ISG - X Meeting

Coherent Synchrotron Radiation Issues

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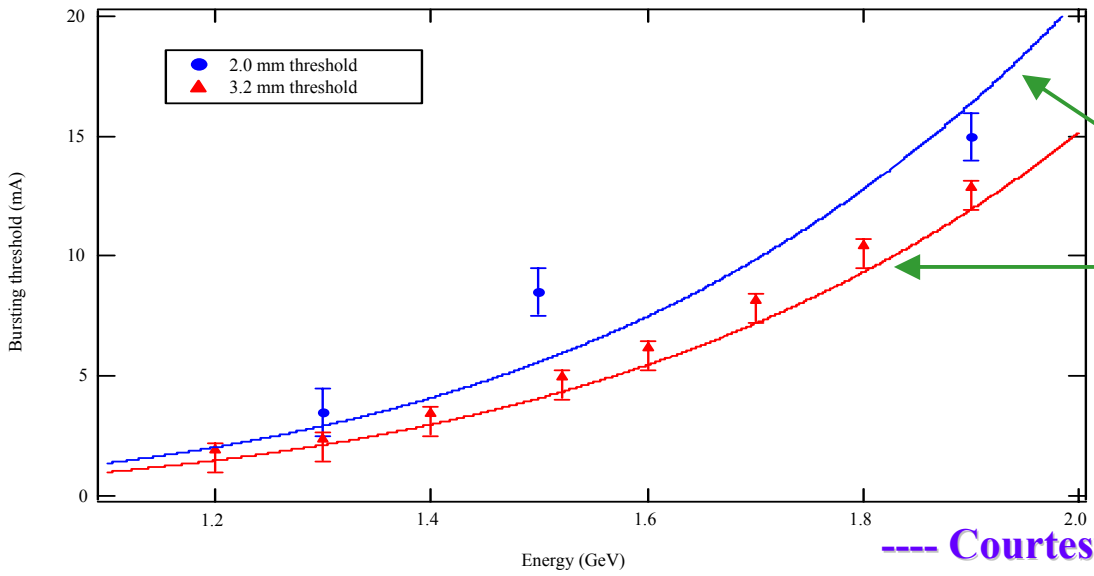
Motivations

- Recent studies indicate that Coherent Synchrotron Radiation could be a potential problem leading to an instability.
- ATF Damping ring is a good test bed for the existing theory and also for further studies.
- Existing experiments mostly study the CSR radiation, we need understand how the CSR radiation acting on the beam.
- Extracted beam measurements at ATF allow unprecedented energy spread measurements

We will study the effect on the beam NOT the light

CSR Instability

- **Theory [Stupakov-Heifets, PRST-AB, 5 (2002) 054402] indicates a potential instability due to the CSR impedance from dipoles;**
- **Experimental observations [Byrd, *et al.* , PRL 89 (2002) 224801; NSLS/BNL; BESSY-II]**



Model predictions

---- Courtesy of J. Byrd

CSR Impedance

- **Free Space Impedance**
  - **Dipoles ($\alpha > 0$) ([Murphy-Krinsky-Gluckstern, PA, 1997])**

$$Z_D(k) = -i\, A\, k^{1/3} / R^{2/3}$$

$$A = 3^{-1/3}\Gamma(2/3)(\sqrt{3}\, i - 1)$$

  - **Wigglers ($\alpha < 0$) ([Wu-Raubenheimer-Stupakov, PRST-AB, 2003])**

$$Z_W(k) = \frac{K^2}{\gamma^2}\left\{\frac{\pi\, k}{4} - \frac{i\, k}{2}\mathrm{Log}\left[\frac{k}{k_{\mathrm{FEL}}}\right]\right\} \quad \text{for} \quad \frac{k}{k_{\mathrm{FEL}}} \in (0, 0.1]$$

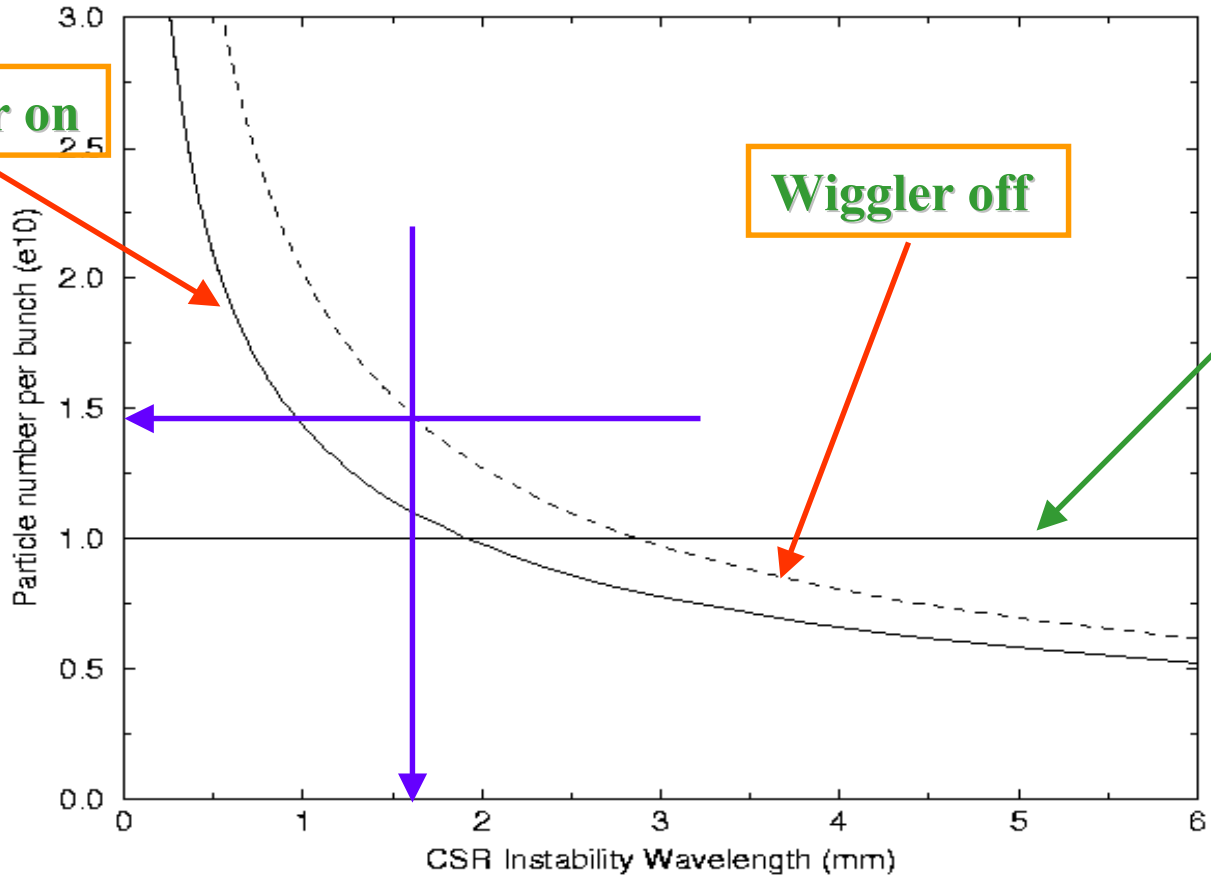
- **Scaling** $k^{1/3} \leftrightarrow \{k \text{ and } k\log[k]\}$

Dipole impedance dominates for long wavelength; ATF wiggler-off operation mode is good!

ATF Damping Ring

Threshold vs. wavelength

- We hope to get experimental verification!



Threshold determined by the longest wavelength

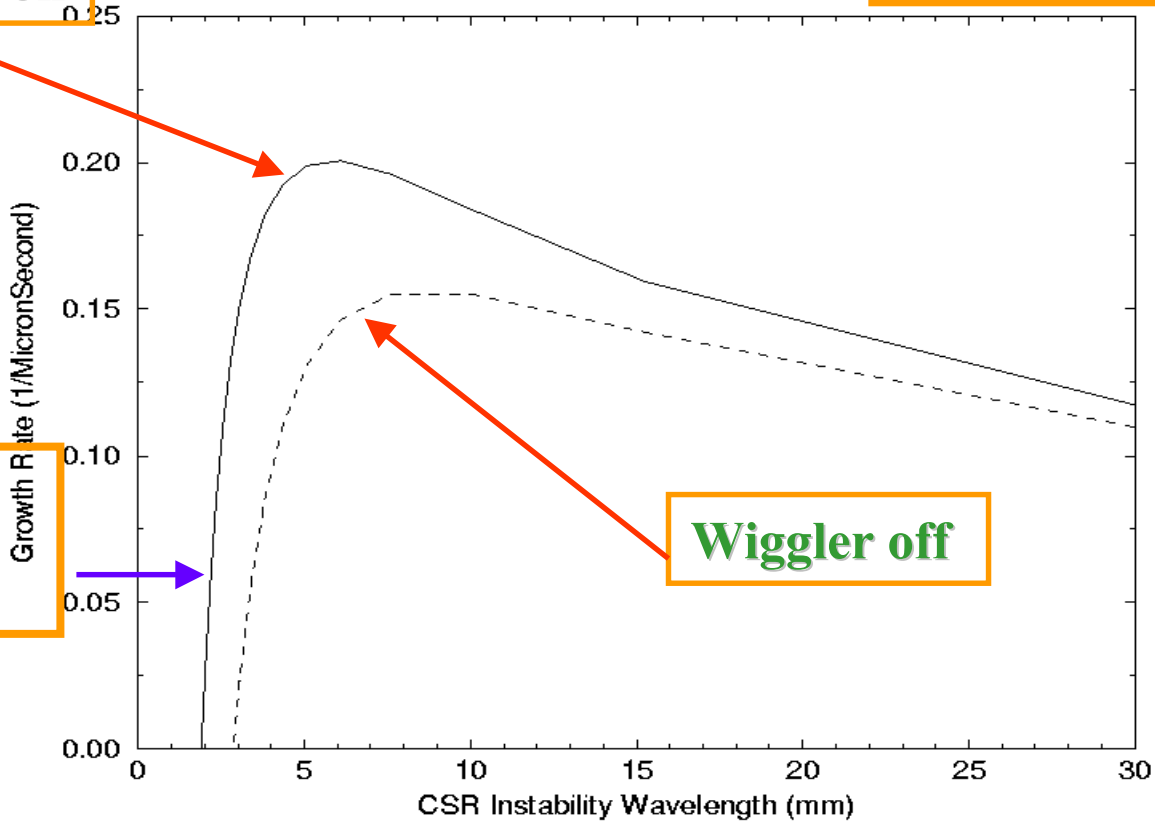
ATF Damping Ring

Growth Rate vs. wavelength

- We hope to get experimental verification!

$$\omega = \sqrt{ic^2 n_b r_e \eta k Z(k)/\gamma}$$

Wiggler on



Landau damping

Wiggler off

$$\tau^{-1} \propto \mathrm{Im}(\omega)$$
$$\propto \mathrm{Im}\left(\sqrt{\pm ikZ(k)}\right)$$

$$Z(k) \propto k^{\varepsilon}$$
with $\varepsilon > 0$

Shielding Cut-off

- **Cut-off ([Stupakov-Kotelnikov, PRST-AB, 2003])**

$$k \approx \frac{2.12}{a}\sqrt{\frac{R}{a}}$$

- **ATF parameters give**

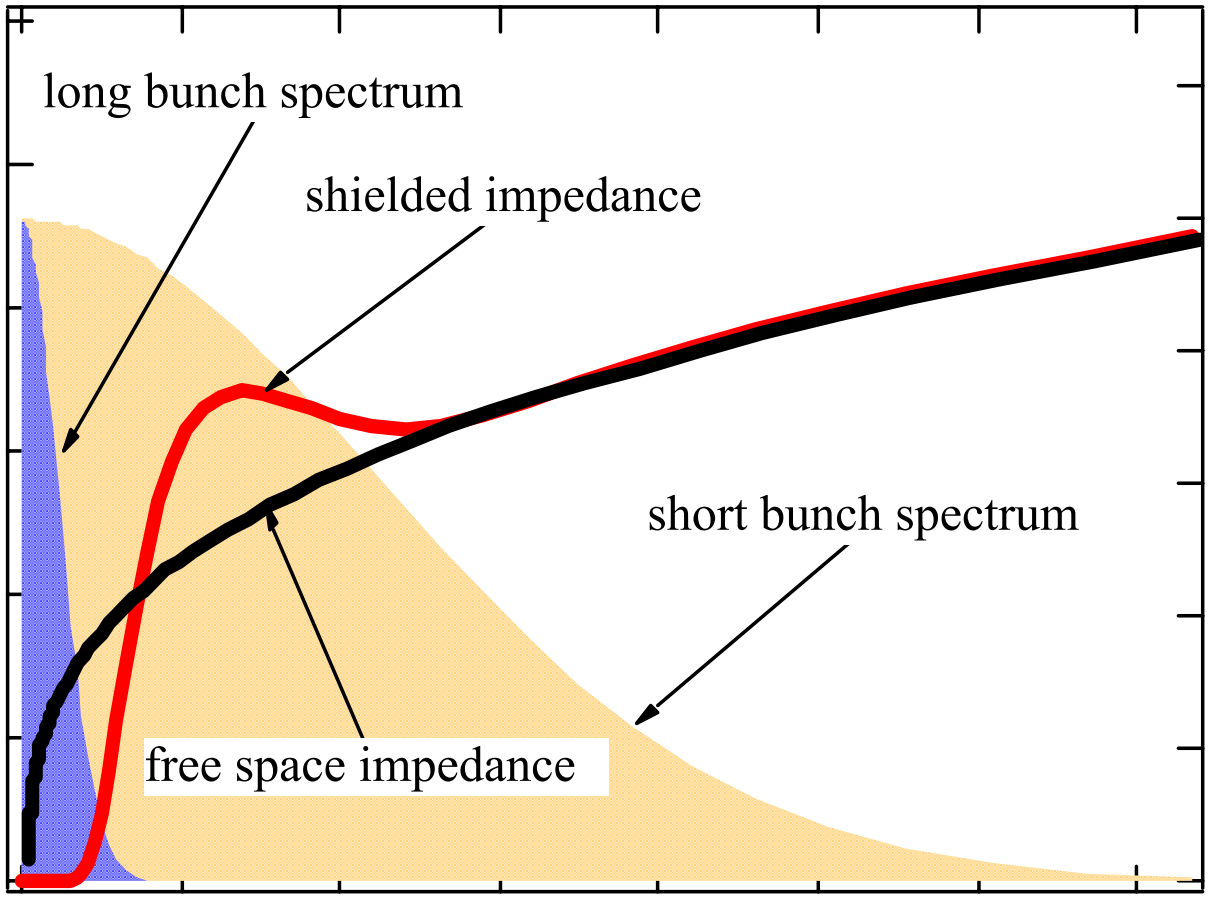
$$\lambda \approx 1.6\,\text{mm} \Rightarrow f \approx 187\,\text{GHz}$$

- **High current operation mode, or local density fluctuations**

Should we see something, and how ?

Shielding Impedance

- **Shielding added as an ad hoc cutoff, but**



---- Courtesy of J. Byrd

CSR Power

- **Coherent enhancement**

Form factor

$$P_{CSR}(\lambda) = [1 + (N-1) f(\lambda)] P_{ISR}(\lambda)$$

- **Gaussian form factor**

$$f(\lambda, \sigma_z) = \exp[-(2\pi\sigma_z)^2 / \lambda^2]$$

- **ATF parameters**

$$\lambda = 1.6\ \text{mm}, \qquad \sigma_z = 5\ \text{mm}$$

$$(1.0 \times 10^{10} - 1) \exp\left[-\left(\frac{2\pi 5}{1.6}\right)^2\right] = 3.67986 \times 10^{-158}$$

Smooth is not enough!

CSR Power

An estimate

- **Density perturbation** $\hat{n}_1 e^{-i\omega s/c + ikz}$
- **CSR-induced energy modulation**

$$\delta = \frac{A\hat{n}_1 r_e c k^{1/3}}{\gamma R^{2/3}\omega(k)} e^{-i\omega s/c + ikz}$$

- **Saturation**

$$\delta \to \delta_0 \quad \Longrightarrow \quad f(1.6mm) \approx 2.5\%$$

- **Estimated power**

$$P_{ISR} \approx 0.35\ \text{nW/mrad}\theta\text{/mm}$$

$N = 2.0\times10^{10}$

$$P_{CSR} \approx 0.17\ \text{W/mrad}\theta\text{/mm}$$

What will seed or initiate the modulation ?

Future Issues

- Theory is relatively simple and need consider other effects
  - Other wakefields (seeding the modulation?)
  - Extend Vlasov to Vlasov-Fokker-Plank
- Verify shielding effect
- Single mode CSR? ([Heifets-Stupakov, 2003])
- Understand the quasi-periodic CSR bursting ([Venturini-Warnock, PRL, 2002])

Need Experiments to verify the existing theoretical understanding and also stimulate further studies