Current Status of Nanometer Beam Size Monitor for ATF2

TIPP 2011
Chicago, 11 Jun. 2011

Yohei Yamaguchi
M. Oroku, J. Yan, Y. Kamiya, S. Komamiya
T. Yamanaka, T. Suehara
T. Okugi, N. Terunuma, T. Tauchi, S. Araki, J. Urakawa
Shintake Monitor’s largest difficulty at present

= Laser crossing angle mode switching

- What’s mode switching?
- Obstacles in mode switching
- Strategies for resolving difficulty
Mode switching

During mode switching, two laser beams must be realigned at the IP using different laser paths.

The modulation must be reconstructed from scratch.

For good interference fringe contrast, laser pathway requires alignment precision of a few microns.

Otherwise, we lose the signal modulation.
Crossing angle & modulation depth

Interference fringe pitch \( (d) \) depends on laser crossing angle \( \theta \)

\[
d = \frac{\pi}{k \sin \frac{\theta}{2}}
\]

Measurable beam size range (proportional to fringe pitch) **controlled by mode switching**

2-8, 30 and 174 deg crossing modes
Crossing angle & modulation depth

During beam tuning, beam size gets smaller step by step

We change the mode accordingly

Beam Tuning
Crossing angle & modulation depth

Mode switching causes sudden modulation drop

→ Modulation is easily lost during mode switching

Beam Tuning
For example:
In 2010 we could not reconstruct modulation when switching to 30 deg mode
Main cause for losing modulation: signal jitter > modulation depth

No signal jitter

Large signal jitter
Run of early 2010

Signal jitter: 20%
already large jitter
M = 0.32
S/N = 30
beam size resolution: 9%

Most recent run

Signal jitter: 30%
too large jitter
M = 0.35
S/N = 0.6
beam size resolution: 12%

Large signal jitter hinders modulation reconstruction
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources
Sources of signal jitter

- **High BG**: increased 10 times from early 2010
- **Low signal**: decreased down to 1/5 of early 2010
- **Laser orbit fluctuation**
- **Beam size jitter**: typically 20%
- **Other jitter sources**

**early 2010:**
- tentative large $\beta_y(x)^*$ beam optics

**optics with design $\beta_y(x)^*$**
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources

bending magnet
Bremsstrahlung generated at final bending magnet can enter gamma detector

Plan to install additional collimator to cut this radiation
Sources of signal jitter

**High BG**
increased 10 times from early 2010

**Low signal**
decreased down to 1/5 of early 2010

**Laser orbit fluctuation**

**Beam size jitter**
typically 20%

**Other jitter sources**

**other BG sources**

ATF2 beam line

IP
Gamma Detector

Extraction + FF line

BGs generated upstream can also reach gamma detector

We are trying to identify sources of BG
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources

bad laser profile
design spot size: 10 μm
measured spot size: 20 μm
affects local laser power density at IP

Total laser pulse power and beam current are satisfactory
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation
• suspected to be a dominant jitter source
• under evaluation with Position Sensitive Detectors
• hardware upgrade for stabilization is going on

Beam size jitter
typically 20%

Other jitter sources
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

**Beam size jitter**
typically 20%

Other jitter sources

Beam size fluctuation can cause signal instability

- This can be constantly monitored by...
  1. beam profile monitor
  2. Q-magnet current monitor
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources

<Checked>
1. relative position jitter
< 200 [mrad] (8 deg mode)

Electron Beam
Beam Position Jitter

Laser Interference Fringe
Fringe Position Jitter
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources

<Checked>
1. relative position jitter
   < 200 [mrad] (8 deg mode)

2. laser power fluctuation
   0.9 % (May 2010)
   2 % (Dec. 2010)

3. beam current fluctuation
   2 - 5 % (measurement resolution)

4. laser timing fluctuation
   600 ps (May 2010)
   900 ps (Dec. 2010)
   (pulse width: 8 ns (FWHM))

These are negligibly small
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

<Still Checking>
1. beam trajectory fluctuation
can be measured with BPMs and correctable

Other jitter sources
Sources of signal jitter

High BG
increased 10 times from early 2010

Low signal
decreased down to 1/5 of early 2010

Laser orbit fluctuation

Beam size jitter
typically 20%

Other jitter sources

<Still Checking>
2. signal separation from BG using shower development in gamma detector degraded when BG spectrum changes
Example of hardware upgrade: laser orbit stabilization

- Laser orbit feedback system with PSDs and mirror actuators
- Stabilizing and monitoring laser system temperature
- Heat insulation box
- Vibration removal in laser transport
- Laser position fluctuation at IP: $\sim 10 \mu m \rightarrow \sim 1 \mu m$
Most recent run

Suppressed signal jitter (simulated)

Signal jitter: 30%

Signal jitter < 10%

Hardware upgrade

• additional collimator
• laser profile improvement
• laser orbit stabilization
• etc...
We are commissioning 30 deg mode...

Because mode switching is challenging...
long time is needed to detect modulation when switching to 30 deg mode

measurable range at 8 deg
Detecting modulation takes time → beam and laser become unstable
Time taken should be below 1 hour

**After hardware upgrades, we can switch modes quicker and easier**

![Graph showing measurable range at 8 deg](image)
Status and plan

Commissioning 30 deg mode then 174 deg mode
Suppressing signal jitter is important

Main candidates for signal jitter at 8 deg mode are...
1. high BG from bending magnet
2. bad laser profile
3. laser orbit fluctuation

To suppress the jitter, we are upgrading our system
The upgrade will finish by this autumn

Beam trajectory fluctuation is significant for 30 deg mode
At 100 nm beam size, beam trajectory jitter must be below 50 nm
IP-BPM resolution must be below 30 nm
Recovery from the earthquake
We improved earthquake resistance of our system.

Performance of all devices are being inspected

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>laser</td>
<td>realigned oscillator working well</td>
</tr>
<tr>
<td>DAQ</td>
<td>still being checked</td>
</tr>
<tr>
<td>control system</td>
<td>working well</td>
</tr>
<tr>
<td>gamma detector</td>
<td>still being checked</td>
</tr>
<tr>
<td>optical system</td>
<td>being realigned</td>
</tr>
<tr>
<td>monitors for laser</td>
<td>still being checked</td>
</tr>
</tbody>
</table>

ATF2 radiation shield repair
2011/5/14
Summary

Signal modulation can easily be lost during mode switching

Resolution degradation due to signal jitter hides the modulation

Sources of signal jitter are under investigation

Hardware upgrades for 30 deg mode are undergoing

We will finish upgrading and be ready to measure under 100 nm beam size by this autumn
backup
In spite of good resolution, discovery of modulation is difficult

Modulation depth is saturated
How to evaluate the **relative position jitter**

This plot shows the interference scan

From this plot, we evaluate relative position jitter
How to evaluate the **relative position drift**

![Graph showing the initial theta of interference scan over time]

---

*May 2010*