Karlsruhe Institute of Technology
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Quasi-isochronous conditions and high order terms of momentum compaction factor at the compact storage ring

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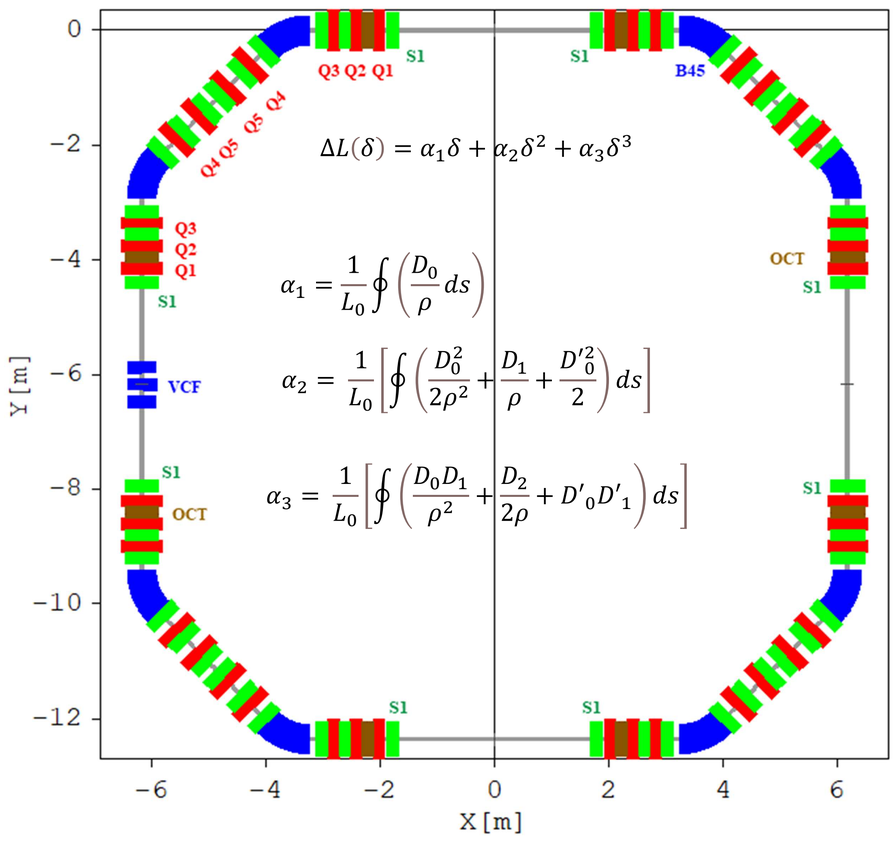
Abstract

The compact storage ring project for accelerator research and technology (cSTART) is realized at the Institute for Beam Physics and Technology of the Karlsruhe Institute of Technology (KIT). Flexible lattice of a ring benefits variety of operation modes. Different physical experiments including direct injection and circulation of Laser Plasma Accelerator (LPA) electrons are planned at cSTART. Deep variation of momentum compaction factor with simultaneous control of high order terms of alpha would demonstrate the capture and storage of ultra-short bunches of electrons in a circular accelerator. Computer studies of linear and non-linear beam dynamics were performed with an objective to estimate arrangement and performance of dedicated three pole chican magnets to provide quasi-isochronous conditions for electrons. Additional families of so called “longitudinal” sextupoles and octupoles were added in a ring to control slope and curvature of momentum compaction factor as function of energy offset of particles in a bunch.



Computer model of cSTART ring including variable compaction factor magnets (**VCF**). Dipoles – **blue**, quads – **red**, SXT – **green**. Family of dedicated **S1** sextupoles suppresses longitudinal chromaticity (α_2 – slope of α) while eight octupoles **OCT** marked in **brown** control α_3 – curvature of α

Zero current bunch length σ_l is given by expression

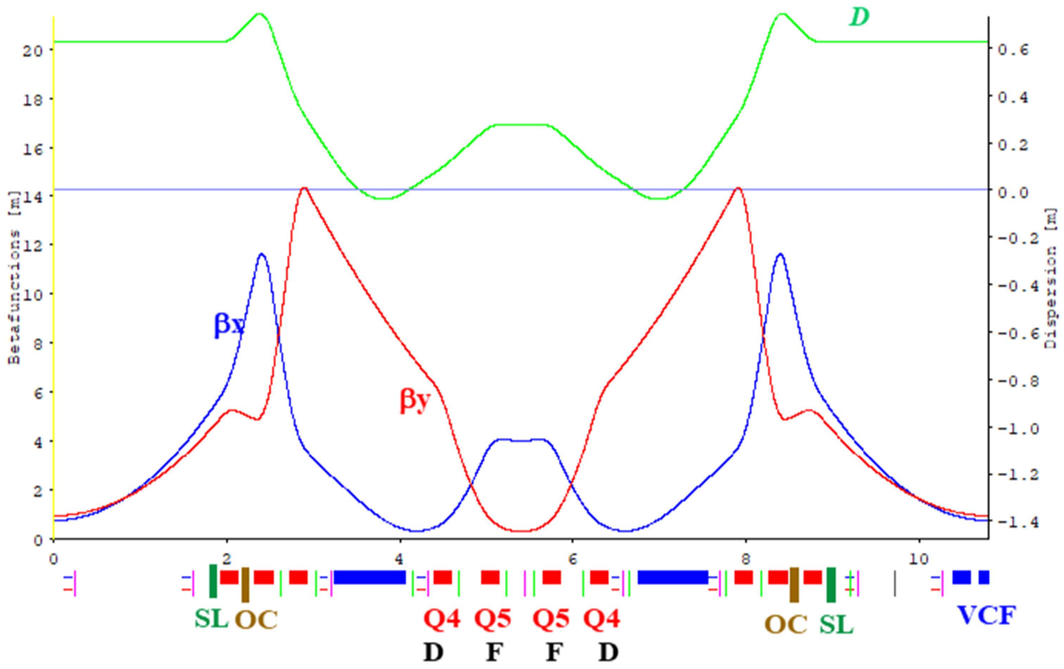
$$\sigma_l = L_0\beta_0\delta_p\sqrt{\frac{E_0\cdot\alpha_1}{2\pi\cdot h\ eU_{RF}(-cos\varphi_s)}}$$

The synchrotron tune, F_s, where α can be defined as a derivative of the relative orbit lengthening with momentum offset $\alpha = \partial(\Delta L/L_0)/\partial\delta$

$$F_s(\delta) = F_0\sqrt{\frac{heU_{rf}(-cos\varphi_s)}{2\pi\beta_0^2 E_0}}\cdot\sqrt{(\alpha_1 + 2\alpha_2\,\delta + 3\alpha_3\delta^2)}$$

$$\Delta\alpha_2 = -\frac{1}{2L_0}\oint D_0^3\cdot\Delta K_{SXT}ds$$

Variation of α_2 by sextupoles is proportional to 3rd power of D_0^3

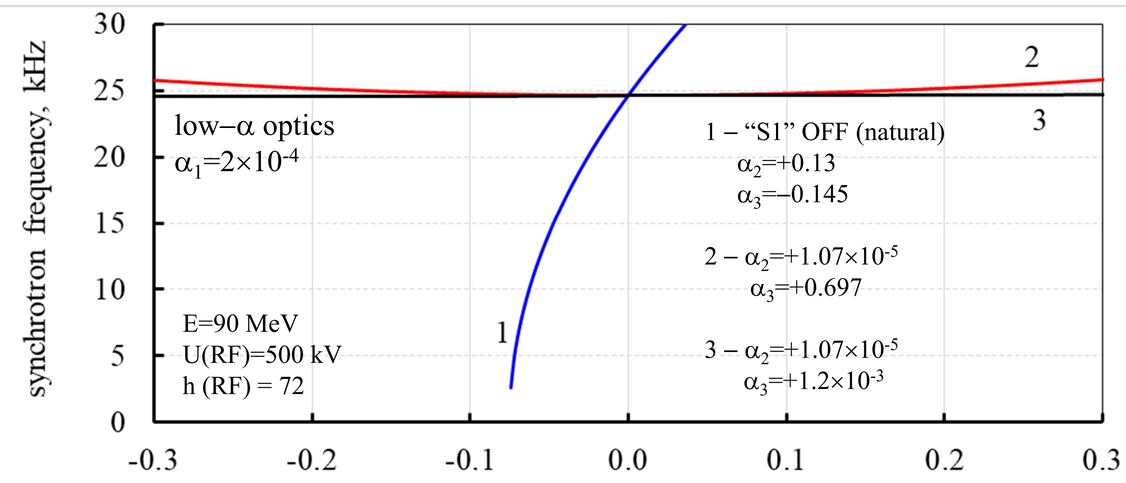


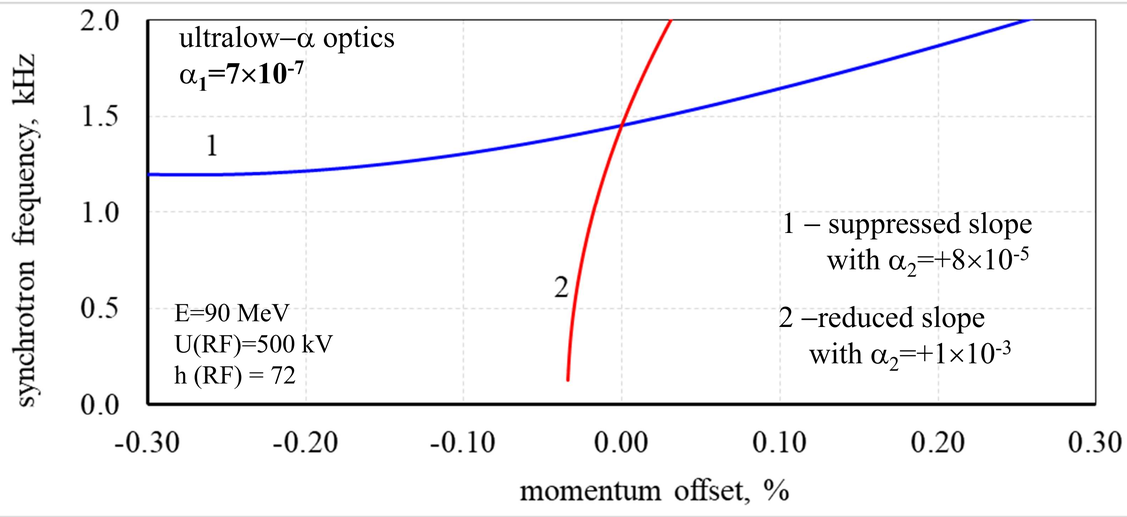
Lattice of one cell of a ring at low–α optics (α=2×10^{-4}). Horizontal betatron function is marked by **blue**, vertical β–function – **red**, dispersion function leaking into straights – by **green**. 45° bends - **blue** strips, quads – **red** blocks, sextupoles – **green**

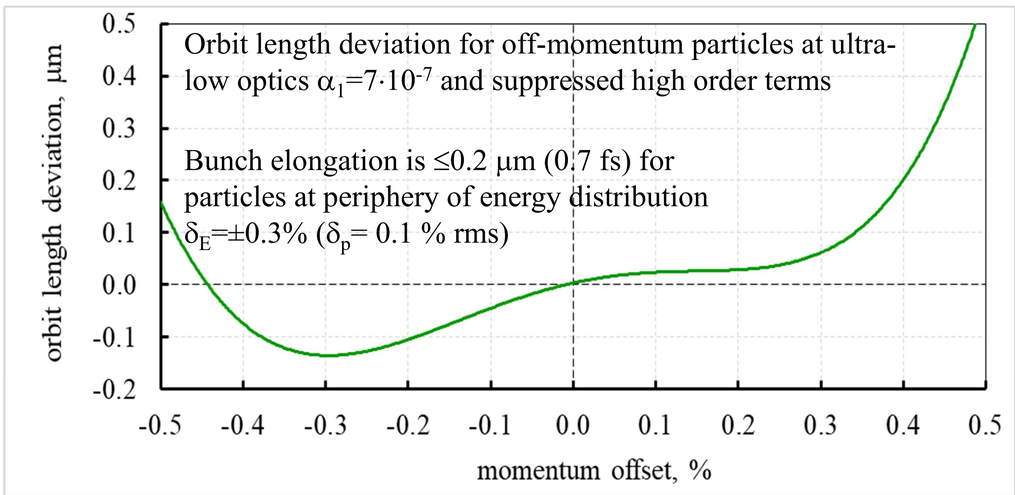
Expected parameters of post-LPA beams

Beam energy	40 to 90 MeV
Magnetic rigidity of a ring	0.30 T·m
Energy spread of main spike	up to 1.2 % (rms)
Number of particles per pulse	6.E+6 to 6E+9
Charge per pulse	1 pC to 1 nC
Pulse width	1 fs to 100 fs
Pulse length	0.3 to 30 μm
Repetition rate of laser pulses	1 to 10 (1/s)
Transverse beam size σ	5 μm (rms)
Transverse divergence, σ′	2 mr (rms)
Beam emittance ε (h,v)	10 nm (rms)
Zero current bunch length	85 fs (δ_p= 0.1 % rms)

Synchrotron frequency as function of momentum offset







CONCLUSION

Recent experiments with additional longitudinal sextupole at KARA ring provide “prove of principles” of dedicated set up with variable compaction factor chican at cSTART ring. Ultrashort bunches of about 900 fs “zero current” bunch length (rms) have been received at KARA. Basic approach to build up ultralow-α optics was confirmed. Flexible lattice with VCF chican at cSTART will benefit research program with ultrashort bunches

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