Processing of the Schottky Signals at RHIC
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Abstract
Schottky monitors are used to determine important beam parameters in a non-destructive way. In this paper we present improved processing of the transverse and longitudinal Schottky signals from a hi-Q resonant 2.07 GHz cavity with the main focus on providing the real-time measurement of beam tune, chromaticity and emittance during injection and ramp, when the beam conditions are changing rapidly. The analysis and control is done in Python using recently developed interfaces to Accelerator Device Objects [1].

Detectors

Fig 1. Detector assembly on one of the RHIC beam pipes.
The cavity is mounted on a 2-D moving frame. It uses four probes to detect signals from the different modes in the cavity. Vertical probe 2.067 GHz. Horizontal probe 2.071 GHz. Longitudinal probe 2.742 GHz.

Fig 2. Schottky cavity.

The cavity is mounted on a 2-D moving frame. It uses four one of the RHIC beam pipes.

Results and Discussion

Fig 3. Signal processing diagram.

Measured Power Spectrum

Signal spectrum at injection

LO = 2.069 GHz

freq = 78 KHz
Harmonic = 26525.5

At top beam energy, the fractional part of the harmonic is adjusted to 0.5. It deviates from that during injection.

Fig 4. Power spectrum is complicated by the existence of image frequencies.

Fig 5. Extracted beam parameters [2], [3].

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Dynamic Peak Recognition

Fig 9. Regions of Interest for coherent/revolution peak (yellow) and betatron peaks (green) at injection energy.

Algorithm:
(1) Calculate ROI (regions of interest) of the coherent peak, based on RF frequency. Two coherent peaks may be present in the spectrum.
(2) Find N=10 of highest local peaks, sort them according to amplitude.
(3) Identity the coherent peak as a highest peak in the coherent ROI.
(4) Iterate over the rest of the peaks and check if they are in the ROI for betatron peaks.

Fig 8. Result of the spectrum analysis.

Adjustable parameters
There are six adjustable parameters:

(1) Filter Order. Default = 4.
(2,3,4): Guess widths of the coherent peak, revolution peak and betatron peaks.
(5,6): Limits for the expected tunes.

Fig 6. Signal spectrum during ramp-up of the beam energy.

Two options have been considered.

(1) Adjust LO frequency as a function of the RF frequency.

(2) Post processing of the changing signals, peak recognition based on known RF.

Complications
• Noise is not gaussian.
• Top of the peaks have fine structure due to synchrotron harmonics.
• Peak shape is not always gaussian.

Fig 7. Signal spectrum at top beam energy.

Processing of the changing signals
Signals are changing rapidly during the ramp. The RF frequency is changing for ~8 harmonics in 30 seconds.

Fig 10. Tune measurement results (black dots) at injection, during ramp-up and at top energy. Shown are the tune set points (blue line) and the result of an analysis using gaussian least-squared fit (red dots). Precision at top energy is ~0.1%

Conclusion
The fast, robust algorithm for extracting beam parameters from the Schottky signals in dynamic beam conditions is presented. It provides the same precision as a conventional algorithm, based on non-linear least-square fitting, but does not suffer from convergence problems.

• The precision of the tune measurement is 0.1% at injection and top energies and 0.4% during ramp.
• The chromaticity is measured with precision 2% at injection and 10% at top energy.
• The power of betatron peaks, which is proportional to emittance, is measured with 1% precision.
• The implementation using Python made it possible to quickly develop new, more efficient algorithms and even gain in processing performance over C++ (the processing time of a 800-point spectrum is ~20 ms).

References