Ideas on a pulsed beam-beam wire compensator

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Contents

All values and curved given/shown in the following are a first estimate and to be considered as an "educated " guesses

0.1 Motivation

Simulations of a current carrying wire placed in the beam-pipe show its capability to reduce the effect of long-range beam-beam interaction significately. In order to compensate each bunch individually (especially the Pacman bunches) a pulsed option is desired. Further details on the simulations can be found in [?].

0.2 General remarks

- Stability: The requirements on the turn-to-turn stability must be fulfilled while a long-time (long compared to the revolution frequency of the LHC) drift is not a problem (within limits).
- It is not important to exactly match the values of the signal pattern. Slight deviations from the linear slope are no problem as long as they are reproduced every turn.
- The design must be flexible to adjust to different bunch pattern (without too much intervention) and must be scalable during the run (lowering all currents by the same factor, to adjust to the beam intensity decay).

- Due to radiation issues the generator will not be placed next to the wire but at least 300m away (either in a protected area underground or on the surface (only passive elements next to the wire).

- the wire will need to be cooled (SPS: water, RHIC: heat sinks)

0.3 requirements

- The following figure shows a typical pattern:

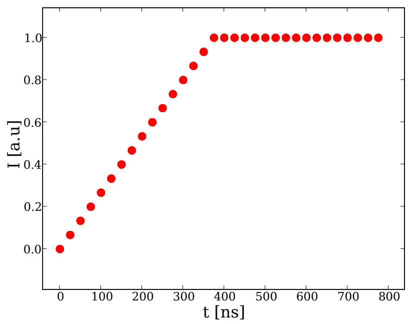

Figure 1: Typical required pattern

- The exact shape is not yet determined (depends on the chosen upgrade optics), but should not vary too much. the maximal needed current will be about 100Am.

- The maximal allowed turn-to-turn-jitter must be smaller than $\approx 3mA$. (for a DC wire this would correspond to a timing precision of 0.02ns) to keep the emittance growth below 10 % in 20h

0.4 Implementation proposal

Figure 2 shows the proposed implementation idea:

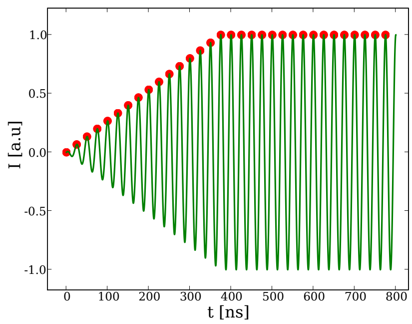

Figure 2: Instead of a DC solution, a 40Mhz sin solution is proposed.

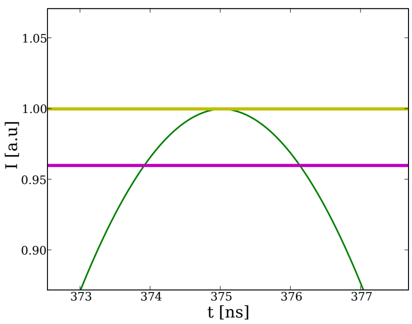

Figure 3: A zoomed view on the sin with the limits of the bunch length (2ns assumed) shows the reduced timing requirements.

The difference between center head and tail should not be a problem and will be simulated soon.

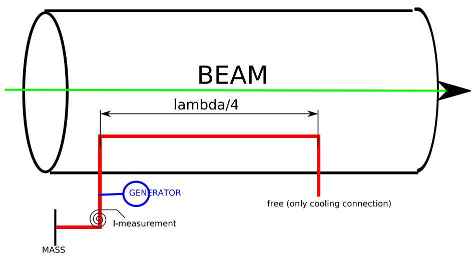

Figure 4: At 40Mhz a 1.875 m long cable is a $\lambda/4$ resonator. The wire is not terminated at the end (only to allow the cooling to escape).

Advantages of this solution compared to a conventional DC approach:

- Due to the reduced slope the required current timing precision should be relaxed to 0.03ns.
- Available RF technology should be usable.
- The HF field is easier to shield to not effect the other beam [1]
- The wave going in the opposite direction acts double (electric and magnetic field). This reduces the required current by a factor of 2 and therefore the required power by a factor of 4
- For the wave going along with the beam the magnetic and electric components cancel each other.
- Using a 2m cable one gains another factor 2 in current, resulting in a factor 4 in power.
- Taking the rms value instead of the peak value, we gain another factor 2 in power ($\sqrt{2}$ in current)
- The real loss is defined by the Q value of the circuit. this should bring another actor of 10 in the power (assuming Q=10).
- The power generator can be placed on the surface and only a passive transformer is next to the wire

Therefore:

[1] HF fields are easy to shielded. In the DC case the field would possibly affect the other beam. Even if the vacuum chamber is used to transport the current back, the shielding is not good in the DC case as the current flow back will be homogeneous around the vaccuum pipe, while the wire is offcentered.

- On a 2m cable we need: 25A peak current running against the beam (=effective 100Am)
- The rms is therfore: 17A rms at $approx 200\Omega$
- 3.5kVrms are needed
- This results in an average power of 3.5kV*17=60kW.
- The factor 10 due to the Q reuces this to 6kW. This should be possible with class C solid state devices.
- Only a fraction of this will actually be dissipated in the wire (and needs to be cooled)

Other remarks: On the loose end a 10kV feed-through is needed. at the other end only a 1kV one.

0.5 The load

The load is a wire surrounded by the beam-pipe. Its Impedance (per unit length) is given by [**?**] as

$$Z_0 = \frac{\eta_0}{2\pi\sqrt{\epsilon_r}} \cosh^{-1}\left[\frac{D}{2d}(1-\phi^2) + \frac{d}{2D}\right] \tag{1}$$

where $\eta_0 = 120\pi$, D the diameter of the outer structure, d the diameter of the inner cable. The radial position of the inner wire is $r = \phi D/2$. For the assumed dimensions for the LHC (D=7cm,d=1mm,r=0.00846m) one obtaines $Z_0 = 236\Omega$. (The already produced SPS-structures with D=140mm, d=2.5mm, r=20mm deliver $Z_0 = 236\Omega$).

- At 40 MHz a 1.875m long wire acts as a $\lambda/4$ resonator. The wire can therefore be used as a cable resonator.
- In order to ramp the current the time constant of the RC-circulator is used.

anstiegszeit von zirkulator bei Q=20 checken was moeglich zeitkonstante ohmscher verlust des wires mit skin effect - guete: erwarte ca 100

0.6 Other

0.6.1 3 turn delay feedback

If the current can be measured precise enough, the current can be corrected for 3 turns later