INTEGRATION OF THE DIAMOND TRANSVERSE MULTIBUNCH SYSTEM AT ALBA

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SYSTEM OVERVIEW

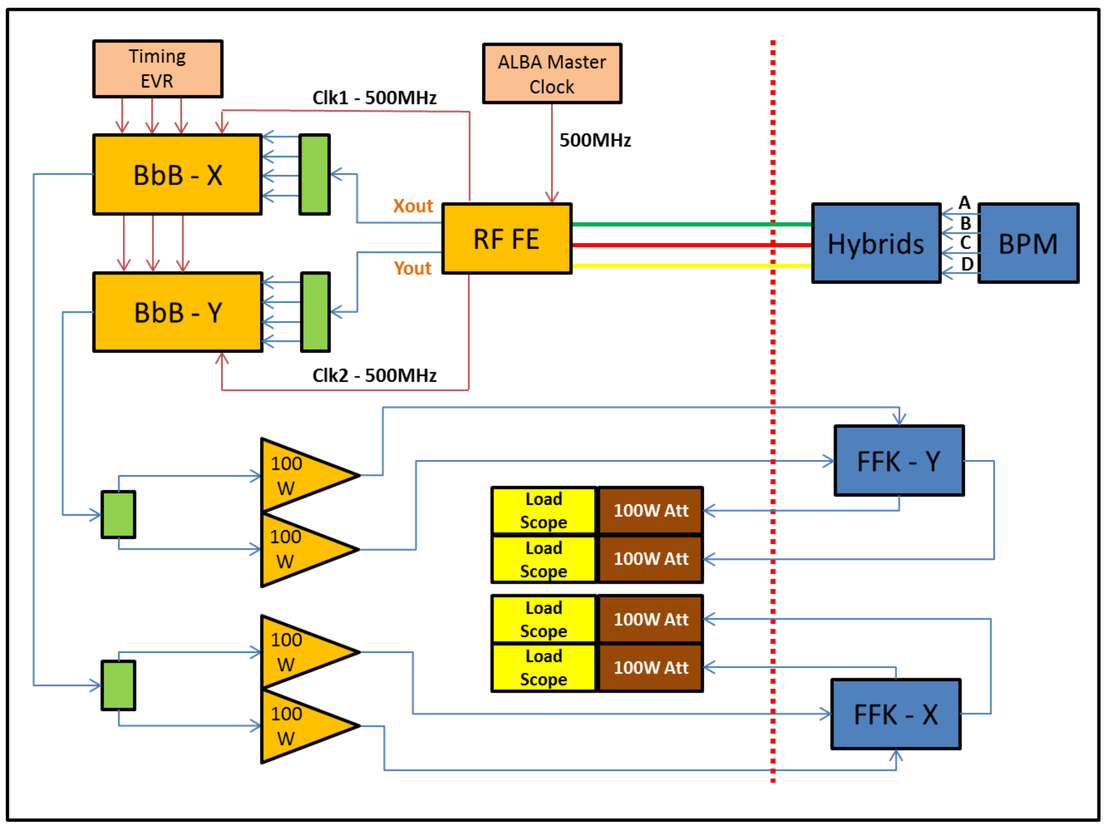
• ALBA Transverse Multibunch Feedback system (TMBF) is designed to cure the transverse betatron oscillations associated with coupled-bunch instabilities
• We have commissioned a TMBF based on the Libera Bunch-By-Bunch electronics, controlled using the EPICS software and FPGA firmware developed at Diamond Light Source (DLS)
• DLS has been developing functionality beyond the pure feedback action, and ALBA decided to profit from this experience

Devices and Layout

• Hybrid combiner @ 1.5 GHz obtains the Horizontal and Vertical components from the BPM signals
• The RF FrontEnd performs an amplitude and phase demodulation of the wideband components
• Libera Bunch-by-Bunch units detect the beam instabilities and calculate the corresponding correction
• 180º splitters provide the drive for the 100 W / 50 dB / 250 MHz amplifiers by IFI
• Signals from the amplifiers are sent to the feedback kickers (FFK) to act on the corresponding bunches

Control Software

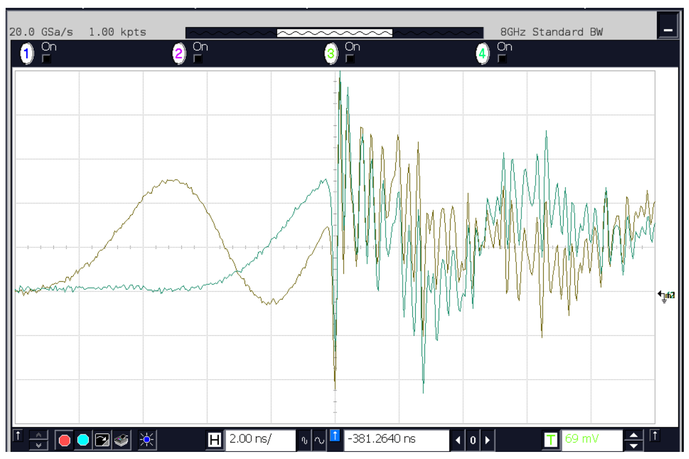
• DLS developed its own FPGA implementation to be run in the Libera Bunch-by-Bunch
• Also developed all EPICS software for controlling the system, the user interface and various python and Matlab utilities for system management
• The control software also includes several features for machine studies:
1- Input and output frequency response compensation by gain pre-emphasis FIR
2- Program sequencing: allows to apply different control parameters while data is acquired
3- Tune detection and fast tune tracking via PLL excitation of either one or many bunches
4- Concurrent sweep tune measurements on up to four bunches
5- Separate feedback parameters for individual bunches (useful for hybrid filling patterns)
• Great effort has been done by DLS to prepare a working software infrastructure to adapt all developments to the ALBA Tango environment, including also the migration of the whole FPGA code from System Verilog to VHDL



TMBF COMMISSIONING AND PERFORMANCE

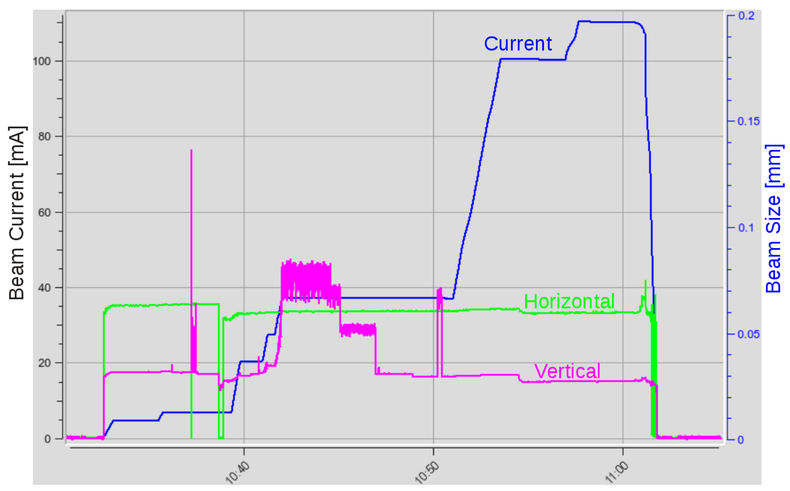
SYNCHRONIZATION WITH BUNCHES

- Phase/delay matching throughout the different components must be carefully checked
- Below: Input pulse and beam passage (high frequency signal at t=0) as seen by one of the kicker electrodes for the initial case (brown trace) and after proper synchronization (blue trace)
- In order to synchronize the bunch passage with the TMBF pulse, we added a 1 ns length cable upstream the amplifier input
- Other 4 ns shift is done acting on the Libera Bunch-by-Bunch unit



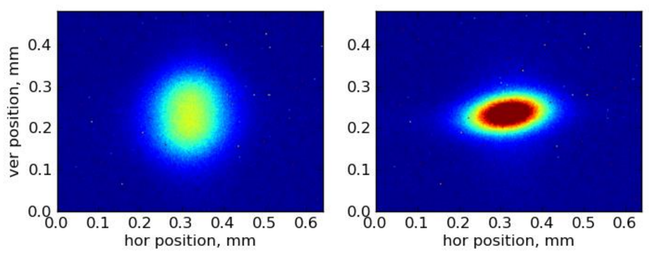
CLOSING THE LOOP

1. Vertical instability started at around 40 mA due to Resistive Wall (RW)
2. At this point, the injection was halted to find the proper feedback phase that closes the loop, which could be seen by a reduction in the vertical beam size (pink)
3. Finally we could inject up to 110 mA, after adjusting the loop gain, keeping the beam instabilities under control



Injection up to 110 mA with vertical ξV ≈ 0. The beam becomes unstable when reaching 40mA and the vertical beam size (pink trace) increases from 28 to 70 μm. Instabilities are next damped by switching the TMBF ON

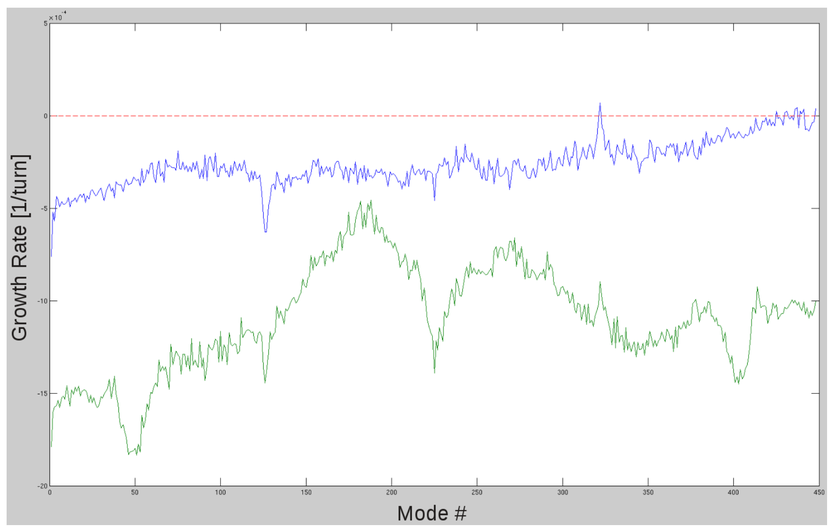
- With TMBF OFF, we are obliged to operate the machine at vertical chromaticity ξV~3.5 to avoid beam instabilities, and use an odd filling pattern in which we fill the machine with 10 trains of 32 bunches each spaced by gaps of 24 ns (in total, 320bunches)
- With the TMBF ON, we can fill the machine with ξV~0 and use an almost uniform filling pattern, increasing the number of bunches from 320 until 440.
- ALBA performance is improved because the injection efficiency improves and the lifetime increases by about 25%



Pinhole image with TMBF Off (left) and TMBF On (right)

MODE DAMPING SCAN

- This is used to measure the growth rates of the individual modes, and to assess the most dangerous modes for ALBA:
1- We excite mode "m" using an NCO and measure its growth time
2- Then the stabilization is switched On and we measure its damping time as well
3- The sequence is then repeated for mode "m+1" and a full characterization spans up to mode 448
4- Sequence is also repeated with the TMBF Off (unstable beam)
- One can see that the most unstable modes (blue trace) are modes between [440,..., 447], which indicates the presence of RW instabilities.
- On the other hand, there also exists mode 324, which needs further investigation
- In any case, all modes are efficiently damped with the TMBF On (green trace)

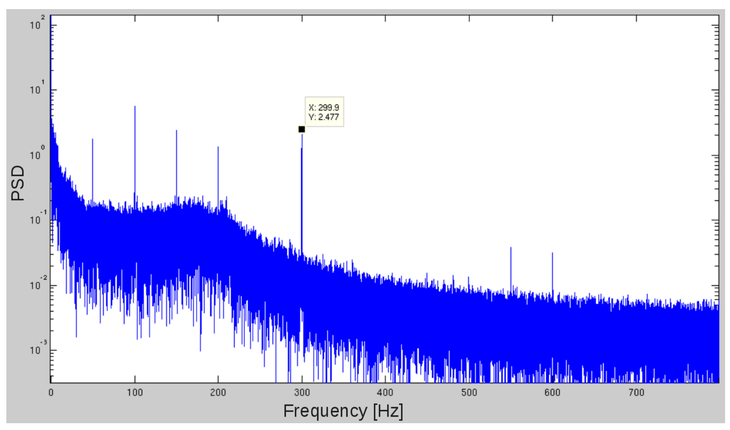


Growth rate for the 448 modes with TMBF On (green) and Off (blue) for a beam of 100 mA and ξV ~ 0.

TUNE TRACKING

- This tune measurement method is based on the following technique:
1- It excites one or many bunches using the NCO
2- Detects the phase of the bunches relative to the excitation
3- Feeds it back through a proportional-integral controller to the NCO frequency

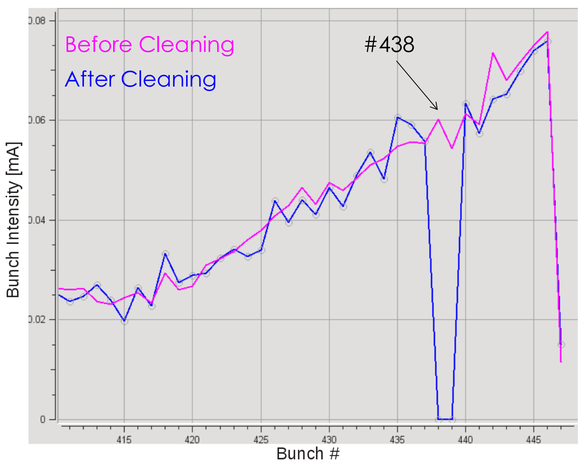
- This allows to measure the tune during long terms with a precision down to 10−5, and thus monitoring the tune jitter with high precision



Spectral density obtained after monitoring the vertical betatron tune during 70 s every 200 turns. One can see that most of the tune jitter is at low frequencies, but there also exists peaks at 50 Hz and its harmonics (particularly, the 300 Hz corresponding the power supplies).

BUNCH CLEANING

- Bunch cleaning is performed by exciting the target bunch with a backwards frequency sweep around the vertical betatron tune
- A first attempt to kill one bunch (#438) showed that actually two bunches were killed as a consequence of the bad phase response of the TMBF amplifiers, which spreads the single kick produced by the Libera to two bunches
- Nevertheless, optimum settings can be achieved to kill all bunches around a selected one to obtain a pure single bunch



Bunch intensity for buckets between 410 and 448 before (pink trace) and after bunch cleaning (blue trace)