ALTERNATING PHASE FOCUSING BEAM DYNAMICS FOR DRIFT TUBE LINACS

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In contrast to conventional drift tube linac RF-structures (e.g., of ALVAREZ-type) operated in TM-mode, novel H-Mode structures (e.g., Interdigital H-Mode) provide for compact acceleration of ion beams and have been established as highly efficient RF-resonators during the last decades. Thus, H-mode based accelerators are widely applied for heavy-ion acceleration with medium beam energies because of the outstanding capability to provide for high acceleration gradients with relatively low energy consumption.

In order to build upon those advantages, an Alternating Phase Focusing beam dynamics layout has been applied and adapted to provide for a cavity design without internal lenses, which allows for a most compact linac design, eased commissioning, maintenance and potential future upgrades. In order to omit magnetic focusing elements within the cavity, the electric focusing of the RF gaps is used for acceleration and additionally for focusing. But Gauss's law, one of the fundamental Maxwell equations, does not allow simultaneously focusing along all directions in charge free space, $\nabla\vec{E} = 0$. Thus, subsequential longitudinal and transverse electric focusing is necessary to provide for overall beam focusing. Negative, as well as positive synchronous phases, i.e. the RF phase when the accelerated particle beam is centred in the RF gap, are applied alternatingly to provide for the transversal and longitudinal focusing. Negative phases are routinely applied for ion acceleration and longitudinal focusing, whereas positive phases found wider application during recent decades, although proposed already in 1953 and refined in following years [1-3]. As predicted by Moore's Law, computational power has increased by several orders since then. It is now possible to provide for a design and detailed analysis of the complex beam transport in Alternating Phase Focusing accelerators. The gradual change from negative to positive synchronous phases is realized by altering the standard $\beta\lambda/2$ resonance acceleration geometry, which usually provides for only longitudinal focusing with -30° synchronous phase. The introduced synchronous phase change $\Delta\varphi$ in between two neighbouring RF gaps leads to a change of the resonator geometry:

$$L_{\text{cell}} = \beta\lambda\frac{\Delta\phi}{2\pi} + \frac{\beta\lambda}{2} \tag{1}$$

A dedicated software has been developed to identify the change of gap phases along an accelerator for efficient beam transport and high beam quality. The features of such channel are demonstrated on the example of two IH-cavities, separated by an external quadrupole triplet. This setup provides for heavy ion (mass-to-charge < 7) acceleration from 300 to 1400 keV/u and will be used as injector part of the superconducting continuous wave accelerator HElmholtz LInear ACcelerator HELIAC [4, 5]. This superconducting accelerator, based also on H-mode cavities (Crossbar H-mode) offers for advanced features as a very low energy spread, a variable output energy and continuous wave operation especially designed for beam delivery to the GSI Super Heavy Element research program, contributing to advance the understanding of fundamental nuclear interactions. Hence, this promising approach generally enables safe routine operation for various applications as super heavy ion research, material science and radiobiological applications and heavy-ion tumour therapy. APF in general is an extremely interesting and attractive option for very different applications, such as LINAC concepts for accelerating electrons or hadrons of different mass.

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