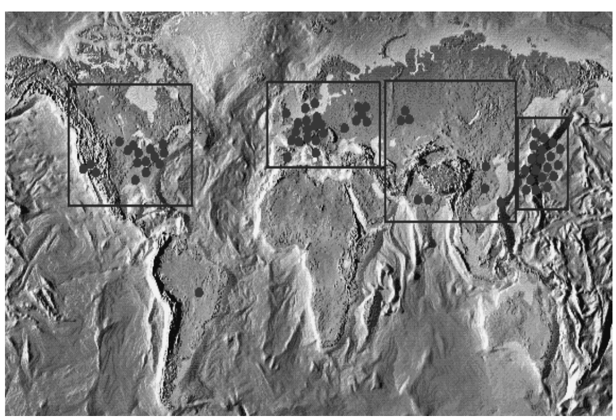
Special Topic: Light Sources

Eric Prebys

USPAS, Hampton, VA 2015

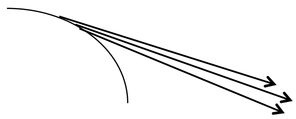
There are a lot more light sources than frontier research machines



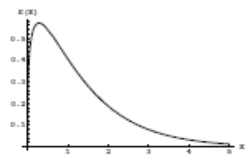
- Wikipedia lists about 60 light sources worldwide

Fundamental Principle

- Bending electrons emit radiation along their path



$$P = \frac{1}{6\pi\varepsilon_0}\frac{e^2 c}{\rho^2}\gamma^4$$

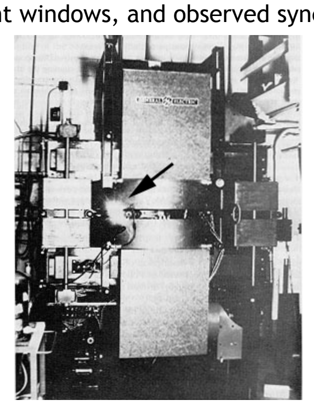


$$S(x) = \frac{9\sqrt{3}}{8\pi} x \int_x^\infty K_{5/3}(u)\,du$$

$$x = \frac{\omega}{\omega_{crit}};\ \text{where}\ \omega_{crit} = \frac{3\gamma^3}{2}\frac{c}{\rho}$$

First Observation of Synchrotron Radiation

- Synchrotron Radiation was first searched for in 1944 at GE's 100 MeV electron
  - Energy loss was seen, but because of a calculational error, they searched in the microwave region and missed the visible light, because the acceleration chamber was opaque
- In 1947, John Paul Blewett got permission to build a 70 MeV synchrotron at GE with transparent windows, and observed synchrotron radiation for the first time.



First Generation: Parasitic Operations

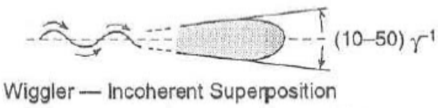
- Examples
  - SURF (1961): 180 MeV UV synchrotron at NBS
  - CESR (CHESS, 70's): 6 GeV synchrotron at Cornell
  - Numerous others
- Typically large emittances, which limited brightness of the beam

Second Generation: Dedicated

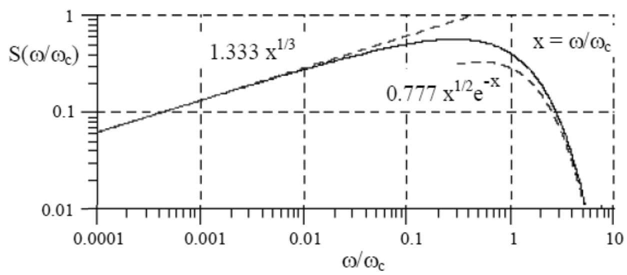
- Examples:
  - 1981: 2 GeV SRS at Daresbury (ε=106 nm-rad)
  - 1982: 800 MeV BESSY in Berlin (ε=38 nm-rad)
  - 1990: SPEAR II becomes dedicated light source (ε=160 nm-rad)
- Often include "wigglers" to enhance SR

Typical 2nd Generation Parameters

- Beam sizes
  - σ_y~1 mm
  - $\sigma_{y'}$~.1 mrad
  - σ_x~.1 mm
  - $\sigma_{x'}$~.03 mrad

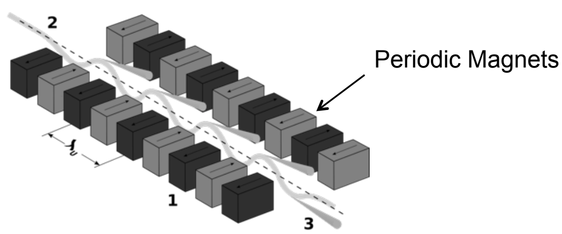


- Broad spectrum



- High flux
  - Typicall 10^{13} photons/second/mradian for 3 GeV, 100 mA dipole source at E_{crit}

Undulators

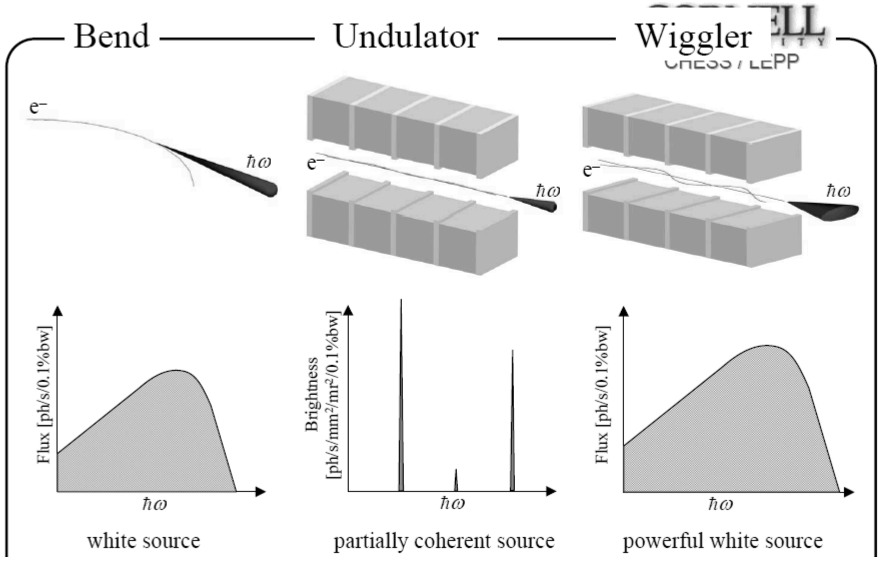


- In rest frame of electron $\lambda^* = \dfrac{\lambda_U}{\gamma}$
- Electron oscillates coherently with (contracted) structure, and releases photons with the same wavelength.
- In the lab frame, this is Doppler shifted, so

$$\lambda = \frac{\lambda^*}{2\gamma} = \frac{\lambda_U}{2\gamma^2}$$

- So, λ on the order of 1cm ➔X-rays.

Bends, Undulators, and Wigglers*



*G. Krafft

3rd Generation (Undulator) Sources

- High Brightness
  - 10^{19} compared to 10^{16} for 2nd generation sources
  - Emittance ~1-20 nm-rad

Summary of Parameters