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Phase stabilization for interferometer in Shintake monitor

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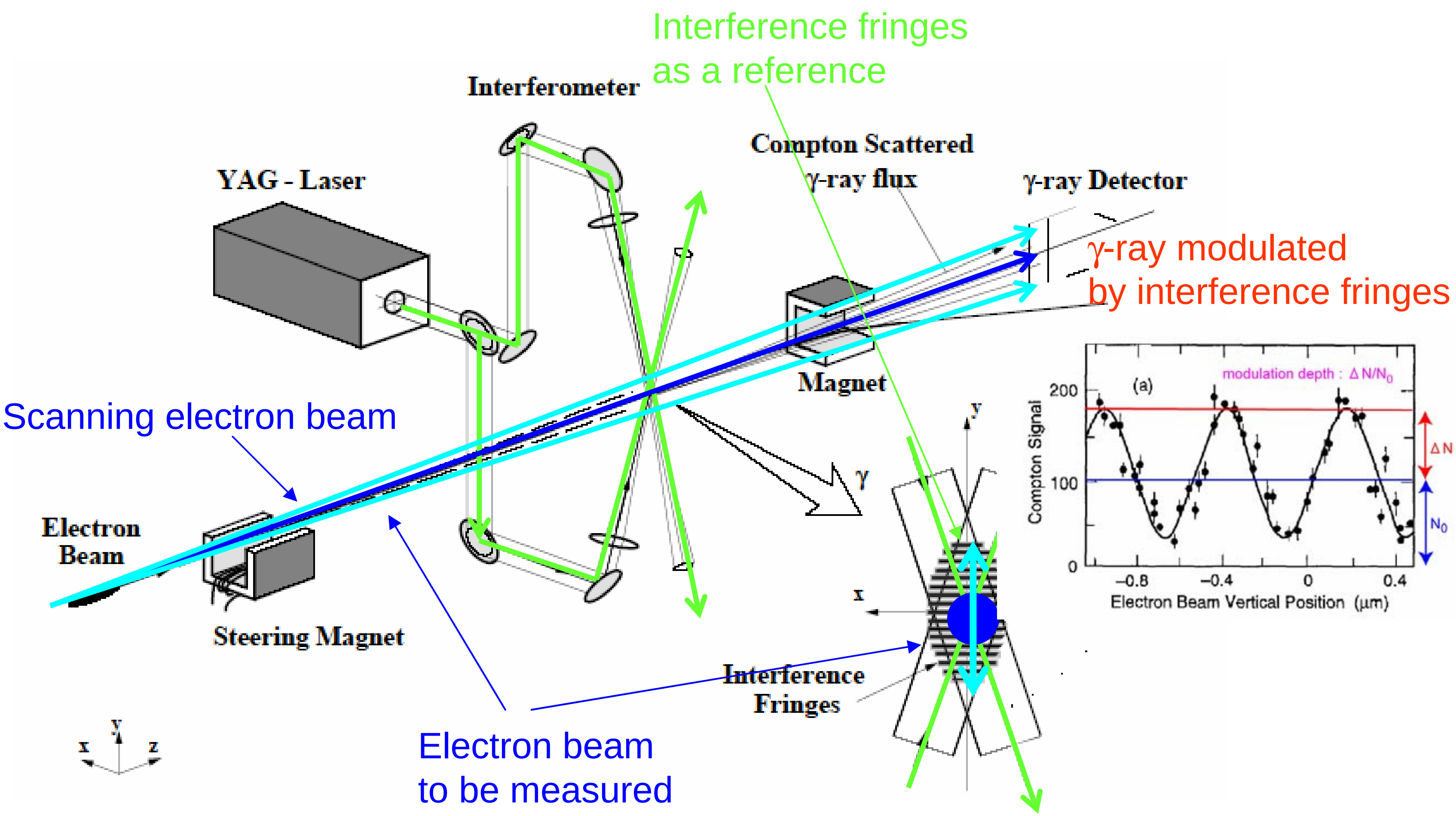
Contents

- Stability expected for interference fringes in Shintake monitor
- Precise phase detection and control (idea)
- Effects of vibrations and fluctuations of optical parts on interferometer (estimation)

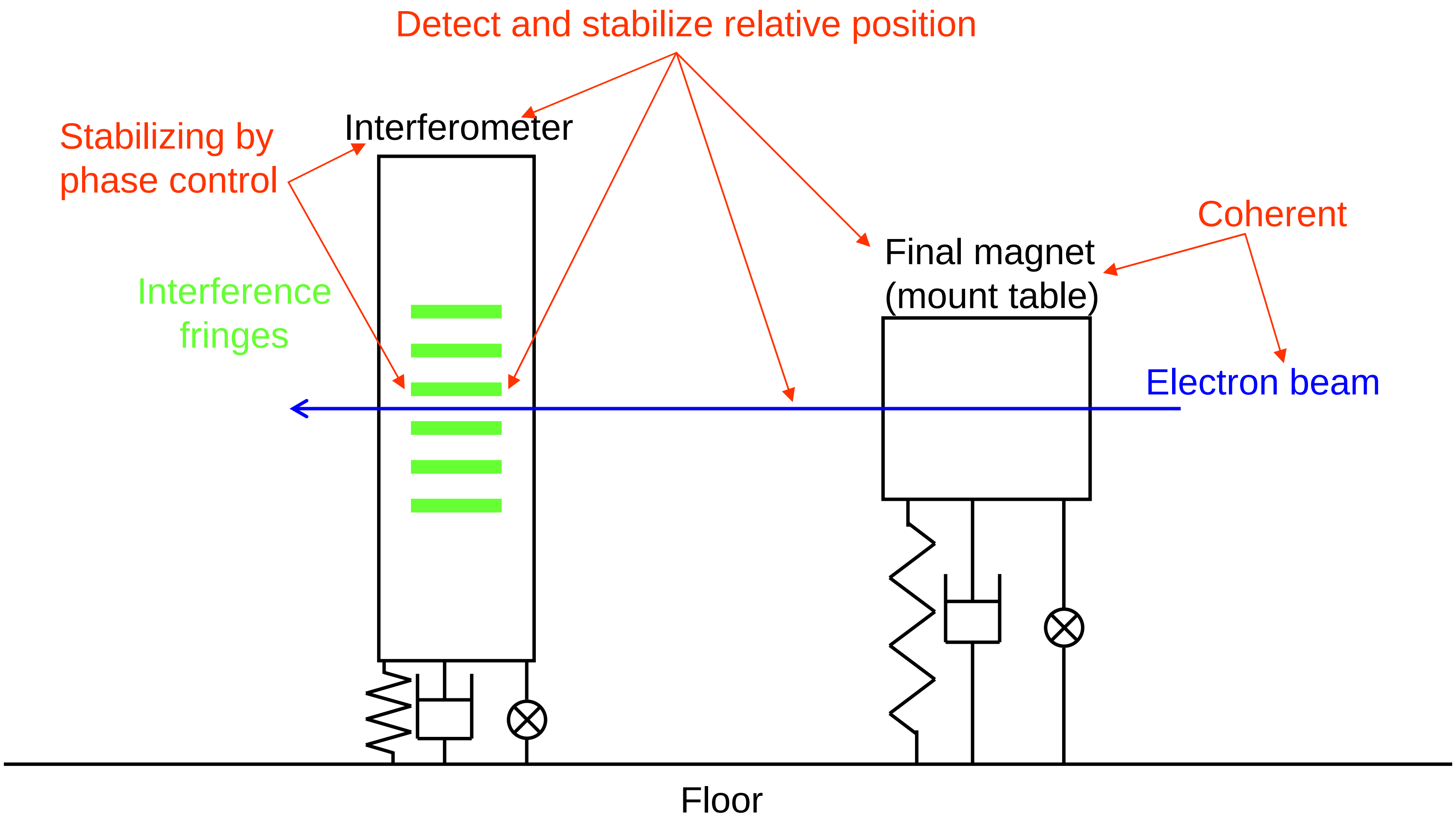
Schematics of Shintake Monitor

Laser fringe(/Compton) beam size monitor



Stabilize interference fringes and electron beam

How stabilize relative position between interference fringes (as a reference) and electron beam (to be measured) for accurate(=low deviation) measurement?



Stability expected for interference fringes

estimated value based on assumption

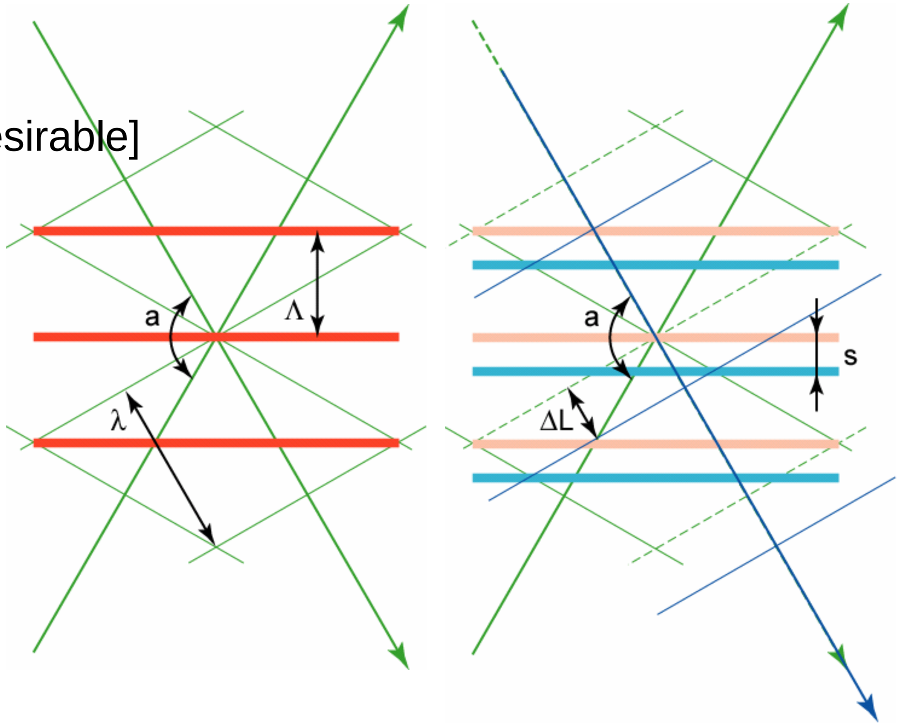
- Measure size of the electron beam converged to be r=37 nm in radius (sigma) with accuracy (repeatability) of 10% or better.
  - >Desirable position stability of s=r/10=3.7 nm (phase stability of 0.03π) or better [Desirable]-> Stability for optical path difference of ΔL=7.4 nm
  - >Position resolution of r= s/10=0.37 nm (phase resolution of ~0.003π) [Desireble]
- Measurement time of ~min - ~10min
  - >Time stability of ~10 min -1 hour [Desirable]

Design for Shintake monitor

a: Angle between two beam, (174 deg)

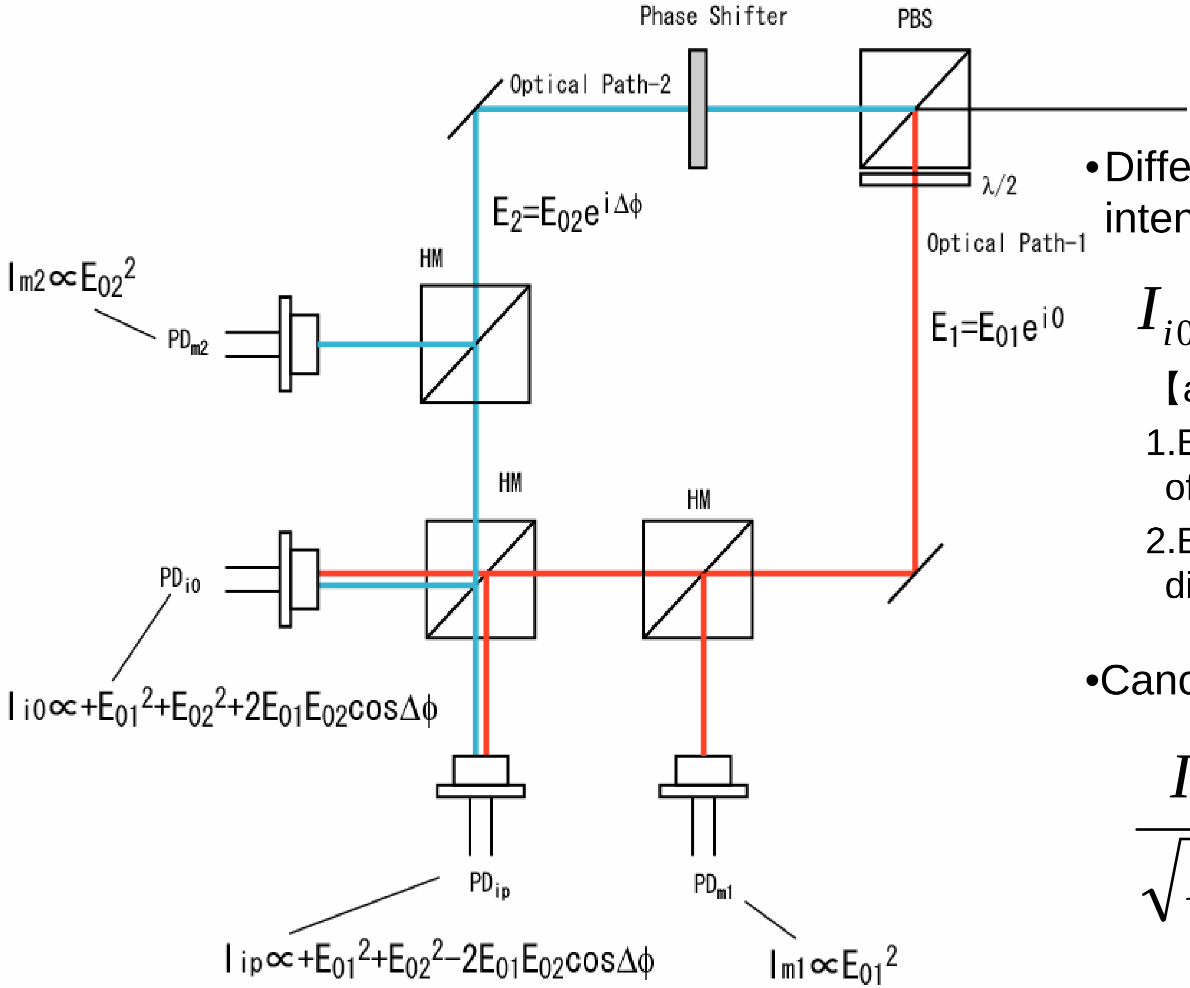
λ: Wavelength, (532 nm)

Λ: Fringe pitch, (266 nm)



Durable and precise phase detection

(Not to affected by intensity change of LASER light source)



- Difference of the 2 interfered light intensities s: I_{i0}-I_{ip}

$$I_{i0} - I_{ip} \propto 2E_{01}E_{02}\cos\Delta\phi$$

【assamptions】

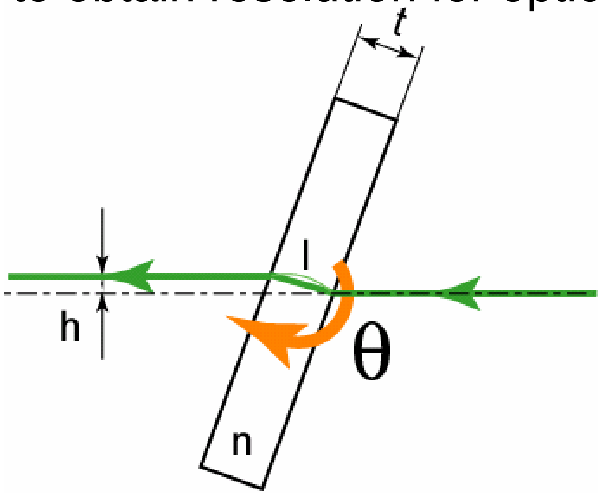
1. Equal transmission/reflection ratio of half mirror :HM,
2. Equal sensitivity of photo diodes:PD_{i0} and PD_{ip}

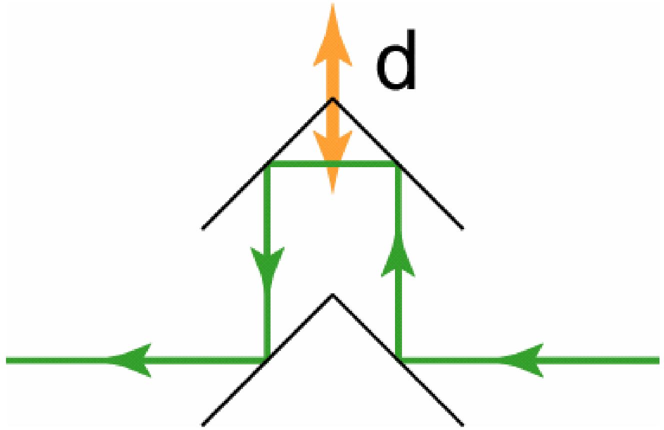
- Canceling E_{01} and E_{02}

$$\frac{I_{i0} - I_{ip}}{\sqrt{I_{m1}\cdot I_{m2}}} \propto 2\cos\Delta\phi$$

Phase shifters for phase control

in order to obtain resolution for optical path length difference of $\Delta L/10=0.74$ nm





•Transmission type

(by rotating angle θ of glass plate)

->Angular resolution of $\Delta\theta=\sim 3$ min ($=8.7*10^{-4}$ rad) is required for 0.74 nm of resolution

->h=~12 μm for 90 deg of fringe phase change

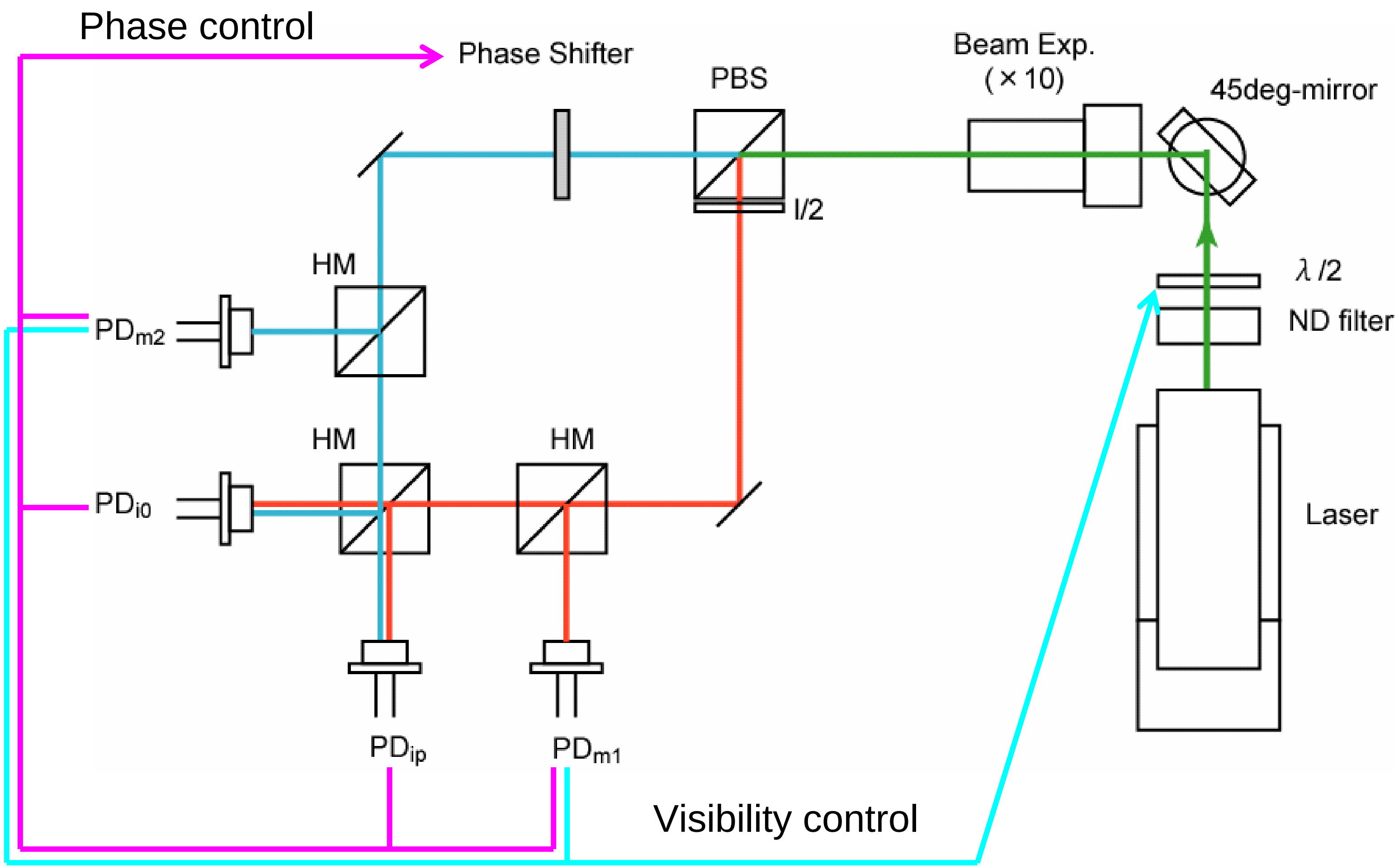
(in case plate thickness: t=3 mm, refractive index: n=1.5)

•Reflection type

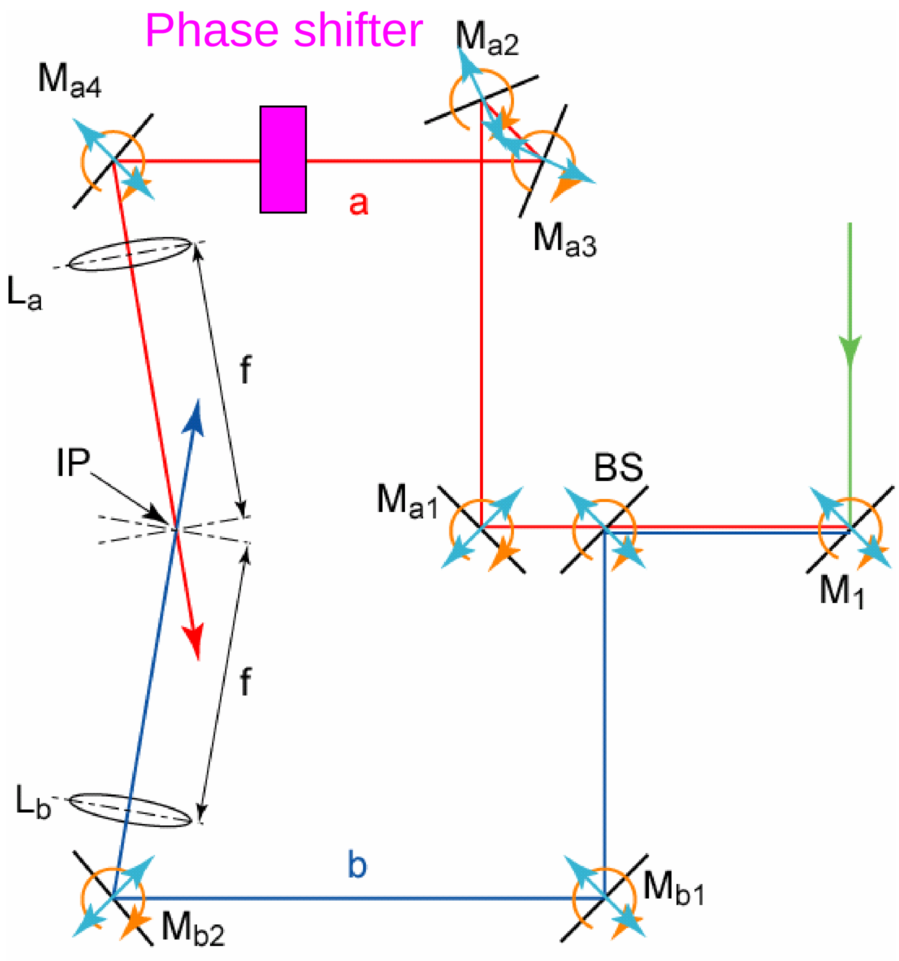
(by changing relative distance d between the two mirror sets)

->Position resolution of $\Delta d=0.37$ nm is required for 0.74 nm of resolution

Experimental setup for controlling phase and visibility of interference fringes



Effects of vibrations and fluctuations of optical parts on interferometer



In order to make fringe change of <3.7 nm (Position stability)

*Assuming that each optical parts fluctuates independently

- Position change for normal direction: Δd_m<1.8 nm
- Rotational change $\Delta\theta_m$<0.12 sec (=5.7×10^{-7} rad)

They seem to be able to cancelled by fringe observation and phase control

Summary

- Interference fringes are to be stabilized within several nm against interferometer.
- Phase observation and phase shift method with resolution of sub nm are to be confirmed by experiment.
- Stabilities of interference fringes are seem to be affected by vibration and fluctuation of optical parts; however, they can be eliminated by phase control.