Observation of Mechanical Triplet Vibrations in RHIC

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Overview of RHIC:

Superconducting two-ring heavy ion collider, 3.8 km circumference, $\gamma_{\text{Au}} \approx 100$. 
Spectra of horizontal BPM signals in both rings:

Total amplitude corresponds to $\approx 5\ldots10\%$ of the rms beam size.

Similar spectra $\rightarrow$ common source.
Schematic overview of a RHIC interaction region:

Triplet quadrupoles share a common cold mass for both beams.
Spectra of horizontal beam and triplet motion (IP 4 triplet):
Dominant frequency lines in the horizontal BPM spectrum, and corresponding triplet locations:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Triplet</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.75</td>
<td>12</td>
</tr>
<tr>
<td>8.825</td>
<td>8</td>
</tr>
<tr>
<td>10.14</td>
<td>4, 11, 12</td>
</tr>
<tr>
<td>10.625</td>
<td>9</td>
</tr>
<tr>
<td>10.825</td>
<td>2</td>
</tr>
<tr>
<td>11.00</td>
<td>11</td>
</tr>
<tr>
<td>11.325</td>
<td>6</td>
</tr>
<tr>
<td>12.700</td>
<td>(10)</td>
</tr>
<tr>
<td>13.000</td>
<td>1</td>
</tr>
<tr>
<td>13.275</td>
<td>unknown</td>
</tr>
<tr>
<td>13.55</td>
<td>9, (2)</td>
</tr>
<tr>
<td>14.325</td>
<td>2</td>
</tr>
<tr>
<td>15.950</td>
<td>2</td>
</tr>
<tr>
<td>16.133</td>
<td>4</td>
</tr>
<tr>
<td>16.500</td>
<td>8</td>
</tr>
</tbody>
</table>
Mechanical resonance frequencies of the cold masses in the cryostat.

Mechanical model:

\[
\begin{array}{c}
\begin{array}{ccc}
\hline
\text{Quadrupole} & f_d/\text{Hz} & f_q/\text{Hz} \\
\hline
Q1 & 21.2 & 15.8 \\
Q2 & 14.0 & 14.3 \\
Q3 & 15.0 & 14.1 \\
\hline
\end{array}
\end{array}
\]

- Resonance frequencies of this simple model are very close to observed ones.
- Vibrations disappeared when machine was warmed up.
RMS closed orbit distortion:

\[ \sigma_{\text{co}}(s) = \frac{\sqrt{\beta(s)} \sqrt{\langle \beta \rangle}}{2 \sin \pi \nu} \frac{\sigma_q}{|f|} \sqrt{N} \]

Observed rms beam jitter corresponds to rms quadrupole jitter amplitudes of \( \sigma_q \approx 0.5 \mu m \). For the triplets as a whole, \( \sigma_{\text{triplet}} \approx 10 \mu m \).

Measured rms amplitudes on triplet cryostats are 200 nm at most.

→ Beam jitter is caused by vibration of the cold masses within the cryostat, rather than by motion of the entire triplet.
Anti-symmetric IR optics results in relative beam offset at IPs:
Modulated beam-beam interaction may be the source of emittance growth at the begin of each luminosity run:

Simulation studies are in progress to investigate this effect.
Conclusion

- IR triplet vibrations have been identified as source of horizontal beam jitter around 10 Hz.
- Driving force seems to be related to cryo system.
- Measurements inside one triplet beam pipe in progress.
- Plan to permanently attach accelerometers to cold masses in one triplet.
- Modulated beam-beam offset probably causes emittance dilution at the beginning of each luminosity run (needs to be investigated).