Measurement of Stability Diagram at IOTA at Fermilab

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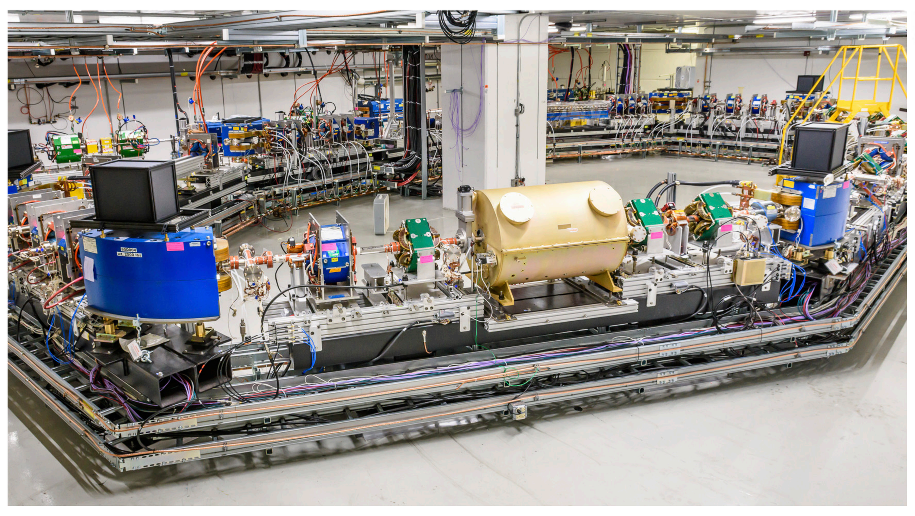
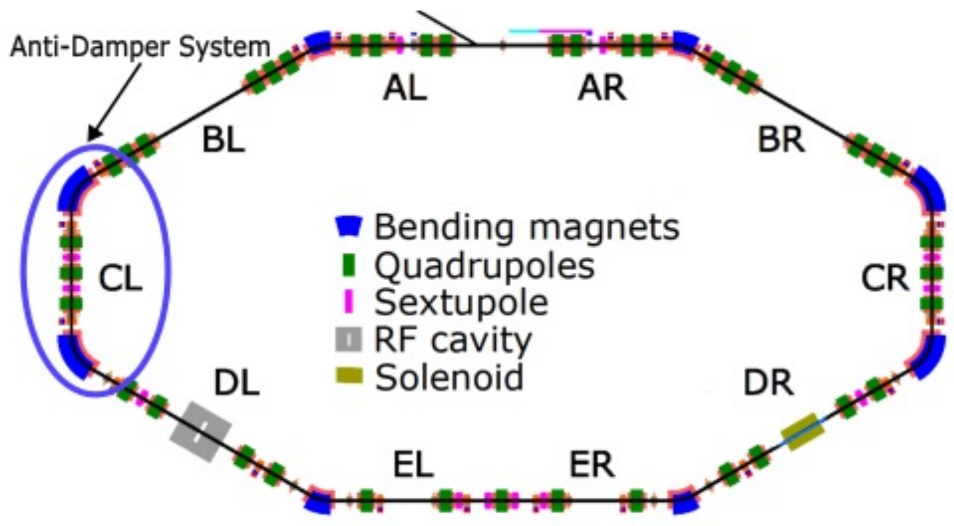
We are using a new method to measure stability diagrams, which will aid in understanding beam stability from Landau Damping.

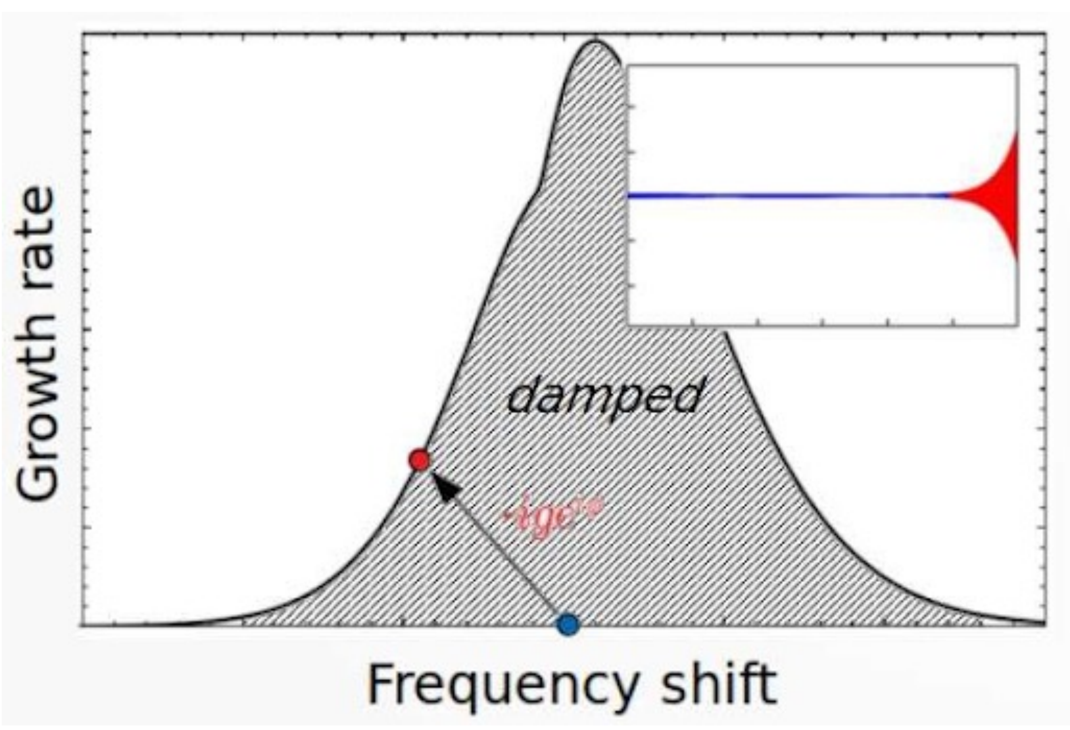
Introduction





- Nonlinear focusing elements enhance the stability of particle beams in high-energy colliders.
- This is done through **Landau damping**, by introducing a tune spread.
- We propose an experiment at Fermilab's Integrable Optics Test Accelerator (IOTA) to investigate the influence of nonlinear focusing elements on the transverse stability of the beam.
- We will examine the impact of the nonlinear focusing element on the beam's transverse stability.
- This will be done by analyzing the **stability diagram**

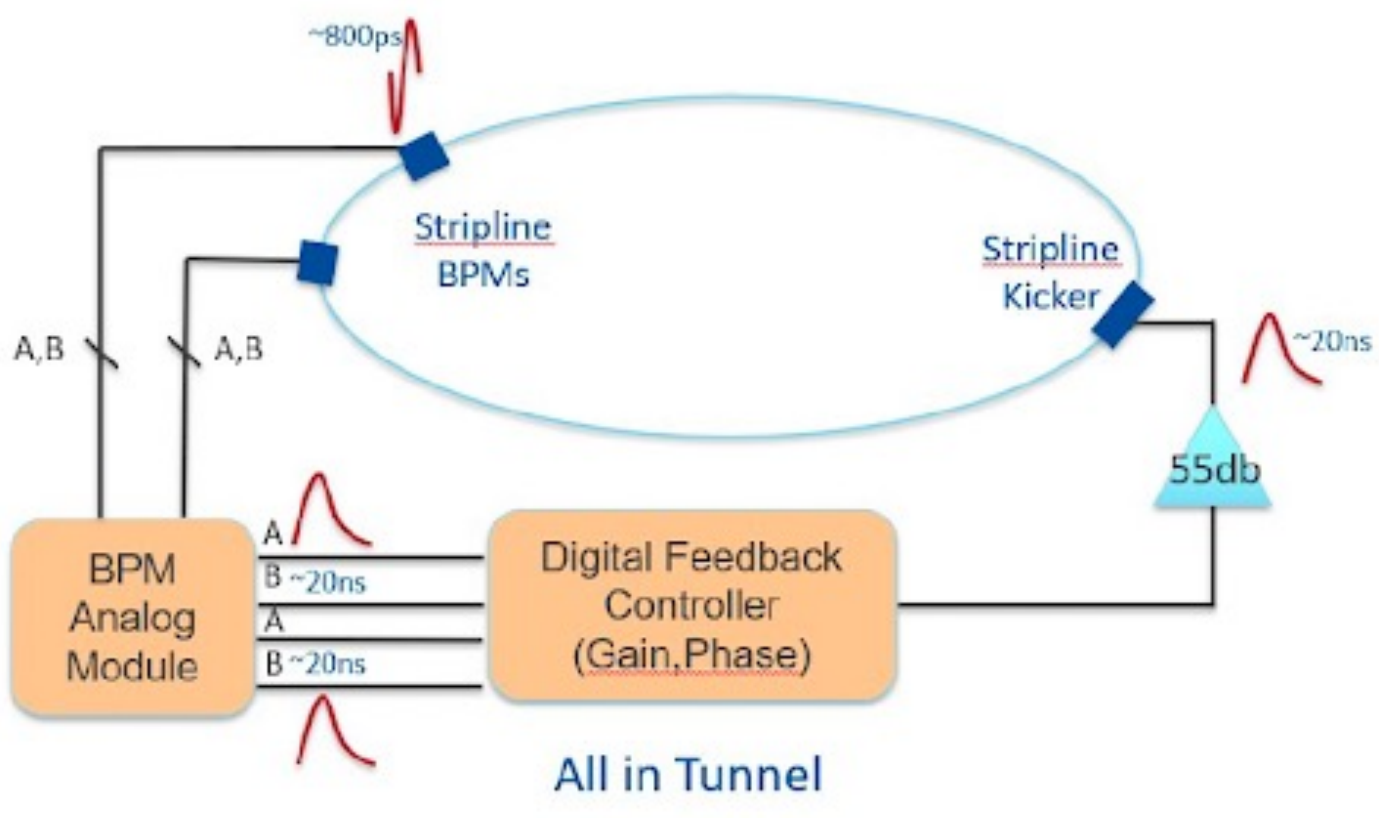
- The stability diagram presents the transverse growth rate as a function of the frequency shift.
- The study will be performed with an anti-damper, an active transverse feedback system, inducing coherent beam instability.



Methods

- The IOTA antidamper system consists of: digital controller, stripline kicker, two stripline BPMs, and BPM analog nodule.
- Beam gets kicked by kicker and total phase from two BPMs is a virtual pickup.
- The stripline BPMs measure the beam position. The two pickups are approx. 110 degrees apart, so both x and x' of the beam can be measured in a single turn.
- Results are used to adjust gain or phase until an instability is observed.
- The anti-damper supplies a constant wake force, where the resulting impedance goes:

$$Z(\omega) \propto g e^{i\phi}\delta(\omega)$$

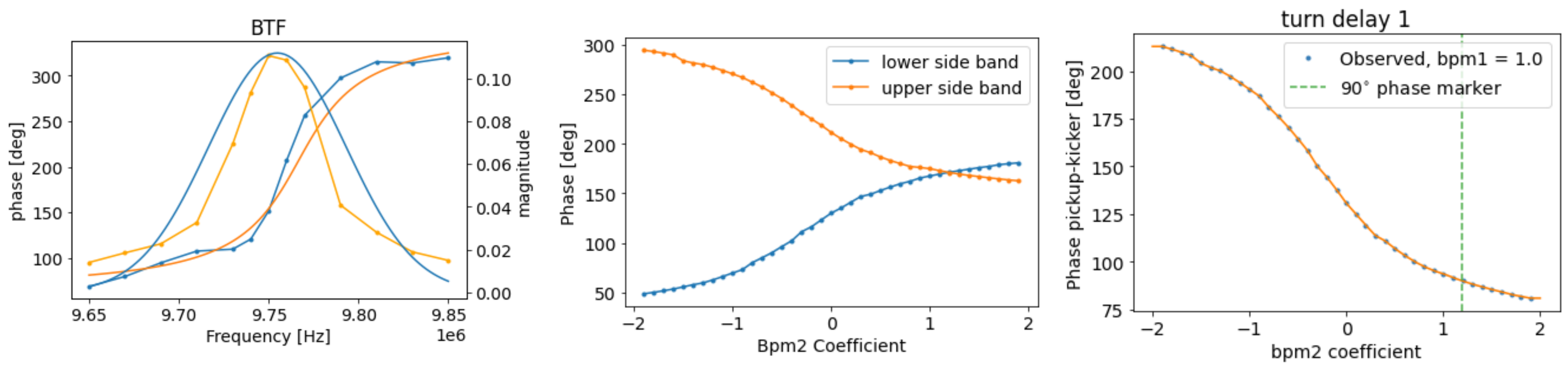


- This coupling impedance shifts the frequencies of collective modes by:

$$\Delta\omega \propto -ige^{i\phi}$$

- By independently adjusting the gain and phase delay, one can set the feedback transfer anywhere in the complex plane, giving a source of controlled impedance.
- For given gain one can observe at what phase the beam becomes unstable. The growth rate can be observed and mapped to a stability diagram.

Results



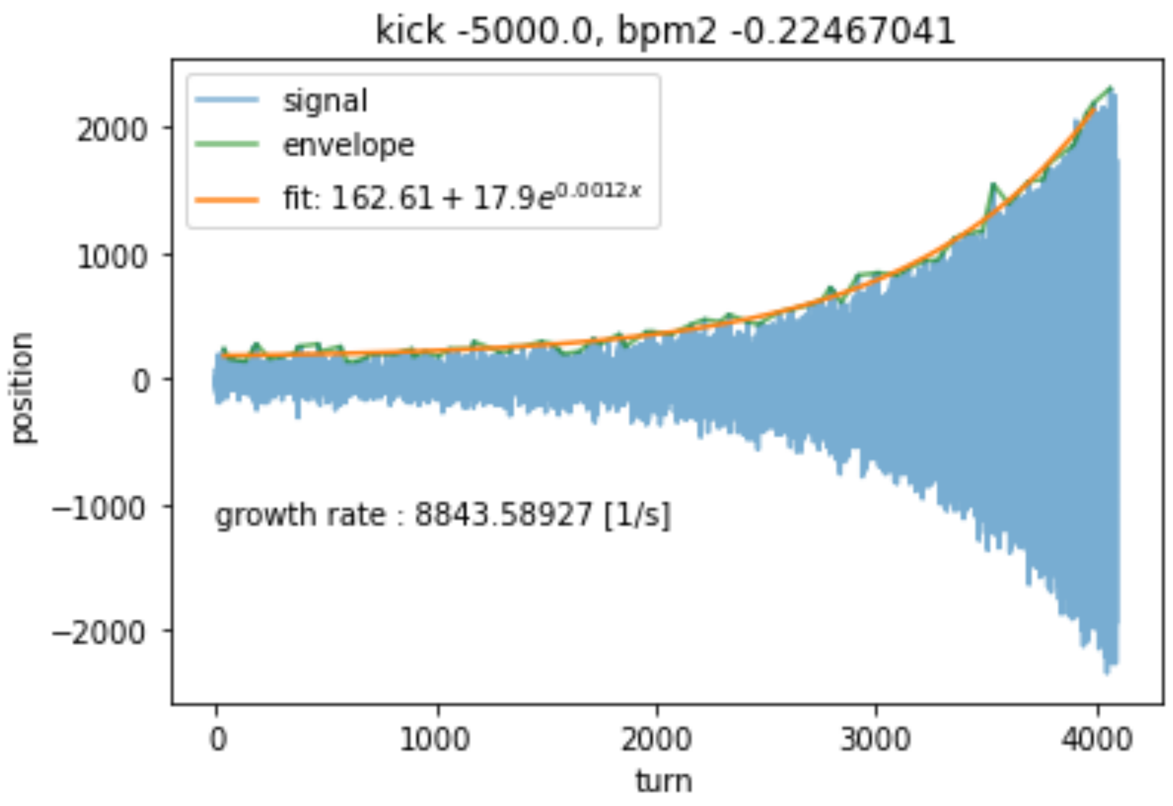
- System first is calibrated to know correspondence between bpm coefficients and phase advance.
- Frequency sweep performed for both the lower and upper sidebands.
- From the phases of these sweeps, a beam transfer function was obtained

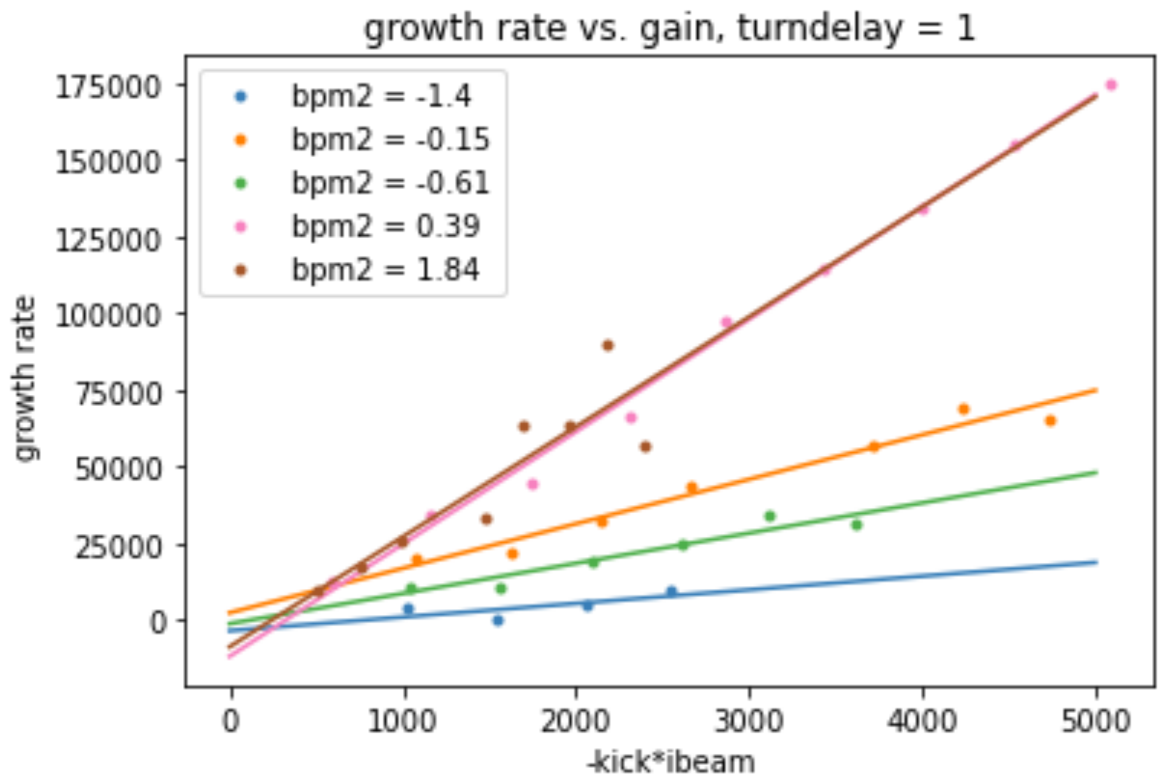
- The difference between the two sideband phases is related to the phase from the virtual pickup to the kicker as:

$$\theta_{lsb} - \theta_{usb} + 180 = 2\phi$$

- The first experimental goal was to incite an instability with the anti-damper.

- Once an instability was detected, an exponential fit was performed on the envelope of the beam's centroid position.
- Then, a sweep through the phases was performed towards making a stability diagram.
- The growth rates at instability were analyzed as a function of the experimental kick of the beam.
- The linear fits can be extrapolated to get the instability growth rate at an experimental kick threshold.





Next Steps

The next steps in this experiment will be first to measure initial stability diagrams. This step is currently underway. We then aim to measure stability diagrams at differing octupole settings, as well as stability diagrams in both the horizontal and vertical plane. Additionally, the results from IOTA will be compared with those from the LHC to investigate the impact of the machine's impedance on the stability diagram.

Acknowledgments

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References

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