Tracking Frequency Reference Phase Changes at Point of Use Based on BPM Measurements.

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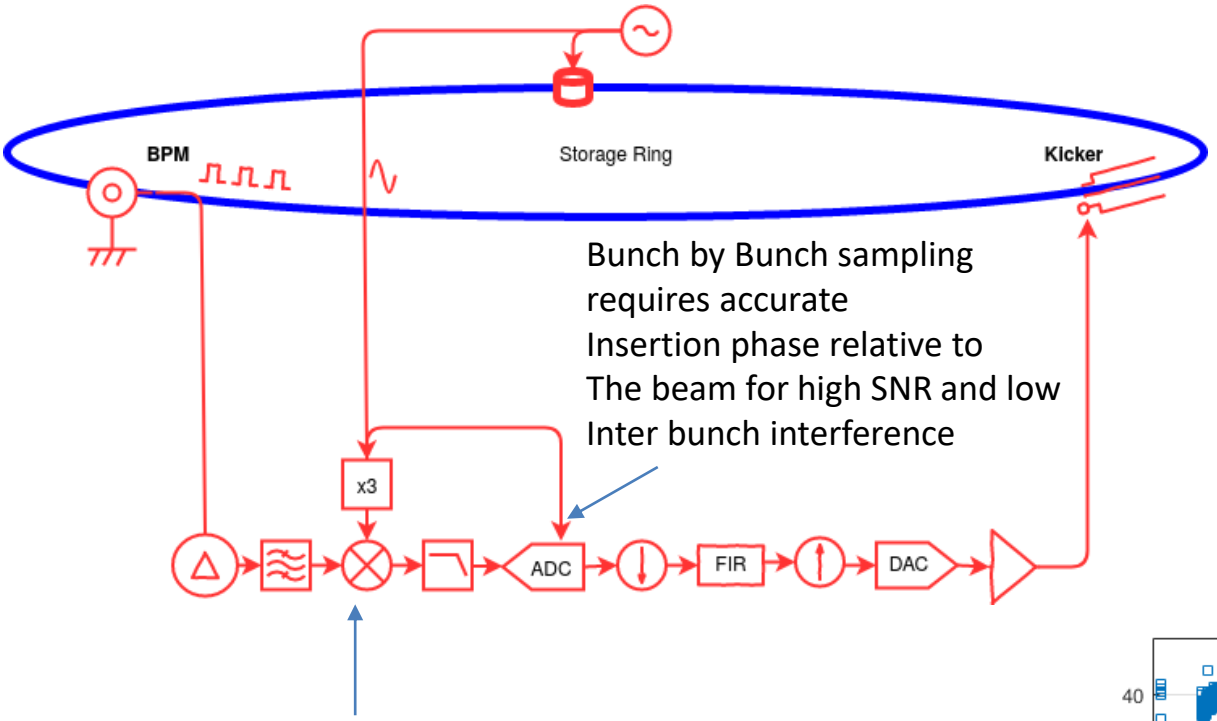
Phase Sensitivities in MBFB

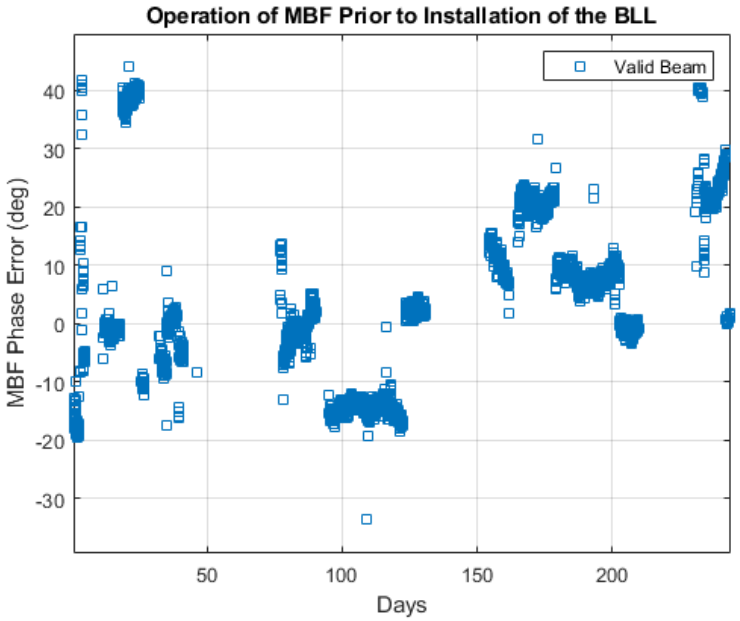


Bunch by Bunch sampling requires accurate Insertion phase relative to The beam for high SNR and low Inter bunch interference

Regular phase adjustment Needed to maintain high performance

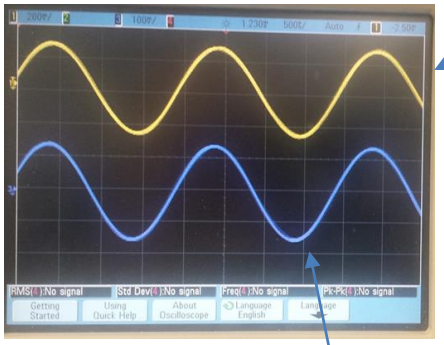
3rd harmonic Homodyne detection requires accurate Insertion phase relative to The beam for high SNR

Beam to Ref Clock phase variation ~ -30/+40 Degrees over operating duration.



For more detail on the MBFB system see:
Architecture of Transverse Multi-Bunch Feedback Processor at Diamond
M.G Abbott, G.Rehm, I.S Uzun Proc ICALEPCS2015 MOPGF097

Feedback using an IQ Modem



MASTER OSC IN

90 deg

Q

I

Feedback Control

Local RF OUT

I

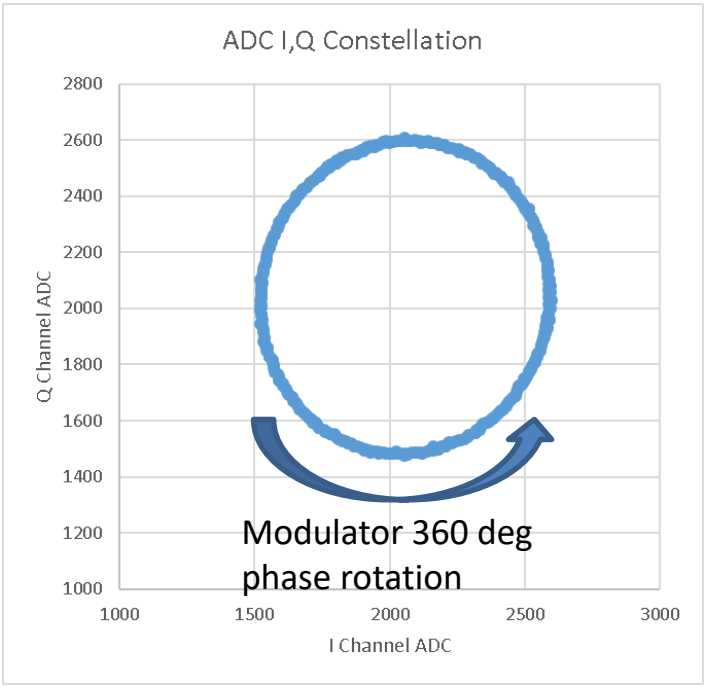
Q

90 deg

Local REF IN (BPM)

Continuous phase detection and adjustment range is possible using an IQ Modem

Detected Phase relative to The local ref in

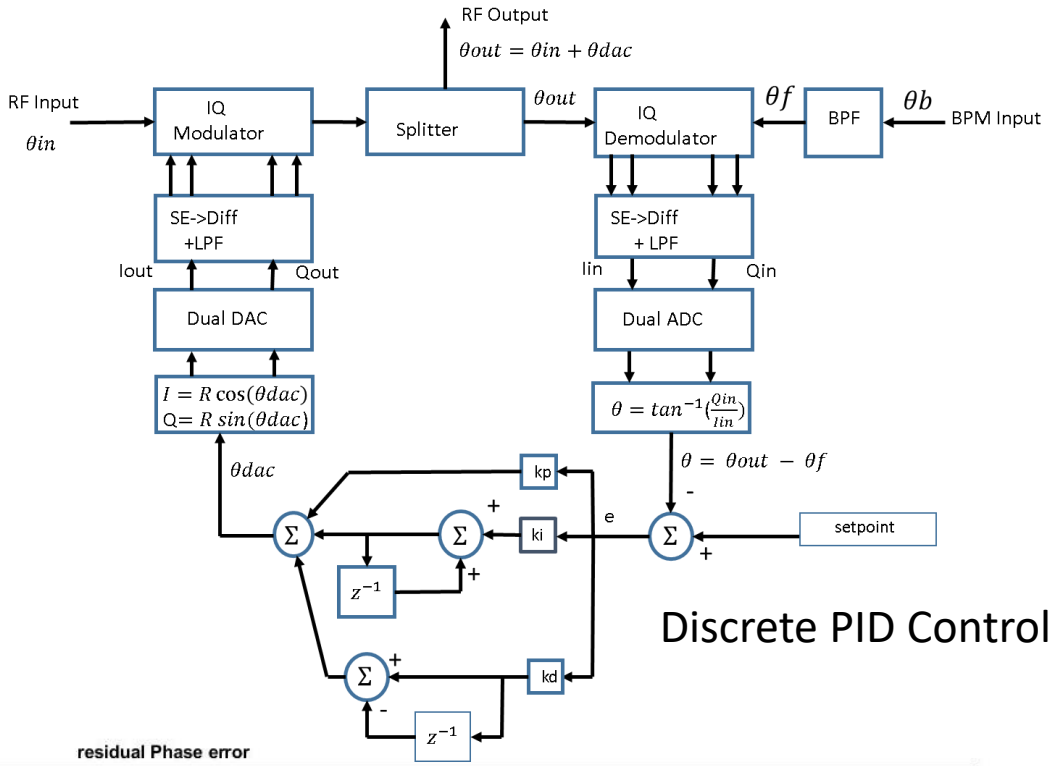


Digital Closed Loop Control

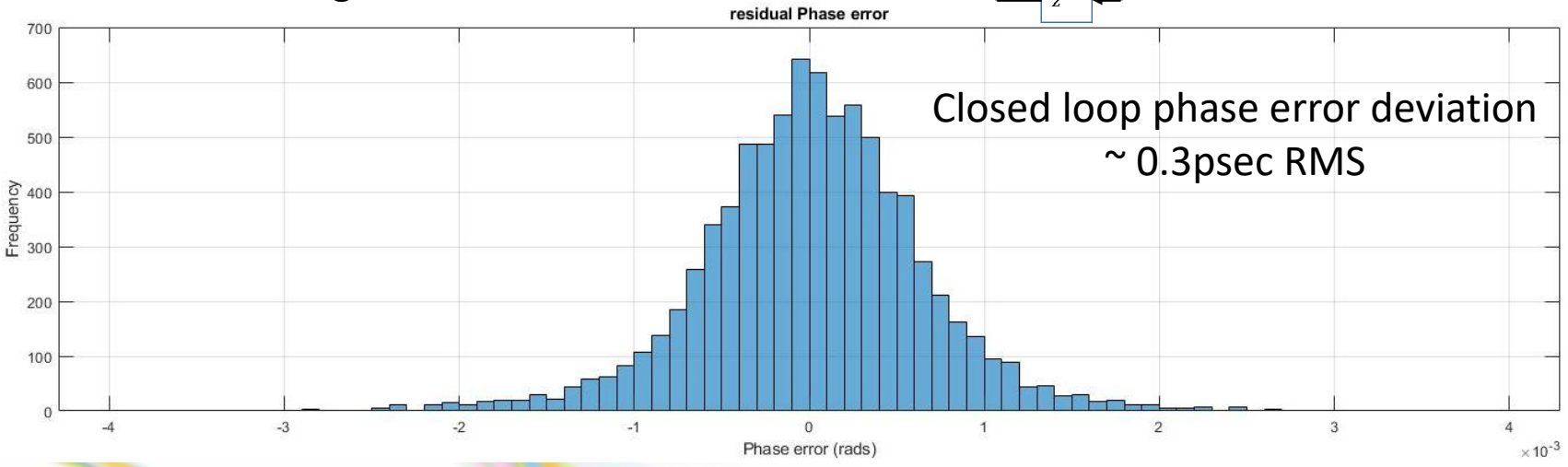
Implemented on an ARM M4 CPU
10msec update rate
12 bit ADC & DAC
Floating point hardware
Variable ADC averaging
Discrete time PID
Anti-windup protection

Closed loop BW ~ 10Hz

External RS232 Comms for
Remote management

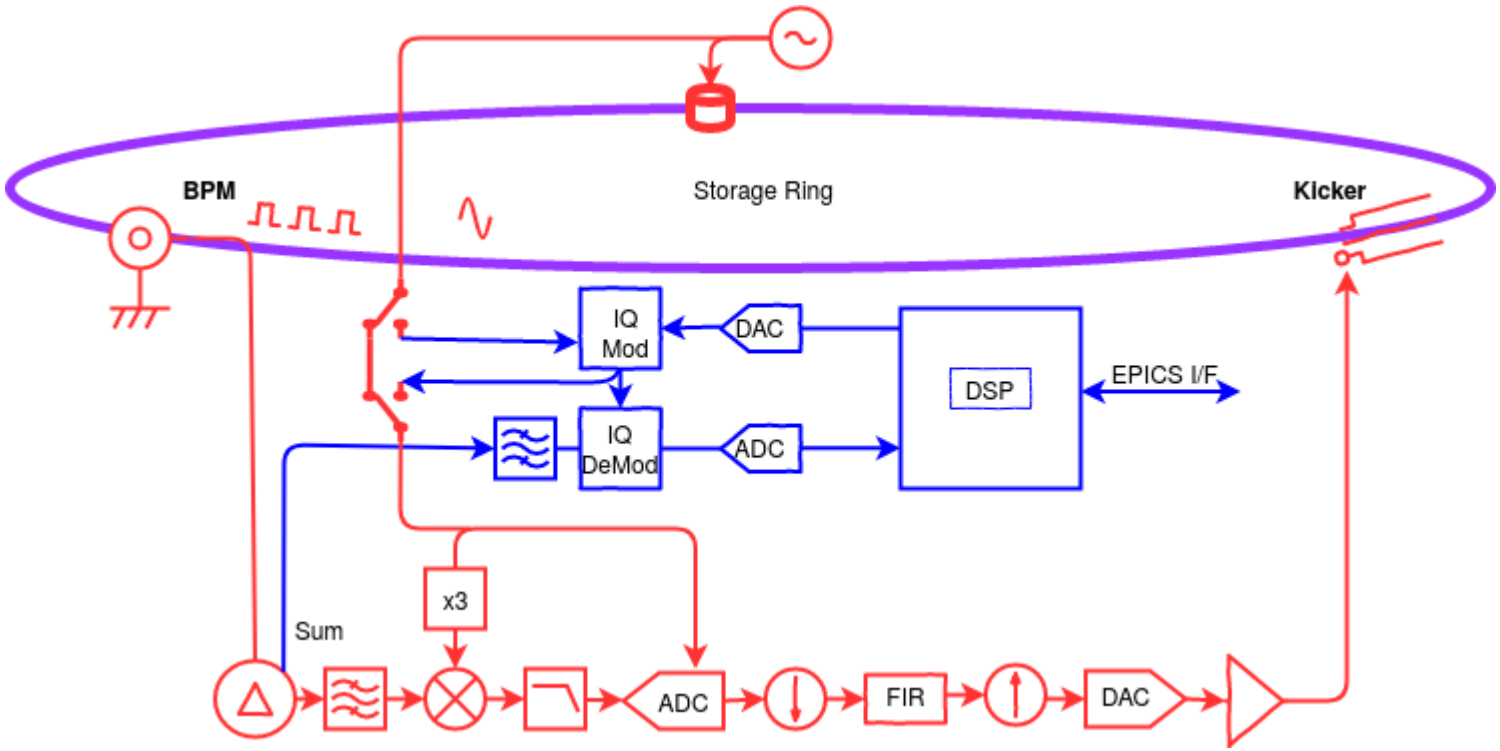


Discrete PID Controller



Closed loop phase error deviation
~ 0.3psec RMS

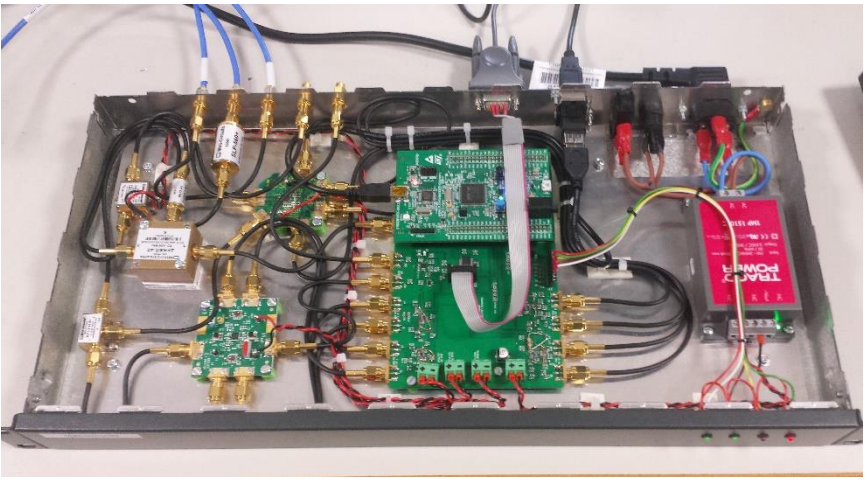
Solution: Beam Locked Loop



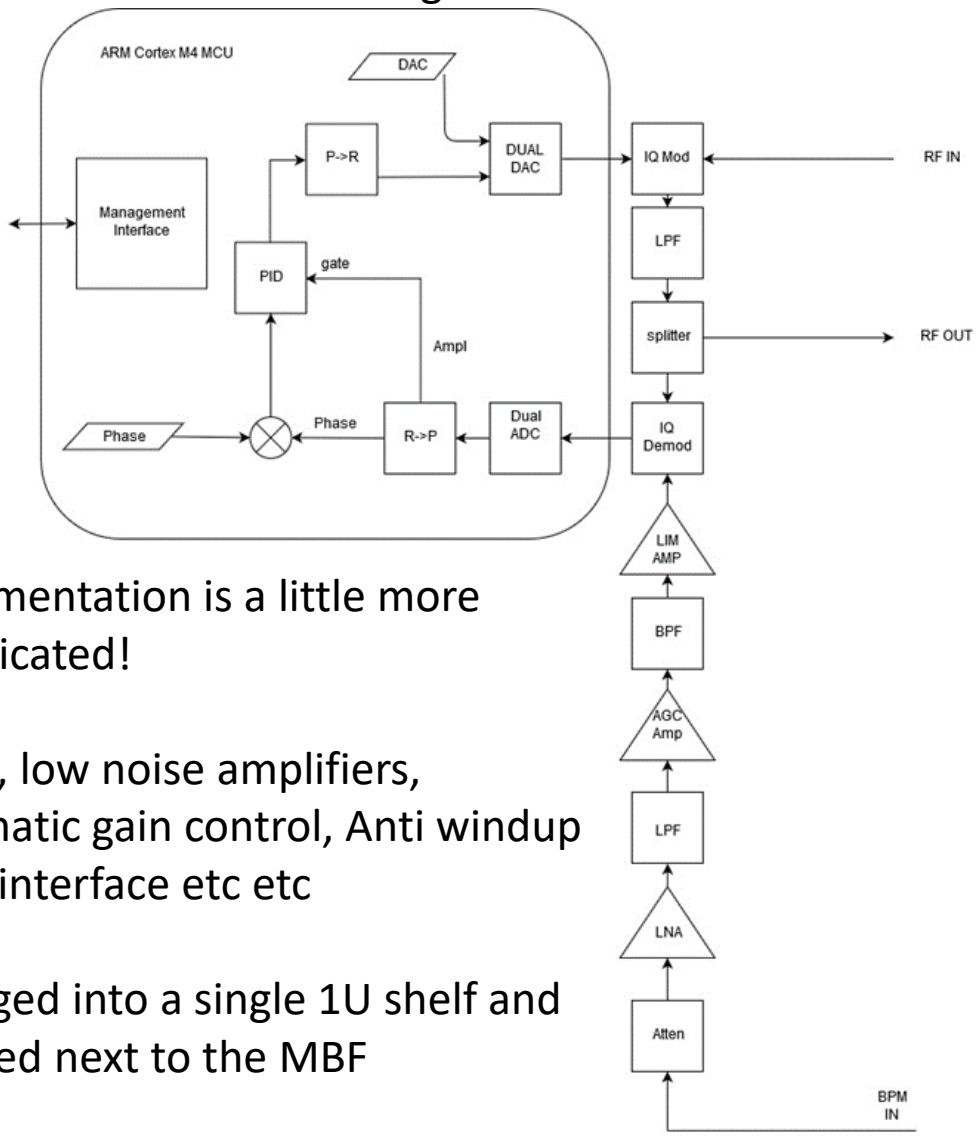
A standalone "Beam Locked loop" intercepts the reference clock and phase locks it to the beam using the sum output of a BPM hybrid.

No changes to the MBF subsystem

Implementation



Final Block Diagram



5 units built and tested
1 unit running live in the Diamond Storage Ring

Implementation is a little more complicated!

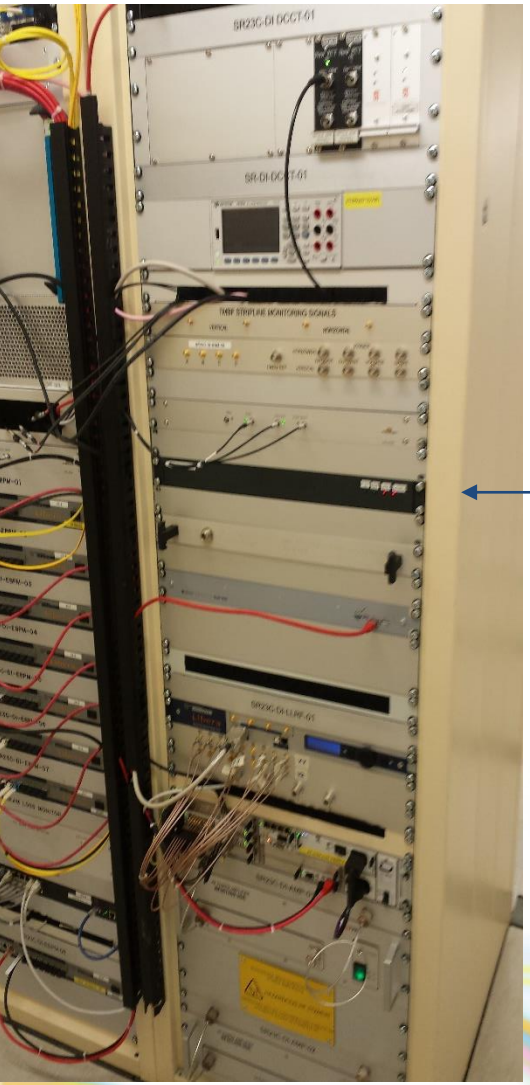
Filters, low noise amplifiers, Automatic gain control, Anti windup EPICS interface etc etc

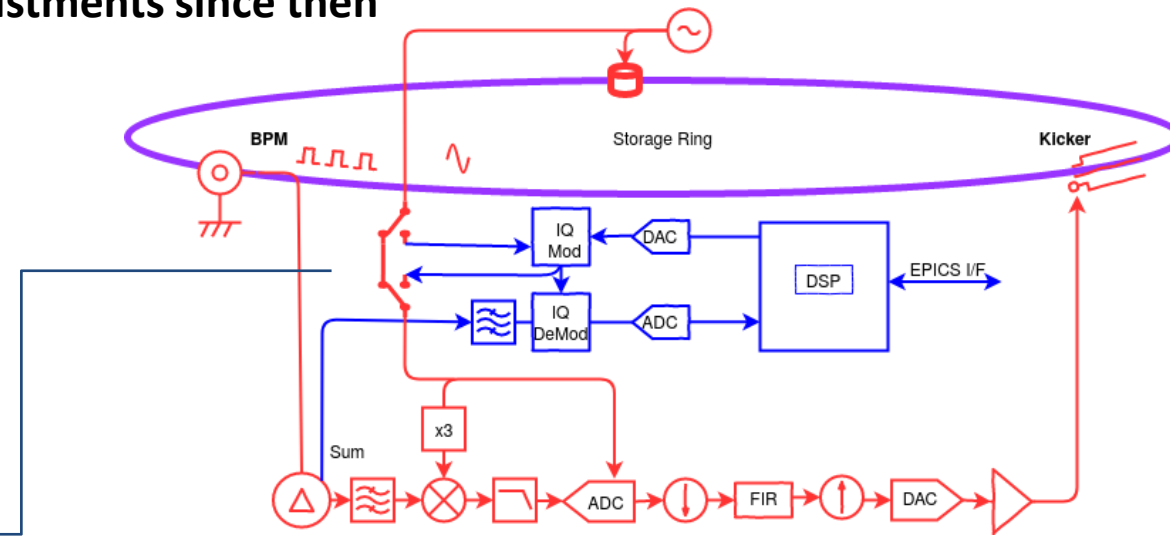
Packaged into a single 1U shelf and installed next to the MBF

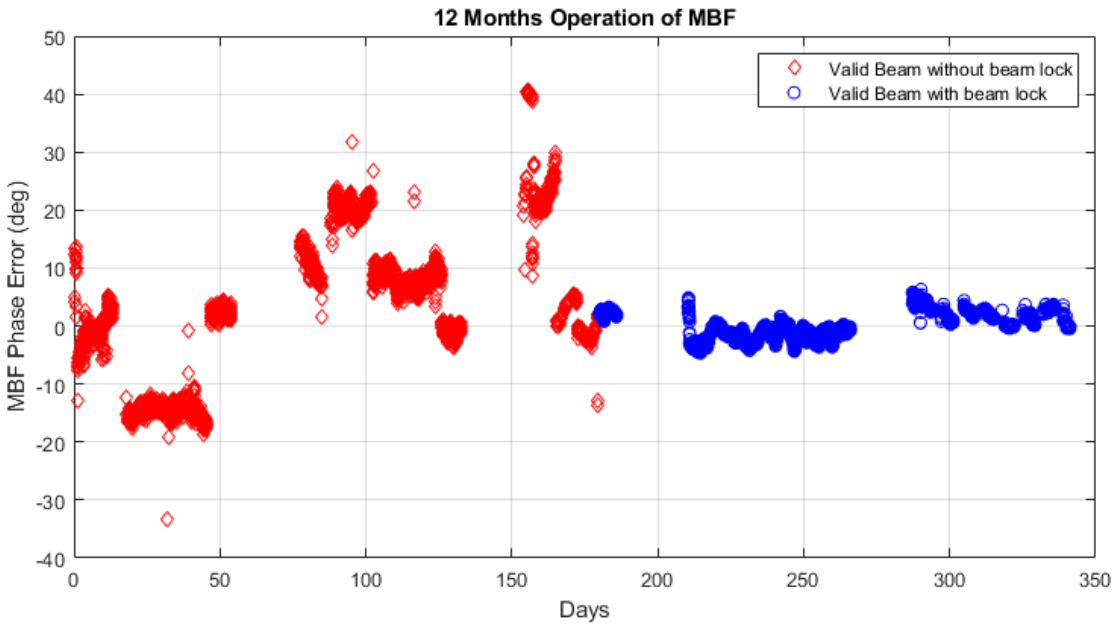
6 Months operation in the SR

Installed in diamond SR Oct 2019 & Fully operational from Dec 2019

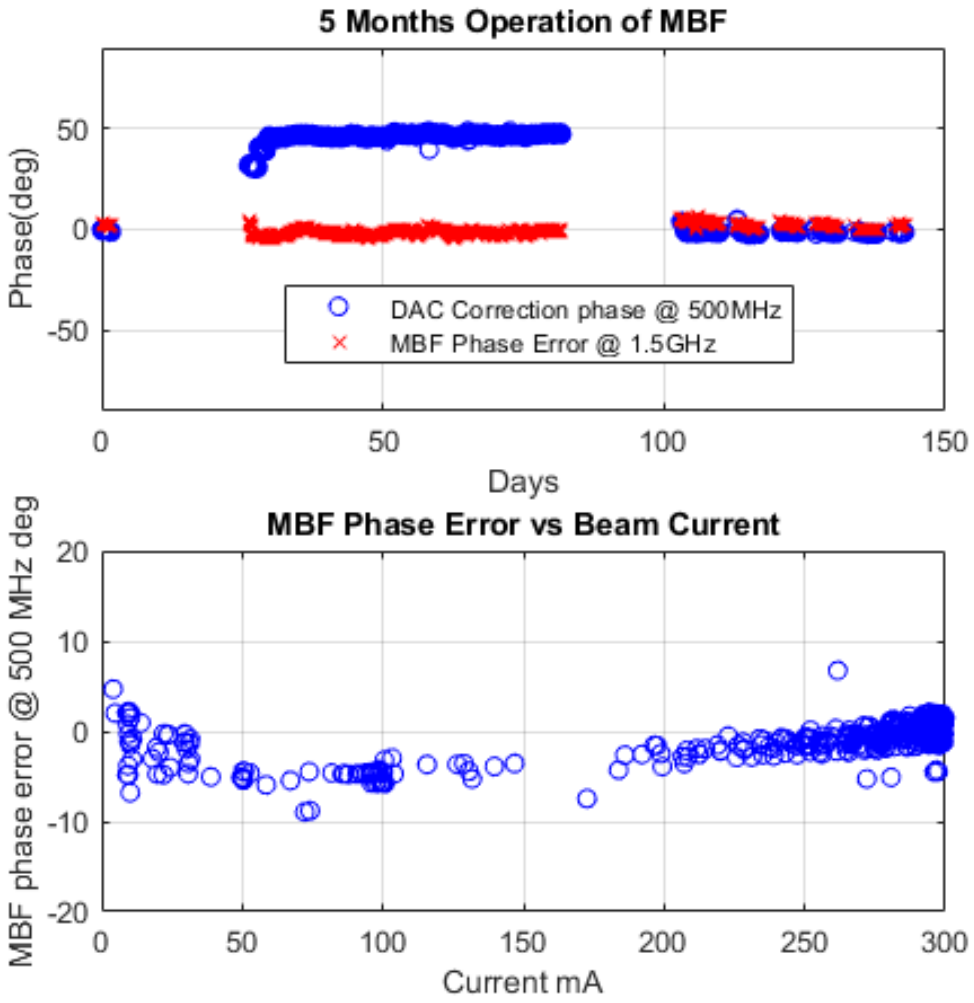
No manual phase adjustments since then







Other Results from Captured Data



~50 degrees variation
In Beam : Ref clock alignment
During 6 months operation
With low residual MBF
phase error

Wide range of operating currents and fill patterns during the 6 month trial with low residual phase error.

Summary

- Current MBF requires regular adjustment due to operational changes to beam phase
- Tracking Frequency Reference Phase Changes via BPM measurement enables phase lock to the beam i.e “Beam lock”.
- A standalone EPICS managed beam locking solution has been packaged in a 1U shelf without any changes to the existing MBF system.
- Beam locking has been demonstrated to Improve phase stability of the MBF system over 6 months live operation with no operator adjustment.