The concept of coupling impedance in the plasma wake field excitation as a new tool for describing the self-consistent interaction of the driving beam with the surrounding plasma

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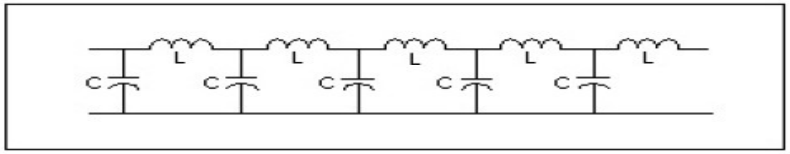
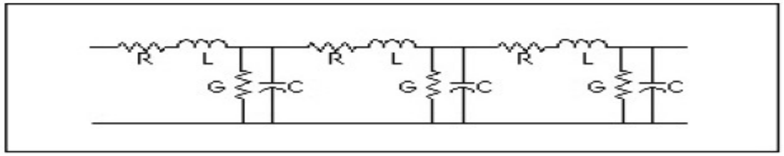
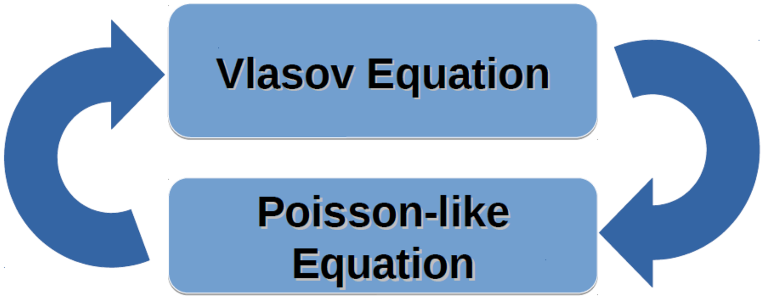
- We have briefly introduced the concept of coupling impedance in conventional accelerators as a quantity that allows to schematized the interaction of a charged-particle beam with the surrounding
- We have described the Plasma Wake Field Excitation (PWF) of a long charged-particle beam in terms of a self consistent interaction of the beam with the surrounding plasma

- We have outlined the analogy between the interaction of the beam with the walls of the vacuum chamber in conventional accelerators and the one with the plasma in the PWF excitation





This analogy has led to introduce an heuristic concept of coupling impedance also in the beam-plasma interaction as ruled by the PWF excitation. This can be done for both the longitudinal and the transverse impedances. However, we have confined our analysis to the longitudinal one but including in simple way the collisional effects between the particle of the beam and the ones of the plasma.



- Linearized Poisson-like equation

$$\left(\frac{d^2}{d\xi^2} + k_p^2\right)\Omega_1 = k_p^2 \frac{m_0 c}{e^2 n_0} \frac{I_{b1}}{\beta\pi\sigma_\perp^2}$$

$$I_{b1} = q\beta c\pi\sigma_\perp^2 n_{b1}$$

- Linearized Vlasov equation

$\xi = z - \beta t,\ \tau = t$

$$\frac{1}{c}\frac{\partial f_1(\xi, \mathcal{P}_{1z}, \tau)}{\partial \tau} + \mathcal{P}_{1z}\frac{\partial f_1(\xi, \mathcal{P}_{1z}, \tau)}{\partial \xi} + \frac{q}{m_0\gamma_0 c^2}\frac{\partial \Omega_1}{\partial \xi}\frac{\partial f_0(z, \mathcal{P}_{1z}, t)}{\partial \mathcal{P}_{1z}} = 0$$

- The above analysis has clearly drawn the possibility to study the stability/instability beam-plasma conditions by means of Nyquist-type universal charts in the plane of the impedance (ZR, ZI)), where Zr and ZI are the real and the imaginary parts of the coupling impedance. In this scheme, while the Nyquists chart are universal but fixed by a specific phase space unperturbed distribution function, the coupling impedance contains all the physics of the system. Therefore, the stability/instability analysis requires to match the impedance properties with the ones of the charts.
- This study is under way where specific physical examples are considered to show the usefullness of coupling impedance as a tool to approach the instabilities processes related to PWF excitation.

$$\frac{Z_L(k,\omega)}{k} = i\frac{\tilde{\Omega}_1(k,\omega)}{\tilde{I}_1(k,\omega)}$$

$$1 = i\eta\left(\frac{Z_L}{k}\right)\int \frac{f_0'\, d\mathcal{P}_z}{\mathcal{P}_z - \frac{\omega}{ck} - \frac{i\nu}{ck}}$$