Design of an ultimate storage ring for future light source

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Outline

- Ring structure and linear optics
- Driving terms and dynamic aperture optimization
- Intrabeam scattering and its effect on beam properties
- Microwave instability and possible FEL process study
- Conclusion and future work

10 pm storage ring

- 10pm storage ring has 40 superperiods with 11 bending magnets in each superperiod.
- Center 9 dipole cells have non-zero dispersion and quadrupole triplets are used to match the dispersion and beta functions to theoretical miminum.
- Outer 2 dipole cells are used to match the dispersion thus we have 10m long non-dispersive straight sections between superperiods for insertion.
- The whole ring can be designed into race track shape and two long straight sections (100m) can be used for FEL process.

10 pm storage ring

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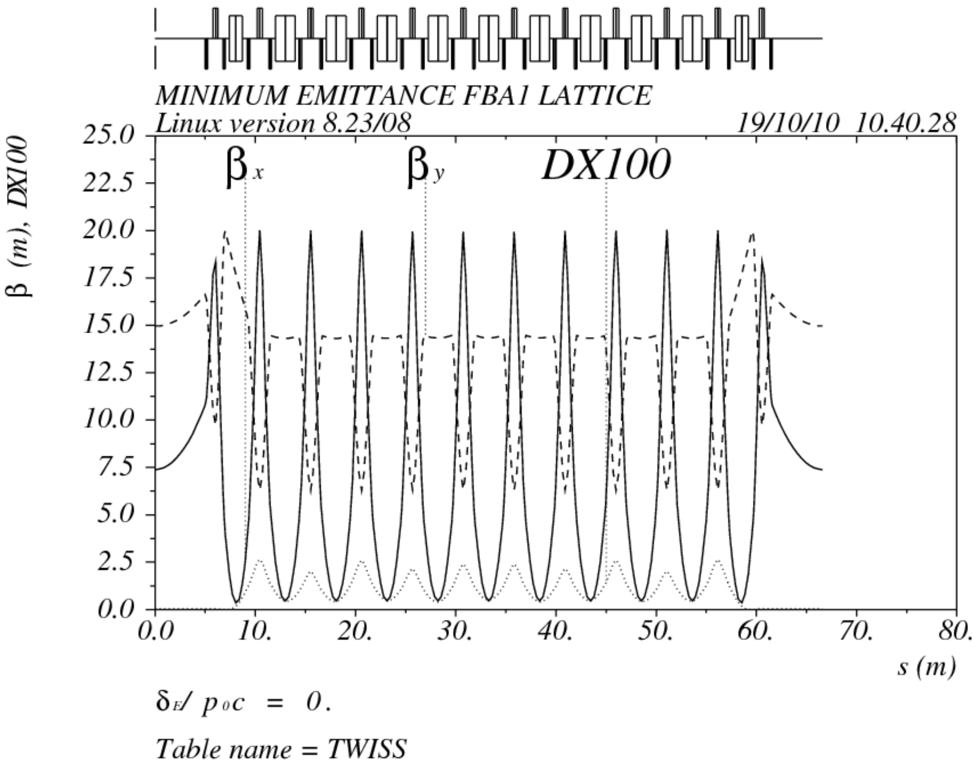

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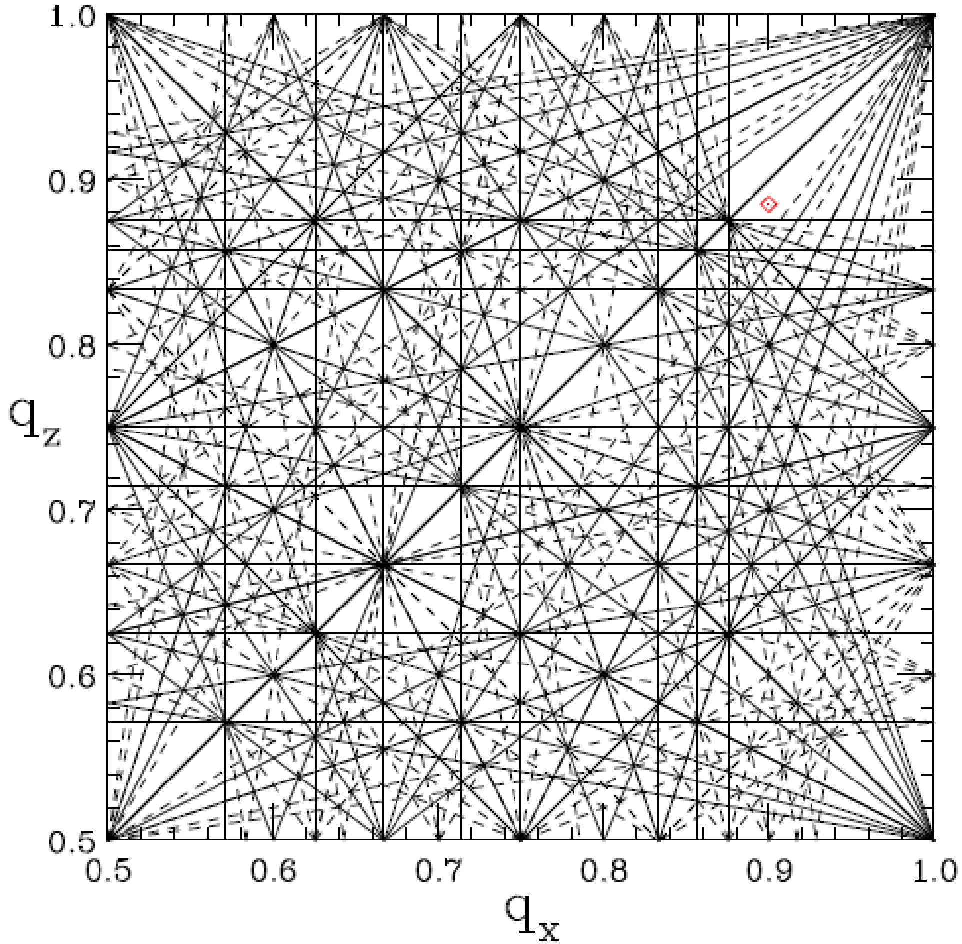
Parameters	Value
Circumference	2663m
Energy	5GeV(4-7GeV)
Natural chromaticities	-595.339(horizontal) -148.741(vertical)
Qx	202.9
Qy	33.884
dE/E	3.8e-4
Momentum compaction factor	1.223e-5
Natural emittance	9.1pm(before coupling)

10 pm storage ring



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Dynamic aperture and driving terms optimization

- Beam properties listed before are equilibrium values and it takes usually few thousand turns for the beam to damp to that point. Study of dynamical aperture and nonlinear driving terms is crucial point for the design.
- Usually driving term h_{abcde} drives certain order of resonances or quantities. E.g. h_{30000} drives $3\nu_x$ resonance and h_{10020} drives ν_x-$2\nu_y$ resonance.
- After careful study, it turned out that for this lattice design, the tune shift with amplitude, $d\nu/dJ$ is most influential and thus limits the dynamic aperture size.

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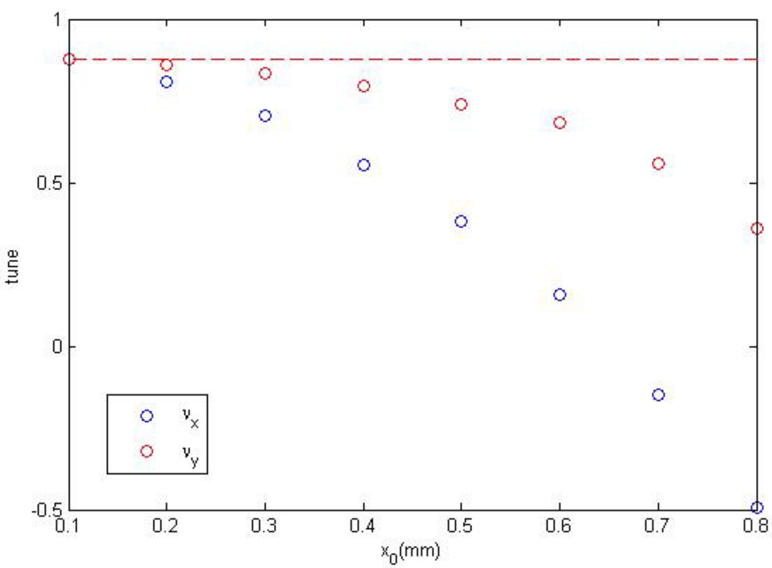

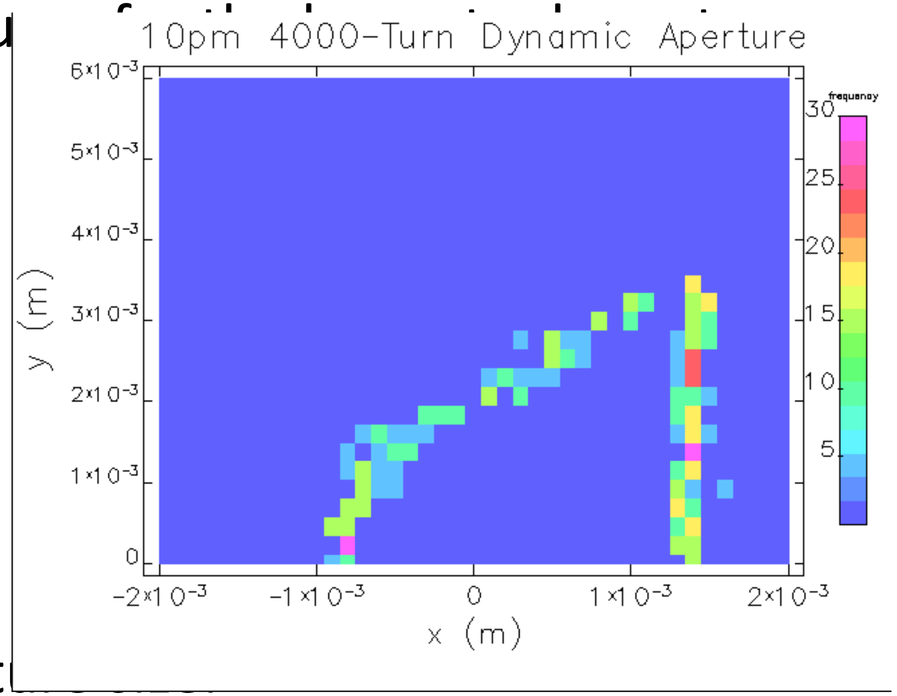

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Resonances at DA boundary

- We study the resonances at DA boundary using ICA method. A chaotic pattern shows up indicating there are many resonances crossing at the DA boundary and particle motion will be chaotic but still bounded.

- Eigenmodes with small amplitude given by ICA shows a much cleaner frequency spectrum.

- This method can be further used for driving terms optimization to improve DA.

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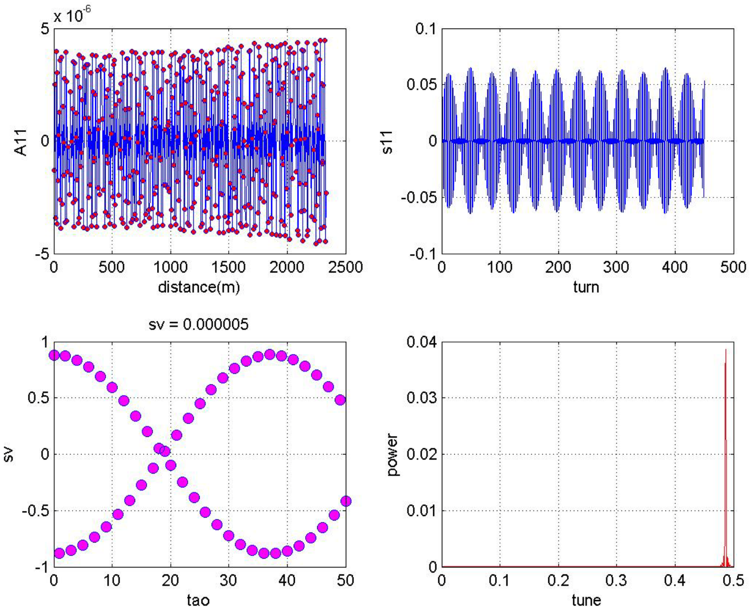
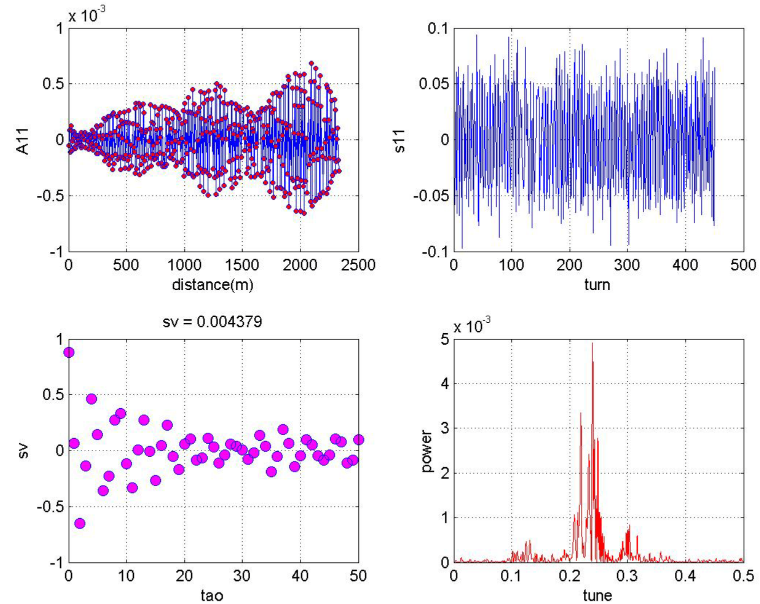


A typical ICA mode with x_0=0.1mm



The same ICA mode with x_0=1.3mm

Intrabeam scattering

- IBS(intra-beam scattering) is short-range particle coulomb scattering which is a diffusive process.
- It is a serious problem when the peak current is high and the transverse emittance is small.
- Similar to space charge effect, it will deteriorate beam quality and blow up horizontal emittances and energy spread which causes serious beam loss.
- Radiation damping, quantum excitation and IBS will reach an equilibrium state and beam coupling plays a key role in this process.

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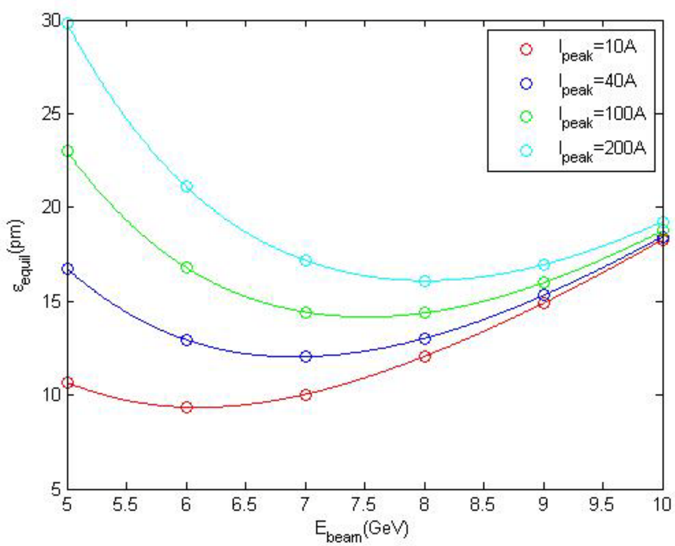

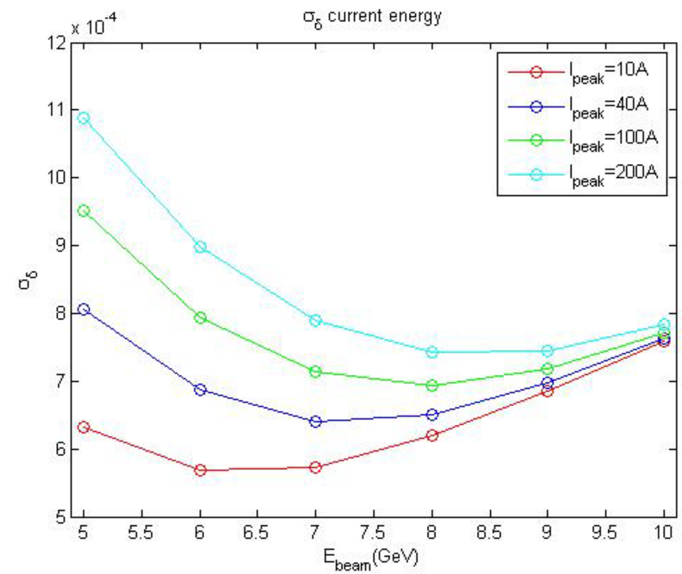

Emittance and energy spread can grow up a few times by the IBS effect when beam energy is low and peak current is high.

Microwave instability

- The non-smoothness of chamber wall or other broadband impedances will generate wake field. This wake field can affect the particles passing thru and sometimes this effect is collective and cause beam emittance, energy spread and bunch length increase thus causes beam loss.

- When collective instability happens, it deteriorates beam qualities very fast and damping does not have time to react.

- Usually in light sources, single bunch beam properties are largely limited by microwave instability.

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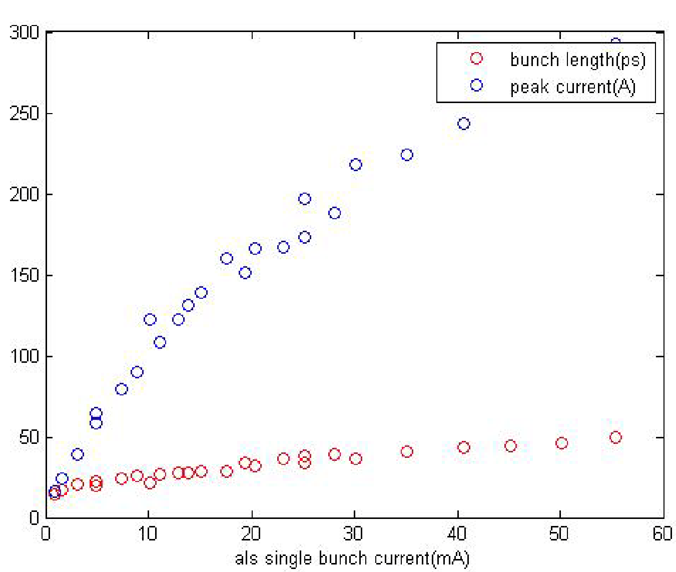

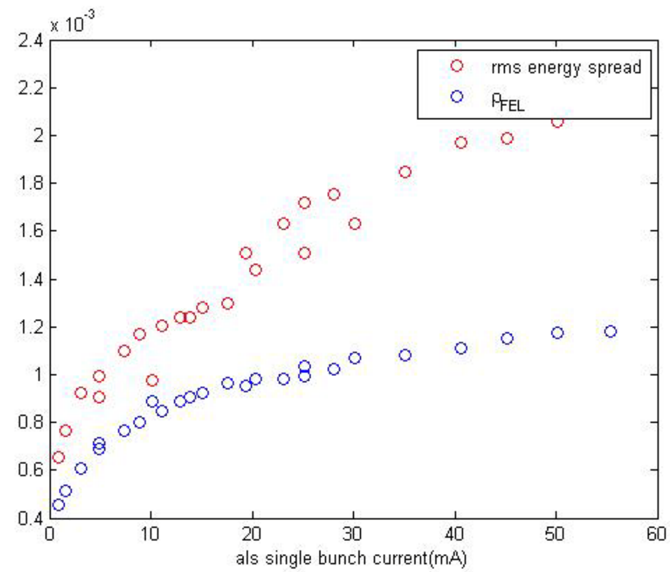

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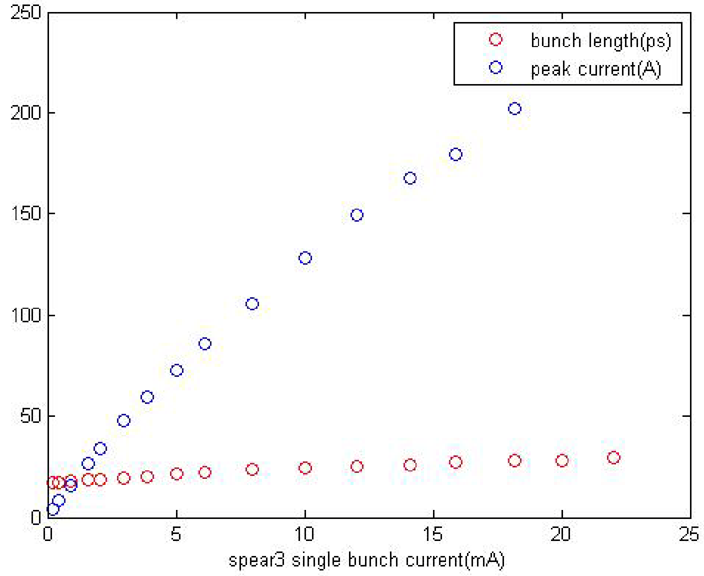
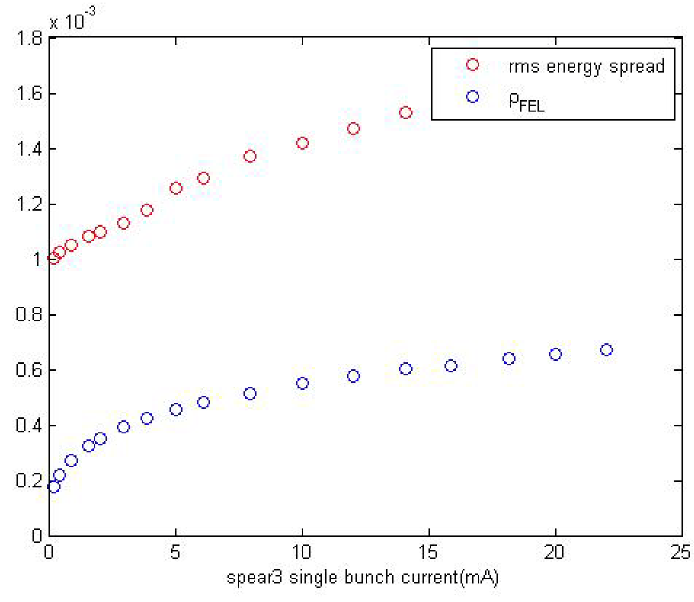
- A typical 3rd generation light source– take ALS as example, has energy spread ~10^{-3}, and alpha$_c$~0.001.

Microwave instability(cont'd)

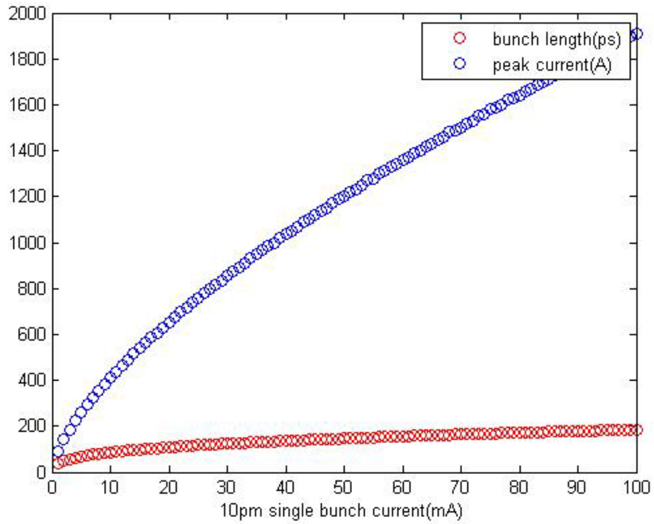


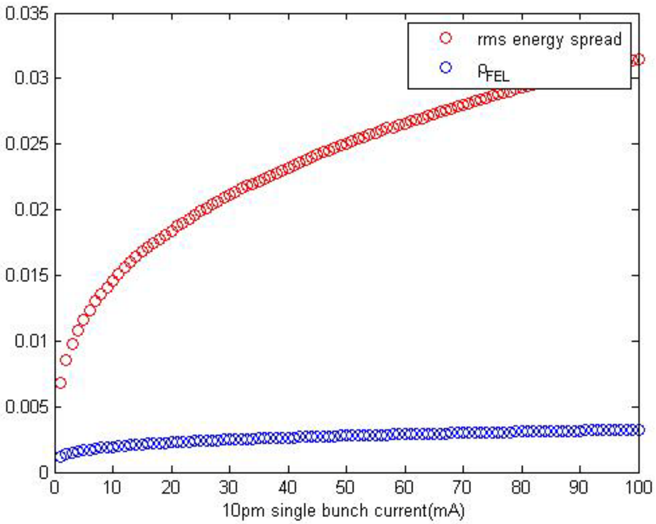


Another example- SPEAR3 has similar beam performance as ALS due to the similar size of the ring ~200m and energy spread ~10^{-3}, and $alpha_c$~0.001.

Microwave instability(cont'd)

- For 10pm storage ring, energy spread is greatly increased by low alpha_c(big size of the ring). Thus ρ_{FEL} is much smaller than σ_E although peak current can be high. Bad for FEL lasing, makes it almost impossible.

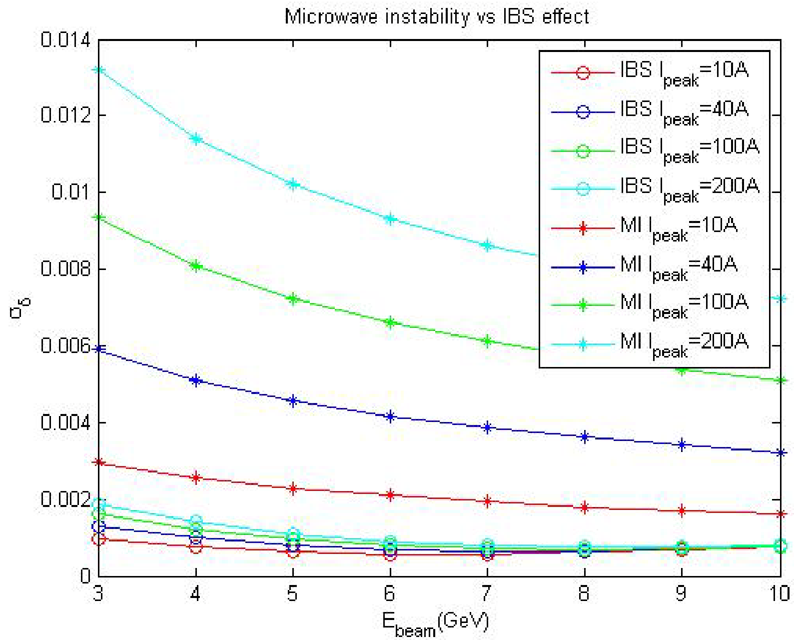




Longitudinal impedance $|Z_{||}/n|$=0.5 ohms for this calculation, although lower value has been proven possible in reality. This value is chosen to show the effect more clearly.

IBS VS Microwave instability

- They are caused by different mechanisms but they are both bad for beam properties and ring operation.
- Microwave instability has much bigger effect than IBS and should be carefully taken care of.



Conclusion and future plan

- A design of ultimate storage ring is undergoing and it can provide totally transverse coherent hard X-ray.
- Microwave instability will induce large energy spread growth thus FEL process is hard to achieve. A smooth vacuum chamber should be designed and low current operation probably is preferable.
- More studies will be done on understanding how driving terms and tune shift with amplitude affect DA and further improvement of the storage ring's DA is undergoing.