Progress of Shintake Monitor (ATF2 IP-BSM)

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Beam Size Measurement Performance Expectation

- The Shintake optical table was installed at the IP. Performance tests was done and dominant error sources for the beam size measurement were evaluated.
- Main measurements are the following.
  1. Laser interference fringe visibility
  2. Laser position stability
  3. Laser phase stability
- They can be the main error sources of beam size measurement, so we need to evaluate the amount of errors of them.

Contents

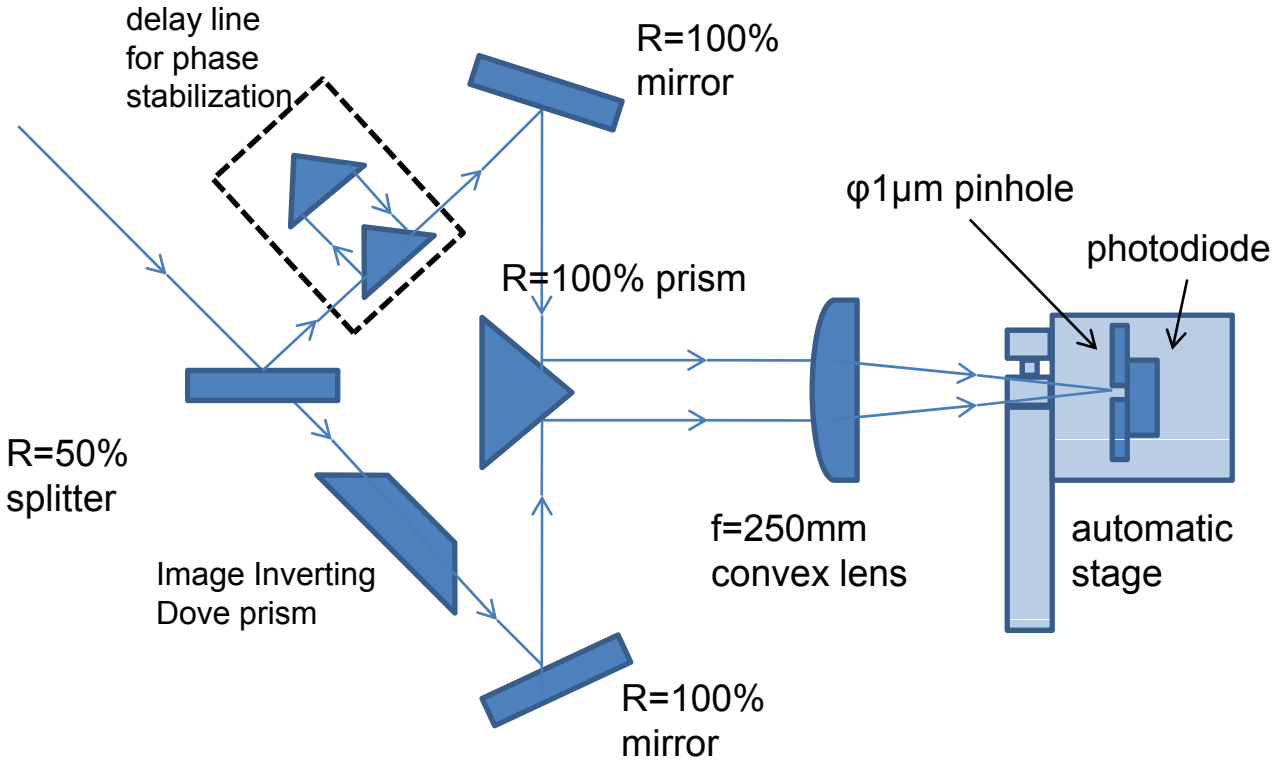
- Introduction of the measurements
- Results of the measurements
  1. Laser interference fringe visibility
  2. Laser position stability
  3. Laser phase stability
- Conclusion
- Schedule from now to Beam Operation

Laser Specification

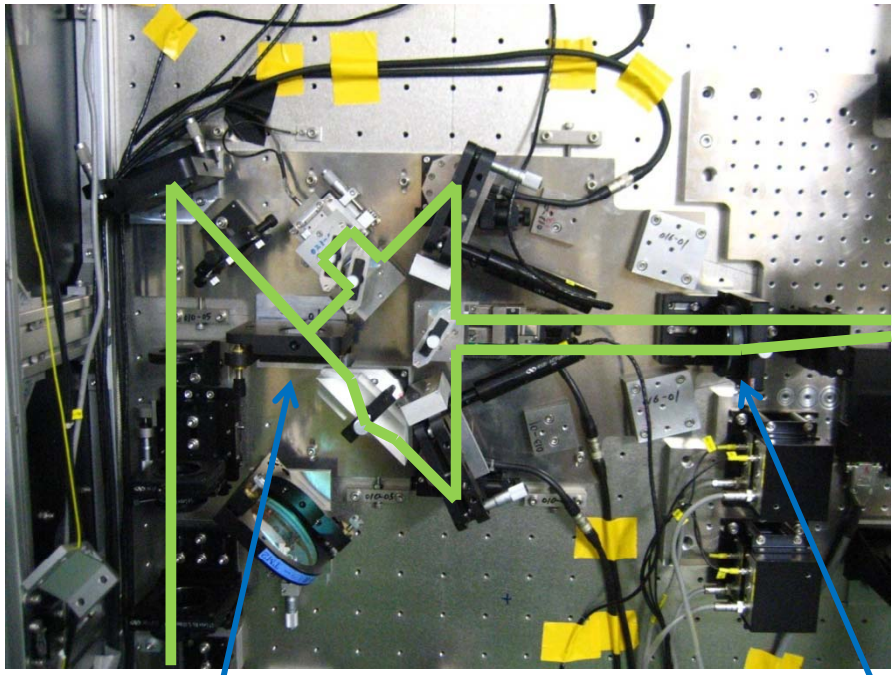
- Pulsed Nd:YAG Laser
- Wavelength: 532 nm (2nd Harmonics)
- Pulse Width: 8 nsec (FWHM)
- Repetition Frequency: 10 Hz
- Maximum Pulse Energy: 400 mJ
- Pointing Stability: ~10 μrad (Measured)

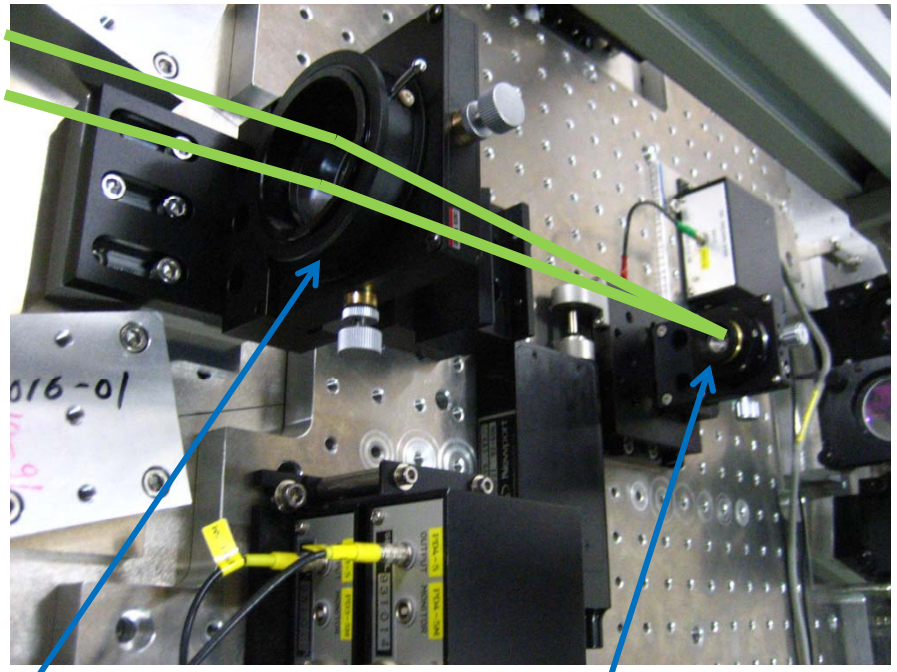
Visibility Measurement of the Laser Fringe

- Scan laser fringe by a photodiode
- ϕ1 μm pinhole is attached in front of the photodiode
- Laser power is also monitored by another photodiode so the laser profile measurement is not affected by the laser power jitter.



Measurement Setup



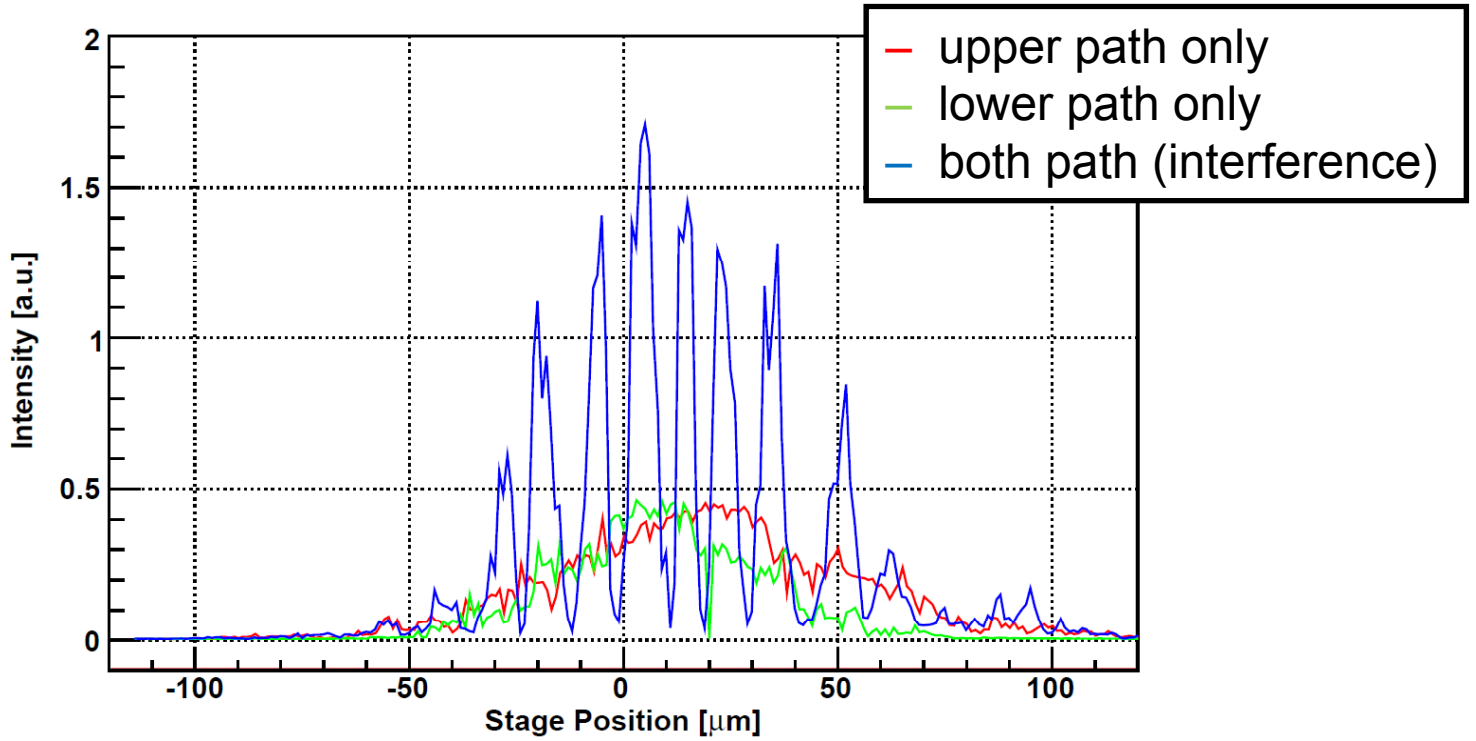


50 % Beam Splitter

f=250 Convex Lens

Pinhole Holder
& Automatic Stage

Measurement Results

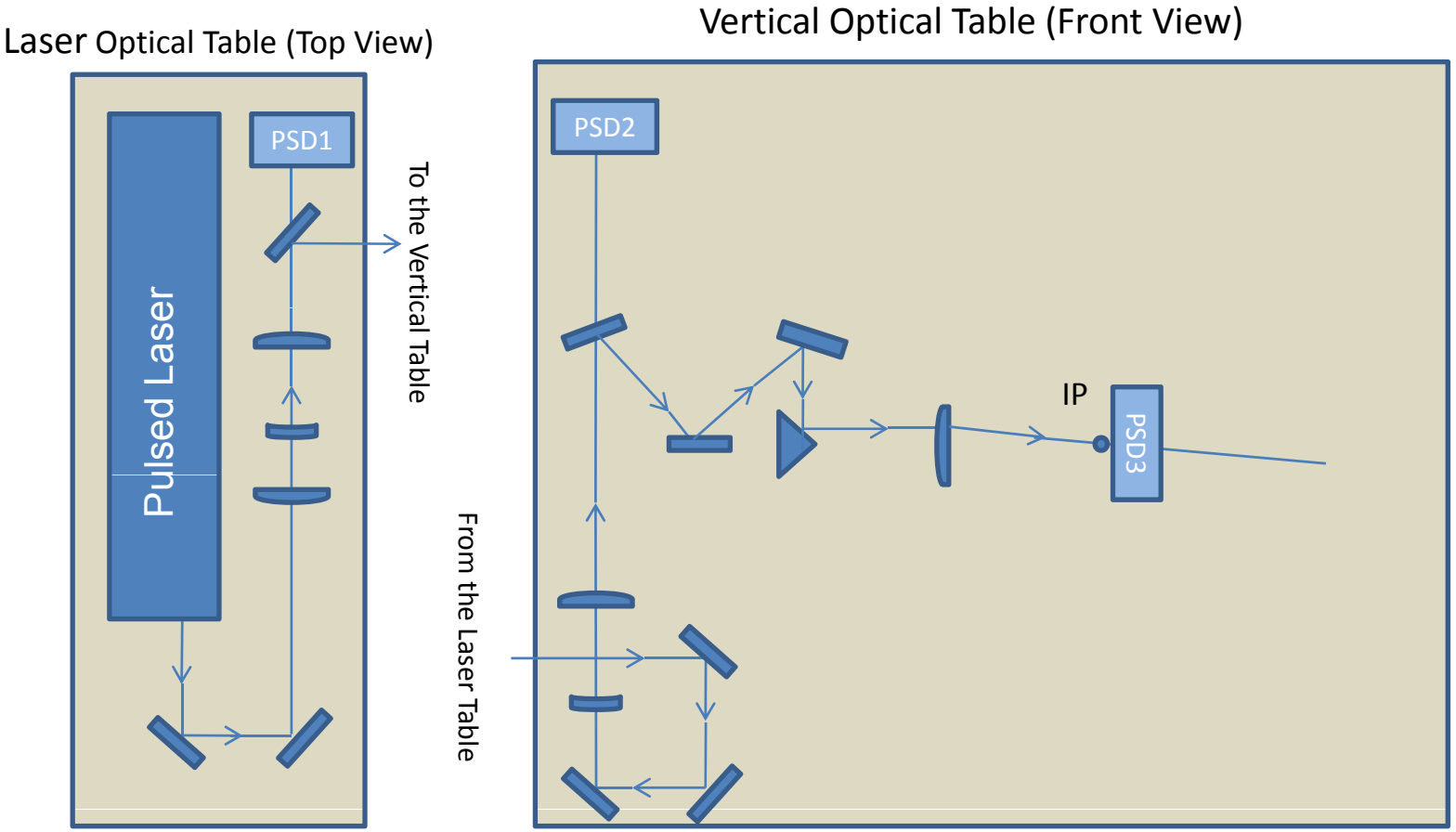


- Visibility = (1.7-0.05)/(1.7+0.05) = 0.94 in this measurement
- Position jitter and phase jitter cause degradation of fringe visibility, this amount of difference from 100 % visibility is possible.
- Irregular pattern of fringe is also caused by position jitter and phase jitter
- Coherency of laser itself is thought be very well and the actual fringe visibility is 100 %.

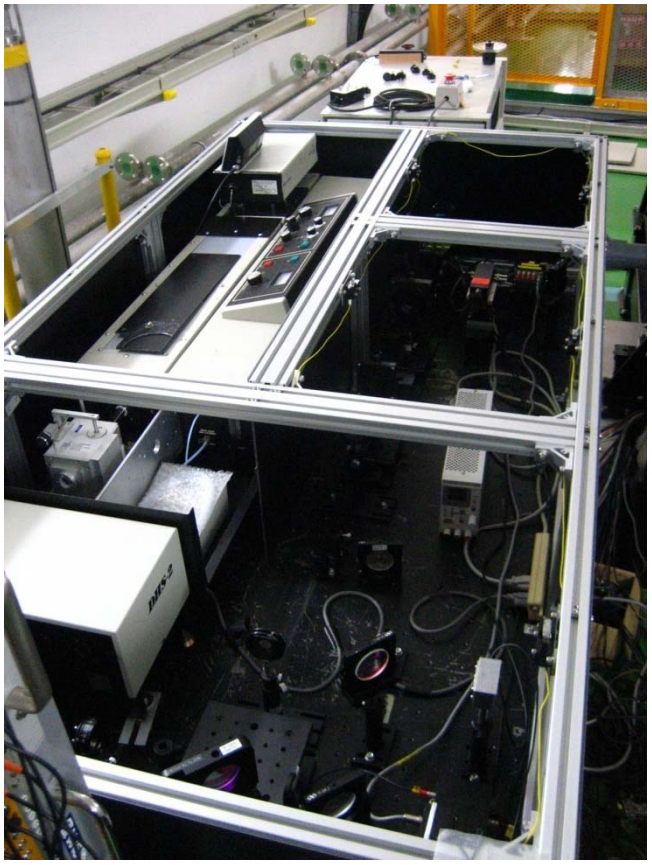
Position Stability

- We use the pulsed Nd:YAG laser and it has large angular jitter. This causes the position jitter at the IP.
- I measured the position jitter at the IP by using the PSD (Position Sensitive Detector).
- We also intend to monitor the laser position at other places and estimate the IP position from these monitored results.

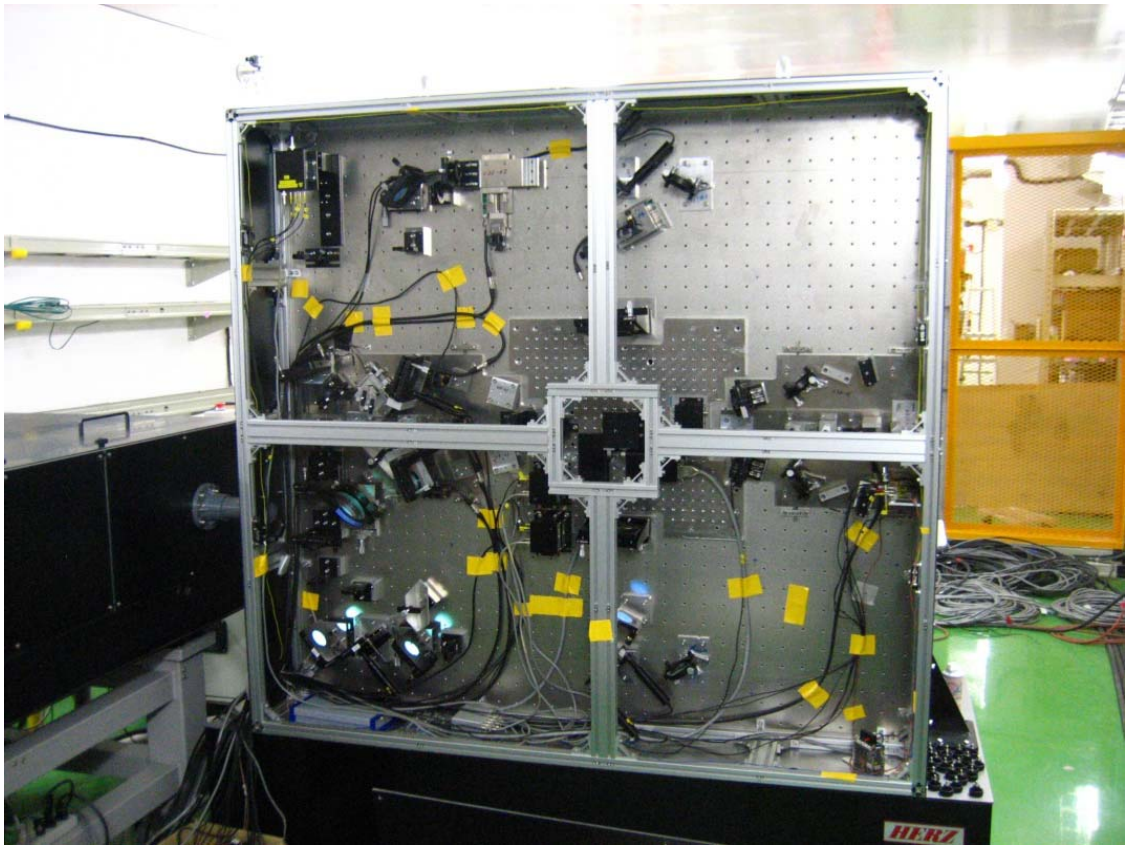
Position Stability Measurement Setup



Measurement Setup



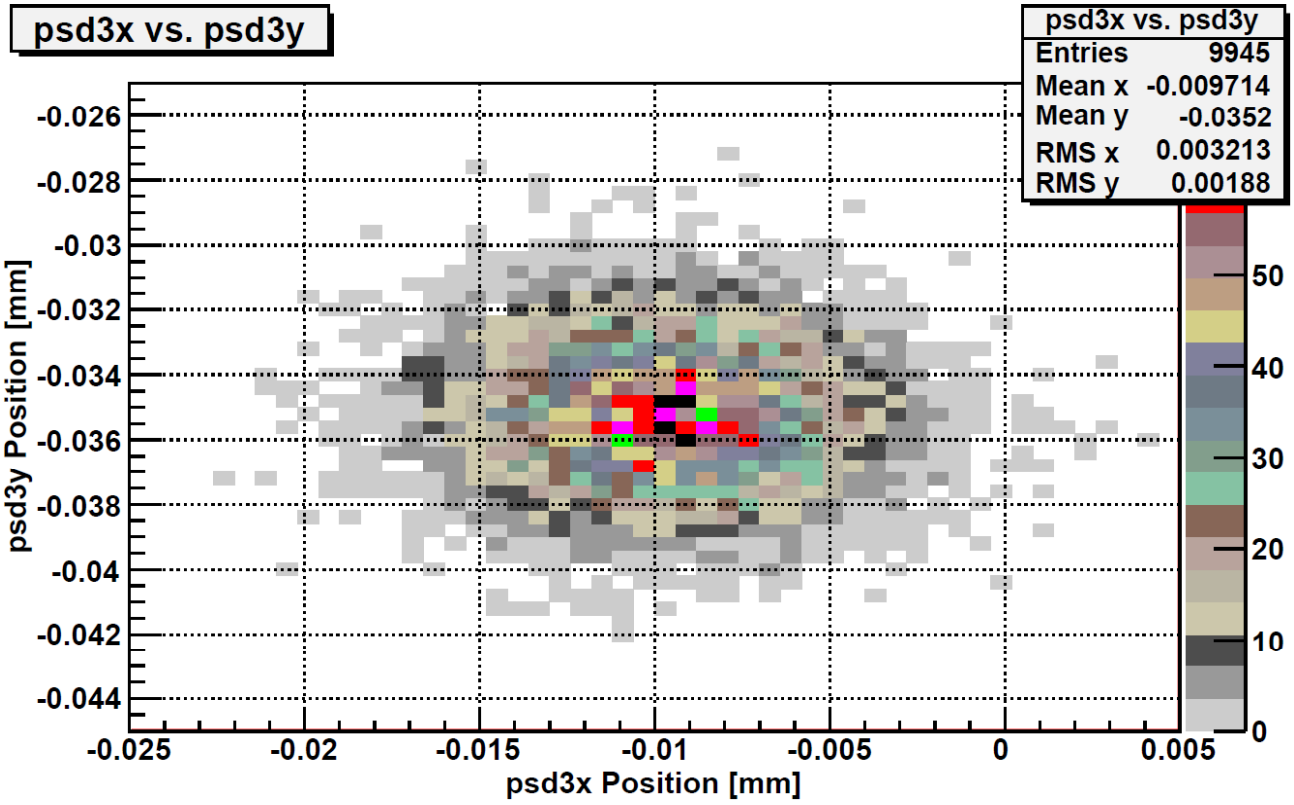
Laser Table



Vertical Table

Measurement Results

Position Stability at the IP
(in 10,000 pulses = 1,000 sec measurement)



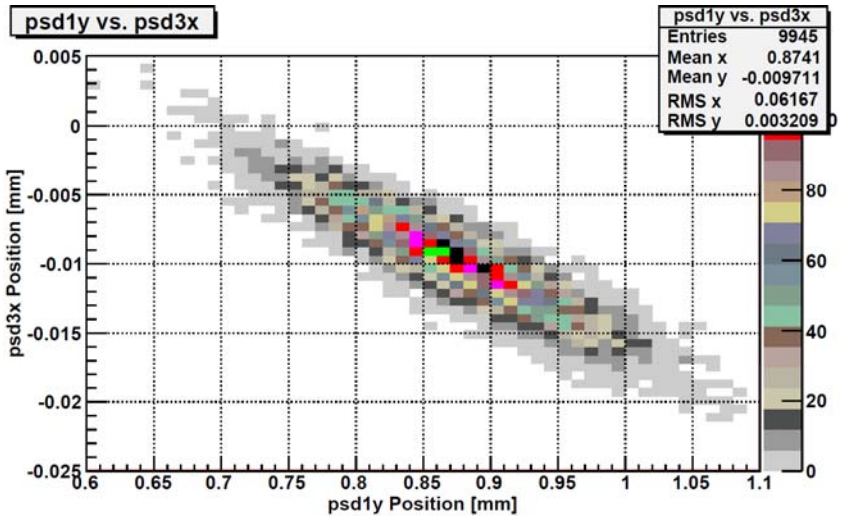
psd3x (vertical direction) : 3.2 μm (RMS)
psd3y(electron beam axis) : 1.9 μm (RMS)

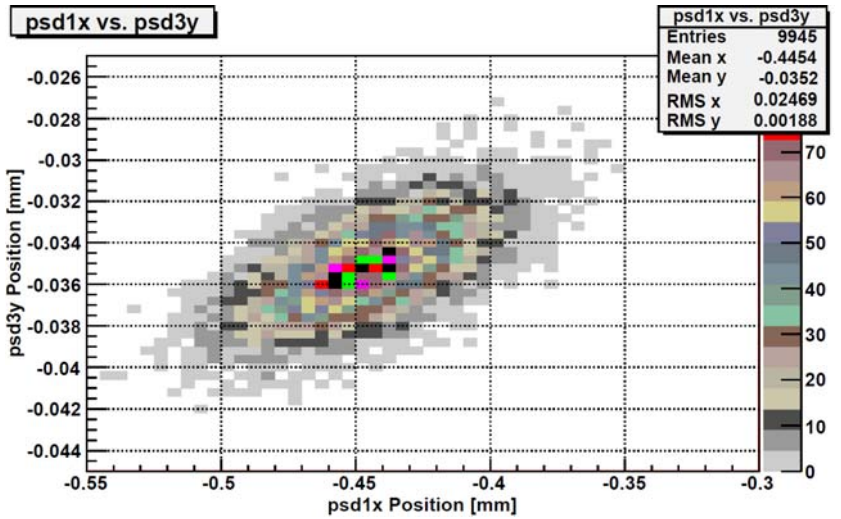
Remarks on the Position Jitter

- The position jitter only affects the laser power at the IP
- Designed laser beam size at the IP is 20 μm (σ= 10 μm), so 3.2 μm and 1.9 μm position jitters correspond to only 5 % and 2 % power reduction respectively.
- Laser position at the IP is monitored by other PSDs indirectly, and we can estimate the position jitter in the actual beam size measurement

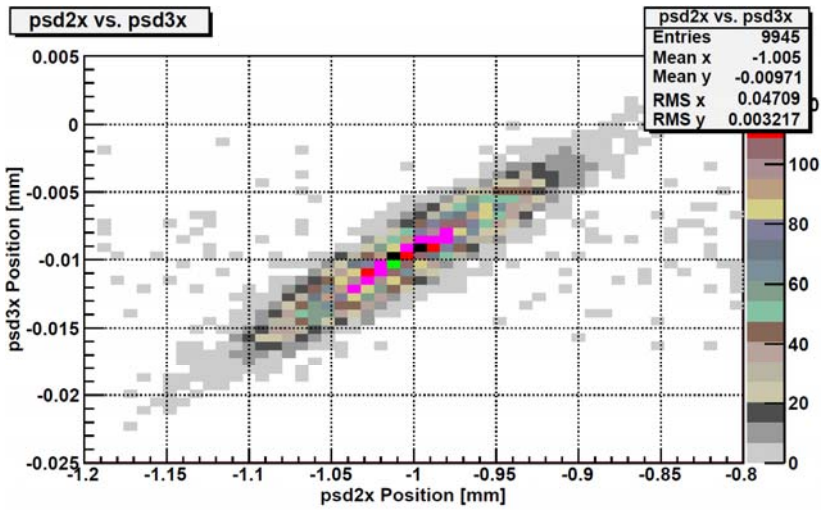
Position Correlation

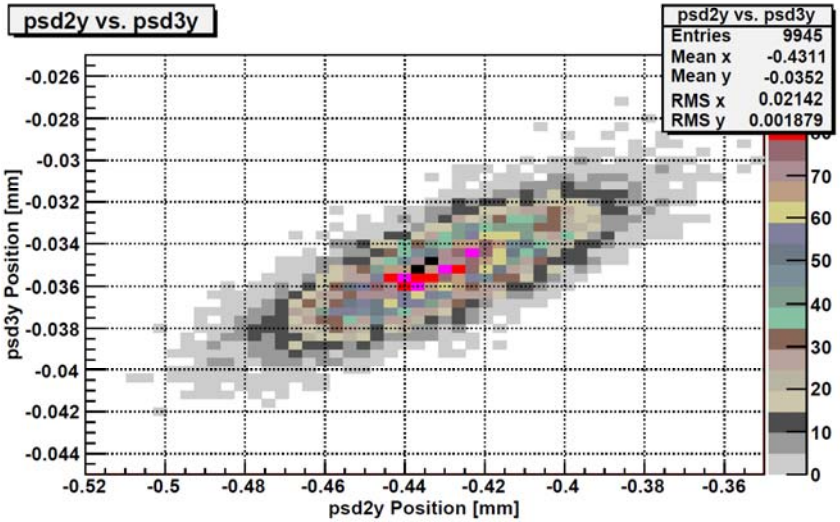
between IP and PSD1





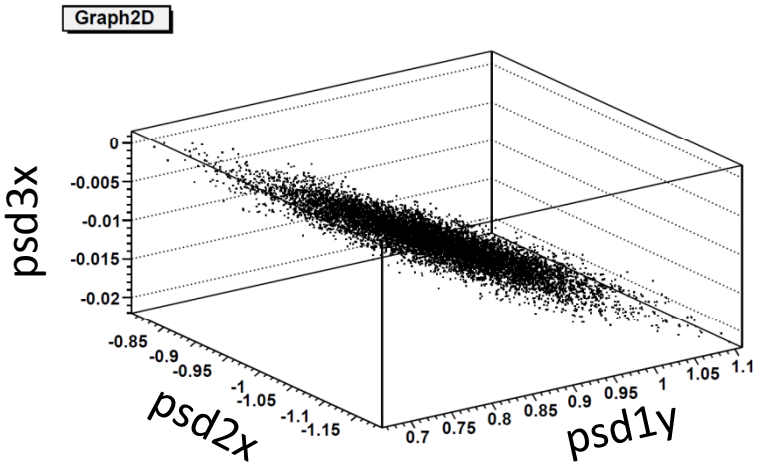
between IP and PSD2



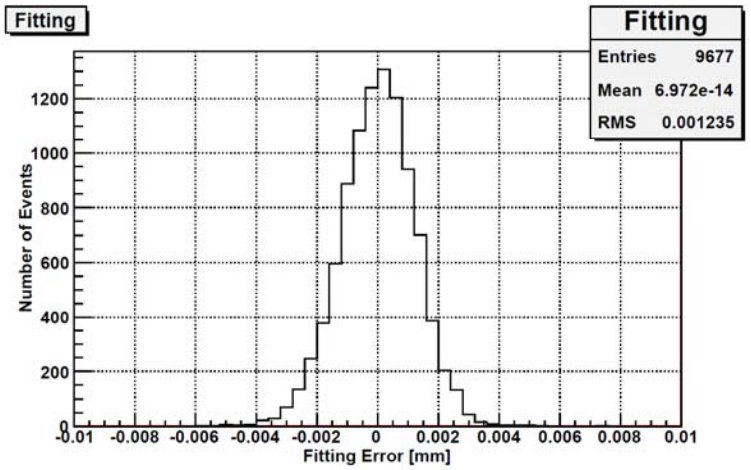


Fitting Result

- By using PSD1 and PSD2 laser position data, we can estimate the laser position at the IP.



Scatter Plot of Position Data



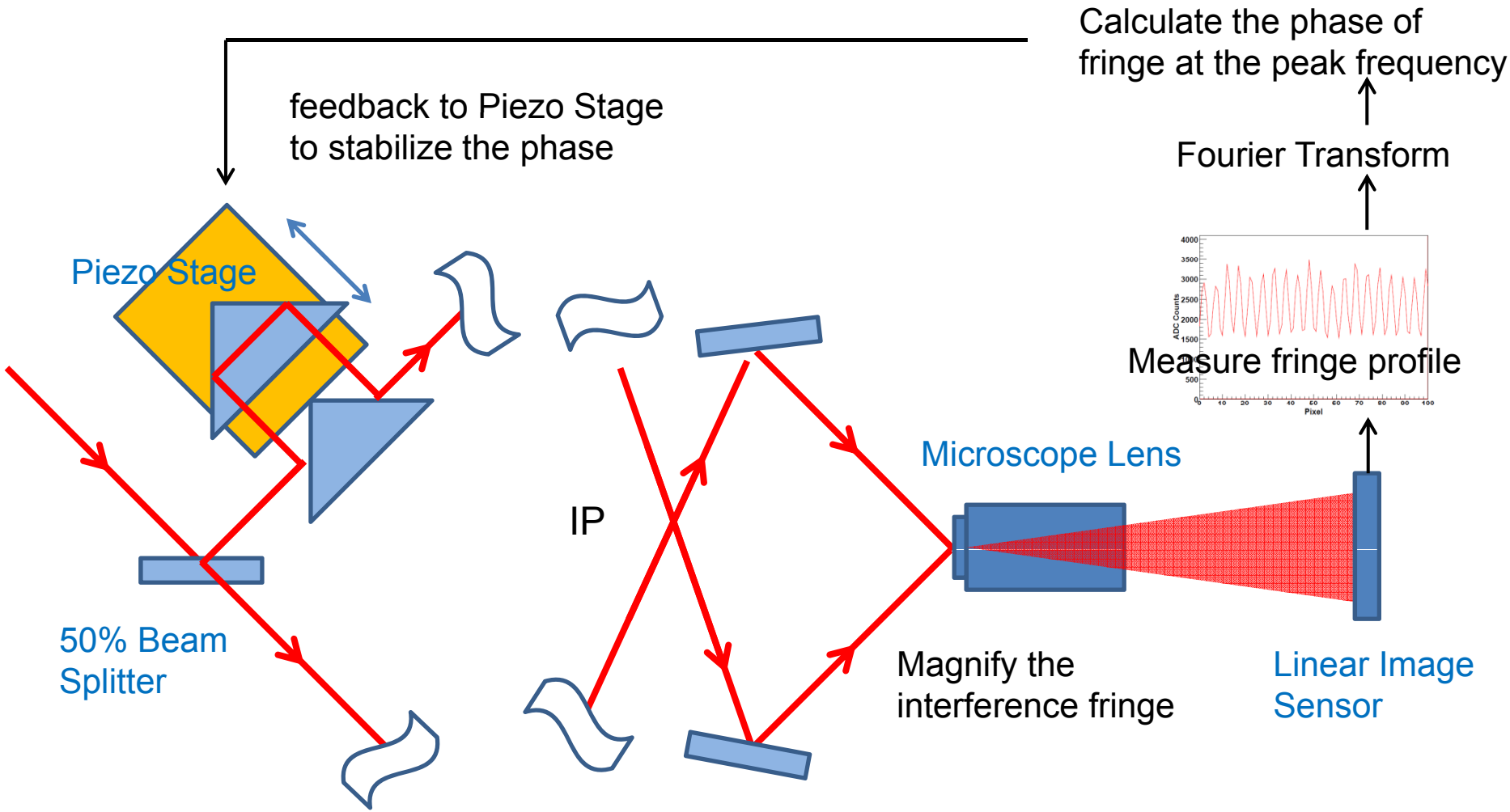
Histogram of Difference between Fitted Position and Measured Position at the IP

Position Stability (Vertical) : 3.2 μm -> 1.2 μm
Position Stability (Beam Axis) : 1.9 μm -> 1.1 μm

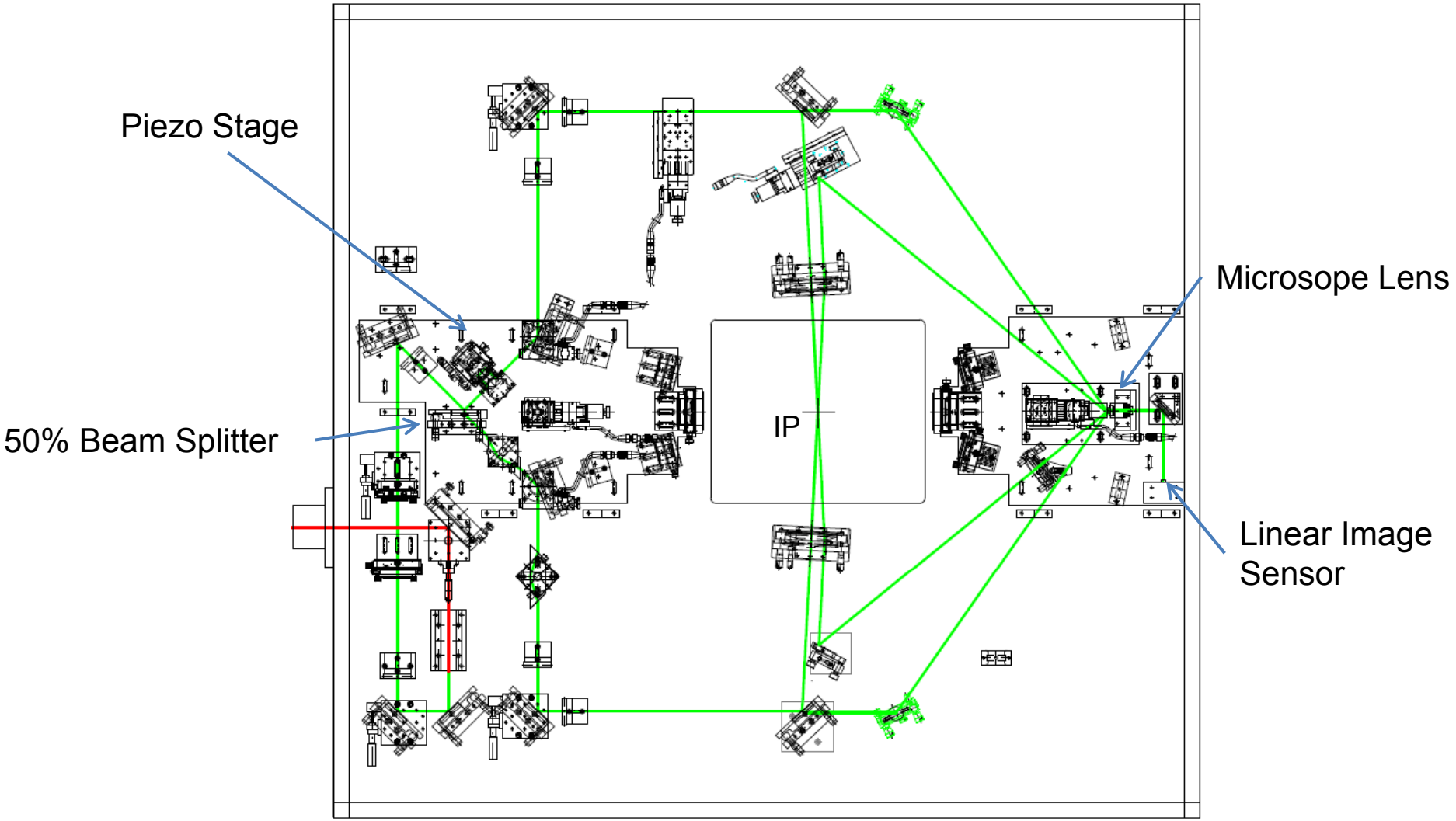
Phase Stability

- Position of peaks and valleys of interference fringe is the laser phase, so the phase stability directly affects the electron beam size measurement
- We need to know the phase stability at the IP but it is impossible to monitor at the IP.
- We designed the phase monitor to estimate the phase jitter at the IP

Principle of Phase Monitor



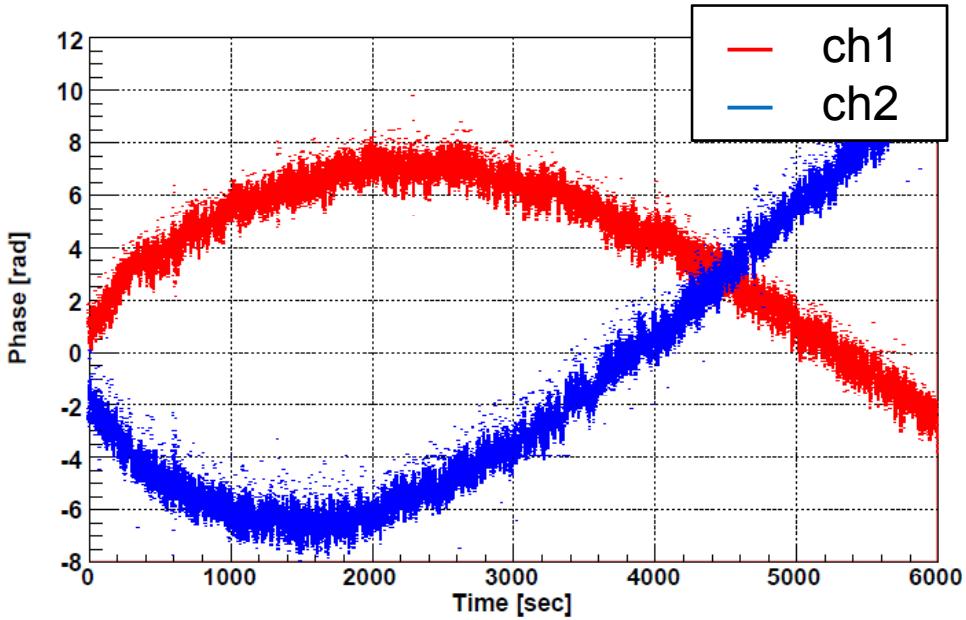
Measurement Setup
（in 174 degree crossing angle mode）

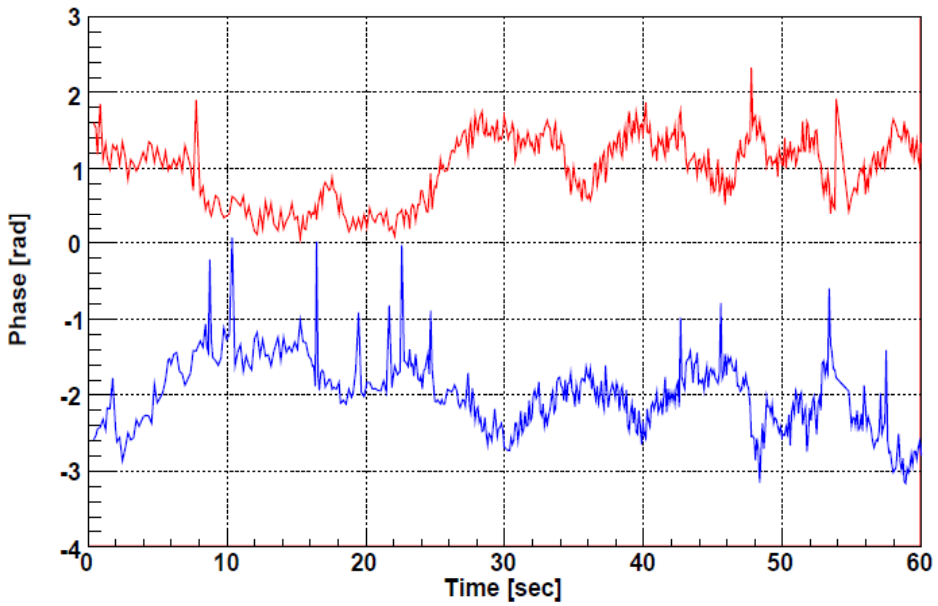


174 degree mode

- the smallest beam size measurement mode
- fringe pitch at the IP is 266 nm
- We set two phase monitor in this mode
- Feedback to the Pieszo stage is determined by the first monitor
- By using the second monitor we can check the result of the stabilization

Measurement Results
（Not Stabilized）





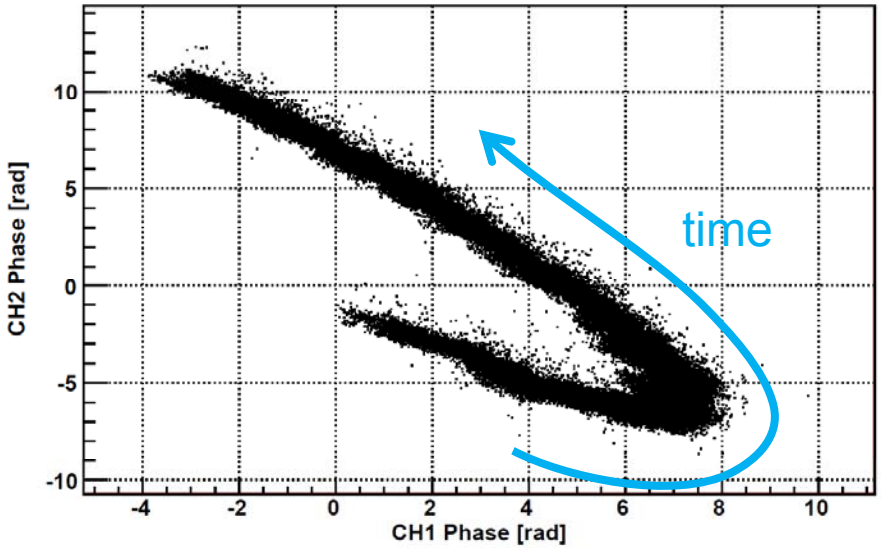
- Long time measurement (6000 sec=100 min)
- There are large drift and small jitter
- It seems to be some correlation between ch1 and ch2 but it is weak

- Short time measurement (60 sec: assumed beam size measurement time)
- Large drift which can be seen in the long time is ignored in this short span.
- There are also small jitter pulse by pulse and seconds order vibration.

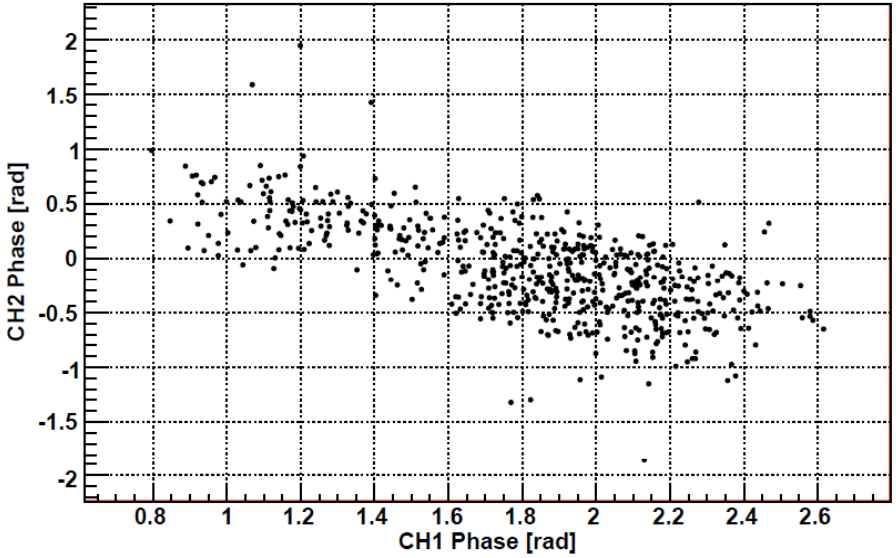
pulse repetition frequency is 10 Hz

Correlation of Phase

Long time (6000 sec)



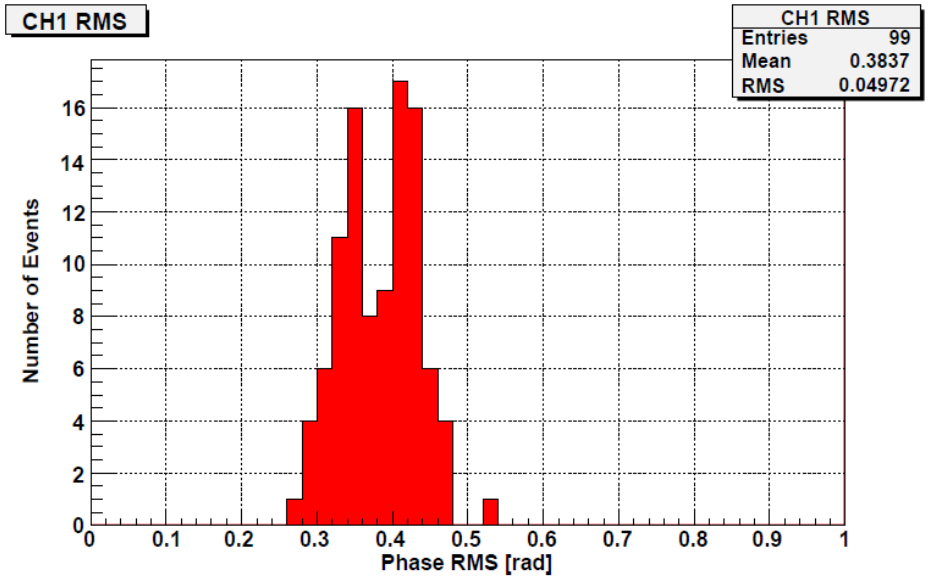
Short time (60 sec)

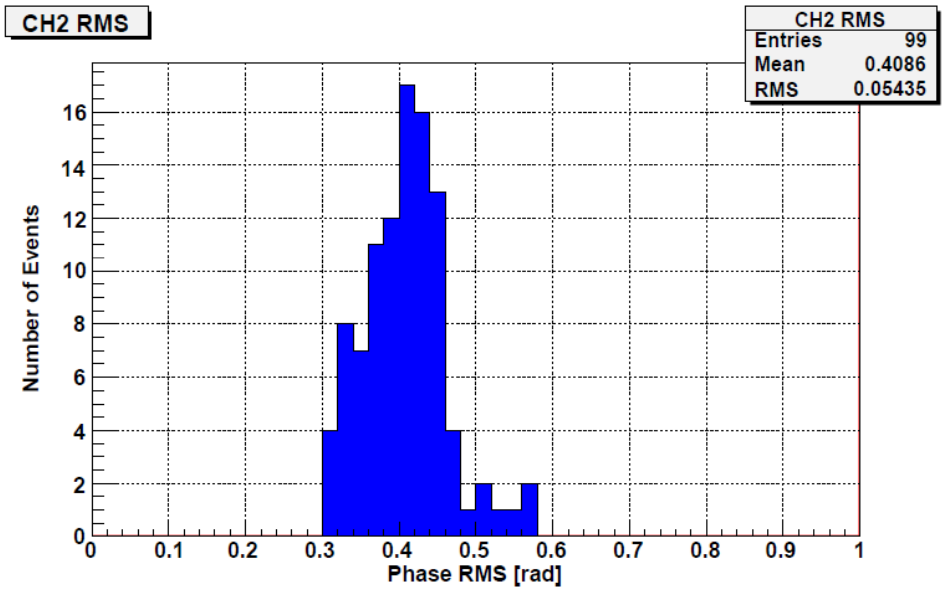


• ch1 and ch2 correlate some extent but it drift in long time

• In short time only weak correlation was seen.

Phase Stability (Not Stabilized)

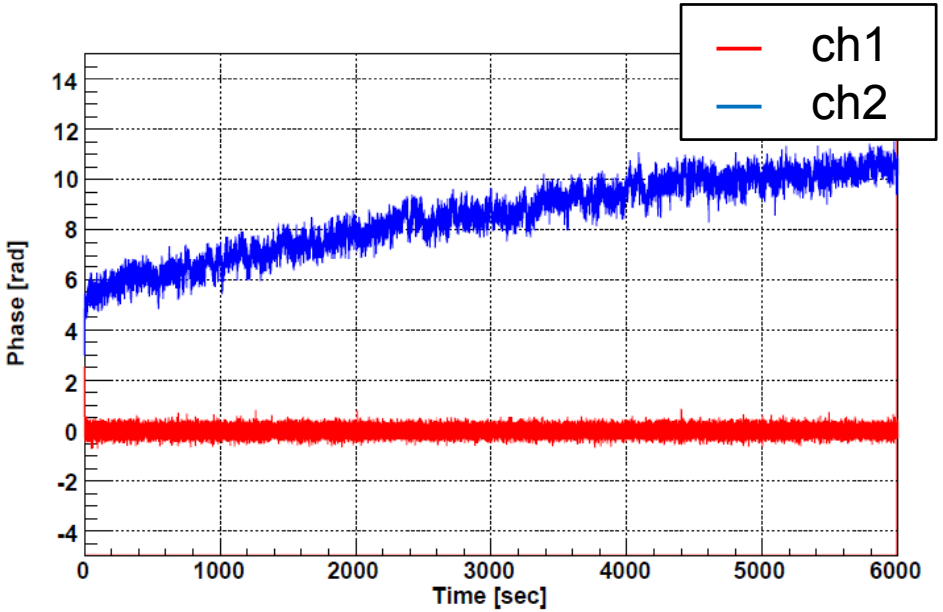


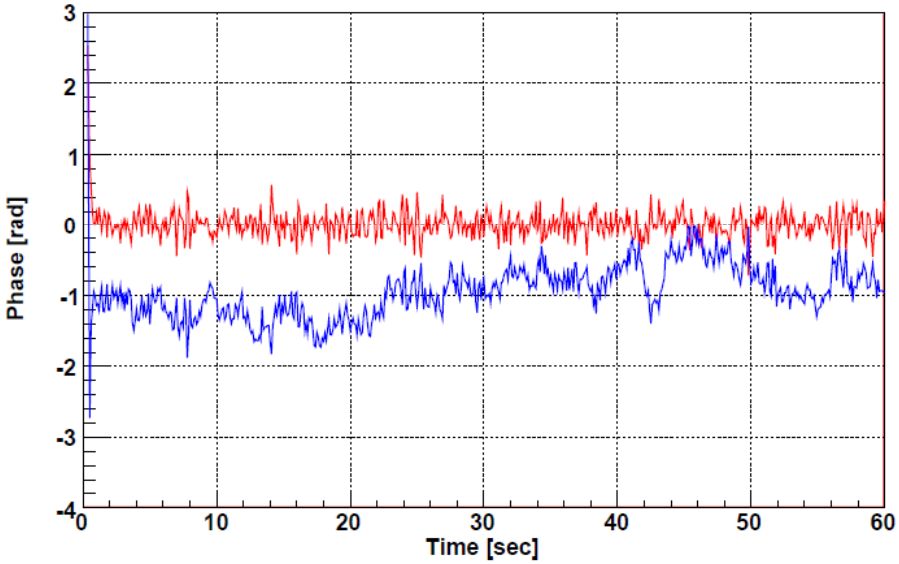


ch1: 1 min Phase RMS = 380 ± 50 mrad
ch2: 1 min Phase RMS = 410 ± 50 mrad

- Results of phase stability in 1 minute measurement
- 400 mrad phase correspond to 16.9 nm in 174 degree crossing mode (266 nm fringe pitch)
- This amount of phase jitter can be problem in the smallest beam size measurement (37 nm).

Measurement Result （Stabilized）

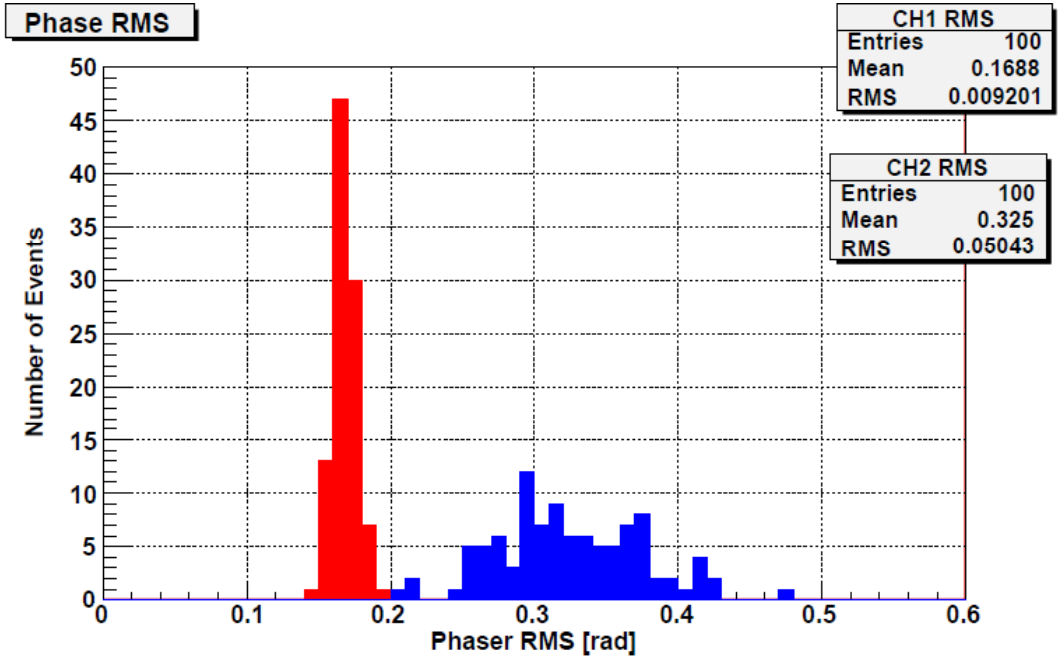




- Long time plot (6000 sec=100 min）
- ch1 is stabilized
- Drift of ch1 was canceled but ch2 was not
- This result indicates that ch1 and ch2 has weak correlation.

- Short time plot (60 sec)
- Long time drift is also negligible.
- Small jitter pulse by pulse is remained in both channels but seconds order vibration is canceled in ch1.
- However, this vibration is remained in ch2

Phase Stability (Stabilized)



ch1 1 min Phase RMS :
169 ± 9 mrad

ch2 1 min Phase RMS :
325 ± 50mrad

- Phase jitter of stabilized channel is well reduced
- Not stabilized channel gets better only a little.
- Phase stability at the IP is assured only ch2 level in this measurement.
- 325 mrad correspond to 13.8 nm (266 nm fringe pitch) and it is a little bit large for our goal.

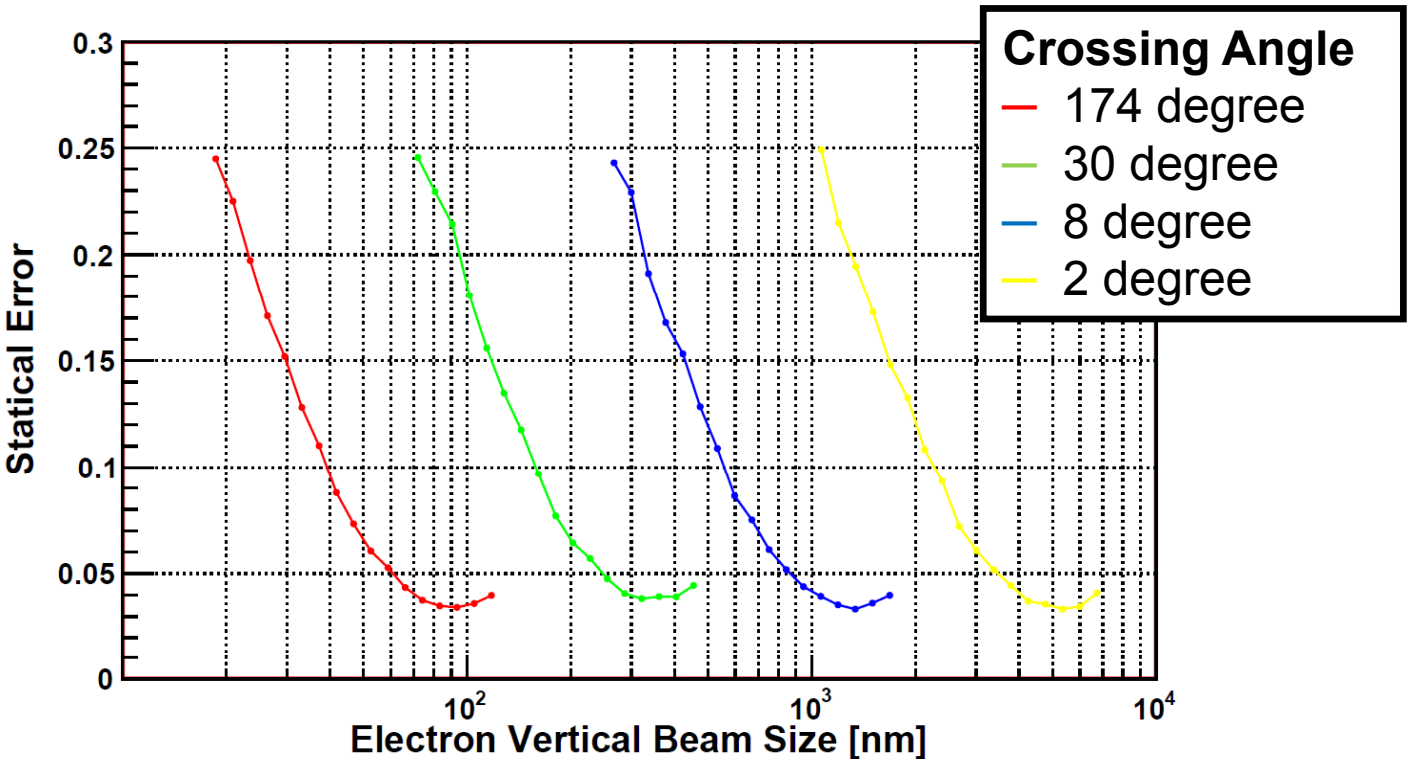
Conclusion

- Visibility of the laser fringe is 100 %
- Position stability at the IP are 3.2 μm and 1.9 μm for vertical and beam axis respectively, which correspond to 5 % and 2 % laser power jitter. They are small enough!
- Phase jitter is estimated to be a littel bit large to measure the small beam size. We may need some improvement on the detectors or devices.

Resolution of Beam Size Measurement

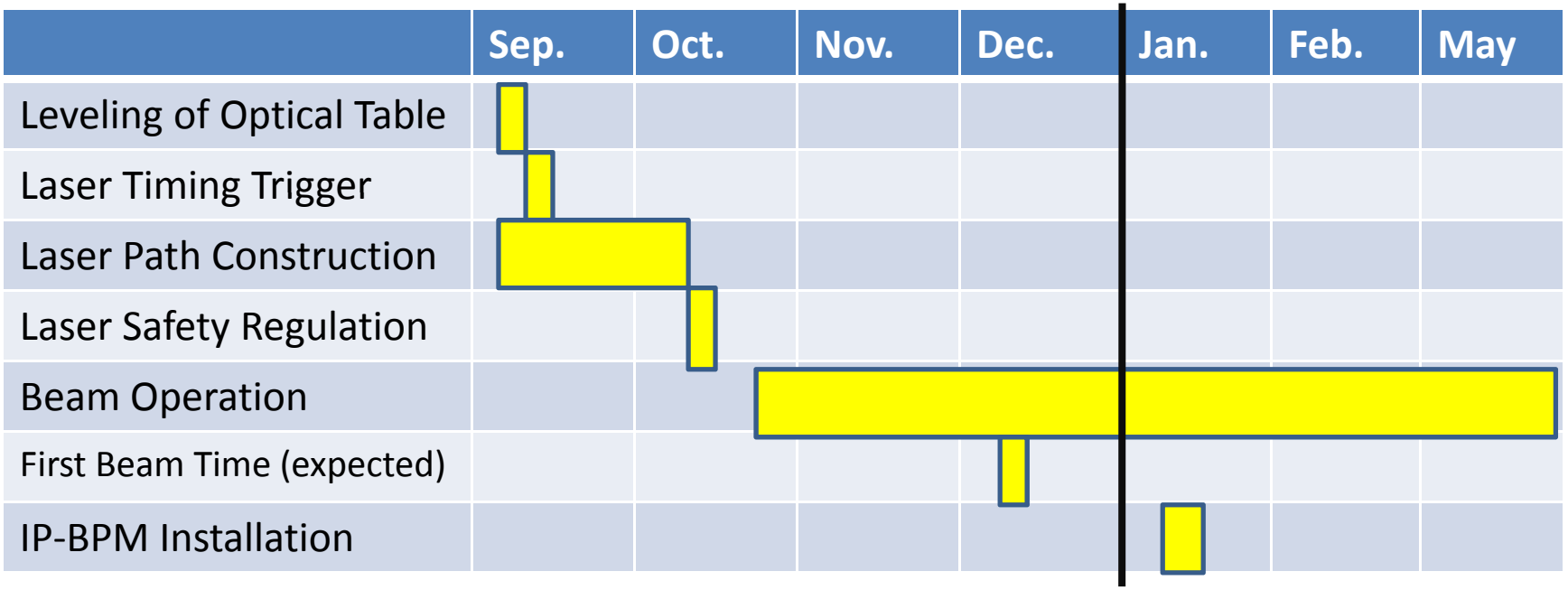
- Resolution estimation by using above values
- Here, 4000 Compton scattered photon (Signal) and 300 Background photon jitter are assummed
- Power jitter 5 %
- Phase jitter 325 mrad
- Beam Frequency 1.5 Hz and measurement time 1 min -> 45 pulse is assumed

Result of Resolution Calculation



- Calculation was done by using primitive fitting method.
- Large phase jitter causes large systematic error (not included in this figure), so reduction of phase jitter is needed. If cannot, correction of the systematic error is needed by using the amount of phase jitter.
- Power jitter is not so dominant in this condition.

Schedule


Sep.
Oct.
Nov.
Dec.
Jan.
Feb.
May
Leveling of Optical Table
Laser Timing Trigger
Laser Path Construction
Laser Safety Regulation
Beam Operation
First Beam Time (expected)
IP-BPM Installation