INTRODUCTION

Motivation
- Effect of electron cloud by observing transverse dipole oscillation

Objectives
- Coupled bunch instability by the electron cloud
- Focussing by the electron cloud
- Head-tail oscillation - synchrotron sideband
MEASUREMENTS AND ANALYSIS

- Filling pattern 1/1153/4/different beam current
- Bunch oscillations were recorded by BOR
  (a high-speed data recording system, KEKB)
- Recorded turn-by-turn for 4096 turns after feedback off
- $\nu_\beta$ - bunch by bunch ffts of the bunch oscillation data
- Correction to those transformed data - $e^{i\omega_\beta \Delta t}$
- Snapshot-like data - inverse fft
- Mode spectrum - turn-by-turn ffts of snapshot data after zero padding
- Growth rates - fits to the growth part
Figure Bunch oscillation recorded by BOR

Figure Growth rate fit of a bunch oscillation
FIGURE Mode spectrums observed in LER when solenoids on a) Horizontal and b) Vertical
Figure Comparison of mode spectrums in solenoids on and off cases at 600 mA beam current
Growth rate changes with beam current in LER
- Mode spectrums are different in solenoids on and off.
- Growth rates linearly increase with beam current.
- Growth rates improve ~35% due to solenoids on.

### Table: Mode of instability

<table>
<thead>
<tr>
<th>Beam current</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solenoids ON</td>
<td>Solenoids OFF</td>
</tr>
<tr>
<td>300 mA</td>
<td>12</td>
<td>-</td>
</tr>
<tr>
<td>600 mA</td>
<td>12</td>
<td>822</td>
</tr>
<tr>
<td>900 mA</td>
<td>35</td>
<td>-</td>
</tr>
</tbody>
</table>

### Table: Growth rates

<table>
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</thead>
<tbody>
<tr>
<td></td>
<td>Solenoids ON</td>
<td>Solenoids OFF</td>
</tr>
<tr>
<td>300 mA</td>
<td>701</td>
<td>-</td>
</tr>
<tr>
<td>600 mA</td>
<td>1506</td>
<td>2037 (35%)</td>
</tr>
<tr>
<td>900 mA</td>
<td>1942</td>
<td>-</td>
</tr>
</tbody>
</table>

|              | Solenoids ON | Solenoids OFF |
| 300 mA       | 59          | -        |
| 600 mA       | 1059       | 1397 (32%) |
| 900 mA       | 2083       | -        |
Figure Horizontal tune shift changes along positron bunch train
**Figure** Vertical tune shift changes along positron bunch train

- **Solenoids off, 600 mA (bunch current 0.52 mA)**
- **Solenoids on, 600 mA (bunch current 0.52 mA)**
**Figure** Horizontal and vertical tune shifts (600 mA)  
**Figure** Tune shift versus beam current
For both cases of solenoids on and off, the horizontal and vertical tune shifts increase with bunch id and tends to saturate.

The saturated tune shift increases with increasing beam current both in horizontal and in vertical directions.

Both vertical and horizontal tune shifts of saturation are higher when solenoids are off.

Vertical tune shift of saturation is higher than horizontal one in solenoids on case.

Horizontal and vertical tune shifts of saturation are approximately the same when solenoids off.
**Figure** Bunch-by-bunch ffts of LER Horizontal a) solenoids on, b) solenoids off
**Figure** Bunch by bunch fft of LER (Vertical) / solenoids on and off
Figure Tune with beam current

Figure Synchrotron side band frequency

\[
\frac{\omega - \omega_B}{\omega_s}
\]
**Figure** Tune with beam current

**Figure** Synchrotron side band frequency

\[
\frac{(\omega - \omega_{\beta})}{\omega_s}
\]
### SUMMARY 3

- **Synchrotron side band appearance**

<table>
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<th><strong>Vertical</strong></th>
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<tbody>
<tr>
<td></td>
<td>Solenoids ON</td>
<td>Solenoids OFF</td>
</tr>
<tr>
<td>300 mA</td>
<td>~ 2</td>
<td>-</td>
</tr>
<tr>
<td>600 mA</td>
<td>~ 2</td>
<td>~ 2</td>
</tr>
<tr>
<td>900 mA</td>
<td>~ 2</td>
<td>-</td>
</tr>
</tbody>
</table>
Discussion

- It is certain that solenoids have removed the portion of electron cloud due to the observation of
  - the difference in mode spectrums between solenoids on and off,
  - the improvement of amplitude growth rates due to solenoids on, and
  - the reduction in tune shift of saturation due to solenoids on.

- Although the saturated tune shifts are approximately equal in solenoids off case, the vertical tune shift is higher than horizontal one when solenoids are on. The electron cloud density distribution might have been disturbed by solenoids.

- Naively, we can say that
  there is head-tail instability from the observation of synchrotron side bands near $z \sim 2$ in horizontal for solenoids on and off, near $z \sim 1$ & 2 in vertical for solenoids on, near $z \sim 2$ in vertical for solenoids off.
However, at the moment we found no systematic relation of synchrotron side band appearance with beam current.

Further study should be done by changing the rf voltage and study the synchrotron side band appearance at various beam currents.

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