An Optical Intra-Bunch Instability Monitor for Short Electron Bunches

T. G. Lucas [A], M. J. Boland [A,B], R. J. Steinhagen [C,D], D. J. Peake [A], P. G. Giansiracusa [A], R. P. Rassool [A]
[A] University of Melbourne, Parkville, Australia
[B] Australian Synchrotron, Clayton, Australia
[C] European Organisation for Nuclear Research, Geneva, Switzerland
[D] GSI, Darmstadt, Germany

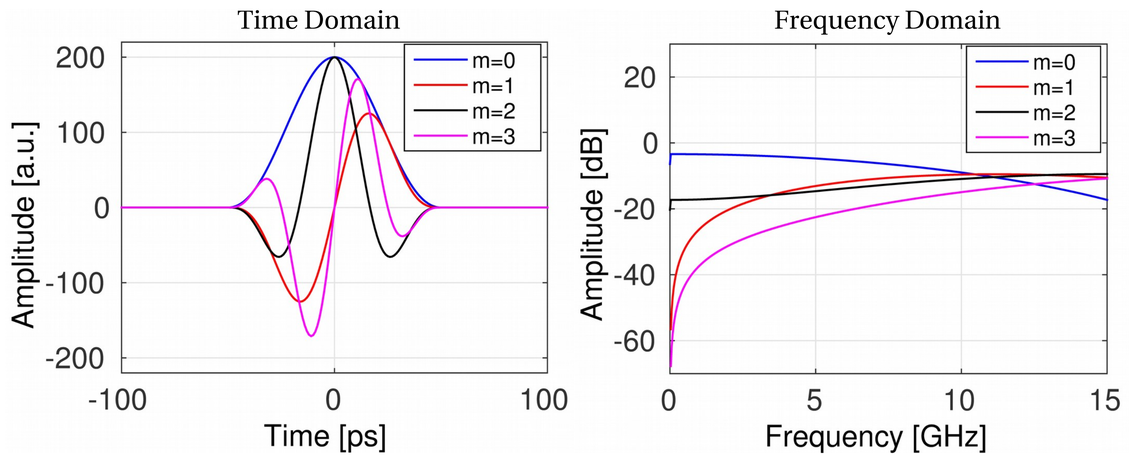
Abstract

An improved understanding of intra-bunch instabilities in synchrotron light source electron bunches is crucial to overcoming the imposed limitations of the achievable intensity. A Multiband Instability Monitor (MIM), designed specifically for the short bunches of a synchrotron light source, has been developed to perform measurements of intra-bunch dynamics. The MIM performs real-time measurements at a diagnostic beamline using optical synchrotron radiation incident on a high speed photodetector. Three frequency bands up to 12 GHz were used to identify characteristic frequency signatures of intra-bunch instabilities. Mixed to baseband using RF detectors, these high frequency measurements can be performed without the need for similarly high frequency digitisers.

MIM Principle

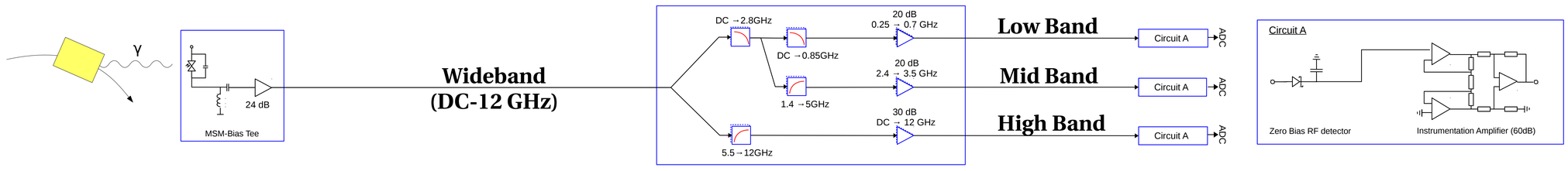
- Sample the bunch spectrum through multiple frequency bands.
- Compare the intensity of the differential (Δ) and summed (Σ) signal for two opposing BPMs.
- Ratio of Δ/Σ is:
  - Constant ↔ No Intra-bunch Instability
  - Variable ↔ Intra-bunch Instability
- By filtering signals into frequency bands, high frequency information can be preserved after downmixing.
- Baseband frequency signals can be digitised without specialised equipment.

Simulated Head-tail Instabilities at the Australian Synchrotron



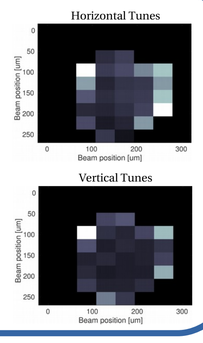
Experimental Setup

MIM System Schematic

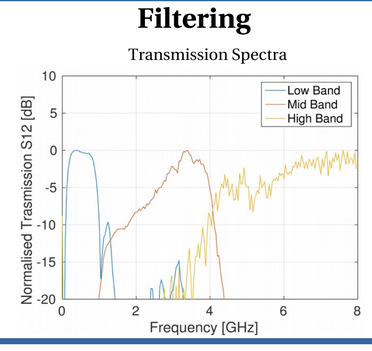


Pick-up

Optical synchrotron radiation from a diagnostic beamline was focussed onto a 12 GHz MSM photodetector monitoring the bunch motion. Betatron oscillations in the bunch are seen as transverse oscillations in the focal point. Consequently beam-spot location determined the sensitivity of the system.

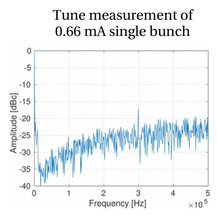


Filtering



Downmixing

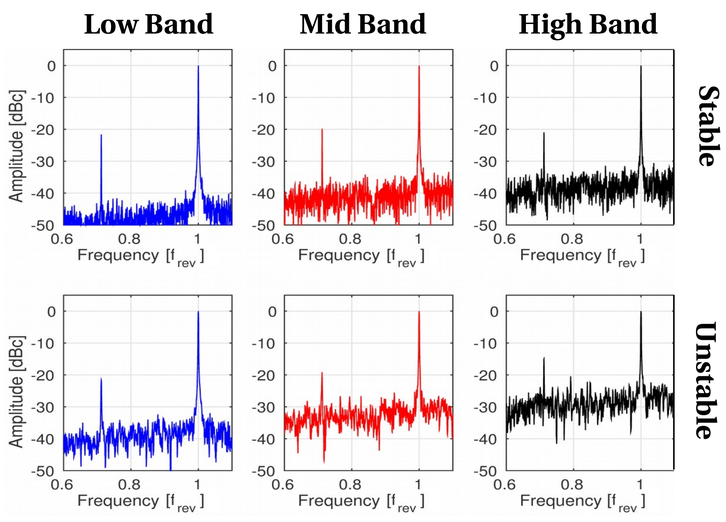
Each output from the three bands is processed simultaneously by identical downmixing circuits. Input into a zero-bias RF detector, the signals are mixed to baseband frequencies. Digitisation is then performed in the sub-megahertz regime allowing for greater resolution.



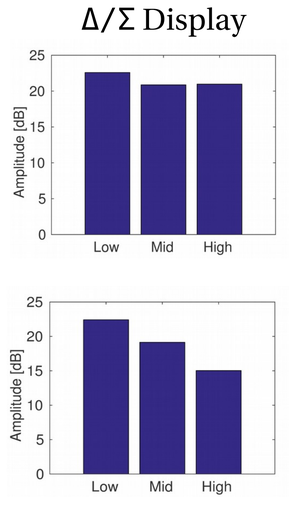
Results

The MIM system was tested at the Australian Synchrotron's optical diagnostic beamline. The following measurements were performed on a 10 mA single bunch injected into the storage ring. While the bunch was stable only small variations in the Δ/Σ ratio appeared. An intra-bunch instability was induced by a reduction in the chromaticity. A 7 dB reduction in the Δ/Σ ratio is visible between the low and high frequency band.

Baseband MIM signals



Δ/Σ Display



Conclusions

- A MIM system for short electron bunches was produced and tested.
- Limitations resulting from the analog bandwidth of electrostatic button BPMs were overcome using a new optical BPM.
- Filtering was performed with minimal loss using cascaded diplexers.
- Stable Beam presented with minimal variation in the Δ/Σ signal. Whereas the introduction of an intra-bunch instability saw a large reduction in the Δ/Σ signal with an increase in frequency, up to 12 GHz.