Design for a New Optical Table of the Shintake Monitor

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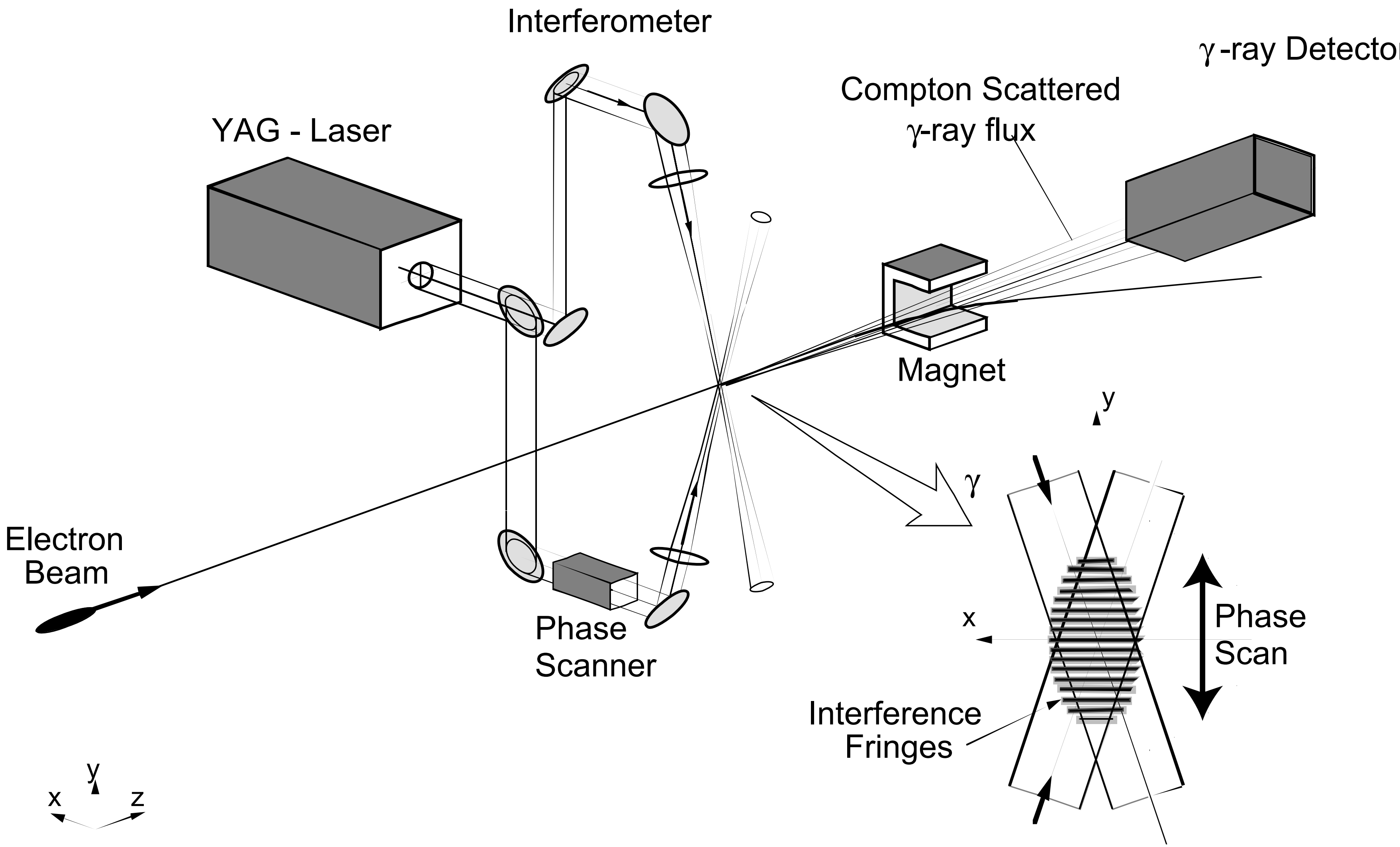
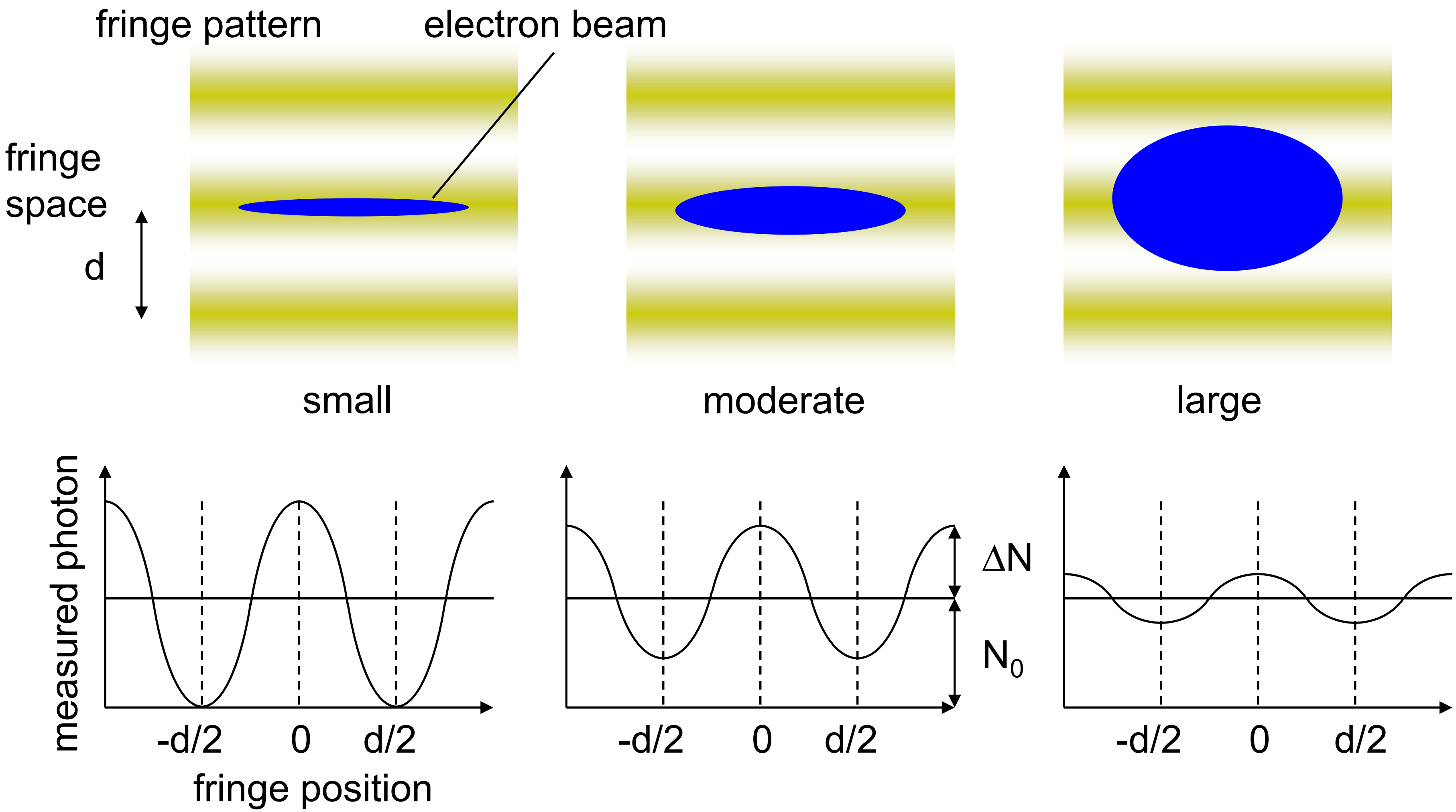
Contents

- Principle of the Shintake monitor
- Mechanism of the phase monitor
- Changes for a new optical table
  - widen the range of measurable beam size
  - stablize the fringe position
  - increase the signal photon
- Status

Principle of the Shintake Monitor

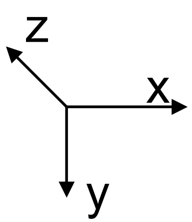


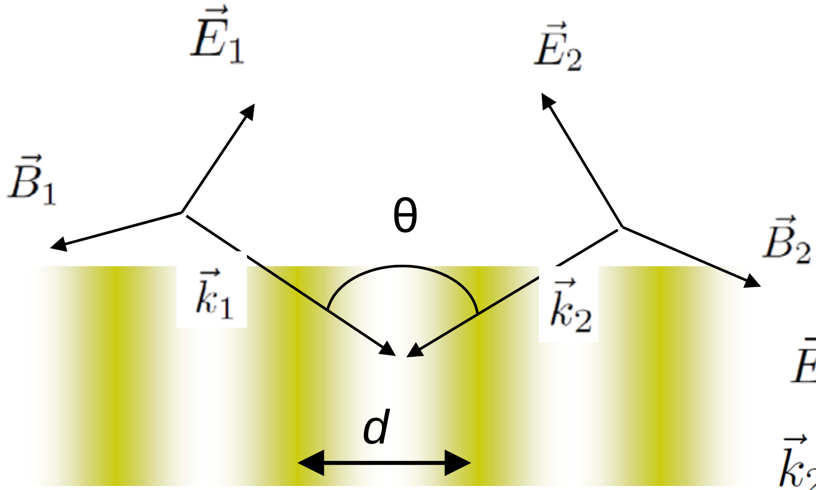
Beam Size Measurement



modulation depth = $\Delta N / N_0$

Fringe Spacing and Crossing Angle





$$\vec{E}_1 = \vec{E}_1^* \exp(i\vec{k}_1 \cdot \vec{x} + i\phi_1)$$

$$\vec{k}_1 = k\left(\sin\frac{\theta}{2}, \cos\frac{\theta}{2}, 0\right)$$

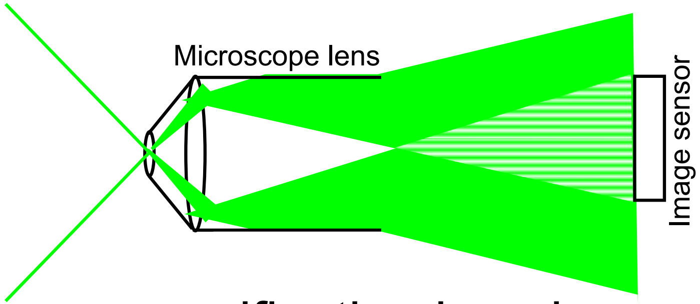
$$\vec{E}_2 = \vec{E}_2^* \exp(i\vec{k}_2 \cdot \vec{x} + i\phi_2)$$

$$\vec{k}_2 = k\left(-\sin\frac{\theta}{2}, \cos\frac{\theta}{2}, 0\right)$$

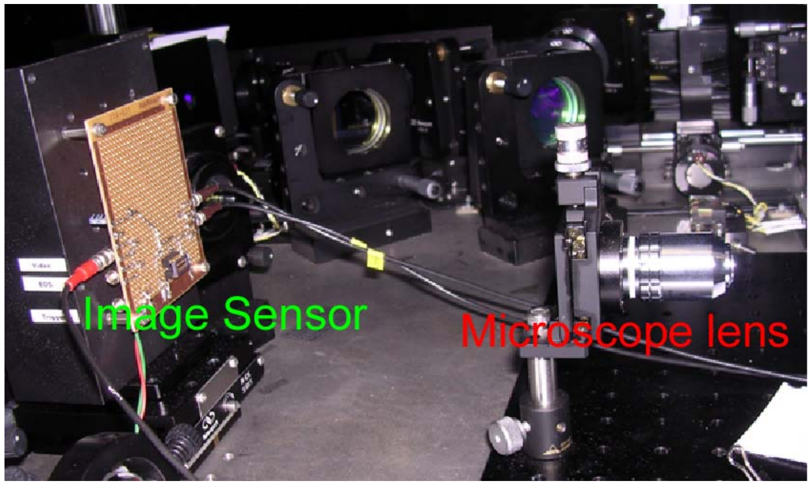
$$\begin{aligned}
|\vec{E}_{\text{tot}}|^2 &= |\vec{E}_1 + \vec{E}_2|^2 \\
&= |\vec{E}_1^*|^2 + |\vec{E}_2^*|^2 + 2\vec{E}_1 \cdot \vec{E}_2 \cos\left(\left(\vec{k}_1 - \vec{k}_2\right) \cdot \vec{x} + \phi_1 - \phi_2\right) \\
&= |\vec{E}_1^*|^2 + |\vec{E}_2^*|^2 + 2\vec{E}_1 \cdot \vec{E}_2 \cos\left(2k \sin\frac{\theta}{2} x + \delta\right)
\end{aligned}$$

$$d = \frac{\lambda}{2\sin\frac{\theta}{2}}$$

Phase Monitor

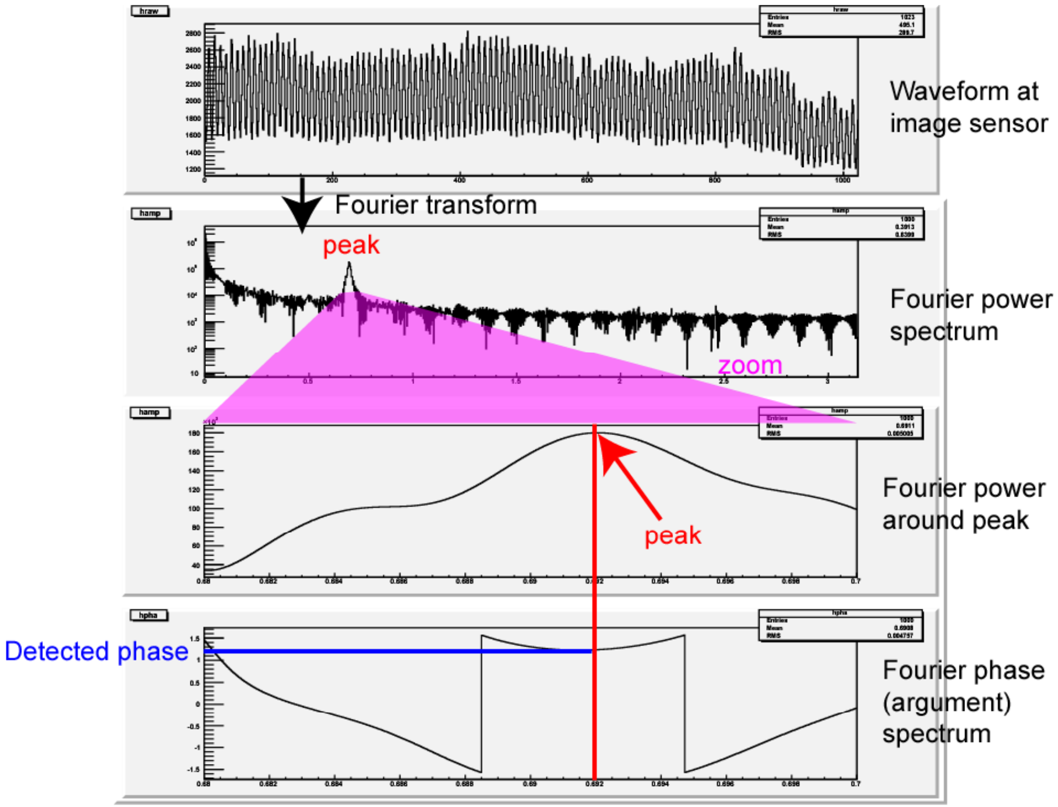


Phase magnification by microscope lens, captured by image sensor



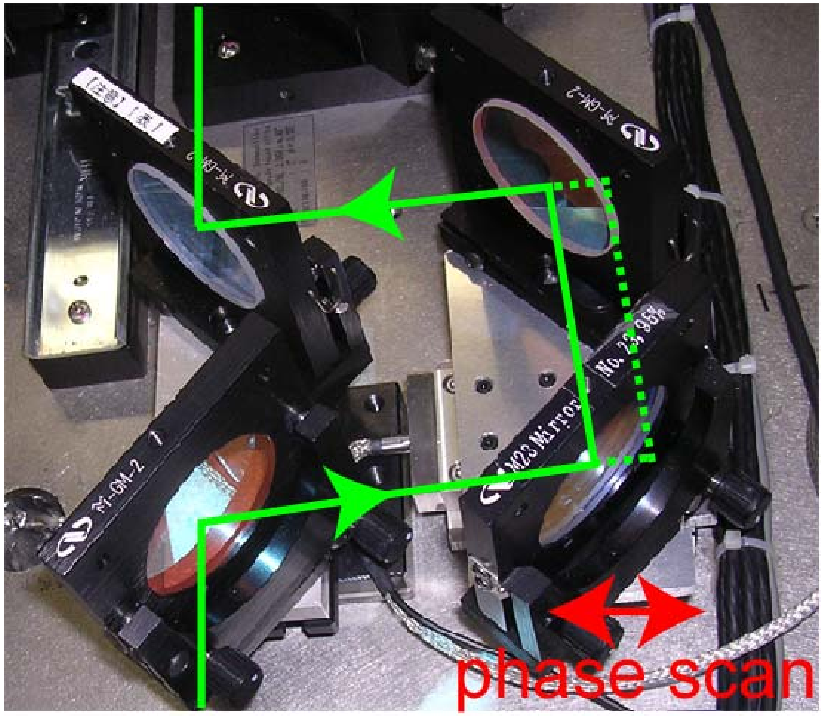
Lens and image sensor

Phase detection sample

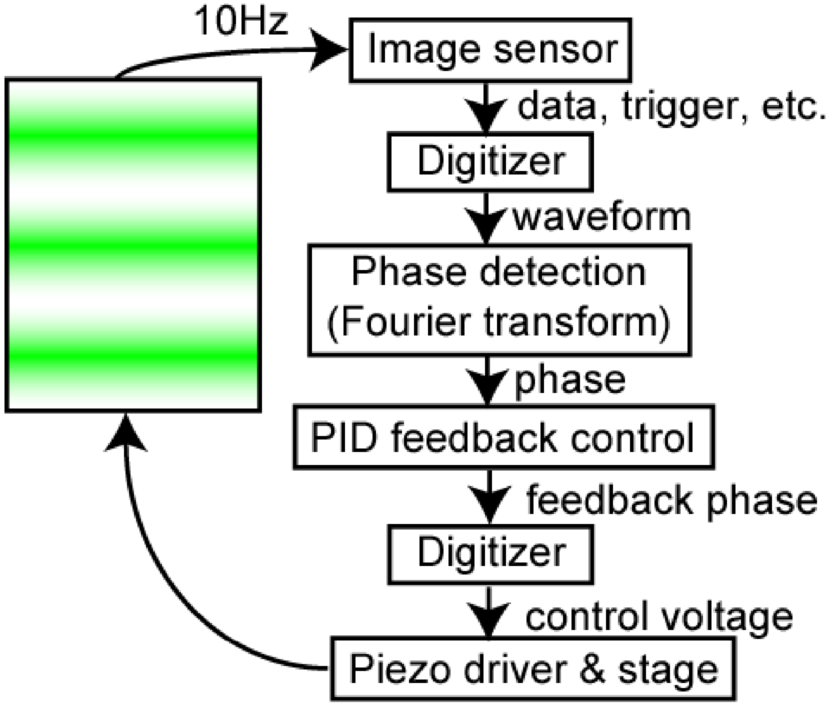


- The phase does not sensitive to vibration of lens & sensor.
- Fourier method suppresses sensitivity to optical noise.

Phase Scan & Control

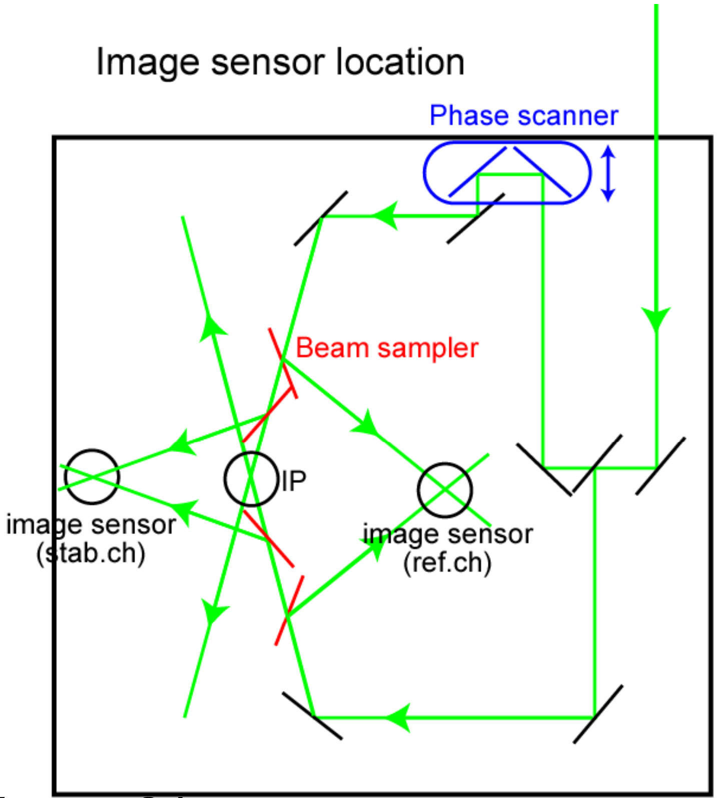


Delay line for phase scanning.
Piezo stage of 0.2nm resolution
is installed under right 2 mirrors.

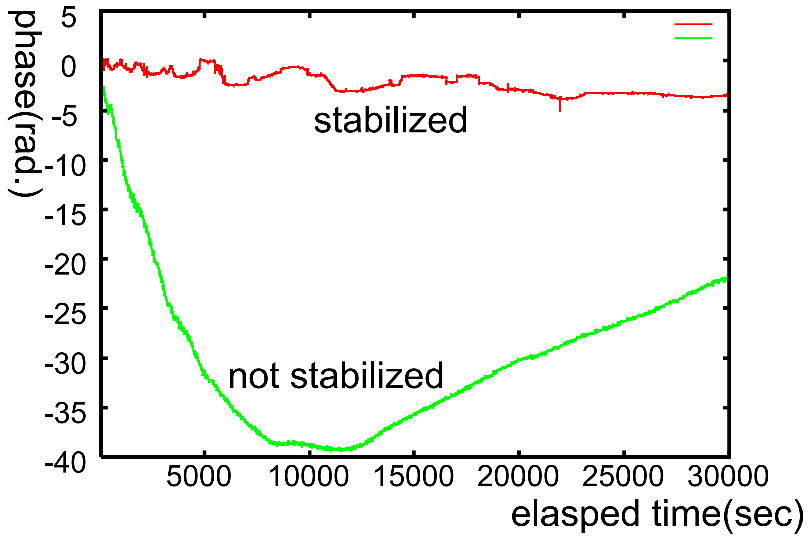


Control system.
Control cycle is 10Hz,
that is the repetition
rate of the pulsed laser.

Stabilization Result (cw. Test Laser)



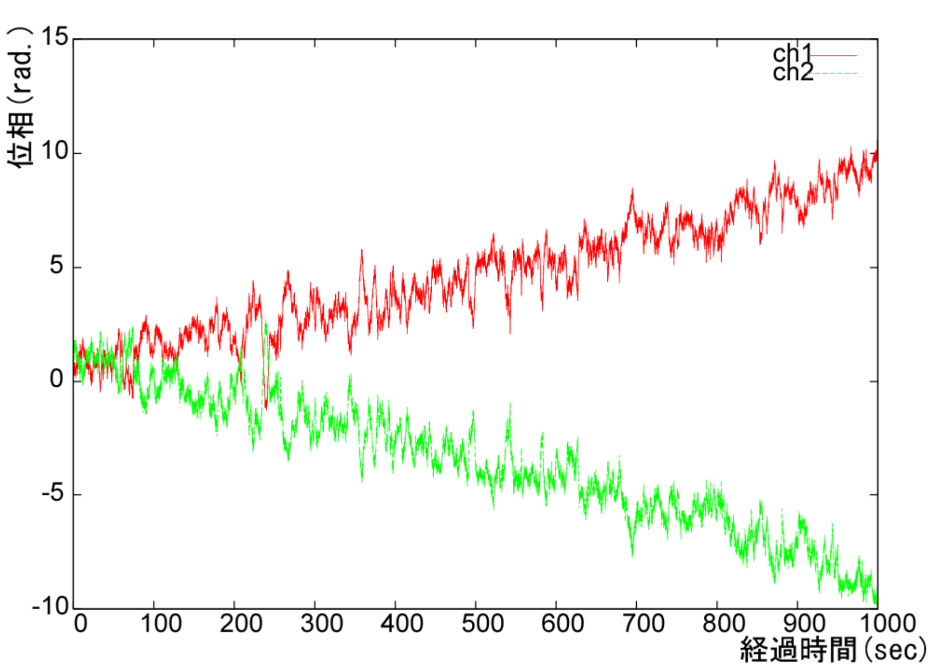
We use 2 image sensors.
• Stab.ch → stabilized
• Ref.ch → not stabilized
Check correlation of 2 ch.
to confirm beam (and IP) phase stabilization.



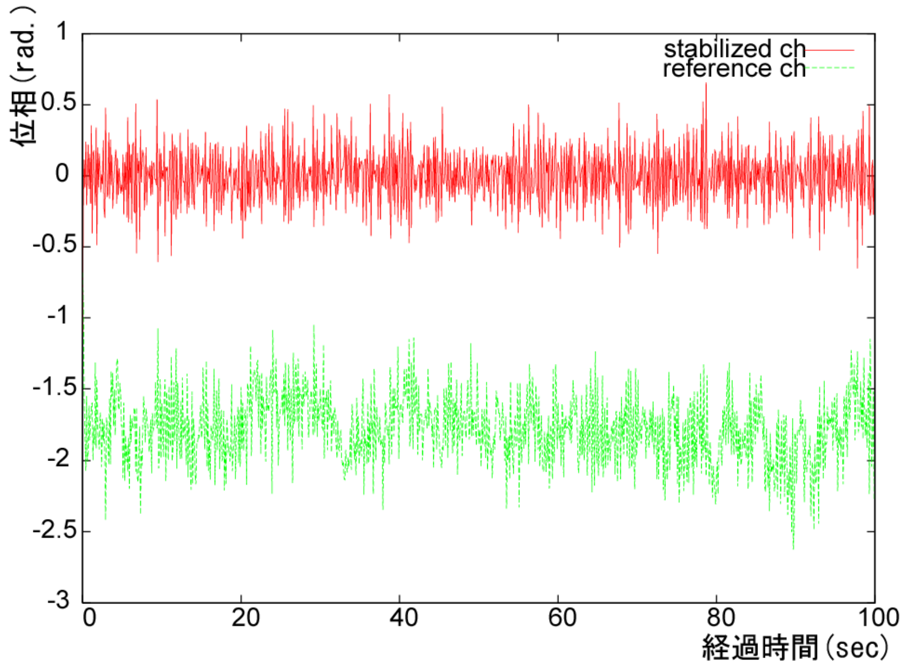
Phase change of ref.ch
Long time drift is suppressed.

Ref.ch phase data shows
• 0.034 rad. (1.5nm) stability in 1min.
• 0.133 rad. (5.6nm) stability in 10min.
Both meet 10nm stability ATF2 goal.

Stabilization Result (Pulse Laser)



Before the stabilization



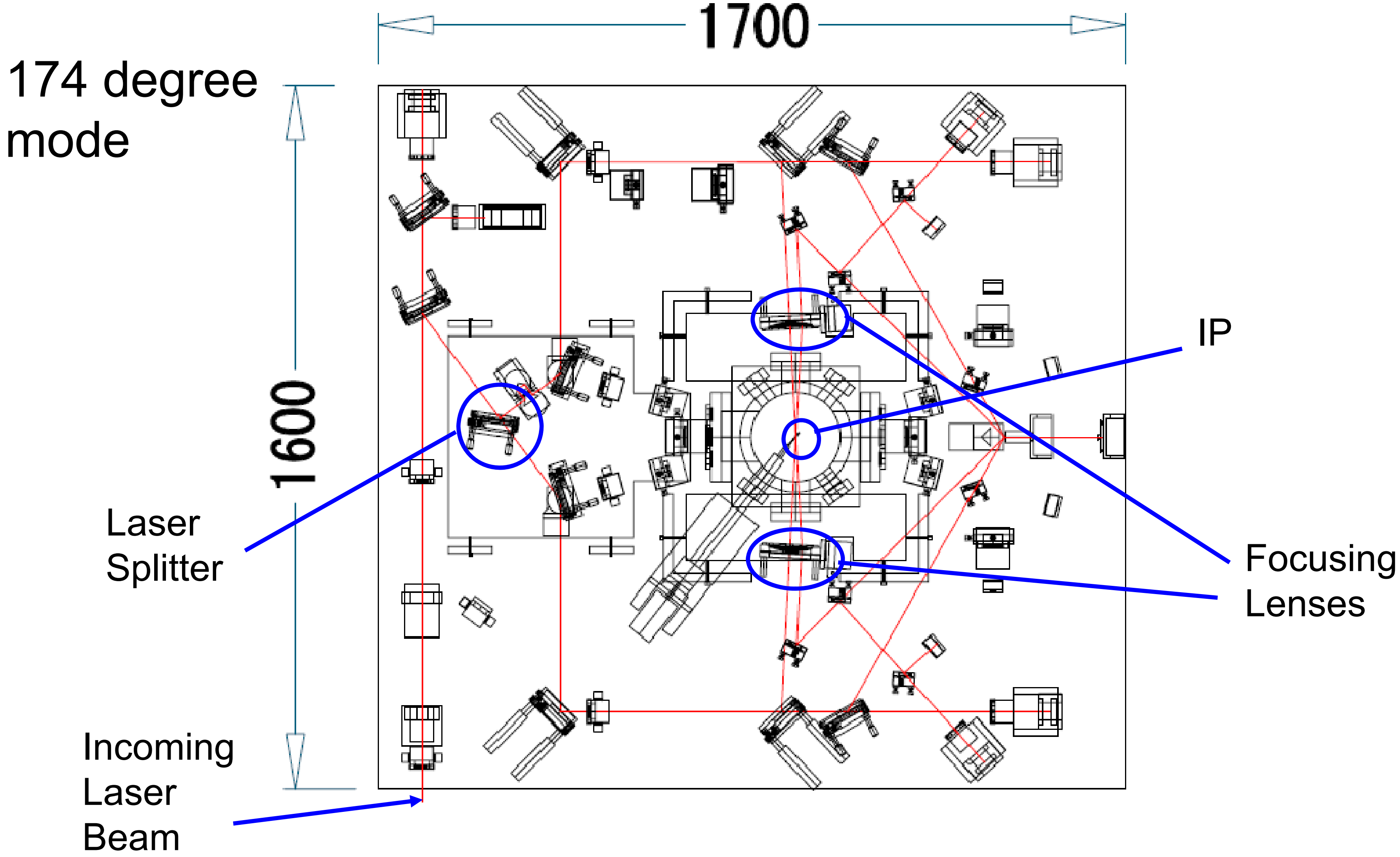
After the stabilization

- We can check the stabilization using the pulse laser
- Fluctuation between pulse-to-pulse is large
- 0.25 ~ 0.3 rad stability (1min) → 12~15 nm
- need to search the source of the fluctuation

Motivations to Design a New Table

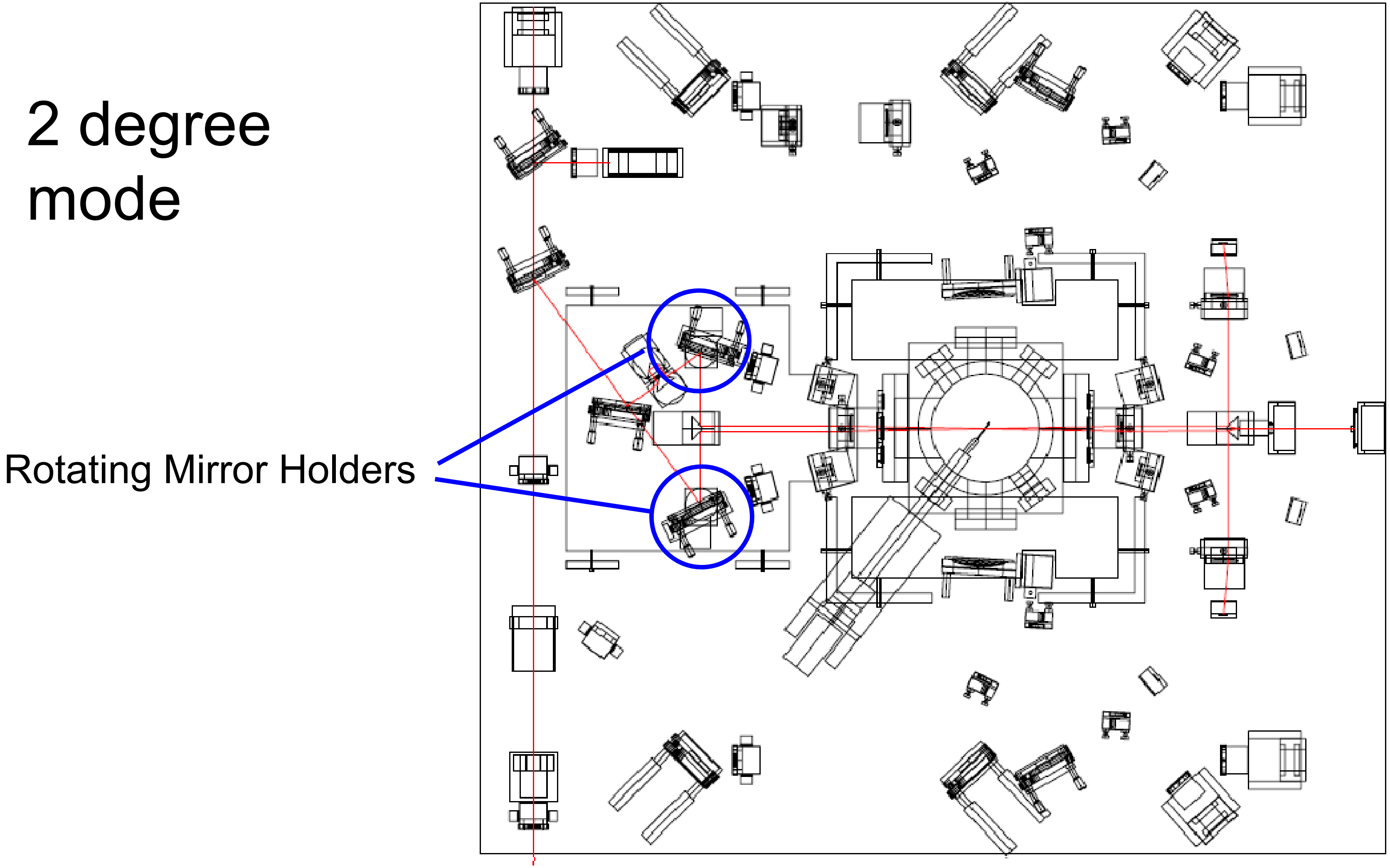
1. Widen the range of measurable beam size (for σ_y)
   – by Increasing number of the laser crossing angles
2. Stabilize the interference fringe position
   – by adding the fringe monitor
3. Increase the signal photons from the collision with electron beam
   – by delivering the laser beam without losing its power

Drawing of the Table

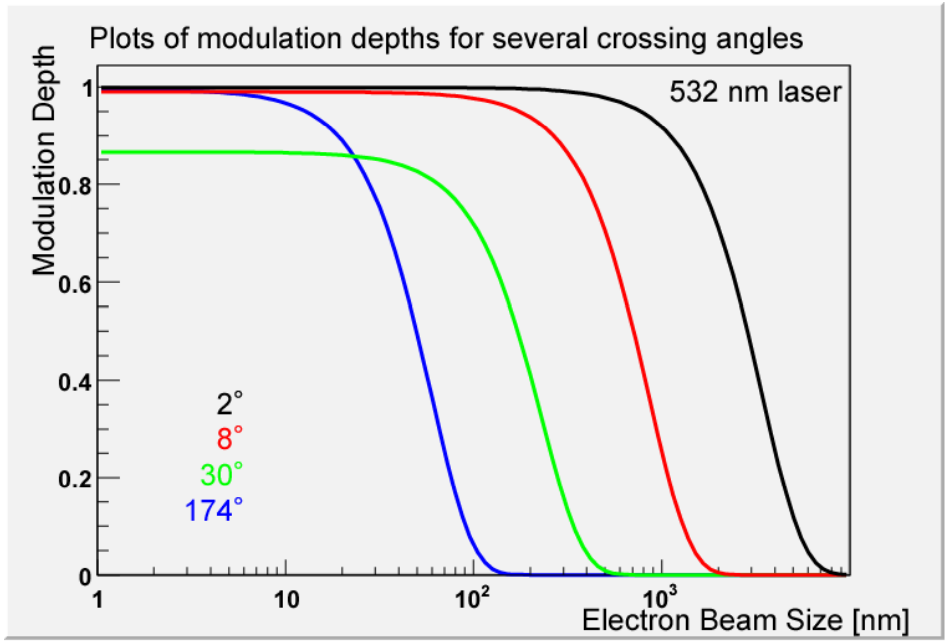


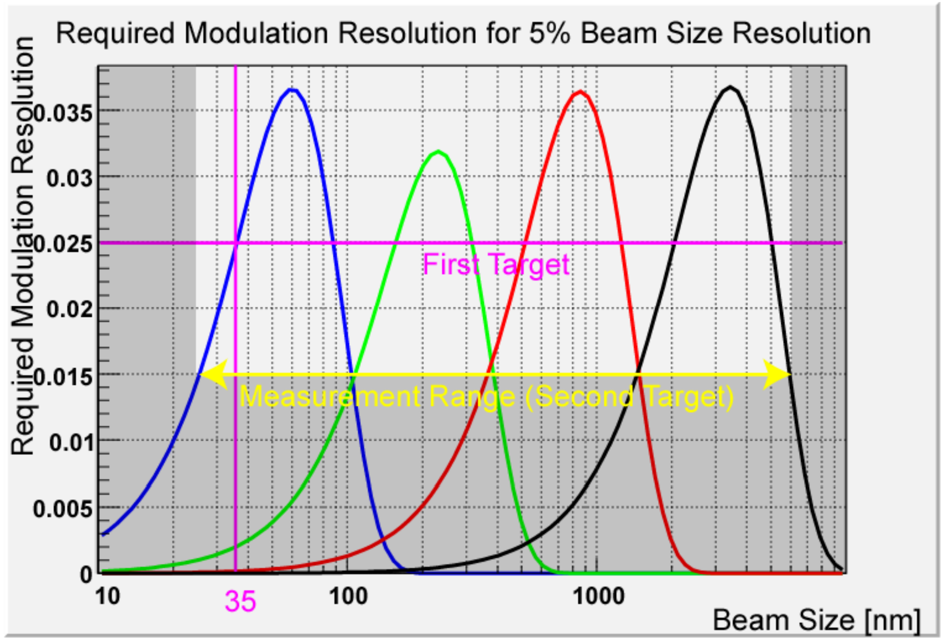
1. Widen the measurable beam size

2 degree mode



Modulation Depth and Mesureable Beam Size

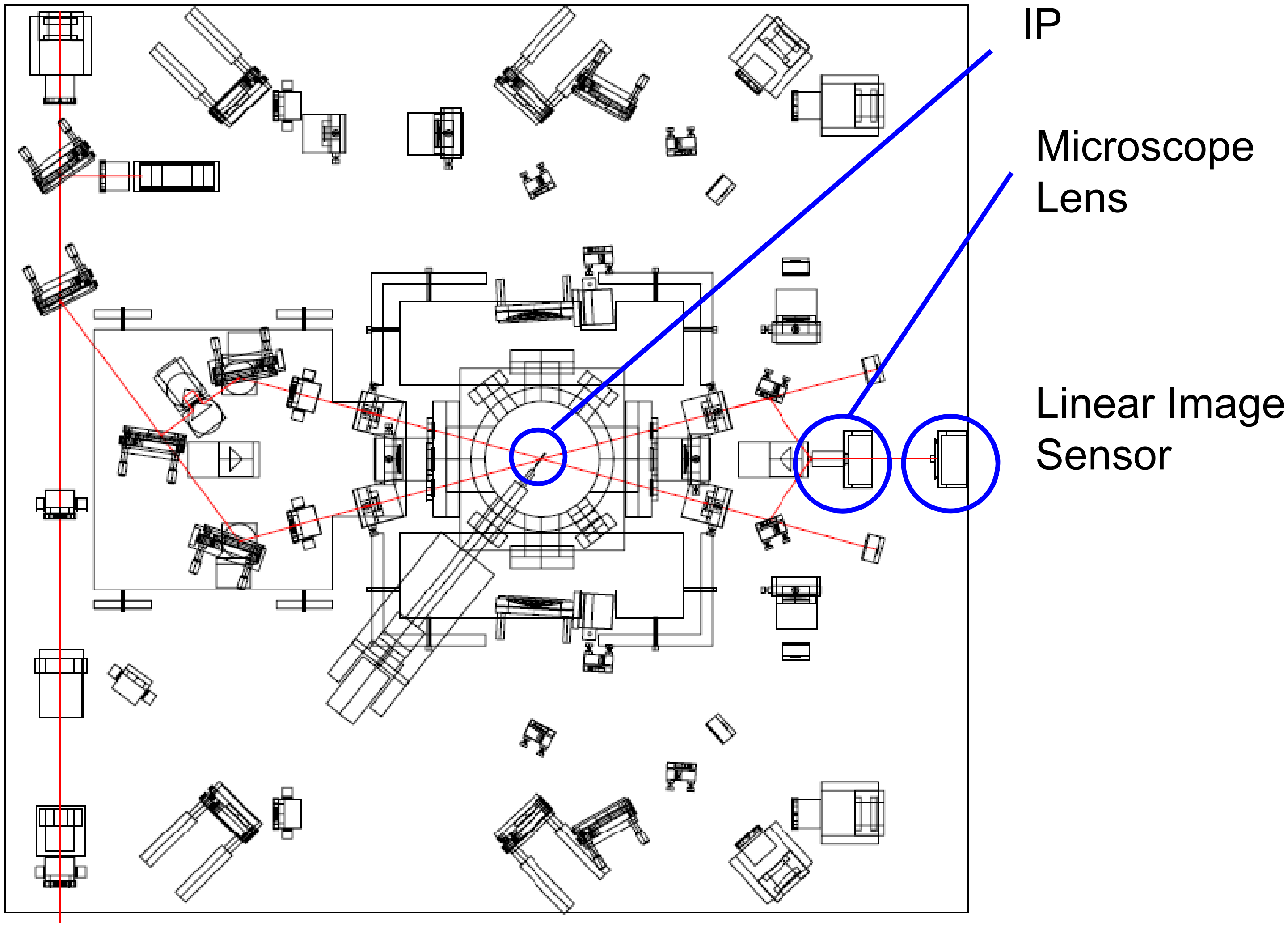




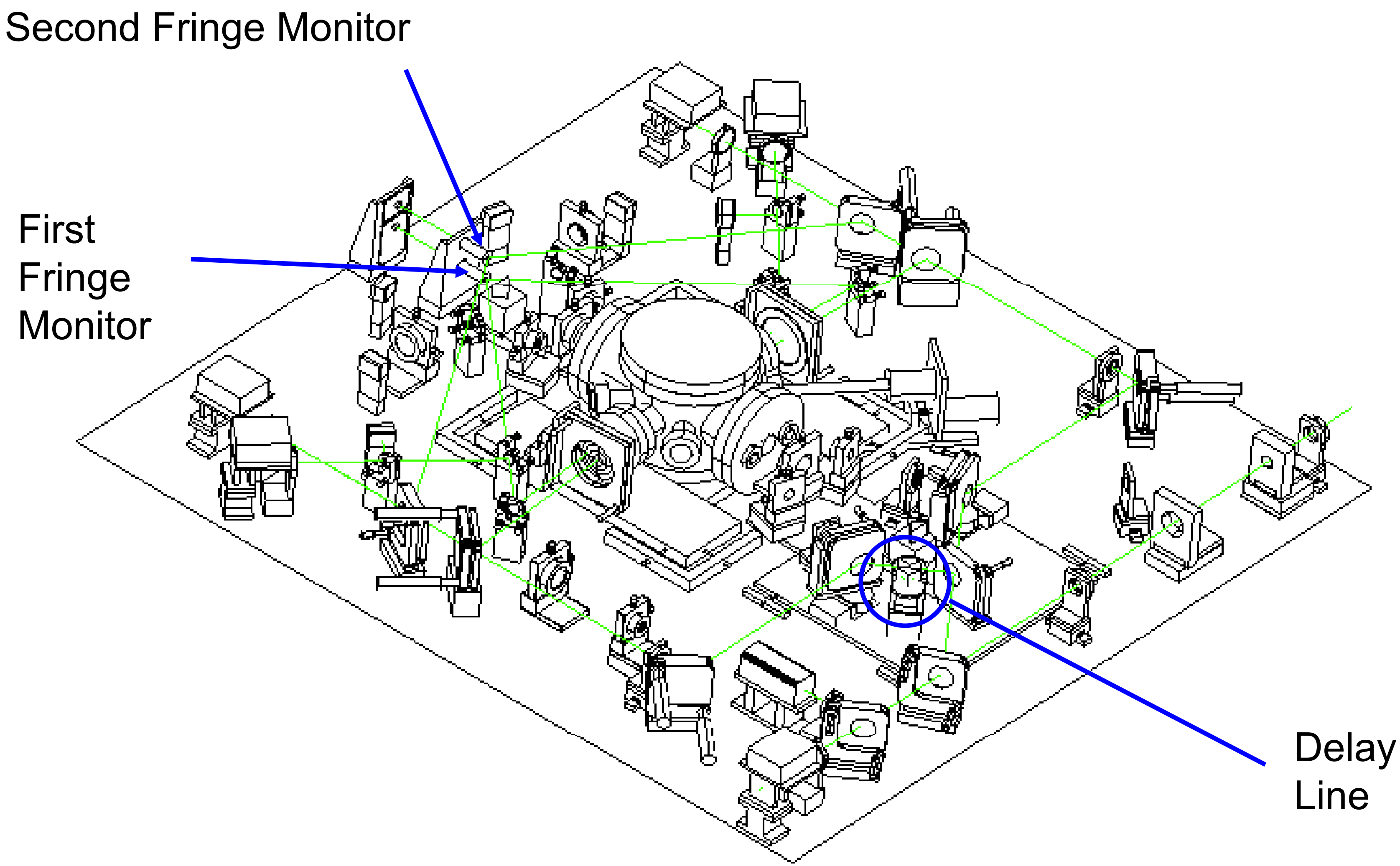
- Most sensitive to the beam size around 50% modulation depth
- To measure 35±2nm , 2.5% resolution is necessary to measurement of modulation
- →First goal: 2.5% resolution @ 68% modulation
- To achieve 10% resolution everywhere, 3.0% resolution is necessary
  →Second goal: 3.0% resolution @ ～90% modulation

2. Stabilize the interference position

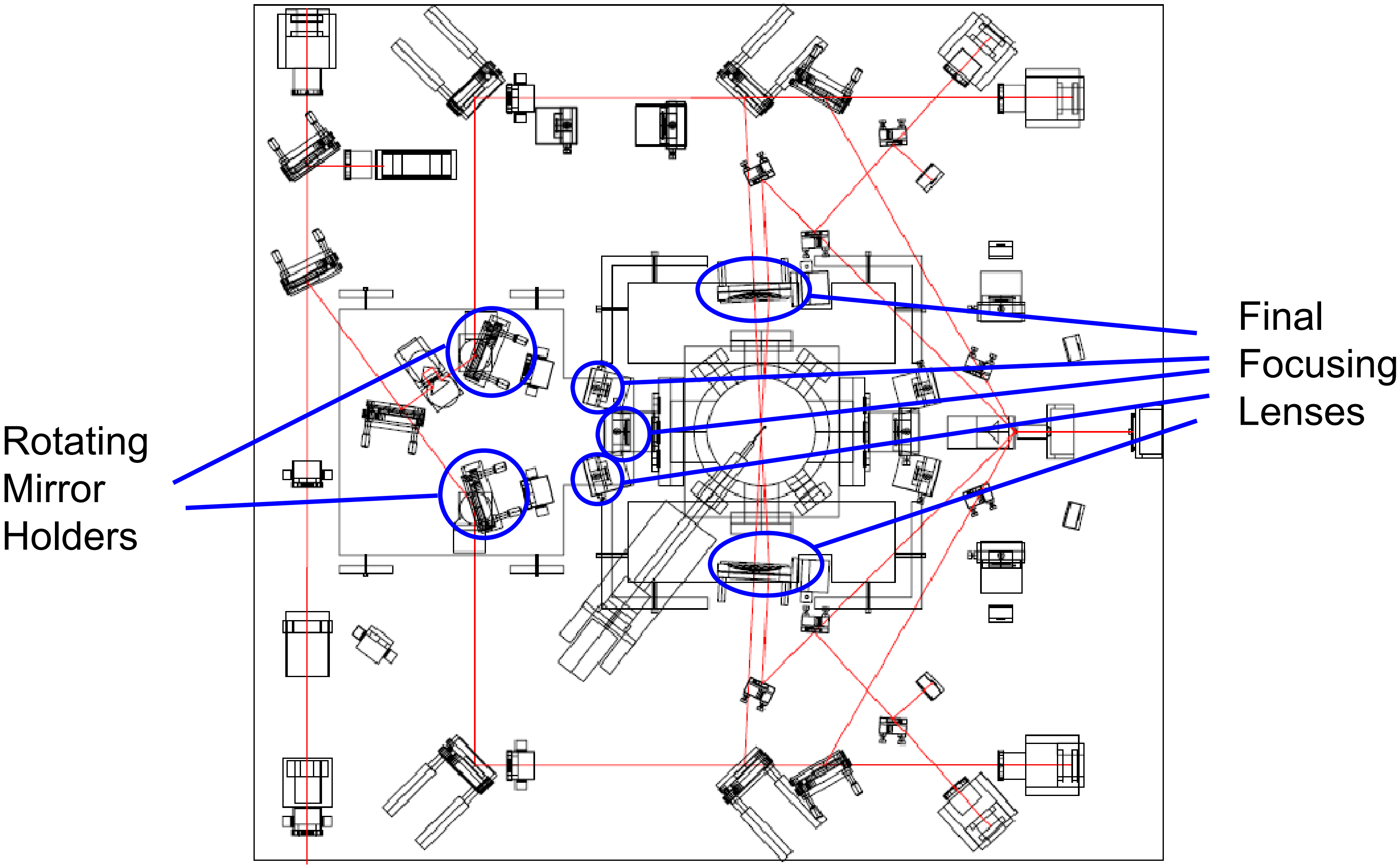
30 degree mode



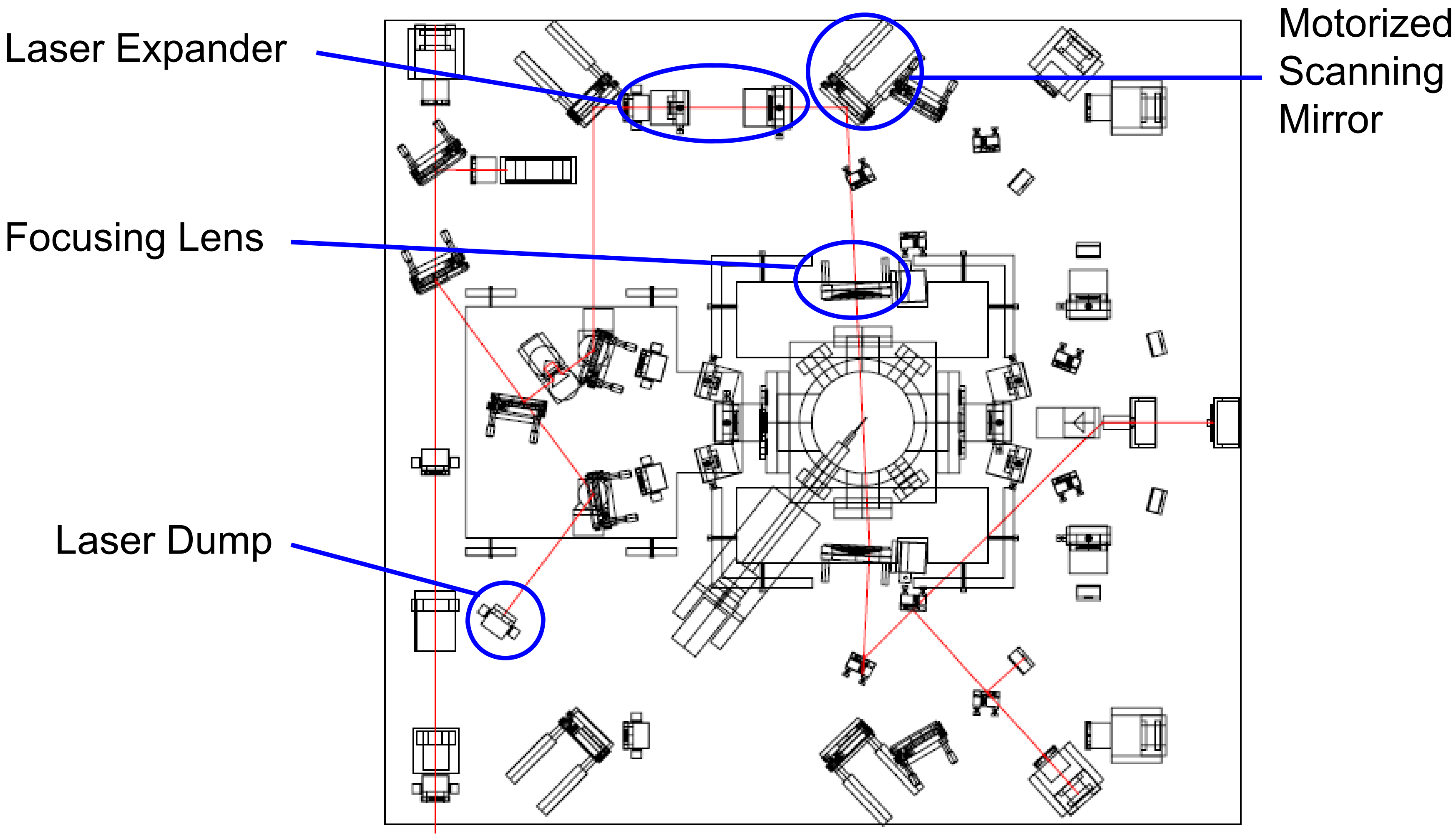
174 degree mode



3. Increase the signal photons



Horizontal Beam Size Measurement



Status

- Design has almost done
- Next tasks are tests of optics
  - Basic tests have finished
  - Detailed tasks are remained
    - Forming the interference fringe in a new optics arrangement
    - Considering the alignment strategy