R&D Status of ATF2 IP Beam Size Monitor (Shintake Monitor)

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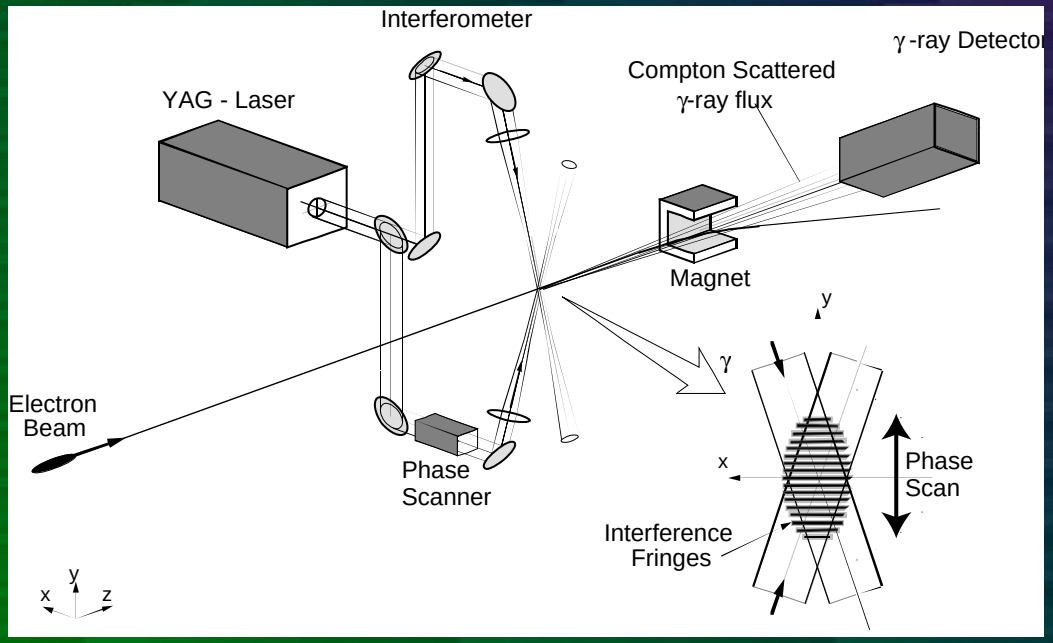
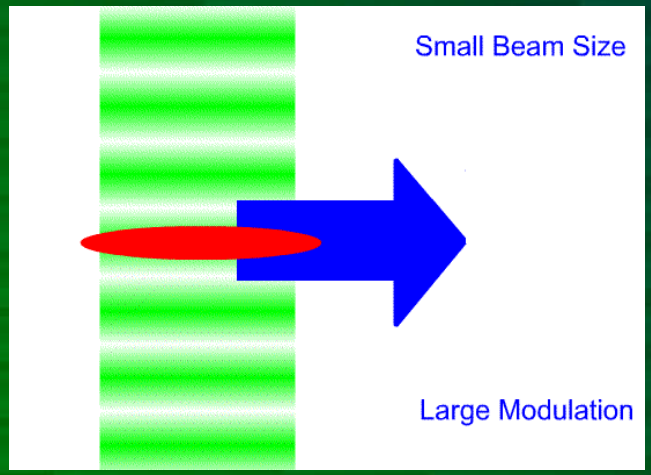
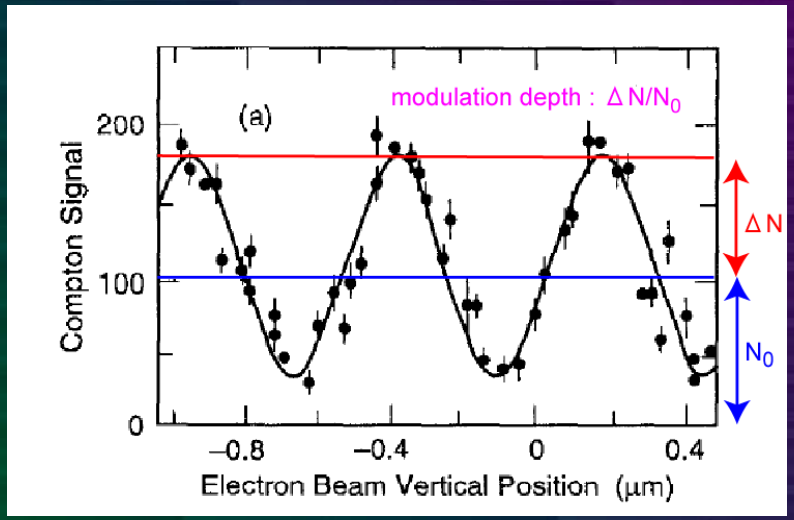
Overview



Schematic

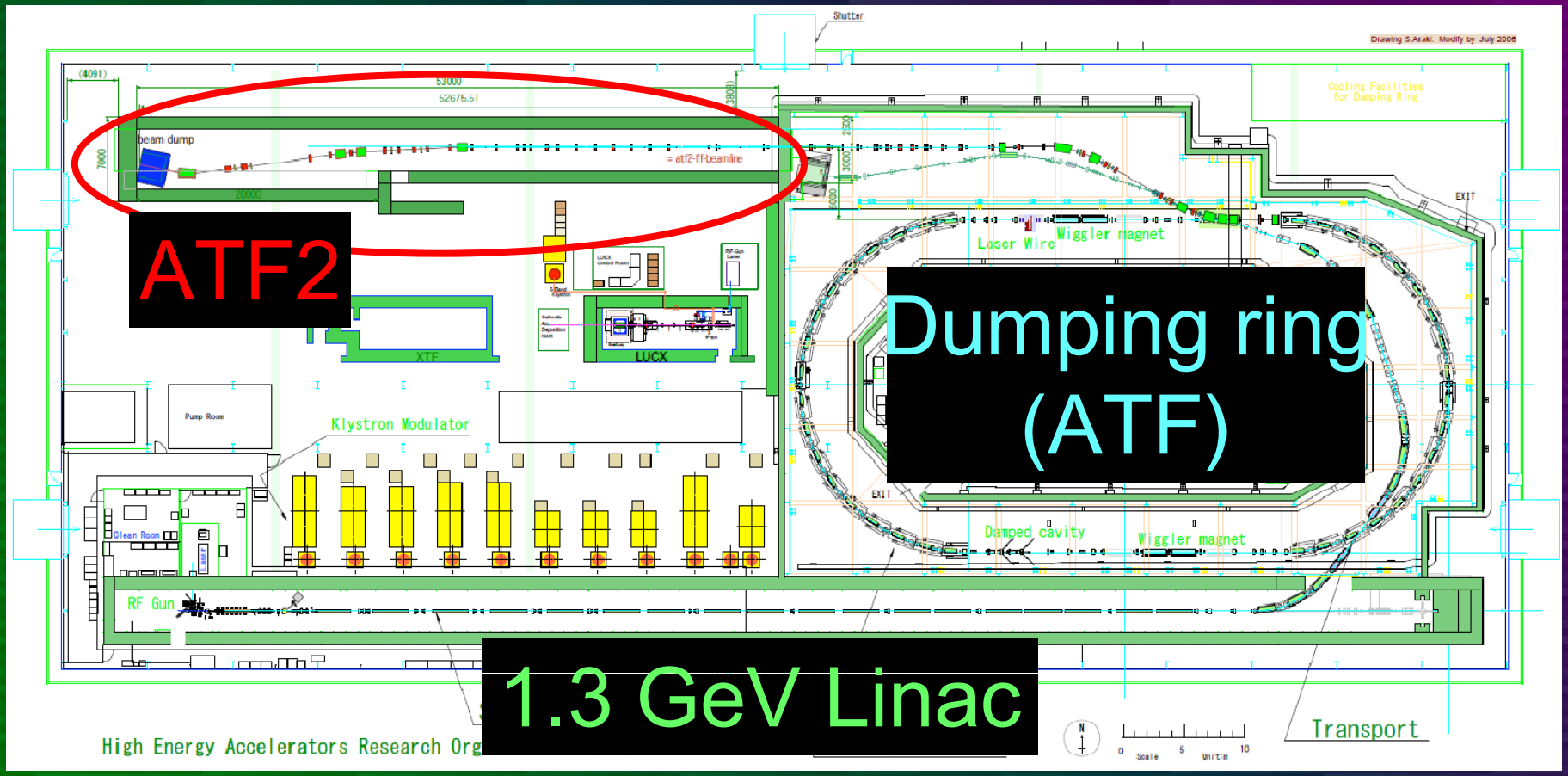
Shintake Optical Table





70nm meas. in FFTB

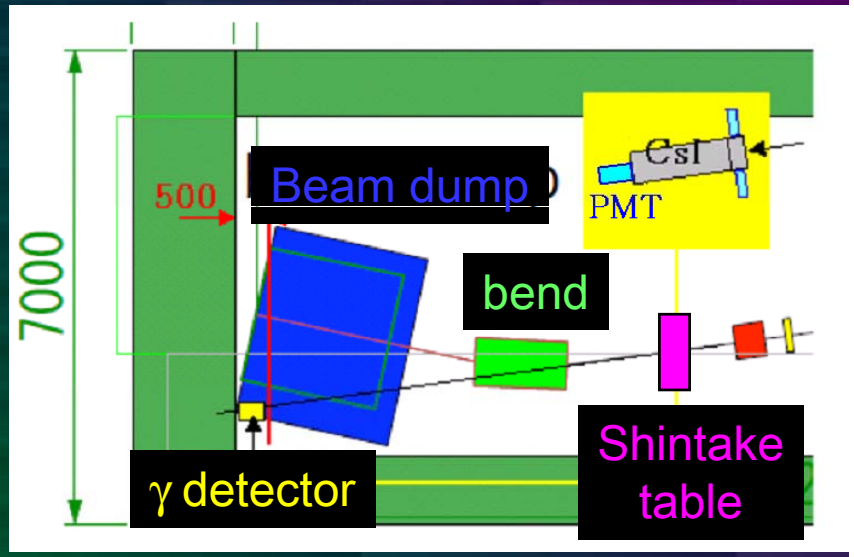
ATF & ATF2 @ KEK



About 110 m

Shintake Monitor for ATF2

- Measure 35nm ATF2 beam, < 2nm error (about half of FFTB experience)
- Upgrades implemented & planned
  - Laser wavelength change (1064nm → 532nm)
  - Laser fringe phase stabilization
  - Background subtraction by γ detector
  - Background collimation (beam & γ-ray)
  - etc.



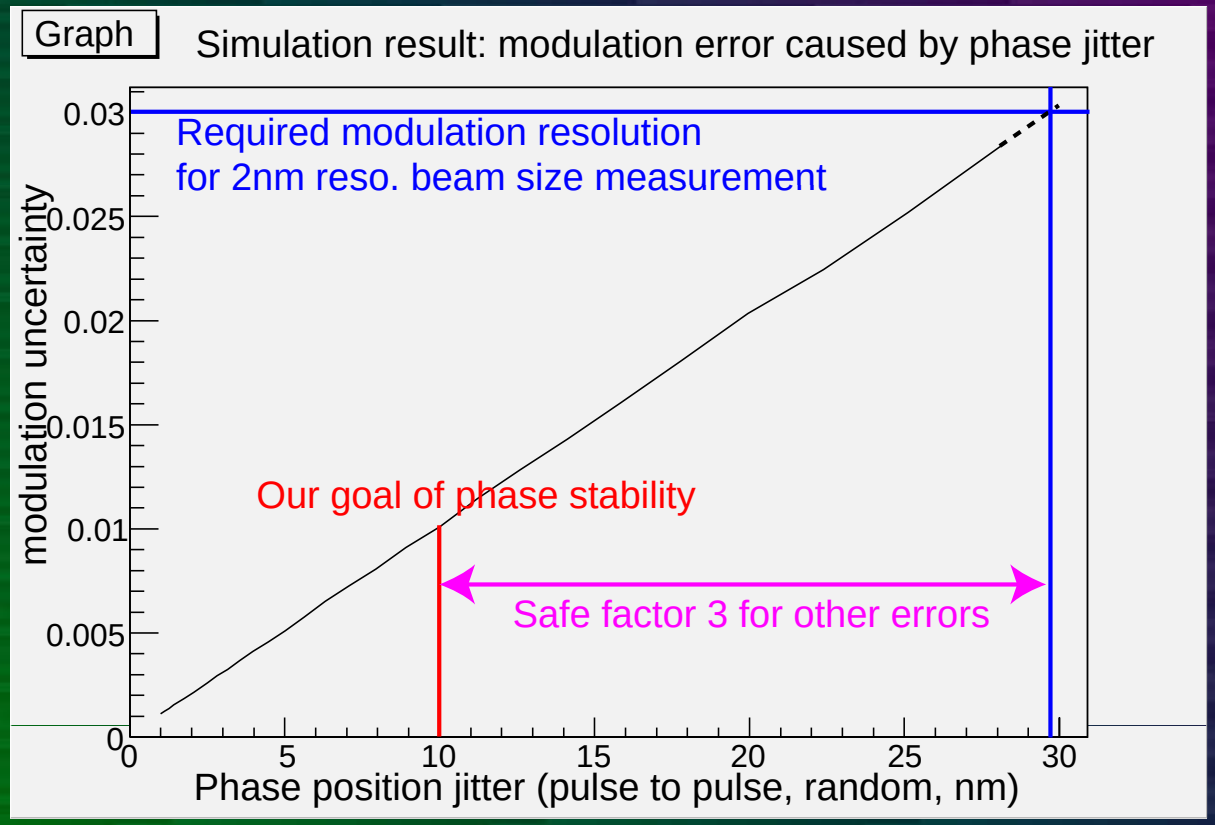
Brief layout around IP

Laser Fringe Phase Control

Required Fringe Stability

2nm beam size (required resolution)

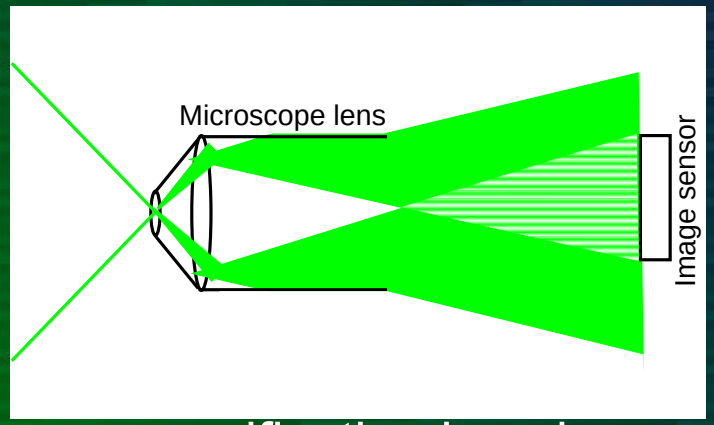
→ 3% modulation resolution.



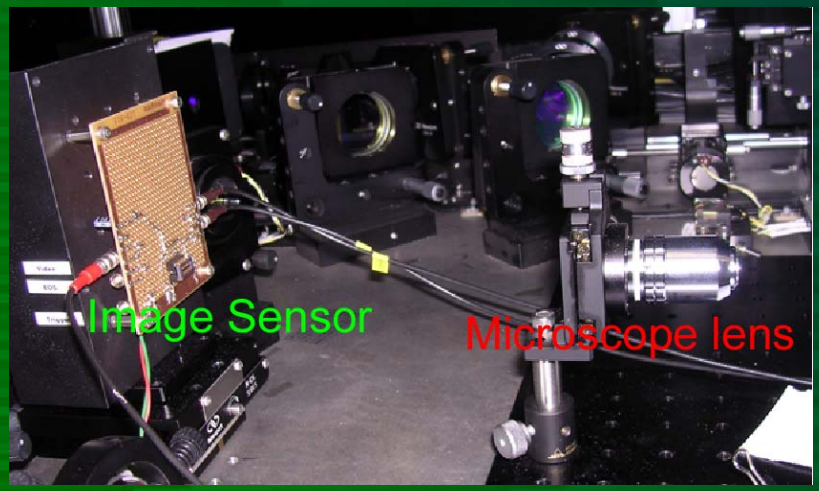
3% modulation error → 10nm phase stabilization.

We need active stabilization system.

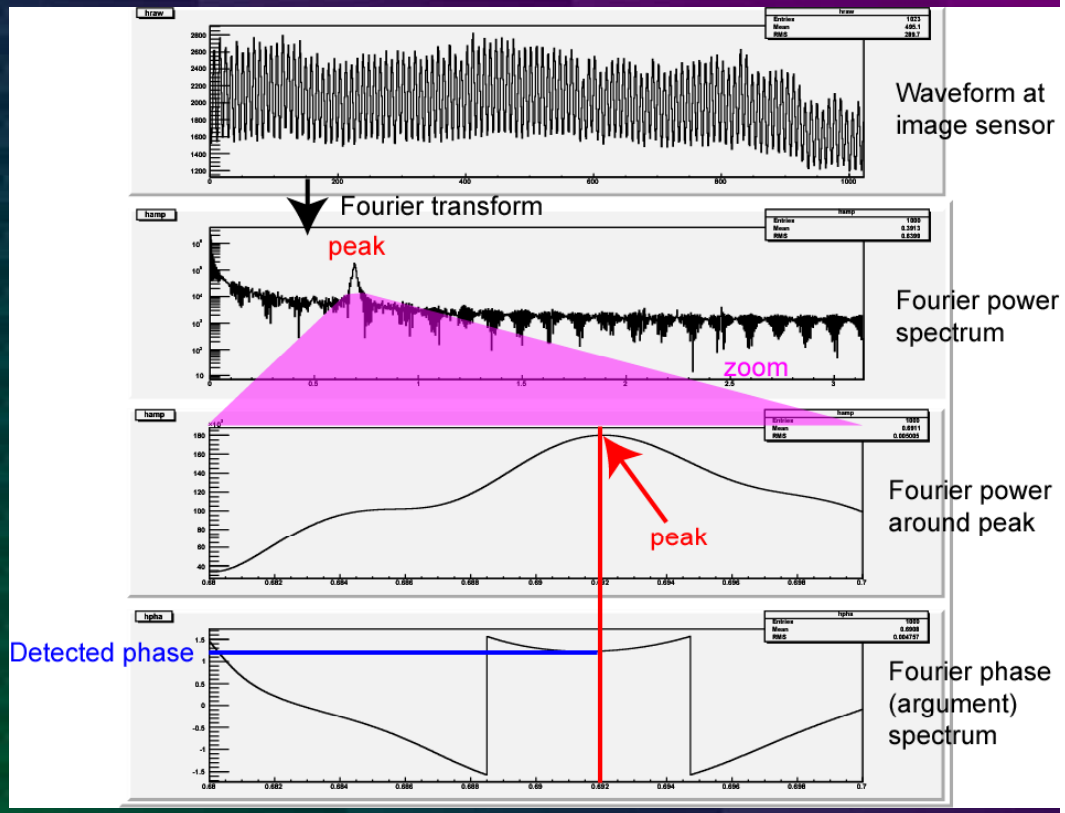
Phase Monitor



Phase magnification by microscope lens, captured by image sensor



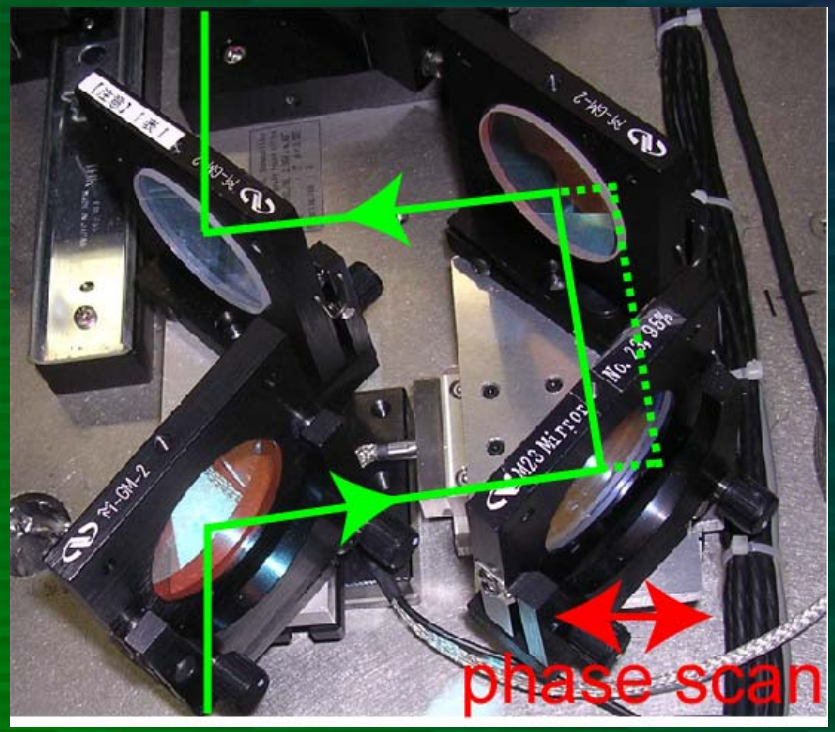
Lens and image sensor



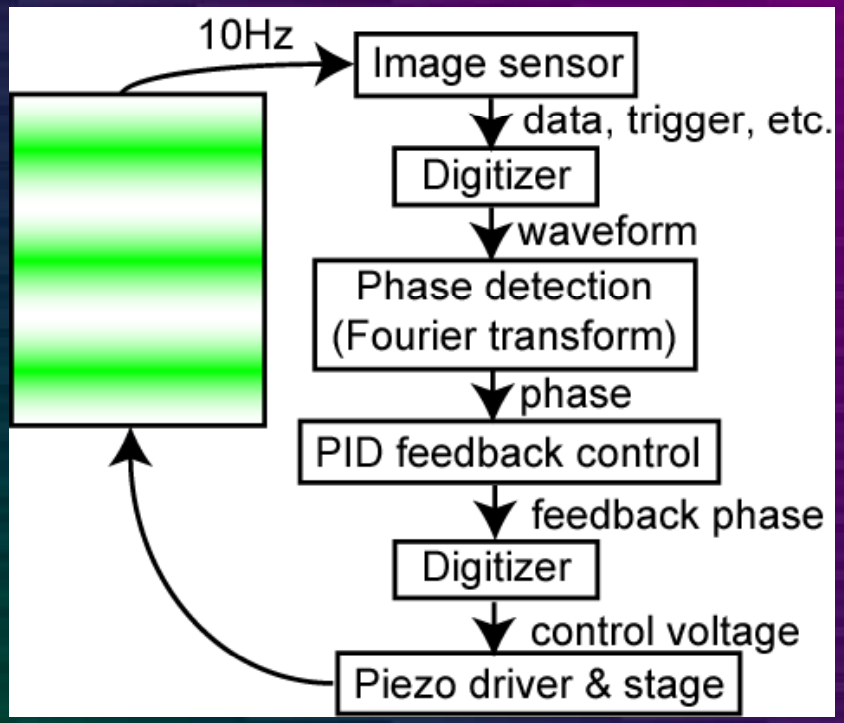
Phase detection sample

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

Phase Scan & Control

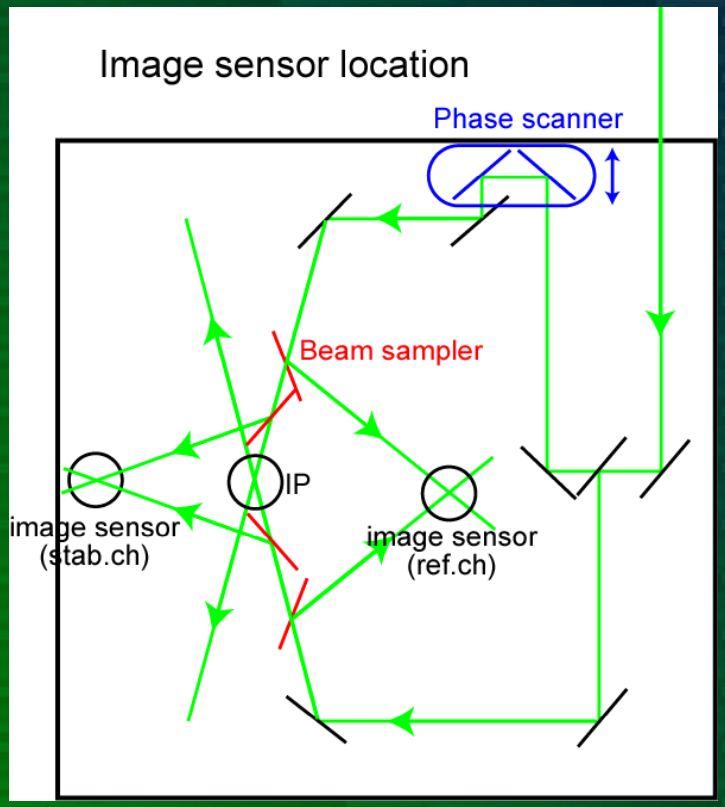


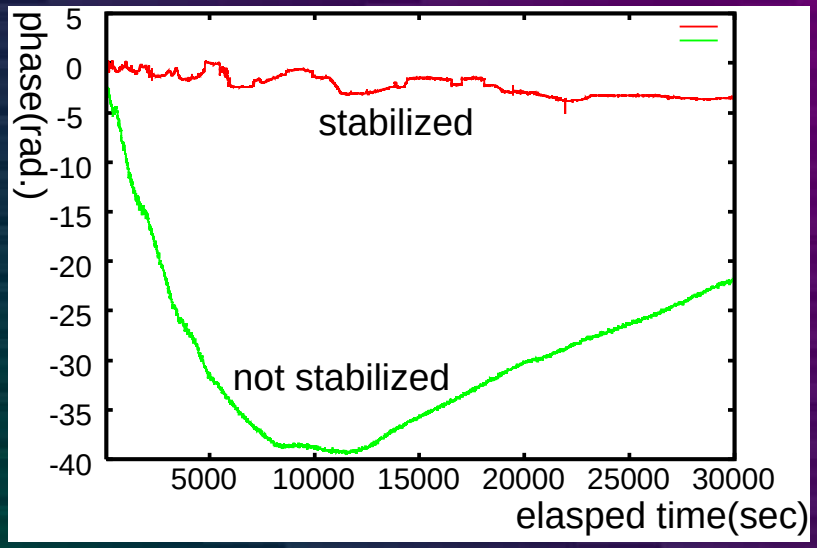
Delay line for phase scanning.
Piezo stage of 0.2nm resolution
is installed under right 2 mirrors.



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

Stabilization Result (cw. Test Laser)





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

We use 2 image sensors.
- Stab.ch → stabilized
- Ref.ch → not stabilized

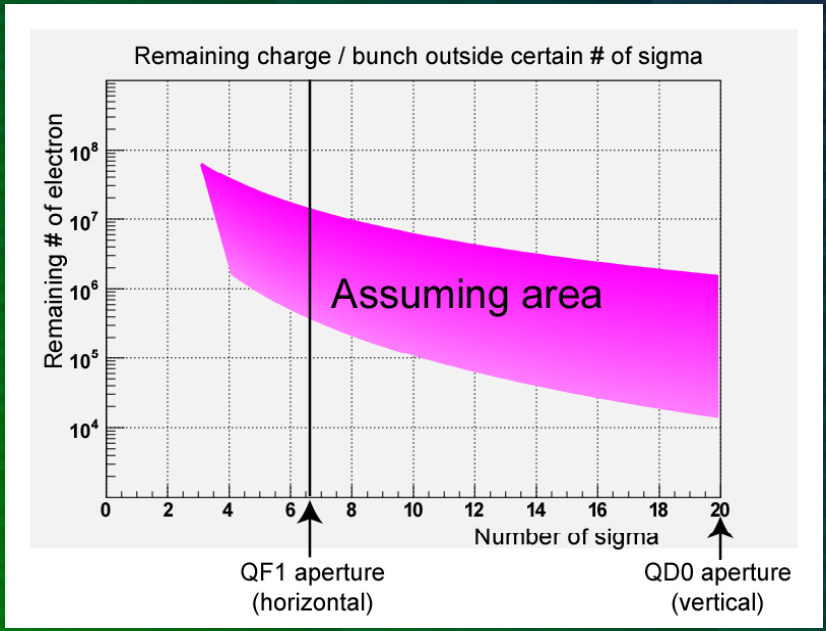
Check correlation of 2 ch.
to confirm beam (and IP) phase stabilization.

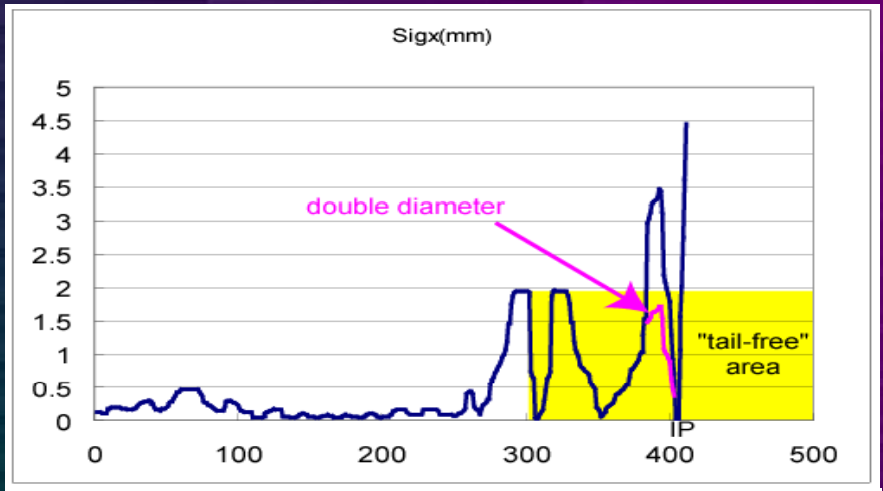
Ref.ch phase data shows
- 0.034 rad. (1.5nm) stability in 1min.
- 0.133 rad. (5.6nm) stability in 10min.

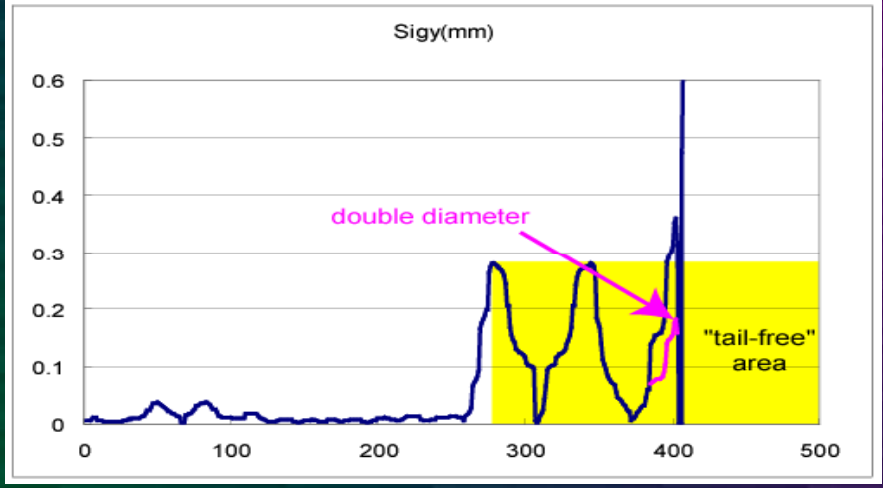
which meets 10nm stability ATF2 goal.

Collimator & Gamma Detector

Beam Tail & Collimator



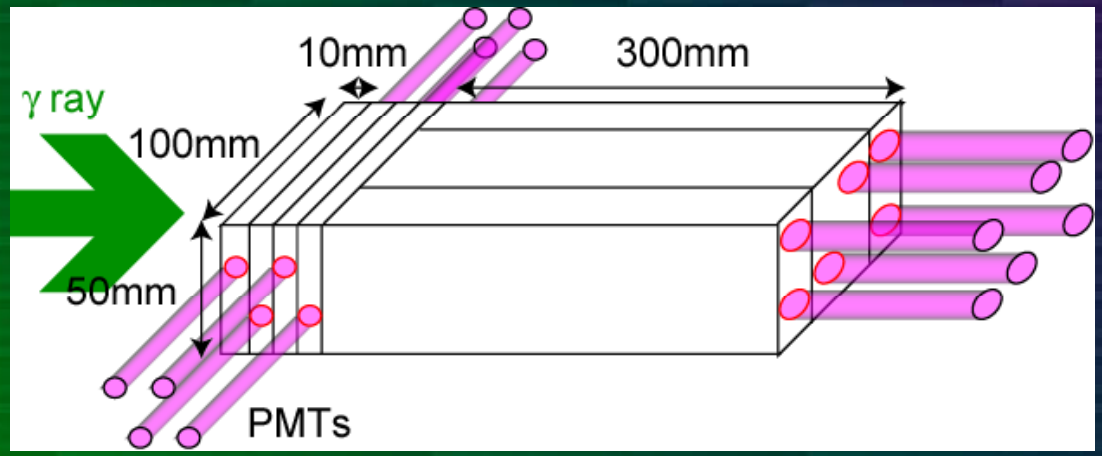




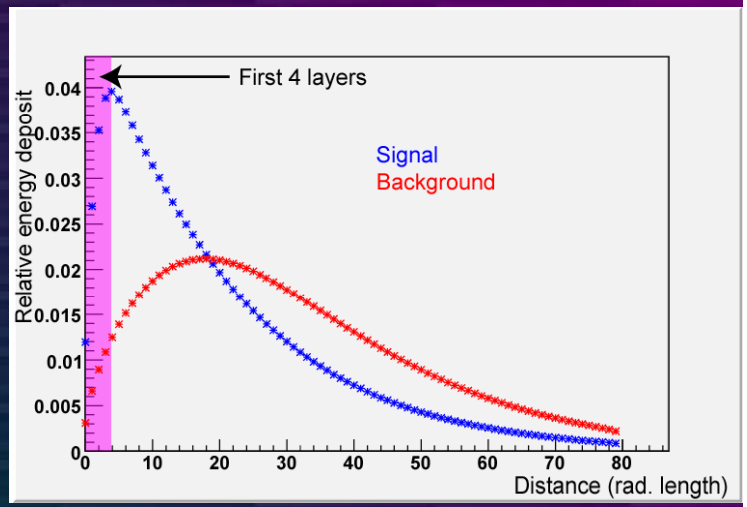
Tail estimation using
ATF ext. background meas.
Beam tail must be cut before FD.

- We need >40mm aperture for OC1,SF1,QF1,SD0,QD0 and additional quad after IP (before bend)
- Effect of tail cut must be checked by tracking simulation.

Gamma Detector



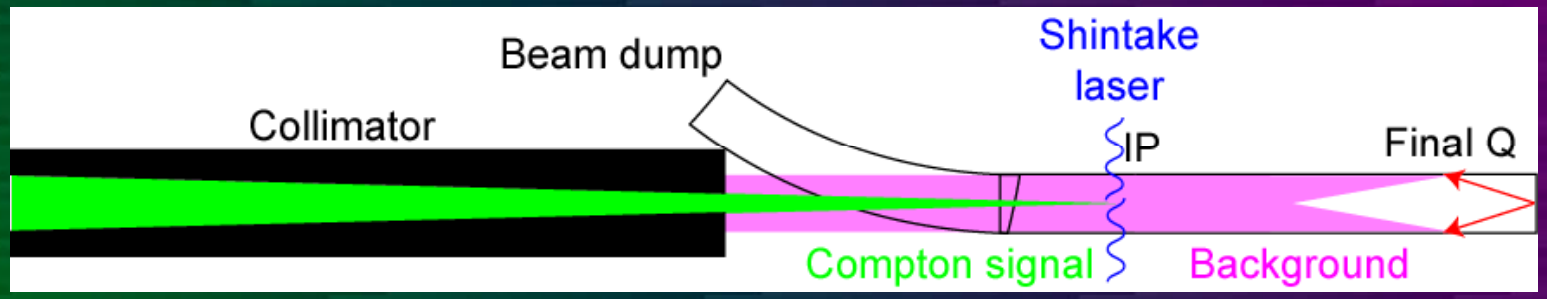
Schematic of gamma detector.
4 forward layers will be used
for background subtraction.



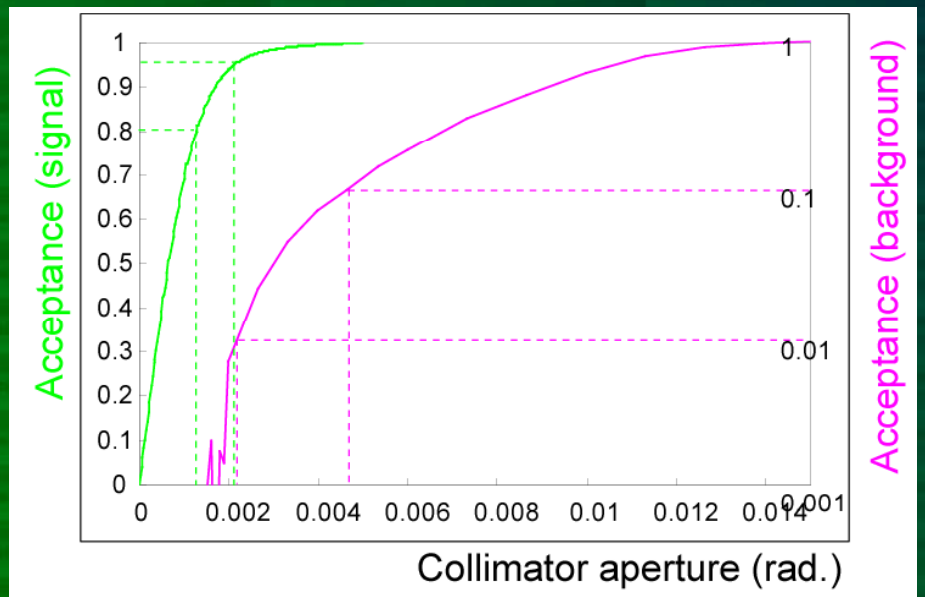
Distribution of energy deposit.
Deposit of signal is concentrated
to forward region.

- Background subtraction will be done by comparing energy deposit of forward and background region.
- Conceptual design of γ detector was finished. Detailed designing is ongoing.
- We will perform beam tests in ATF ext. by end of this year.

Effect of Gamma Collimator



Compton signal is well focused while background has a relatively broad spacial distribution.
We will put a cone-like collimator to select Compton signal.



Background: 1mrad pipescat at FD region
Collimator: cone-type, lead, very long (from just after bend to detector)

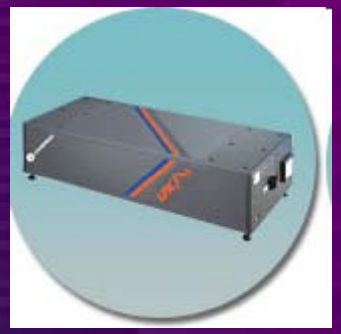
Simulation result.
~1.5mrad aperture (~2mm radius at top) accepts 80% of signal and ~0.1% of background from Final Q.
~2mrad (~3mm r) accepts 95% of signal and 1% of bg.

Shintake Monitor for ILC

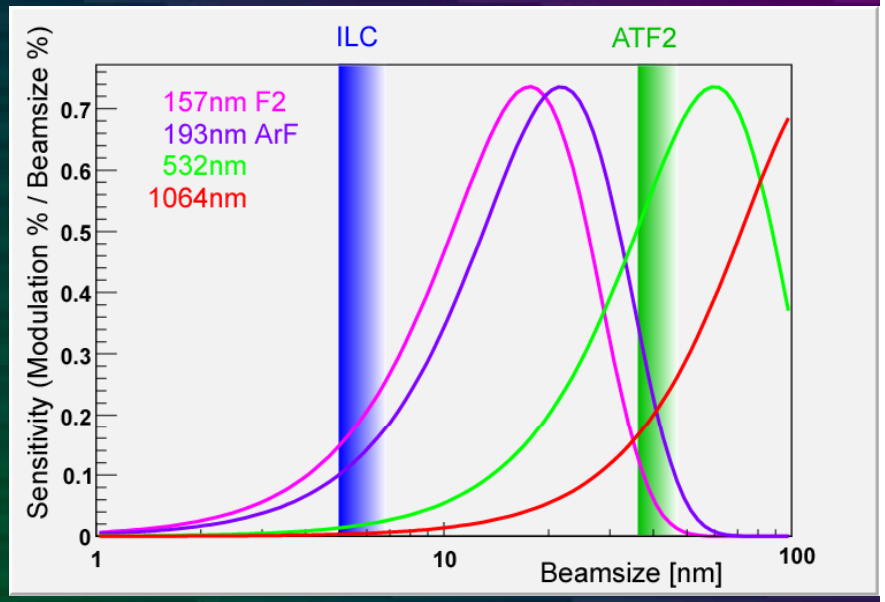
Taikan SUEHARA et al., LCWS2007 & ILC2007 @ DESY, 2007/06/01

Lasers for 5nm Measurement

- F2 laser (157nm)
  - Shortest wavelength of commercial lasers
  - 92.3% mod. @ 5nm, 0.147 % mod. / 1% BS
  - 50mJ/20ns available, need special optics
- ArF excimer laser (193nm)
  - Shortest wavelength of excimer lasers
  - 94.8% mod @ 5nm, 0.101% mod. / 1% BS
  - 650mJ/25ns (enough) widely available excimer optics
- FEL ??



Coherent LPXPro series F2 and ArF eximer



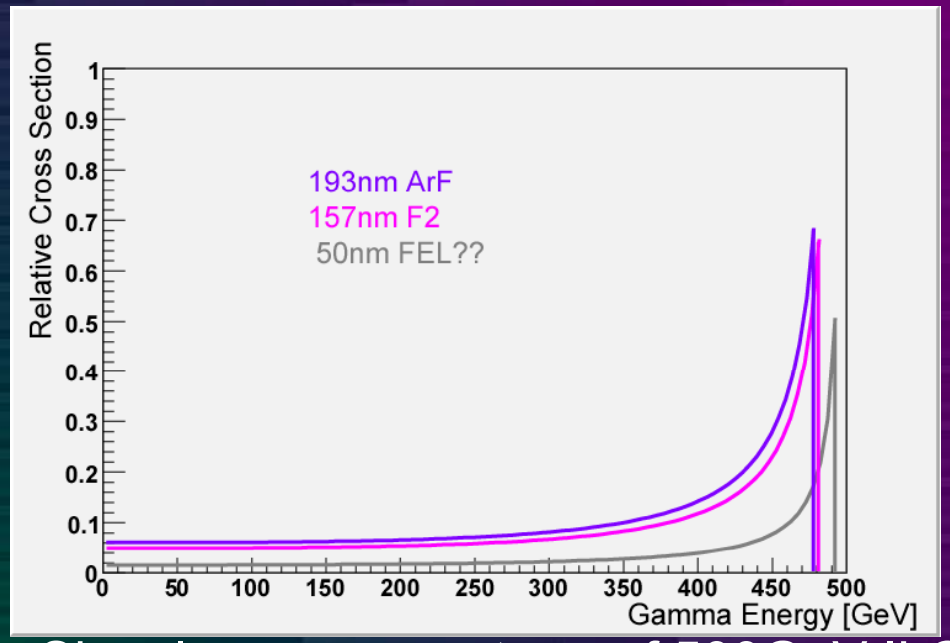
Sensitivity for ILC & ATF2

Resolution for 5nm Measurement

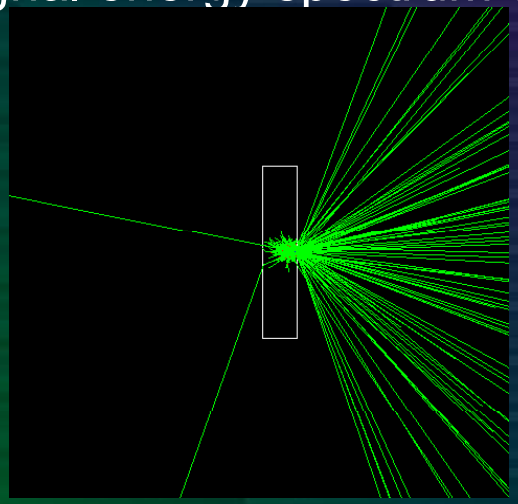
- Assuming 157nm F2 laser
- 3% modulation error (same as ATF2 goal)
  $\rightarrow$ 20% beam size error (5 $\pm$ 1 nm)
- Stability of Laser Fringe Phase
  - Requirement is factor 3.38 harder
    (depend on laser wavelength, 532/157=3.38)
  - 3nm stability required for same condition as ATF2
- Signal photons
  - Compton cross section is around 1/10 of ATF2
    (high energy suppression)
  - At least ~600 photons required for statistics (4%)
    We must raise laser power or decrease laser spot size

Background Sources @ ILC

- Signal photon energy is near beam energy
- Brems. background up to beam energy
  - Beam halo must be collimated upstream
- Synchrotron radiation up to O(100MeV)
  - Must be cut by thick shield just before detector (Pb:10~20cm)



Signal energy spectrum of 500GeV ILC



Most of 100 MeV γ stopped by 20cm Pb shield

Summary

- Shintake monitor aims to measure ATF2 35nm beam size within 2nm error.
- Fringe phase stabilization system was established, 1.5nm (1min.) & 5.6nm (10min.) stabilization achieved using cw. test laser, that meets ATF2 goal stability (10nm).
- Background subtraction by γ detector will be performed using difference about shower development. The detector is under detailed design.
- Collimator for γ can reduce background from final Q to 1%~0.1% (but alignment is difficult because of narrow aperture of the collimator)
- For ILC, 5nm beam size measurement can be done using DUV F2 or ArF laser. 3nm phase stability and other errors same as ATF2 correspond to 5 $\pm$ 1 nm resolution.

Thank you!!