Reflections on the bend-based CeC designs

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CeC meeting …

My consideration of the CSR [3, 4] actuality in physics of CeC designed as a multi-cell microwave amplifier (MWA) with use of electron bends (following a long inertial section) is based on an argument that, effective region (length) of collective Coulomb interaction in relativistic beams in longitudinal direction is about $\frac{\sigma_\perp}{\gamma}$, while MWI of CSR is actual for distances larger than R/γ^3, where $\sigma_\perp$is beam transverse size , R is bend radii and $\gamma \gg 1$ is Lorentz factor. In terms of the Furrier space harmonics (wave vectors k) effective area of Coulomb amplification is limited as follows:

$$\frac{\gamma^3}{R} < k \leq \frac{\gamma}{\sigma_\perp}.$$

From here one concludes that Coulomb interaction dominates in the collective dynamics only at sufficiently large bend radii, namely at:

$$R \gg \gamma^2 \, \sigma_\perp \, ;$$

otherwise, CeC MW dynamics i.e. amplification is driven by the CSR. Other aspect of CSR impacts is, of course, the related radiation noise which affects the electron beam itself.

For example, assume the following set of an MBEC design parameters:

$R = 2.7M; \quad \sigma_\perp \sim 0.3mm; \quad \gamma \approx 300 \;\longrightarrow\; \gamma^2 \, \sigma_\perp \approx 27 \; M$.

Thus, in this area of parameters we have

$$R \ll \gamma^2 \, \sigma_\perp \, .$$

This inequality indicates with certainty that, in the shown set of parameters CSR dominates over the Coulomb interaction in the e-beam when passing through the chicanes.

Strong bends are introduced in the proposed design with a purpose to facilitate maximally the electron longitudinal mobility $\frac{dv_z}{cd\gamma}$ in the chicane sections :

$$(l_C^{-1})_0 \sim \frac{k}{\gamma} \left| \frac{J}{J_A} \frac{dv_z}{cd\gamma} \right|^{\frac{1}{2}}$$

Here l_C is Coulomb “increment length”, J is peak current, $J_A = 17 \; KA$, and v_z is electron transport velocity as function of energy.

- **However, *strong CSR* exceeding in strength the Coulomb interaction inside the beam area arrives here [4]** ($(l^{-1})_{CSR}$ is inverse increment length of the CSR MWI [4]):

$$(l^{-1})_{CSR} \sim (l_C^{-1})_0 (\frac{\gamma^3}{kR})^{\frac{1}{3}} \;; \qquad k < \frac{\gamma^3}{R}.$$

- **Concerning the Landau damping due to energy spread, and smearing due to emittance**

Also very unfortunately, large increase of orbit curvature, dispersion at large beam size due to emittance (weak focusing) in chicanes leads to huge powering of two more unwanted dragons:

- **Super-fast *Landau damping* against MWI, - due to the existing energy spread:**

$$(l^{-1})_{LD} = k(\gamma \frac{dv_z}{cd\gamma}) \frac{\Delta\gamma}{\gamma}$$

- **Fast smearing of the MWI increment by the transverse horizontal emittance:**

$$(l^{-1})_{sm} \sim k \frac{\sigma_\varepsilon}{R}$$

A few of the history

- ***Negative longitudinal mass (NMI) MWI*** was proposed in [2] and even earlier in first note of 1980 about the CeC idea. Obviously, its realization takes strong enough bends that normally delivers negative longitudinal mass. In my view, a multi-chicane CeC amplifier of D. Ratner is a full equivalent of the NMI idea.

References

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[3] Y.S. Derbenev et al. DESY Sept.19, 1995.

[4] G. Stupakov and S. Heifets. PRSTAB v.5 054402 (2002)