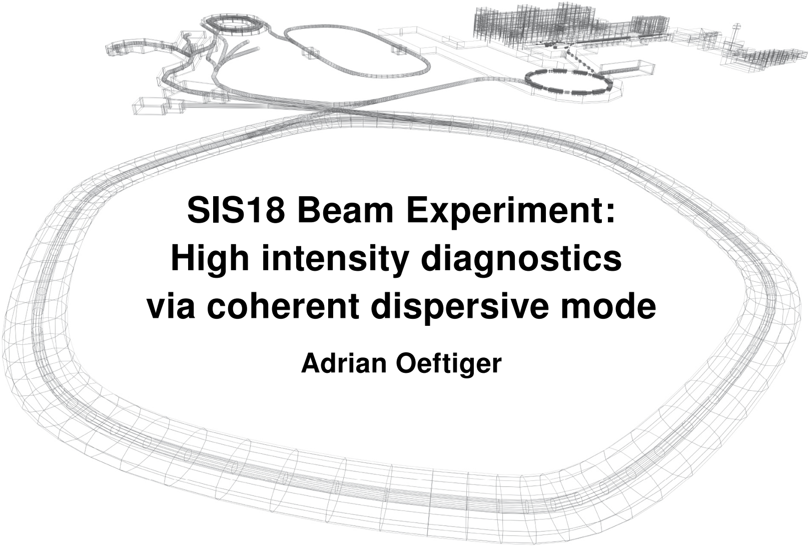


SIS18 Beam Experiment: High intensity diagnostics via coherent dispersive mode

Adrian Oeftiger

Experimental Approach

SIS-AP-030.01 ↗ aspects:

1. quadrupolar spectrum at injection, confirm Ref. Singh et al. [1]
2. dipolar excitation in frequency sweep
   - ⟶ induce head-tail mode
     - ⟹ provide correlation $\left\langle x \frac{\Delta p}{p_0} \right\rangle$, i.e. amplitude in coherent dispersion mode
   - ⟶ verify head-tail pattern in dipolar pick-up mode
   - ⟶ dispersion mode = 2nd order, shifted by space charge
   - ⟹ measure dispersion mode shift in quadrupolar pick-up mode
3. RF voltage scan for 1. $\Longrightarrow$ Q_s scan
   - ⇝ spectral distance between head-tail modes
4. intensity scans for above 1.+2.
5. mismatched vs. optimised multi-turn injection for 1.
6. scan RF frequency at injection for 1. $\Longrightarrow$ vary dispersive mismatch

Observables

Observables in control room:

- 4 channels of BPM in SIS18 sector 4 (left, right, top, bottom plates)
- DCCT (DC current transformer) for intensity
- FCT (fast current transformer)
- dipolar exciter, plugged waveform generator (for frequency sweep)
- IPM (ionisation profile monitor) for transverse profiles

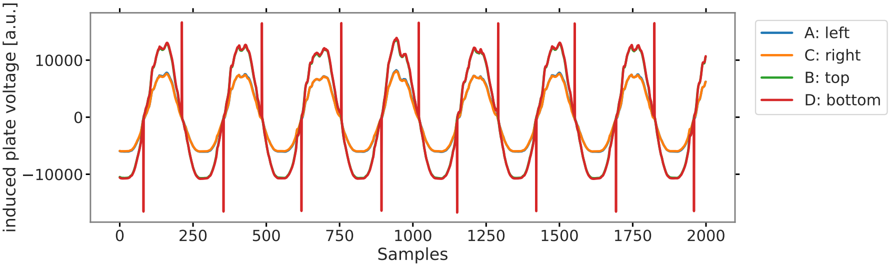


Figure: 5 consecutive bunches visible in BPM data

Beam Conditions

2 night shifts:

- first night up to 12 mA of Ar, working with mismatched injection
- second night up to 20 mA of Ar, nicely tuned injection

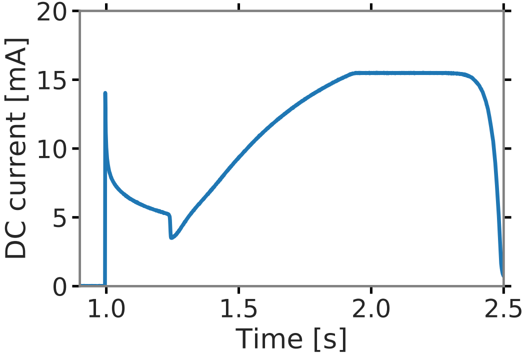


Figure: example case for DCCT recorded current.

References I

[1] R. Singh et al. “Understanding The Tune Spectrum Of High Intensity Beams”. In: *Proceedings, 2nd International Beam Instrumentation Conference (IBIC2013): Oxford, United Kingdom, September 16-19, 2013*. 2013.

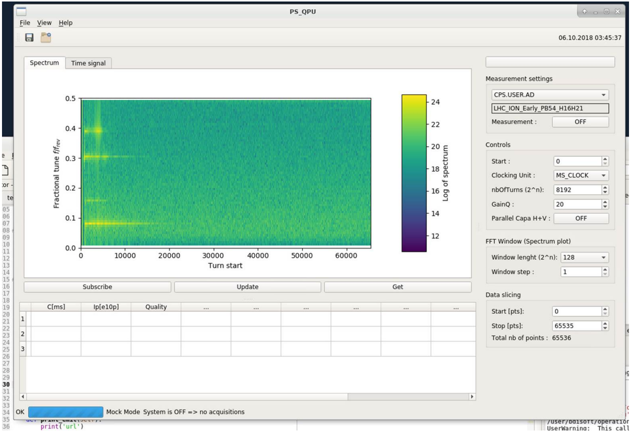
[2] R Singh et al. “Observations of the quadrupolar oscillations at GSI SIS-18”. In: *International Beam Instrumentation Conference*. 2014.

[3] Joel Alain Tsemo Kamga, Wolfgang F. O. Müller, and Thomas Weiland. “Analytical and numerical calculation of the second-order moment of the beam using a capacitive pickup”. In: *Phys. Rev. Accel. Beams* 19.4 (2016), p. 042801. DOI: 10.1103/PhysRevAccelBeams.19.042801.

Outlook: App Development

First app prototype for CERN CC developed by M. Coly and A. Oeftiger:

`https://gitlab.cern.ch/mcoly/ps_qpu`



Motivation

Quadrupolar pick-up (QPU) experiment: measure the coherent dispersive mode $\left\langle x \frac{\Delta p}{p_0} \right\rangle$ vs. space charge (SC) conditions

Context

- past experience with QPU signals from injection mismatch (e.g. Ref. [2])
- in preparation for 2020 follow-up experiment with quadrupolar kicker (amplifier to be acquired)
  - $\Longrightarrow$ measure quadrupolar betatron modes, SC induced shift
- frequency domain provides rich information, time domain methods unrewarding (in view of establishing diagnostics)

Motivation

Quadrupolar pick-up (QPU) experiment: measure the coherent dispersive mode $\left\langle x \frac{\Delta p}{p_0} \right\rangle$ vs. space charge (SC) conditions

Experiment goals

- align with / confirm **past experience**
  - SIS18, SC shift of head-tail modes (cf. Ref. [1])
  - CERN PS, intrinsic head-tail instabilities $\Longrightarrow$ observation of coherent dispersive mode
- demonstrate of second-order beam motion **during cycle** in SIS18
- measure **SC induced tune shift** of coherent dispersive mode
- explore new method for **high-intensity beam diagnostics** (direct measurement of SC)
- provide measurement data to **compare with simulations** for high-intensity operation

Quadrupolar Pick-up

Schematics of a quadrupolar pick-up (see Ref. [3]):

Induced voltage on electrodes:

$$U_{right} \propto I_{\text{beam}}\left(1 + z_{1x} + z_2 + ...\right)$$
$$U_{left} \propto I_{\text{beam}}\left(1 - z_{1x} + z_2 + ...\right)$$
$$U_{top} \propto I_{\text{beam}}\left(1 + z_{1y} - z_2 + ...\right)$$
$$U_{bottom} \propto I_{\text{beam}}\left(1 - z_{1y} - z_2 + ...\right)$$

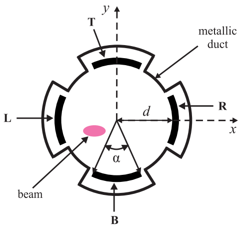


Figure: from Ref. [3]

where

$$z_{1x} \propto \frac{\langle x \rangle}{d},$$

Quadrupolar Pick-up

Schematics of a quadrupolar pick-up (see Ref. [3]):

Induced voltage on electrodes:

$$U_{right} \propto I_{\text{beam}}\left(1 + z_{1x} + z_2 + ...\right)$$
$$U_{left} \propto I_{\text{beam}}\left(1 - z_{1x} + z_2 + ...\right)$$
$$U_{top} \propto I_{\text{beam}}\left(1 + z_{1y} - z_2 + ...\right)$$
$$U_{bottom} \propto I_{\text{beam}}\left(1 - z_{1y} - z_2 + ...\right)$$

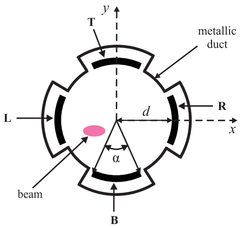


Figure: from Ref. [3]

where

$$z_{1x} \propto \frac{\langle x \rangle}{d},$$
$$z_{1y} \propto \frac{\langle y \rangle}{d}, \quad \text{and}$$

Quadrupolar Pick-up

Schematics of a quadrupolar pick-up (see Ref. [3]):

Induced voltage on electrodes:

$$U_{right} \propto I_{\text{beam}}\left(1 + z_{1x} + z_2 + ...\right)$$
$$U_{left} \propto I_{\text{beam}}\left(1 - z_{1x} + z_2 + ...\right)$$
$$U_{top} \propto I_{\text{beam}}\left(1 + z_{1y} - z_2 + ...\right)$$
$$U_{bottom} \propto I_{\text{beam}}\left(1 - z_{1y} - z_2 + ...\right)$$

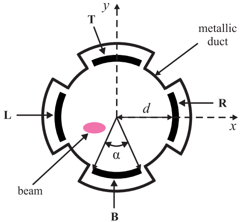


Figure: from Ref. [3]

where

$$z_{1x} \propto \frac{\langle x \rangle}{d}, \quad z_{1y} \propto \frac{\langle y \rangle}{d}, \quad \text{and}$$

$$z_2 \propto \frac{\langle x^2 \rangle - \langle y^2 \rangle}{d^2} = \frac{\sigma_x^2 - \sigma_y^2 + \langle x \rangle^2 - \langle y \rangle^2}{d^2}$$

(neglecting dispersion)

Quadrupolar Pick-up

Schematics of a quadrupolar pick-up (see Ref. [3]):

Induced voltage on electrodes:

$$U_{right} \propto I_{\mathrm{beam}} \left(1 + z_{1x} + z_2 + \ldots\right)$$
$$U_{left} \propto I_{\mathrm{beam}} \left(1 - z_{1x} + z_2 + \ldots\right)$$
$$U_{top} \propto I_{\mathrm{beam}} \left(1 + z_{1y} - z_2 + \ldots\right)$$
$$U_{bottom} \propto I_{\mathrm{beam}} \left(1 - z_{1y} - z_2 + \ldots\right)$$

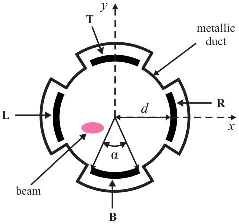
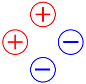


Figure: from Ref. [3]

$\Longrightarrow$ combine voltages to measure **dipolar** beam moments (usual BPM):

$$\langle x \rangle \propto U_{right} - U_{left}$$
$$\langle y \rangle \propto U_{top} - U_{bottom}$$



Quadrupolar Pick-up

Schematics of a quadrupolar pick-up (see Ref. [3]):

Induced voltage on electrodes:

$$U_{right} \propto I_{\text{beam}}(1 + z_{1x} + z_2 + ...)$$
$$U_{left} \propto I_{\text{beam}}(1 - z_{1x} + z_2 + ...)$$
$$U_{top} \propto I_{\text{beam}}(1 + z_{1y} - z_2 + ...)$$
$$U_{bottom} \propto I_{\text{beam}}(1 - z_{1y} - z_2 + ...)$$

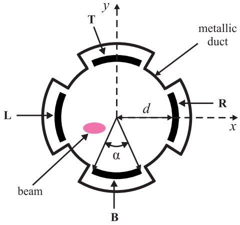


Figure: from Ref. [3]

$\Longrightarrow$ or combine voltages to measure **quadrupolar** beam moments:

$$z_2 \propto \sigma_x^2 - \sigma_y^2 + \langle x \rangle^2 - \langle y \rangle^2$$
$$\propto U_{right} + U_{left} - U_{top} - U_{bottom}$$