Minutes Longitudinal Painting – kickoff meeting, 27/10/2016

Presents:

Vincenzo Forte; Elena Benedetto; Alan James Findlay; Maria Elena Angoletta; Chiara Bracco; Gian Piero Di Giovanni; Greta Guidoboni; Gregoire Hagmann; Simon Albright; Bettina Mikulec

PSB longitudinal painting: concept and control

Slides by Vincenzo Forte.

Nice introduction of the longitudinal painting from the beam dynamics point of view (see animations in the ppt version).

A first draft of a control algorithm to define and give as output: energy swing function (PIMS) and energy spread (debuncher) in form of GFAs and chopping sequence (chopper).

Inputs are divided in "fixed" and "variable": Linac4 current before chopping, target intensity, longitudinal emittance, # modulations are fixed, max. energy swing, energy spread and energy swing rate are variable.

Comments:

- The Linac4 current can be varied by playing with the optics in the chopper line
- The longitudinal emittance may not be the best parameter to pass as input, consider adding a bit more of beam dynamics, such as cavity voltage, bunch length and/or percentage of the acceptance, etc.…

In addition, the RF bucket contour and in general the iso-hamiltonian lines should also be provided, an option would be to provide the equation of motion or the potential well, which could include space charge. To be further elaborated.

The main Loop consists of:

1) first guess of chopping factor, overestimated from min-max phase of target contour,

2) this gives a first estimate of # of turns

3) based on that, generate the triangular energy modulation function

4) compute the intersections with the wanted RF contour

This gives the real chopping factor turn-by-turn and based on that one can compute the accumulated intensity and iterate 2) 3) 4) with an updated number of turns.

The output are:

- Boolean table 0/1 to the chopper --> could also produce fancy distributions, like hollow-bunches
- an array of the voltage points over time to the PIMS (amplitude & phase)
- swing rate: debuncher and RF feedback

Question on whether we can keep 1/2 modulation empty? Can the adaptive feedforward cope with that?

In addition, one may envisage an extra measurement loop [(I-I_target)<tolerance]: chopper factor to be slightly reduced if there are fine modif to be done or change the #turns on the next cycle. To be further elaborated how to incorporate this info in the main loop for the preparation of the next cycle.

Vincenzo has proposed to monitor the peak line density, for a given number of synchrotron oscillations after injection, as a figure of merit for painting optimization (and space-charge mitigation). i.e. the smaller the oscillations → the smaller the filamentation, the lower the value → the best for space charge.

One could also measure the source current in advance (provided that it is stable over ~few hours) to have a better estimate of the # of turns.

Moreover, a better first guess of the chopping factor (turn-by-turn) can be estimated in advance by knowing the bucket shape. This might save iterating. To be evaluated if there is a gain.

Actions: Vincenzo will incorporate the suggestions received in the new version of the algorithm and present an update in a next meeting.

LLRF for the Longitudinal Painting

Slides by Gregoire Hagmann.

Description of the CTU (Chopper trigger unit)

The chopper will receive from the PSB the Ring Start timings , the timings are called BI#X.SCHOPPER.

The synchronous chopper logic (FPGA) is clocked to the Linac4 RF @ 352.2 MHz, therefore the chopping pattern has an uncertainty of 1 or 2 linac periods at every PS-Booster ring start timing

FESA class implementation:

The chopping pattern is defined by 4 tables of 0/1 bits at 352.2 MHz to the CTU module (1 table per ring, 8 kbytes). There are two ways to set the chopping pattern:

- With Duty cycle and Delay (individual settings per ring) which define a periodic chopping pattern and which will be repeated for N turns, synchronously to the linac

RF. Available in the Linac4 working set (LN4:CHOPPER) with direct access to the 4 tables of 0/1 bits (e.g. for the longitudinal painting). The CTU will read binary tables and play back the data serially when the ring start timings are received. The 4 tables can be set in the CTU FESA class by the longitudinal painting application (PSB). Last bit shall be 1 (should be forced to be 1).

The Chopper latency, i.e. the interval of time from BI#X.SCHOPPER till the chopper table for Ring_i is played, is negligible compare to the timing distribution (from PSB to Linac4) and can be compensated by the timing delay settings. The CTU receives dedicated Ring start timings whose delays can be set independently to the PSB distributor and PSB RF.

In the definition of the chopper tables, need also to take into account the distributor rise-time.

M. Paoluzzi, comment after the meeting: also the maximum chopping frequency (2MHz) and a minimum Off time between pulses (15ns).

Need to implement all these rules to play the correct pattern.

2 different cases:

- Ring inhibit (via optical fiber, one interlock per ring): the chopper is ON to prevent ring filling and the filling of the subsequent rings is not advanced, i.e. there is a "hole".
- Ring blanking (triggered by PSB - timings) --> next ring is advanced

Concerning the last 2 cavities for the energy modulation:

Needs Amplitude/phase array from INCA (and a make-rule to convert to IQ) and the RF feedback will make sure this is followed.

Synchro PIMS: They will not receive the RingStart# and the only timing that is received is the BIX.W10-CT advanced by 100 us --> the chopper pattern and the PIMS are not synchronized !!!

Actions: Greg will check with Philippe whether it is possible to add 4 extra timings to the PIMS (and the debuncher?) and/or from the chopper to the PIMS (and the debuncher). This would imply new cables. Elena will contact back Greg and Philippe in 2 weeks time.

AOBs:

Comment by A. Findlay (after the meeting): We should keep the option for injecting directly into h=2 and/or h=2+4 buckets for the MTE type beams. We should just confirm that everything remains compatible with this option.

--> Should be ok for what concerns the longitudinal painting algorithm and the output sent to the chopper (i.e. as sequence of 0/1), PIMS and debuncher, but to be kept in mind for the synchro.

E. Benedetto, 2/11/2016