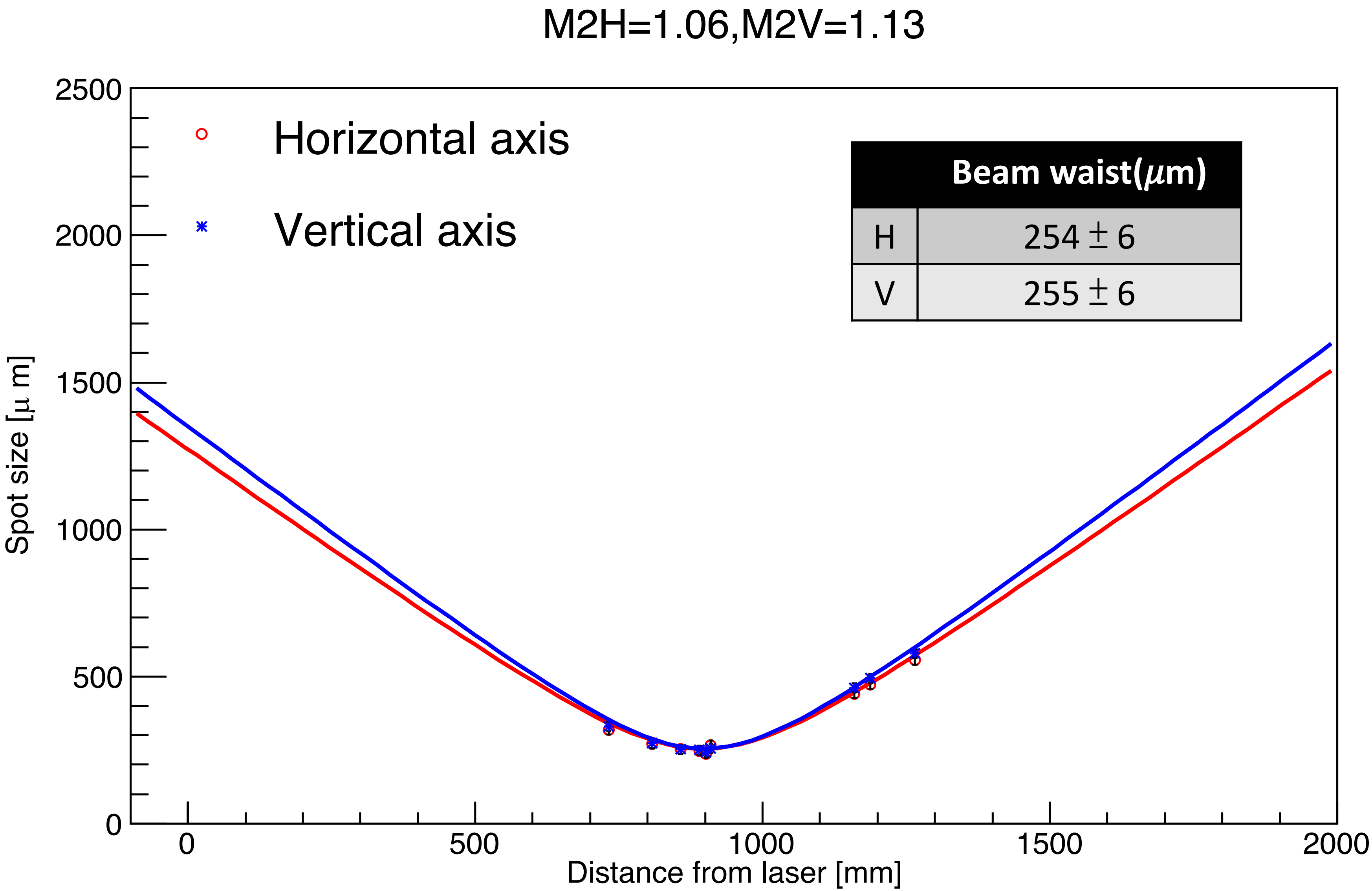
$W_0 = 3501\ \mu m$
$Z_0 = 39.93$ m

Beam waist with lens Path 1



Beam waist(μm)	
H	261 ± 5
V	265 ± 5

Beam waist with lens Path 2



	Beam waist(μm)
H	254 ± 6
V	255 ± 6

Comparison

		Path 1	Path 2
M^2	H	0.97±0.01	0.98±0.01
	V	1.02±0.01	1.04±0.02
$W_0(\mu m)$	H	261.24±5.41	254.06±6.48
	V	265.42±5.40	254.95±6.32
$Z_0(mm)$	H	879.14±6.73	896.73±7.58
	V	884.56±6.43	897.94±7.09

		X	Y
M^2	H	0.97±0.01	1.00±0.01
	V	1.02±0.01	0.98±0.01
$W_0(\mu m)$	H	261.24±5.41	261.63±4.42
	V	265.42±5.40	261.87±4.46
$Z_0(mm)$	H	879.14±6.73	849.90±6.09
	V	884.56±6.43	844.89±6.31

M^2: Beam quality factor

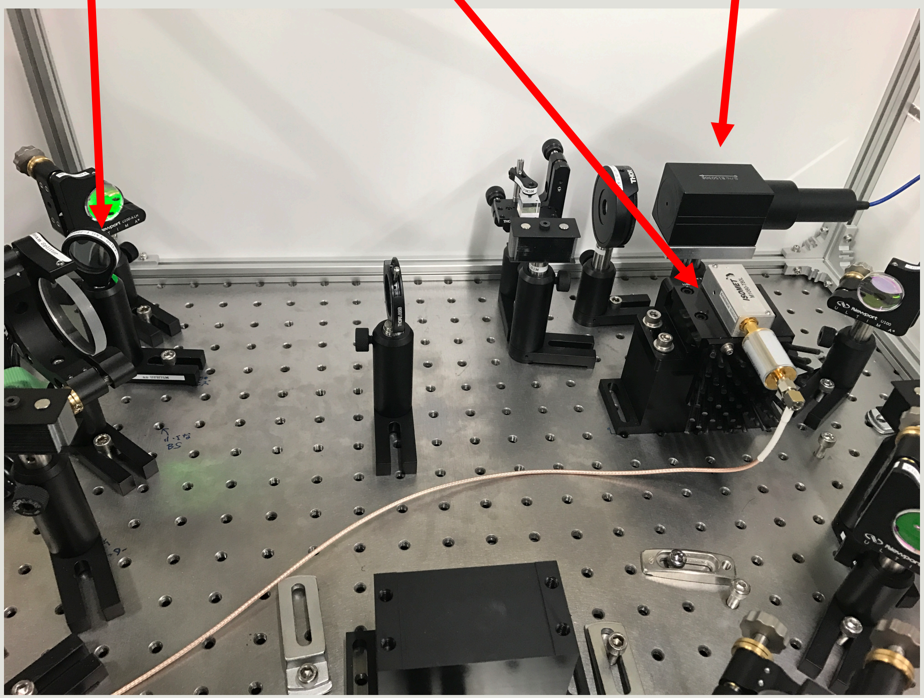
W_0: Beam waist

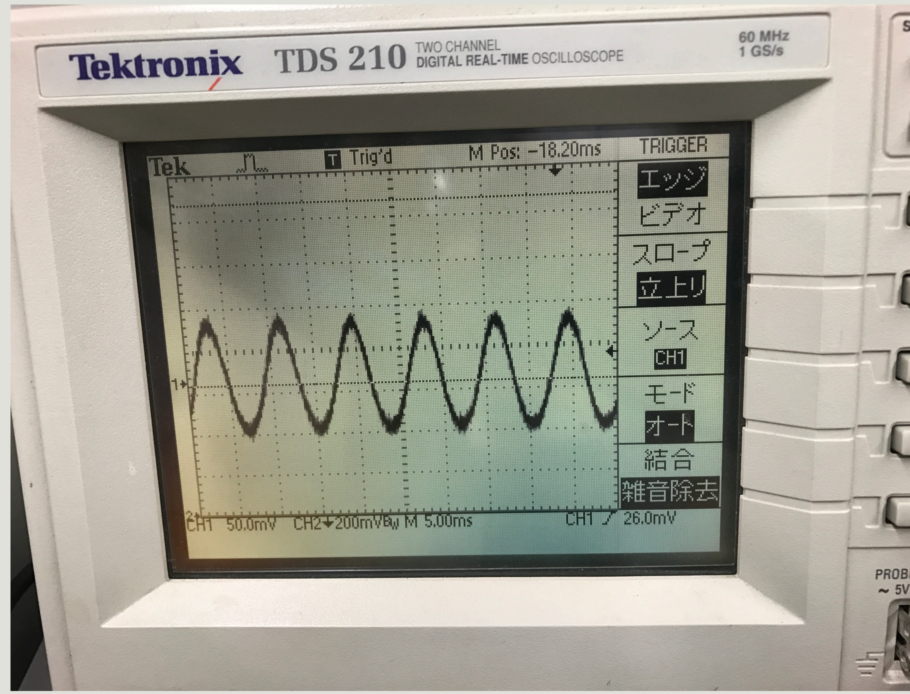
Z_0: Beam waist position

AOM Modulation

Frequency: 120 Hz

Lens AOM Laser



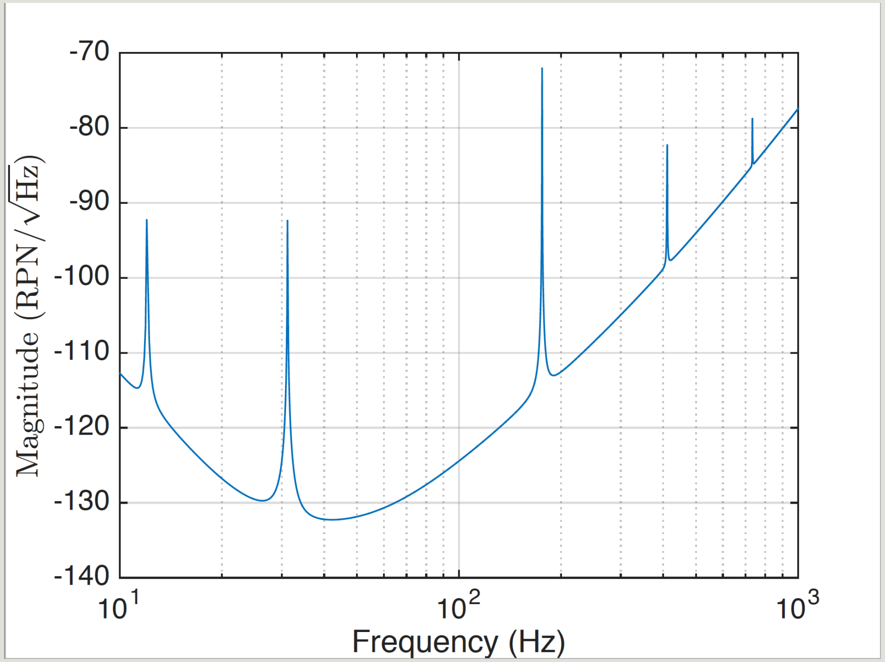


Optical Follower Servo (OFS)

Purpose: Reduce the Relative Power Noise (RPN) of the laser
Reduce the harmonic noise of AOM

Optical Follower Servo

RPN Requirement



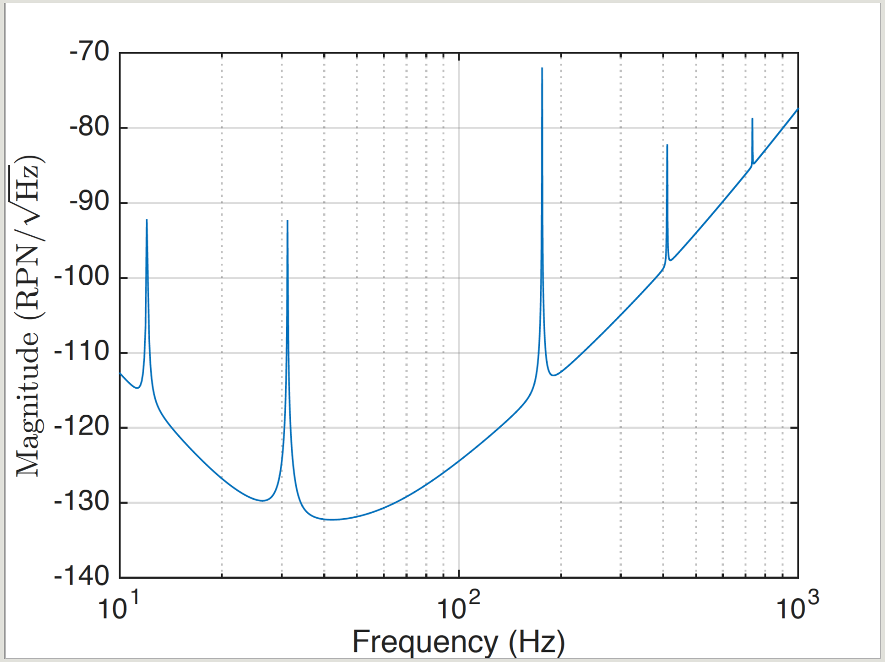
Relative Power Noise

$$\Delta L(f) = \frac{2\Delta P\cos\theta}{c}\frac{1}{M(2\pi f)^2} < \frac{1}{10}\Delta h(f)L$$

Force — Transfer function — Strain sensitivity curve of KAGRA

$$\Longrightarrow \Delta P < \frac{cM(2\pi f)^2\Delta h(f)L}{20\cos\theta}$$

$$\mathrm{R}PN \equiv \frac{\Delta P}{P}$$



Future Work

1. Measure the Relative Power Noise with 20W power
2. Measure the performance of Optical Follower Servo (OFS)

Summary

- We used 20W high power laser in our Tx module.
- The beam waist of our laser is 260 μm.
- We did mode matching and decided the type and the position of the lenses and the position of AOM, and measured beam profile for two paths
- We modulated the AOM with 120 Hz sine wave.
- We calculated the requirements of the RPN and built a OFS chassis to reduce the noise.

The end

Thank for your listening!