Steady-State Microbunching for EUV

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SLAC

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U.S. DEPARTMENT OF ENERGY
Office of Science

SLAC NATIONAL ACCELERATOR LABORATORY

Modern light sources

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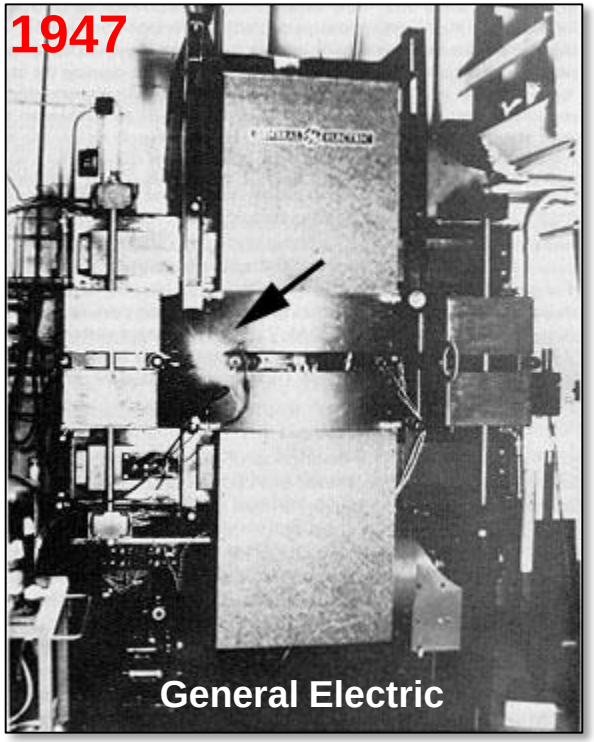
Light from accelerators

Nearly 70 years of synchrotron radiation!



Courtesy NSLS

Modern light sources

The steady work-horse

Super repetition rate, lower energy per pulse

Modern light sources

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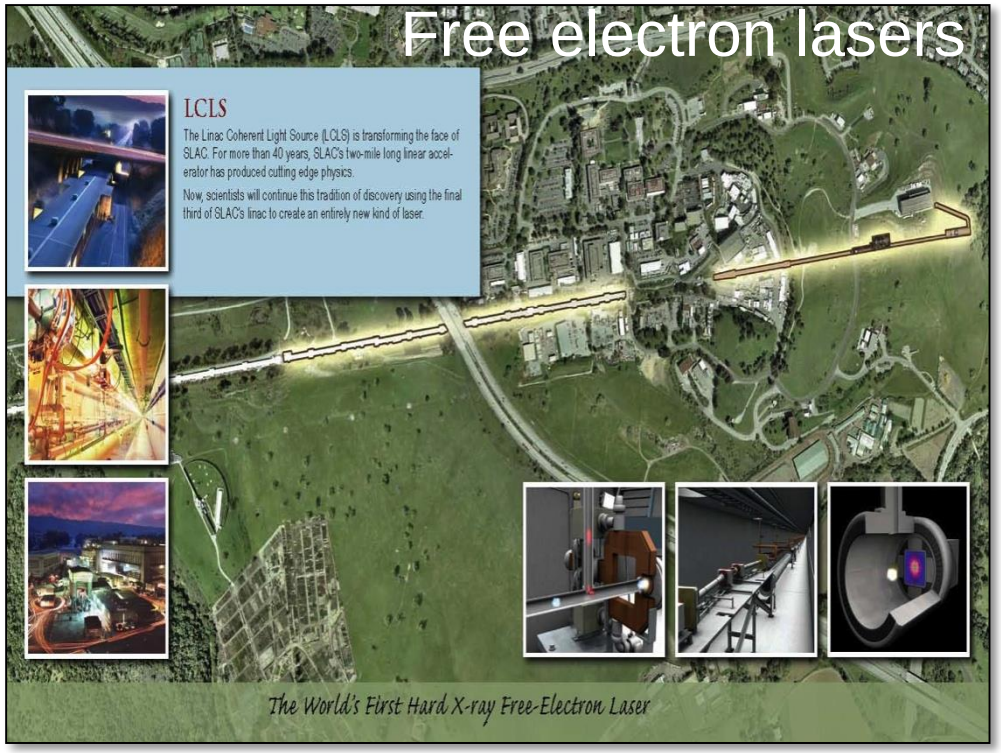
The flashy new toy



High energy per pulse, low repetition rate

Modern light sources

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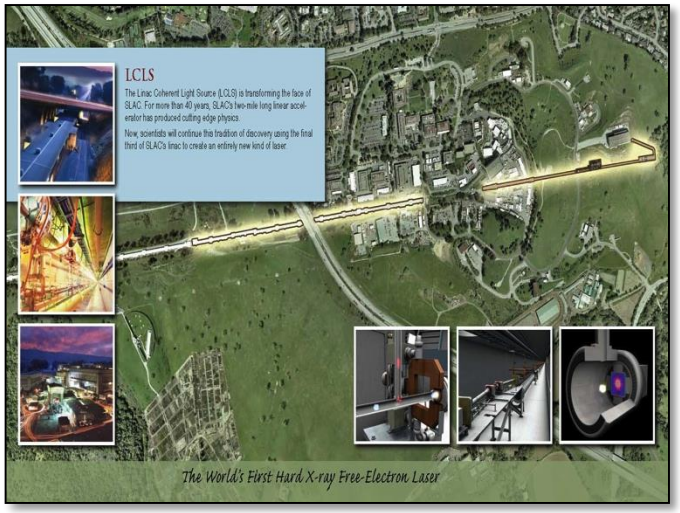
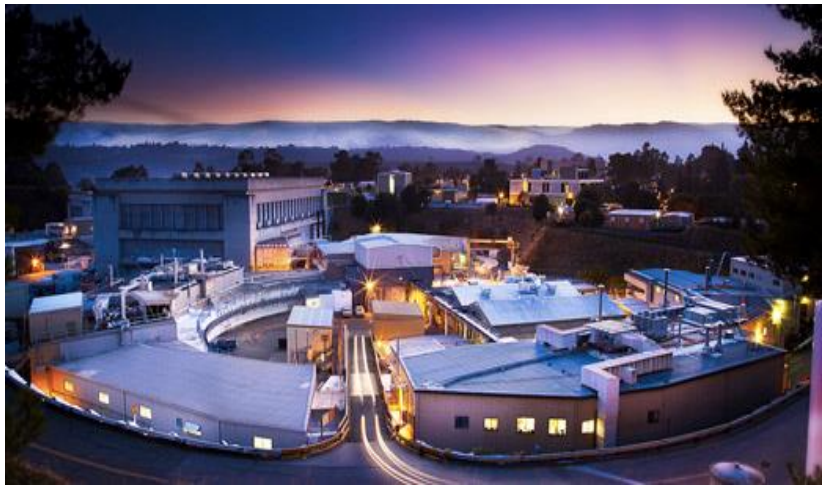
High brightness



+

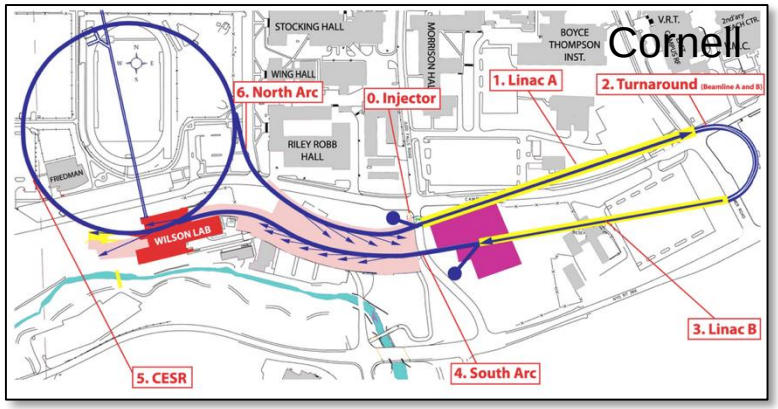
High repetition rate



Can we have our cake and eat it?

Repetition rate

Energy recovery linacs



Super-conducting linacs

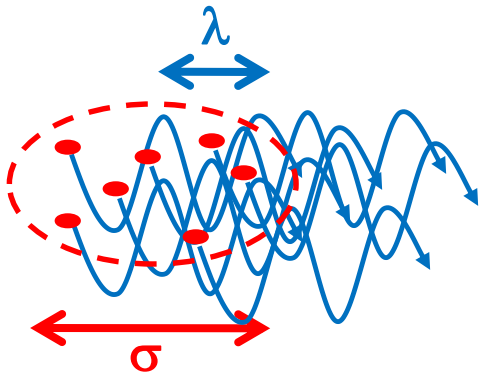
FELs in rings, Oscillator FELs, ERLs, SC, etc…

The original: storage rings

Microbunching

Coherence in accelerators

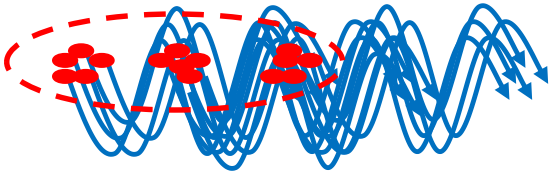
Shot Noise



Number of electrons

$$P_{rad}(I) \mu N_e$$

Microbunching

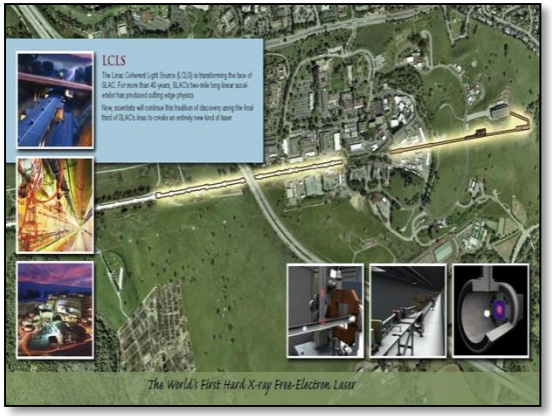


$$P_{rad}(I) \mu N_e^2$$

Steady-state microbunching

Microbunching in a ring

High brightness



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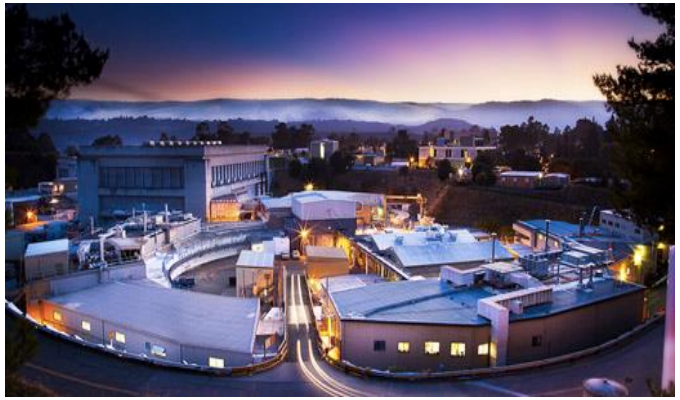
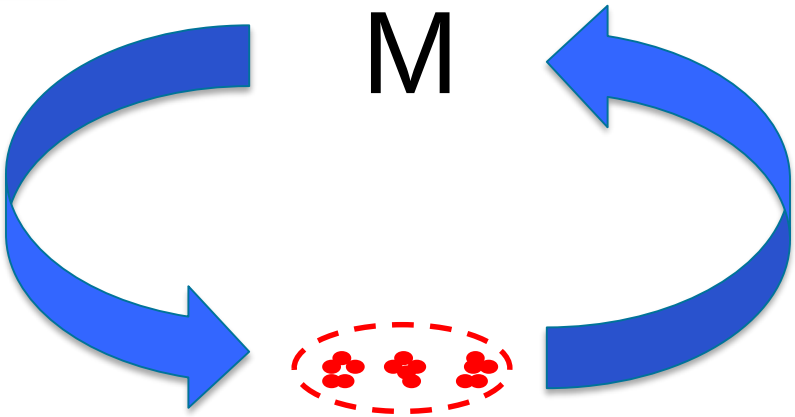
High repetition rate

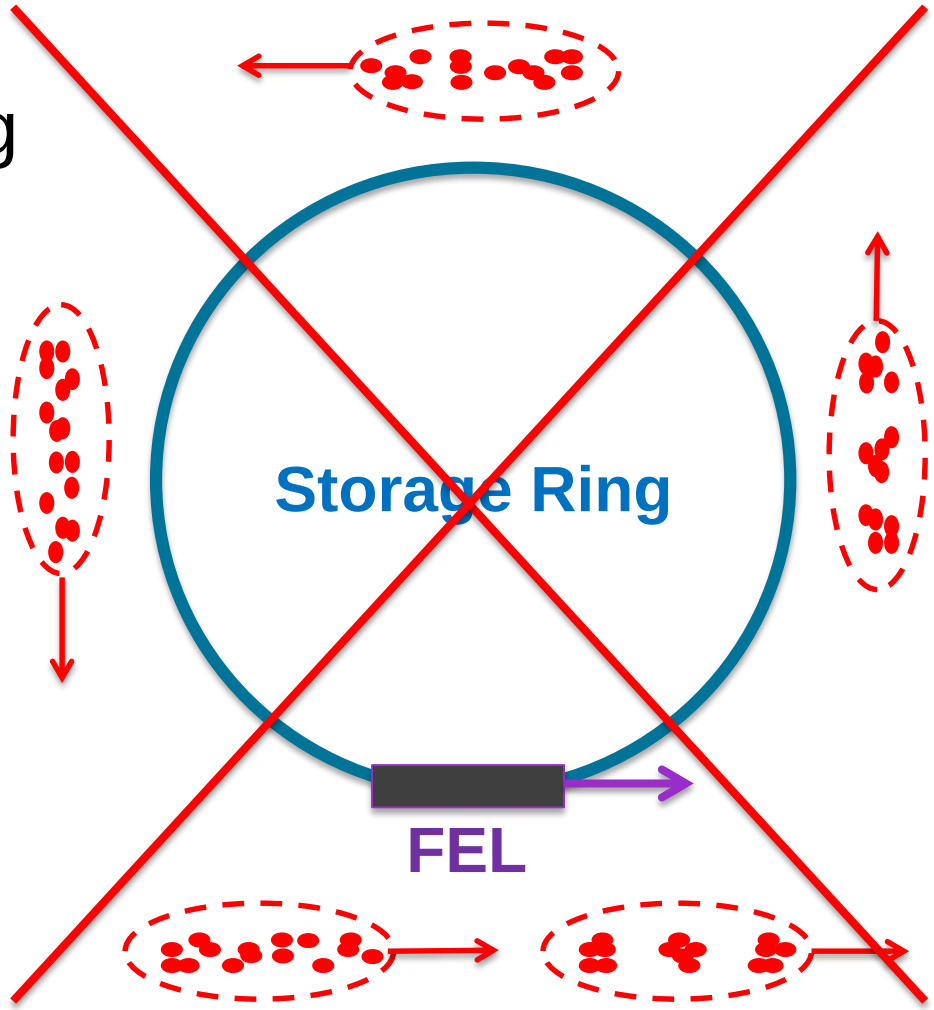




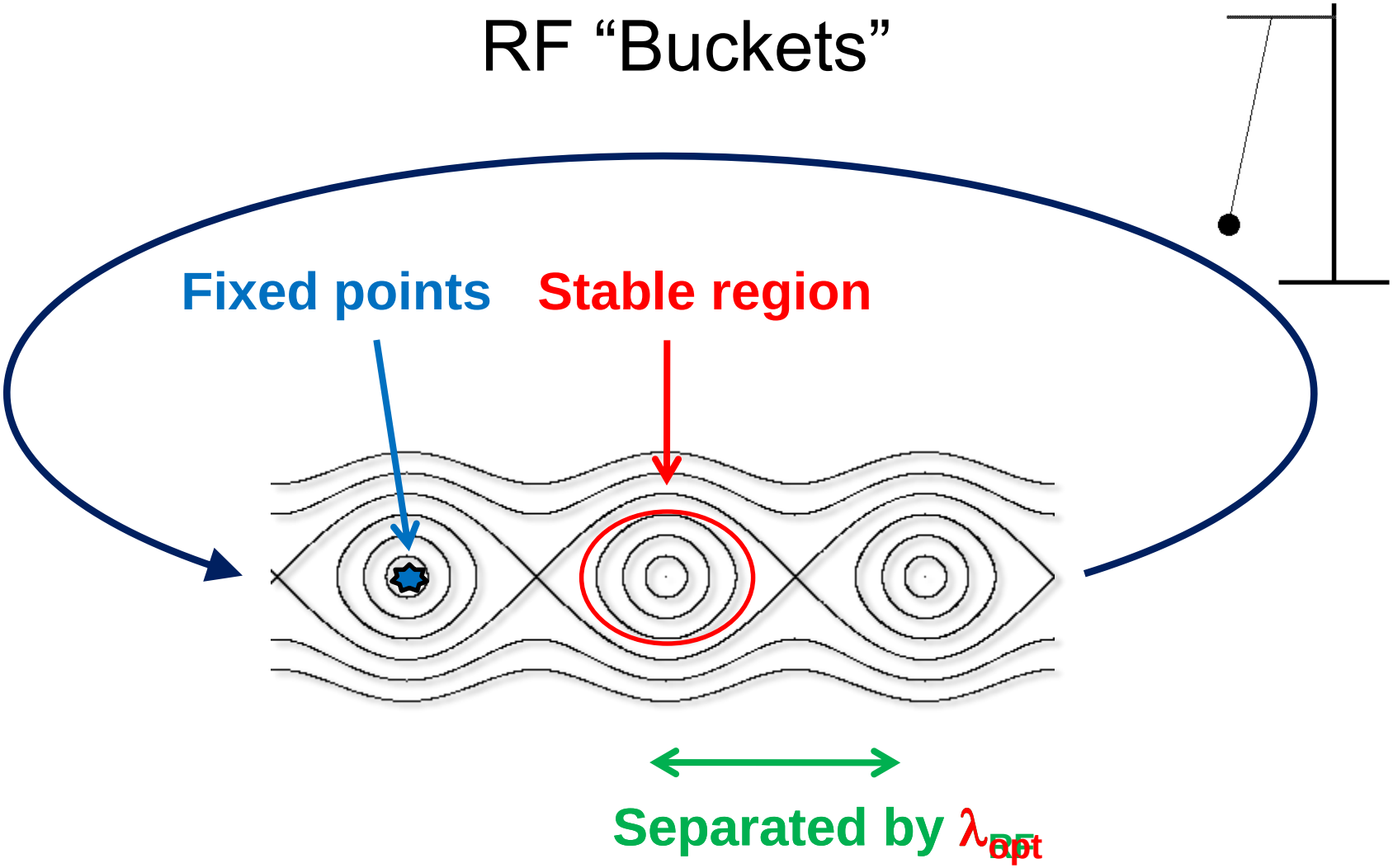
$$X_0 = (z_0, p_0)$$

Steady-state microbunching

FEL in a ring

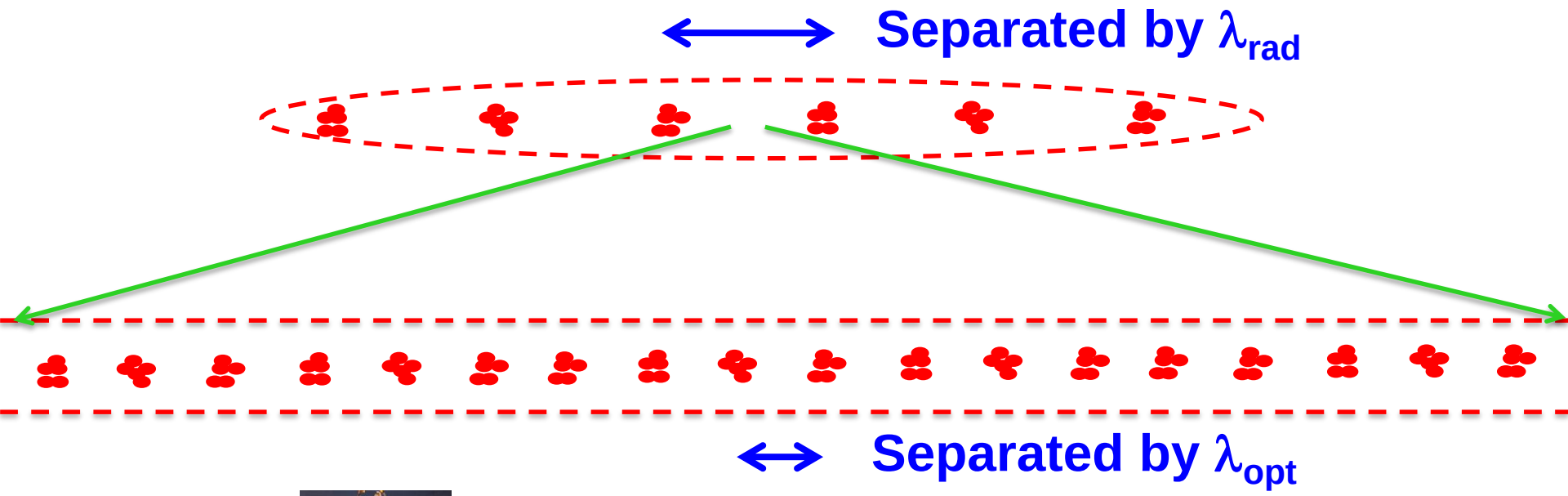


Steady-state microbunching



Steady-state microbunching

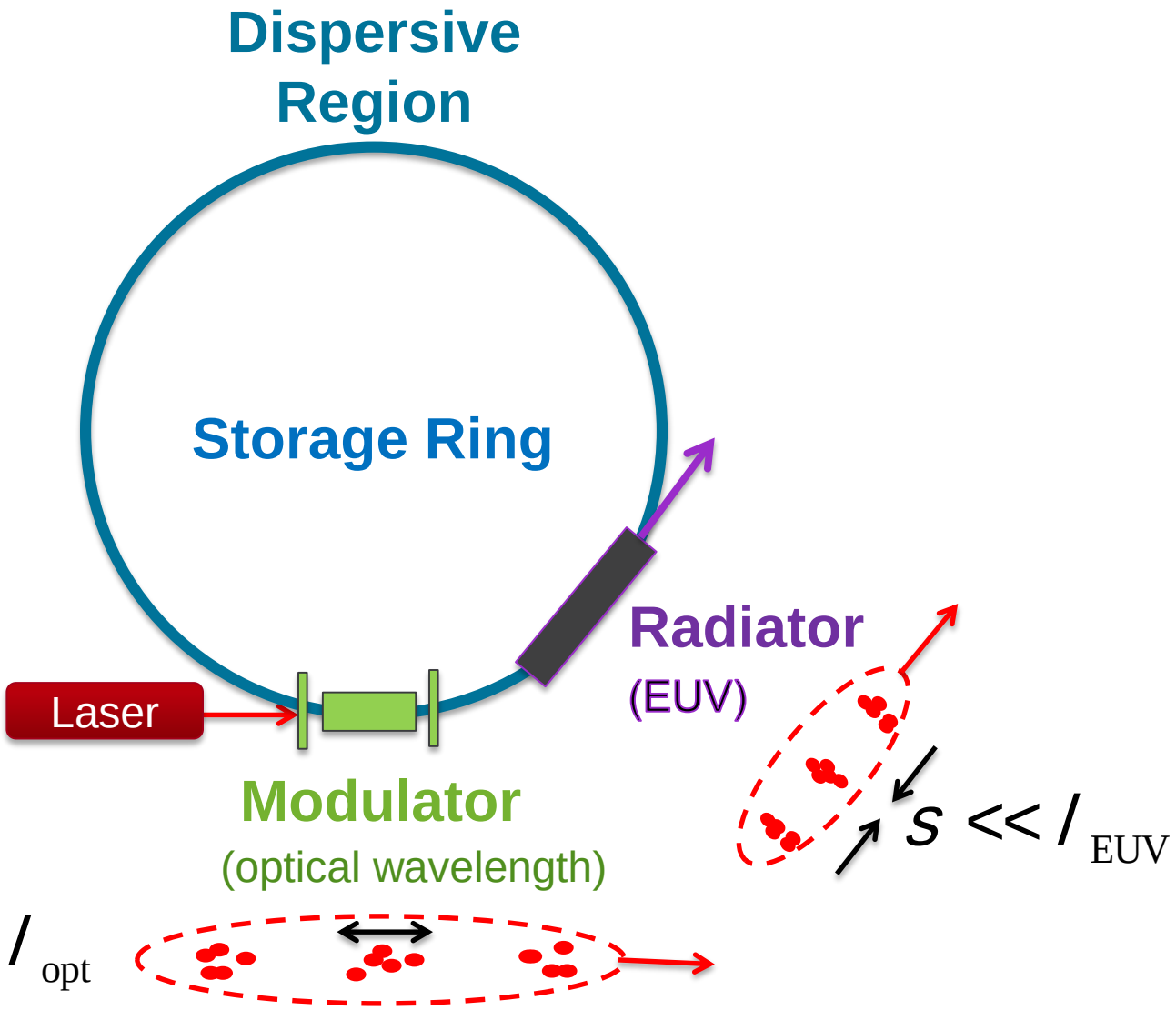
RF Buckets ➔ Optical Buckets



klystron ➔ laser

Steady-state microbunching

SSMB:
Maintain
bunching



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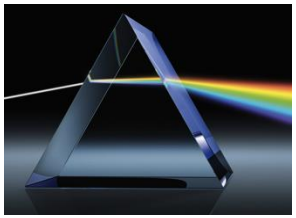
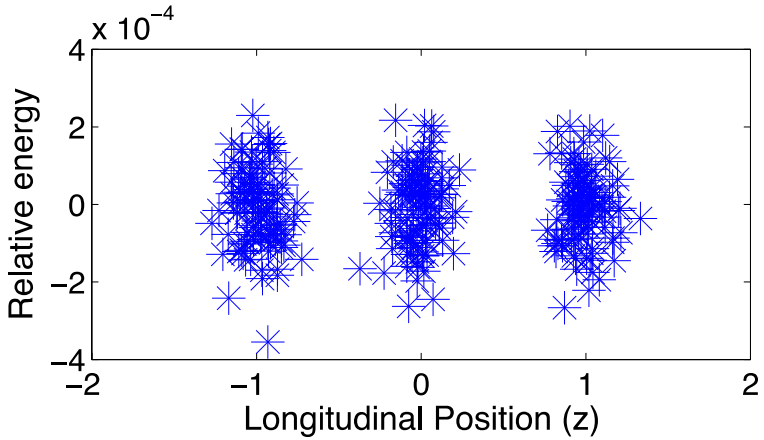
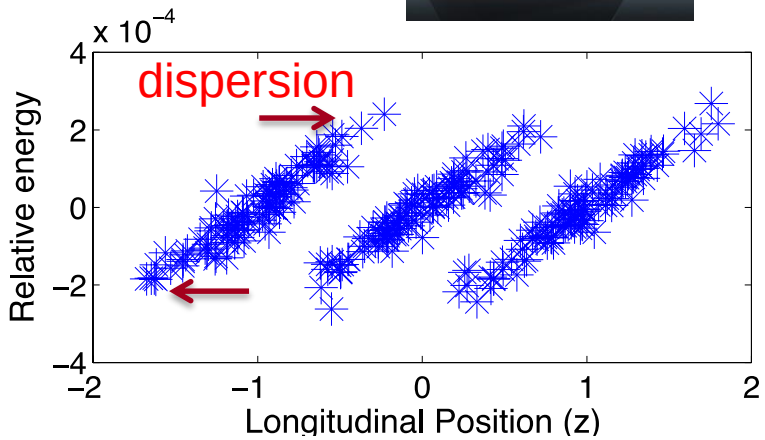
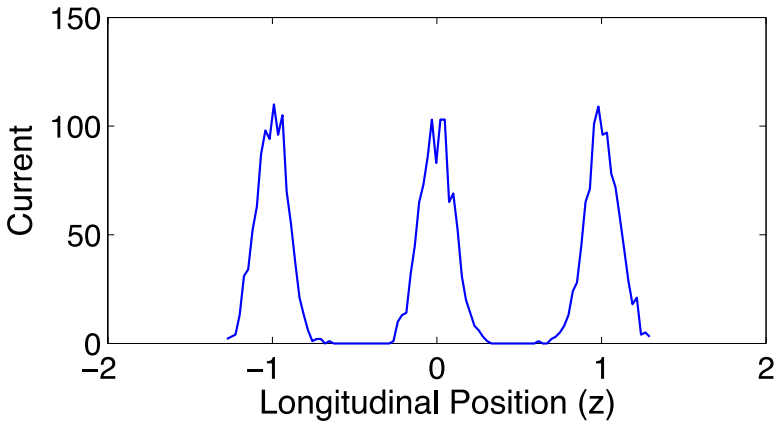
Bunching in a ring

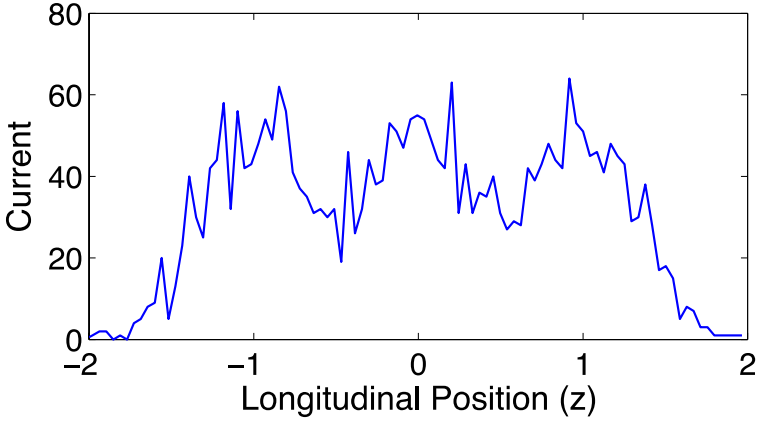


➔ Need low dispersion ring





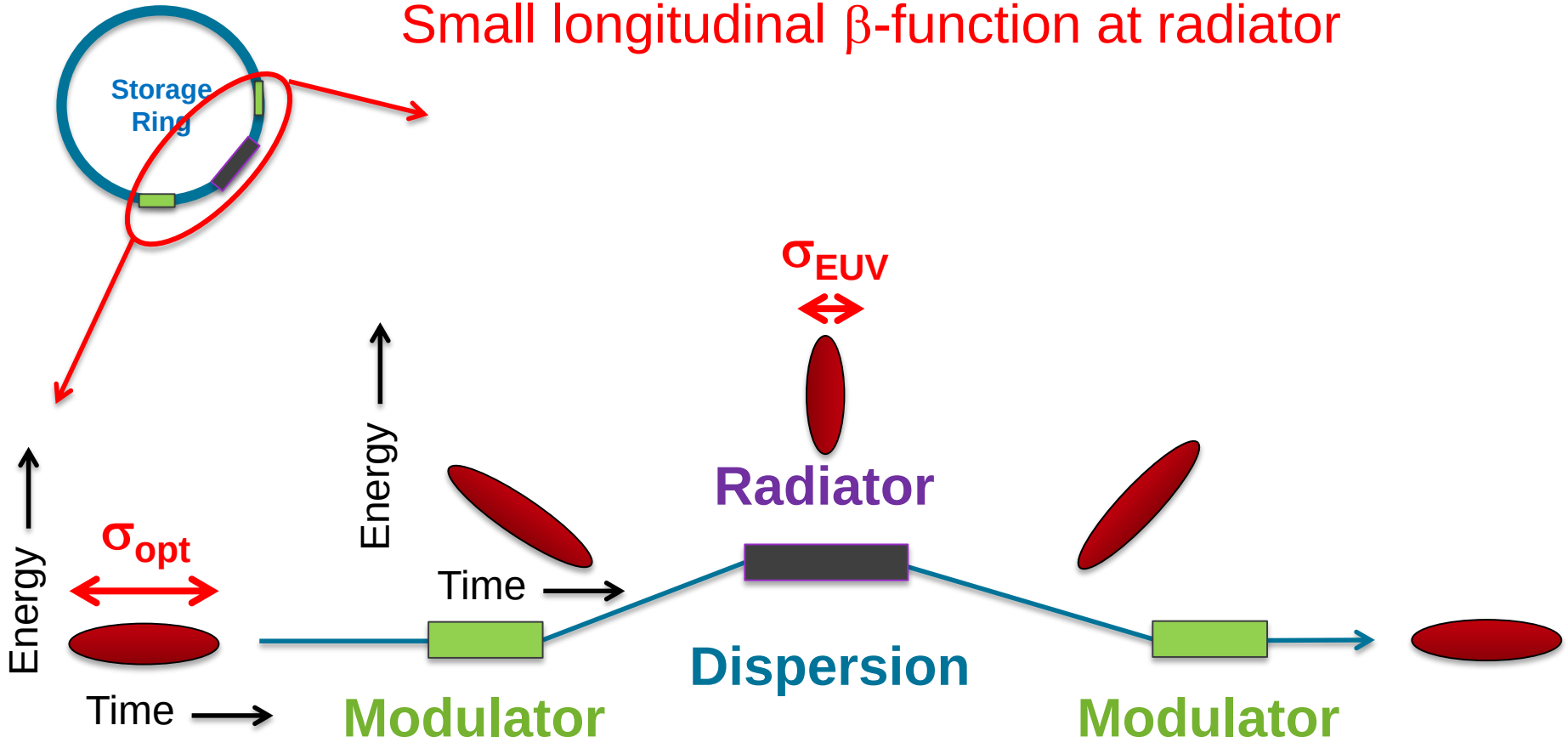




Steady-state microbunching

Strong focusing “superperiod”

Small longitudinal β-function at radiator

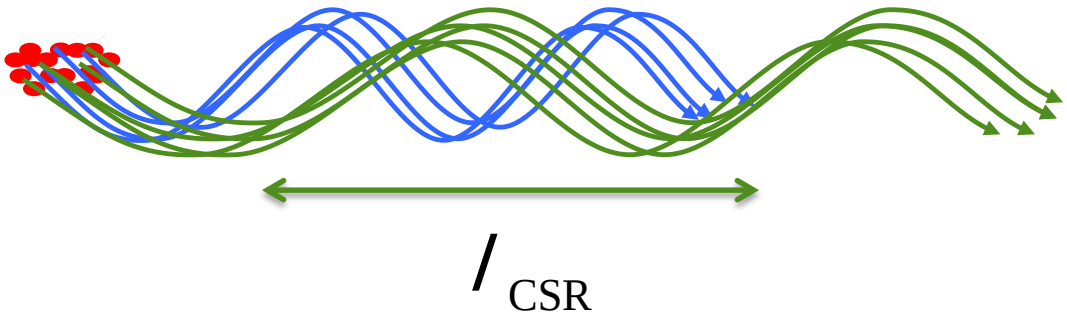


Steady-state microbunching

Limits to peak current

High peak current ➔ high average power

Normal operating mode



Coherent Synchrotron Radiation (CSR):
strong radiation at wavelengths longer than bunch

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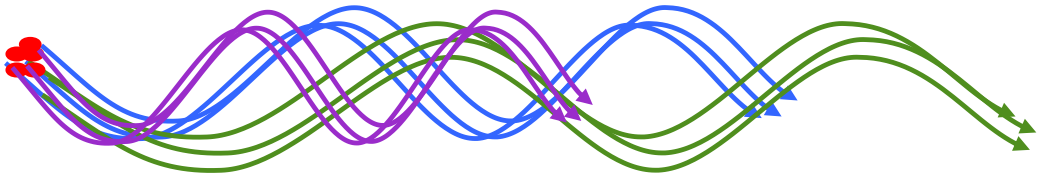
Limits to peak current

High peak current ➔ high average power

Normal operating mode

Low dispersion operating mode



More wavelenths ➔ CSR gets worse!

$$I_{peak} \mu s_z^{-1/3}$$

$$I_{avg} \mu s_z^{-4/3}$$

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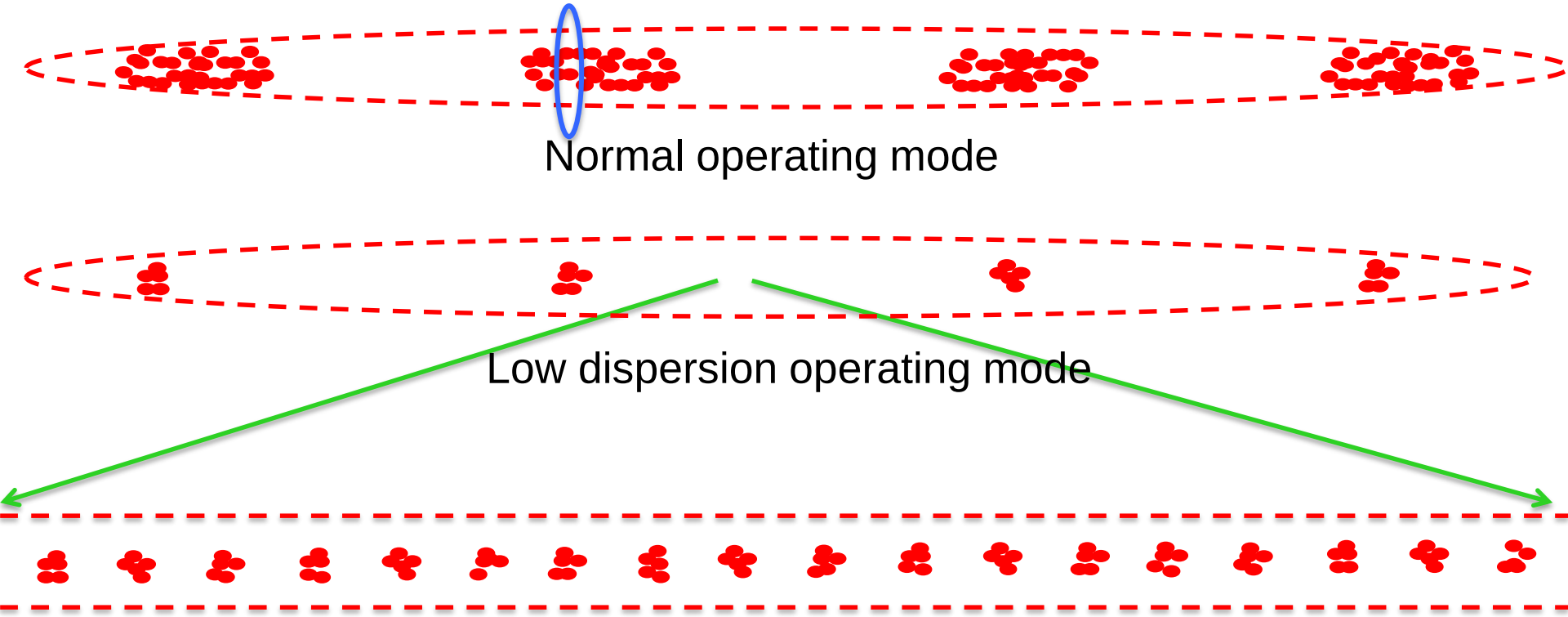
Limits to peak current

High peak current ➔ high average power



Low dispersion, SSMB: same peak current ➔ same average current

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Limits to peak current

High peak current ➔ high average power

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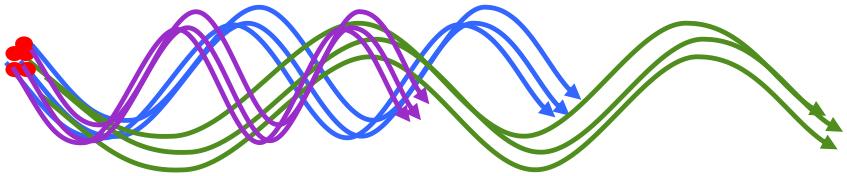
Threshold studies of the microwave instability in electron storage rings

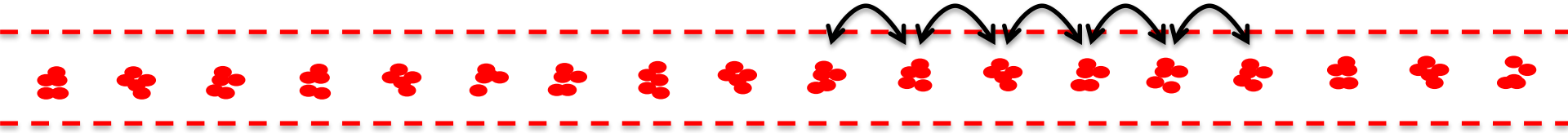
K. L. F. Bane, Y. Cai, and G. Stupakov



Single bunch wake

$$I_{SSMB} \mu s_z^{-1/3}$$

Multi-bunch resistive wall



Low dispersion, SSMB: same peak current ➔ same average current

Next steps

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So what can we get?

Sample parameter set

EUV parameters	
Ring size (diameter)	30 m
Average current	1 A
Dispersion (α)	1.6×10^{-7} (R_{56} = 0.02 mm)
Beam energy	600 MeV
Beam energy spread (mod)	6×10^{-4}
EUV power	4 kW

Next steps

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Proof-of-principle experiment

Challenges

1. Stable low alpha mode
2. High average current (instabilities)
3. High stored laser power

SSRL test parameters	
Cavity Q	1000
Input laser power	10 kW
Stored laser power	10 MW
Alpha (α)	3×10^{-6} (R_{56} = 0.4 mm)
Beam energy	1000 MeV
Modulation wavelength	10 um
Modulation length	2.5 m

Next steps

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Where does this leave SSMB for EUV?

Plus side:

Potential for high average power in EUV

Based on mature technology (storage rings)

No need for high power beam dump

Down side:

Still very much R&D

Technical issues to resolve (laser/cavity power, ring)

Not going to solve EUV needs in the next 5 years

Hope to learn more soon!

Next steps

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Thanks for your attention!

And thanks to contributions from:

X. Huang, Z. Huang, M. Levenson, R. Ruth, G. Stupakov, K. Tian

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Strong focusing “superperiod”