UNIVERSITY OF NEBRASKA-LINCOLN
Physics & Astronomy

Synchrotron radiation and its monochromaticity

Xiaozhe Zhang

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University of Nebraska Lincoln

Synchrotron radiation

Synchrotron radiation has the following features:

- Ultra-bright
- Highly directional
- Spectrally continuous (Bending Magnet/Wiggler) or quasi-monochromatic (Undulator)
- Linearly or circularly polarized

Emission mechanism

The electromagnetic radiation emitted when charged particles are accelerated radially ($\mathbf{a} \perp \mathbf{v}$) is called synchrotron radiation.

In synchrotrons using bending magnets, undulators and/or wigglers.

Synchrotron radiation may be achieved artificially in synchrotrons or storage rings, or naturally by fast electrons moving through magnetic fields.

The radiation produced in this way has a characteristic polarization and the frequencies generated can range over the entire electromagnetic spectrum.

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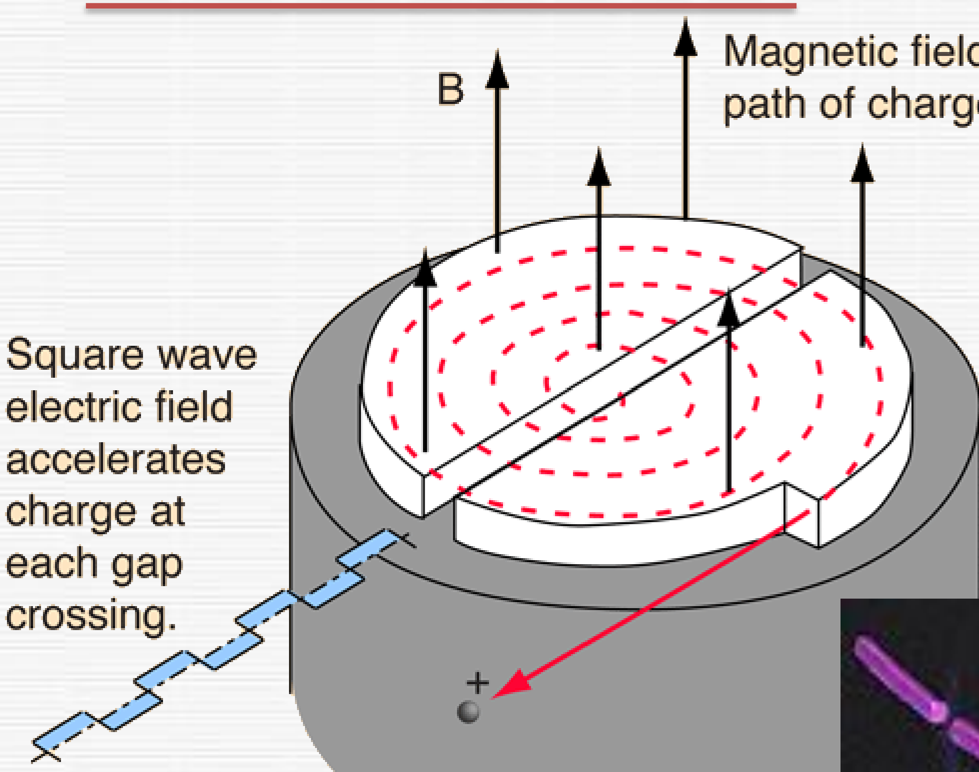
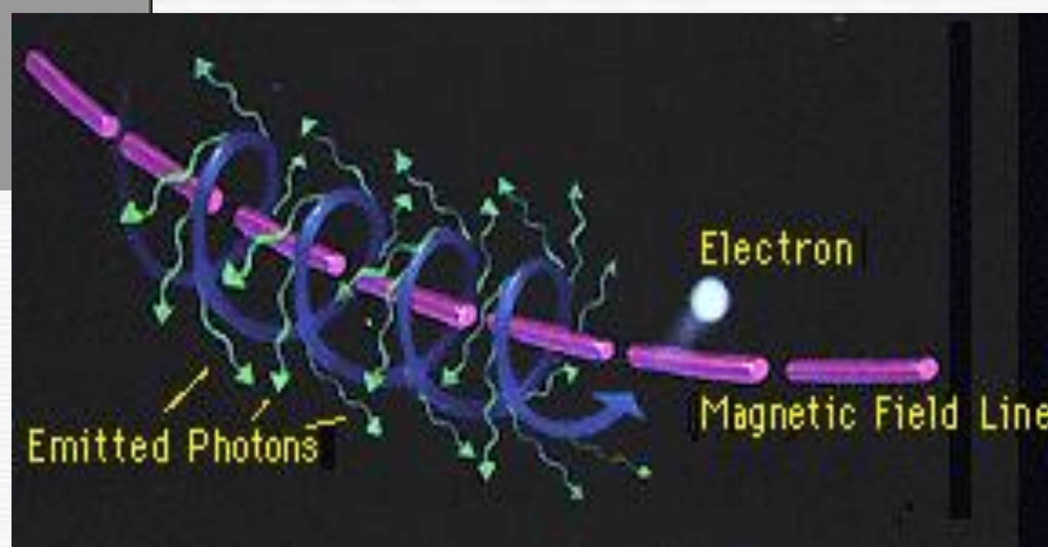
Cyclotron and Synchrotron Radiation



Cyclotron

It is similar to cyclotron radiation except that synchrotron radiation is generated by the acceleration of ultra relativistic charged particles through magnetic fields.

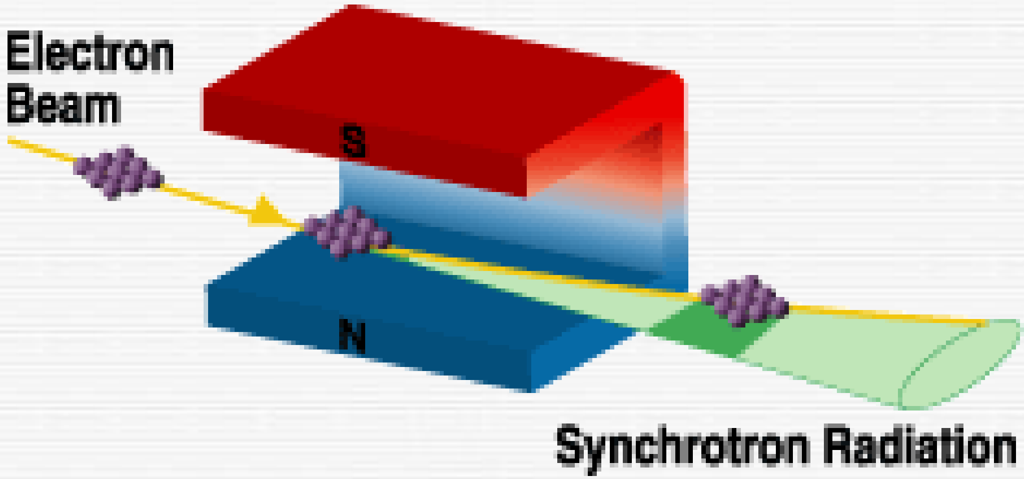


Synchrotron radiation

Synchrotron radiation is emitted at a bending magnet or at an insertion device. The insertion device is comprised of rows of magnets with alternating polarity and is installed in a straight section of the electron orbit. There are two types of insertion devices, distinguished by magnetic field strength: the undulator and the wiggler.

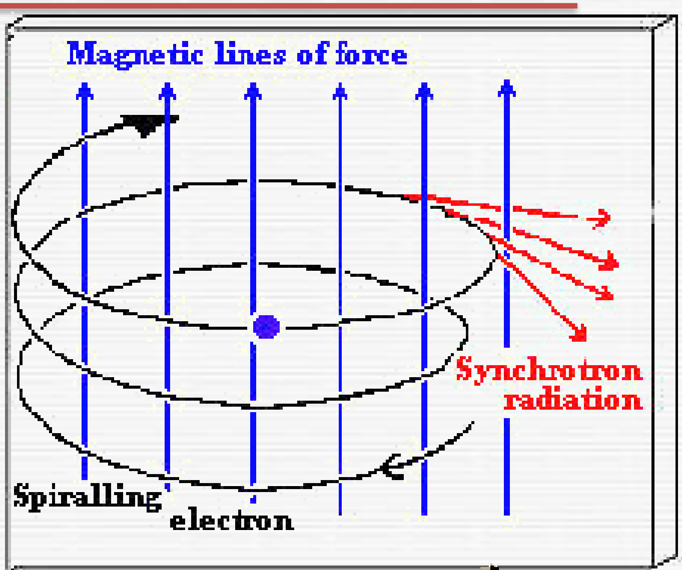
Bending magnet

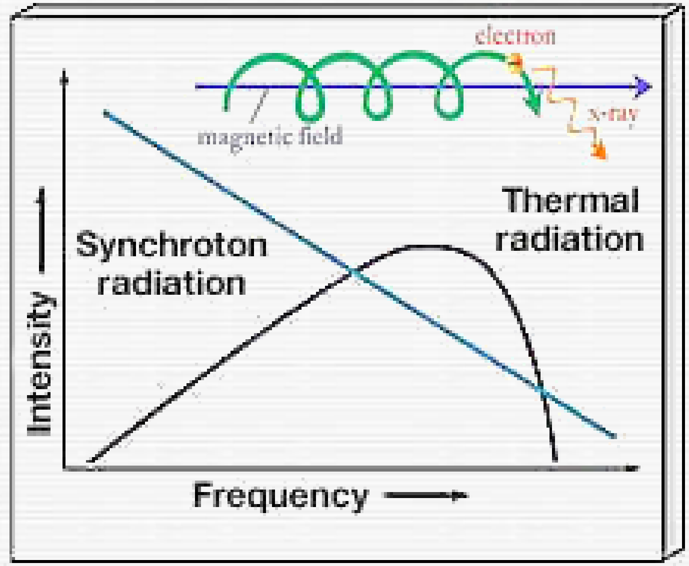
Stored electrons run on a circular orbit and emit synchrotron radiation with a continuous spectrum when they encounter the bending magnet.

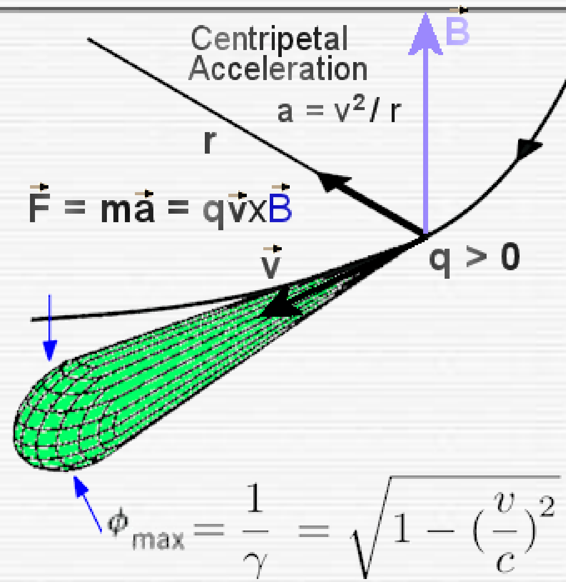


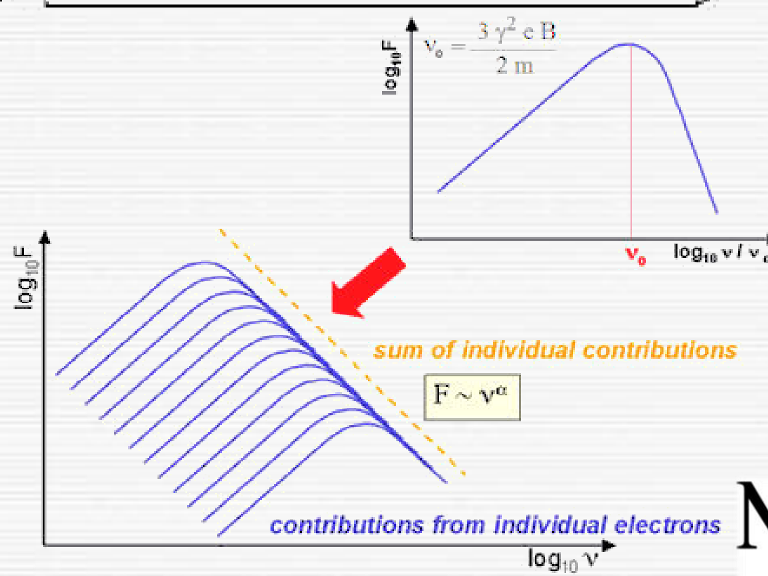
Synchrotron radiation produced at a bending magnet

Bending magnet



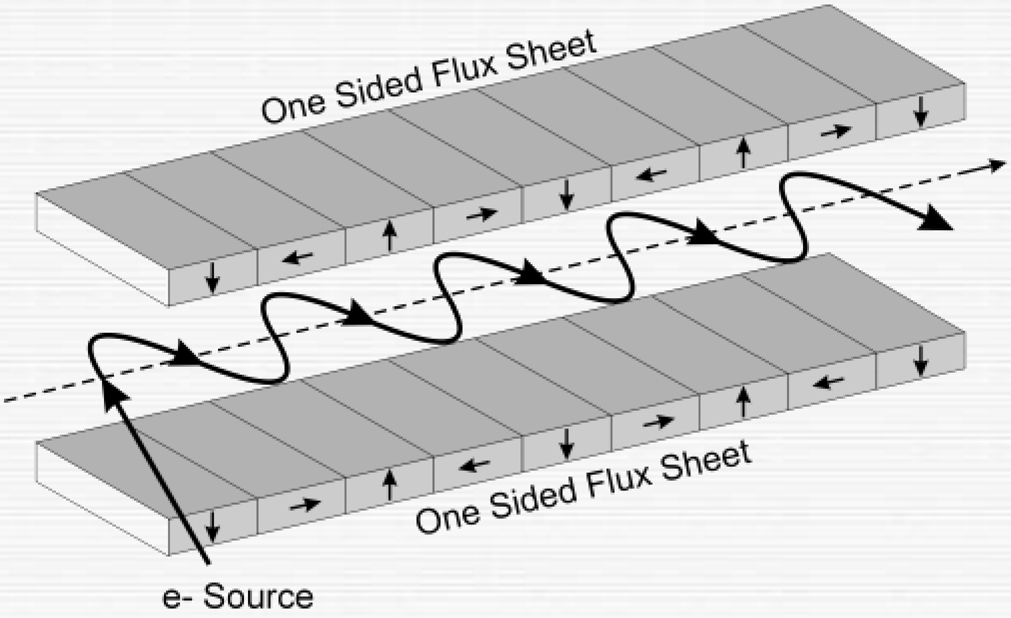






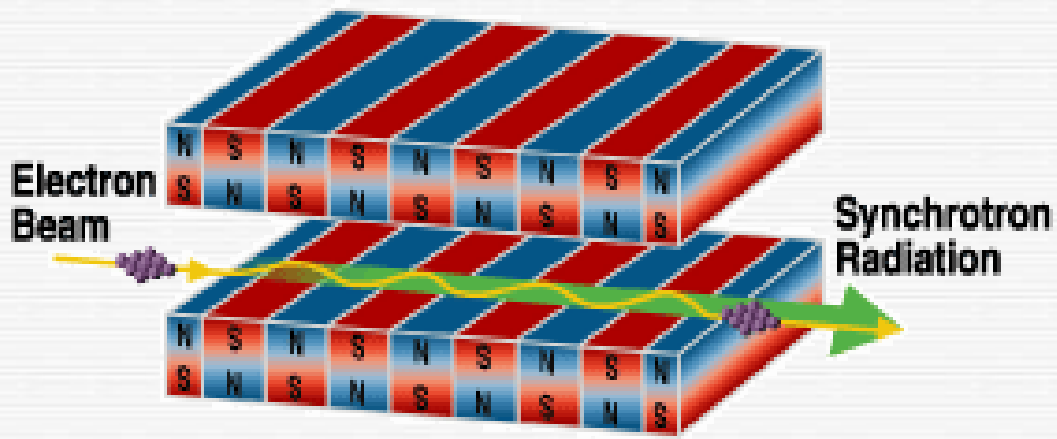
Wiggler (synchrotron)

The electron beam wiggles with a large deviation angle. As a result, bright and spectrally continuous light with short wavelengths is obtained.



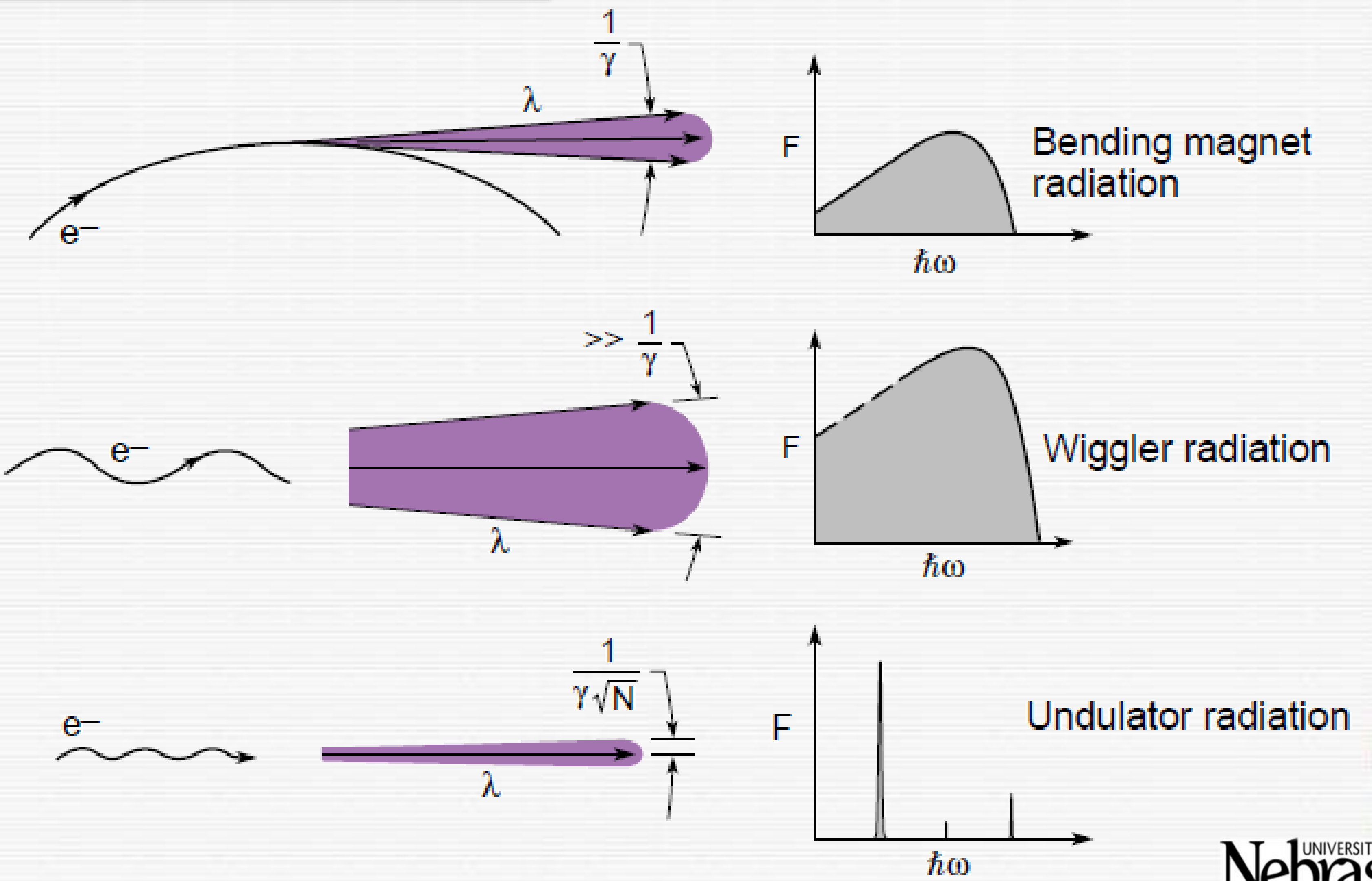
Undulator (synchrotron)

The electron beam wiggles with a small deviation angle. As a result, ultra-bright and quasi-monochromatic light is obtained by the interference effect.

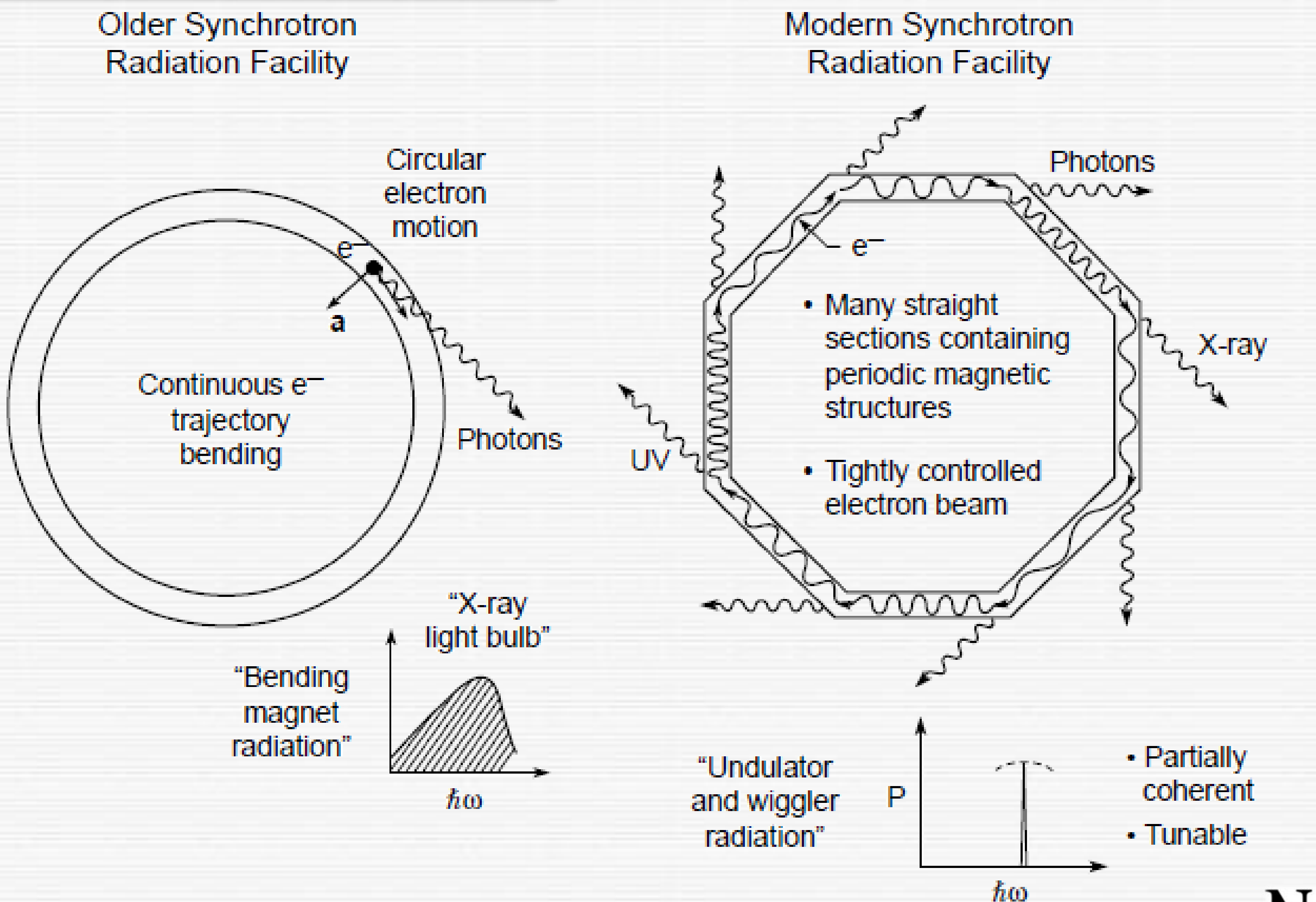


Synchrotron radiation from an undulator

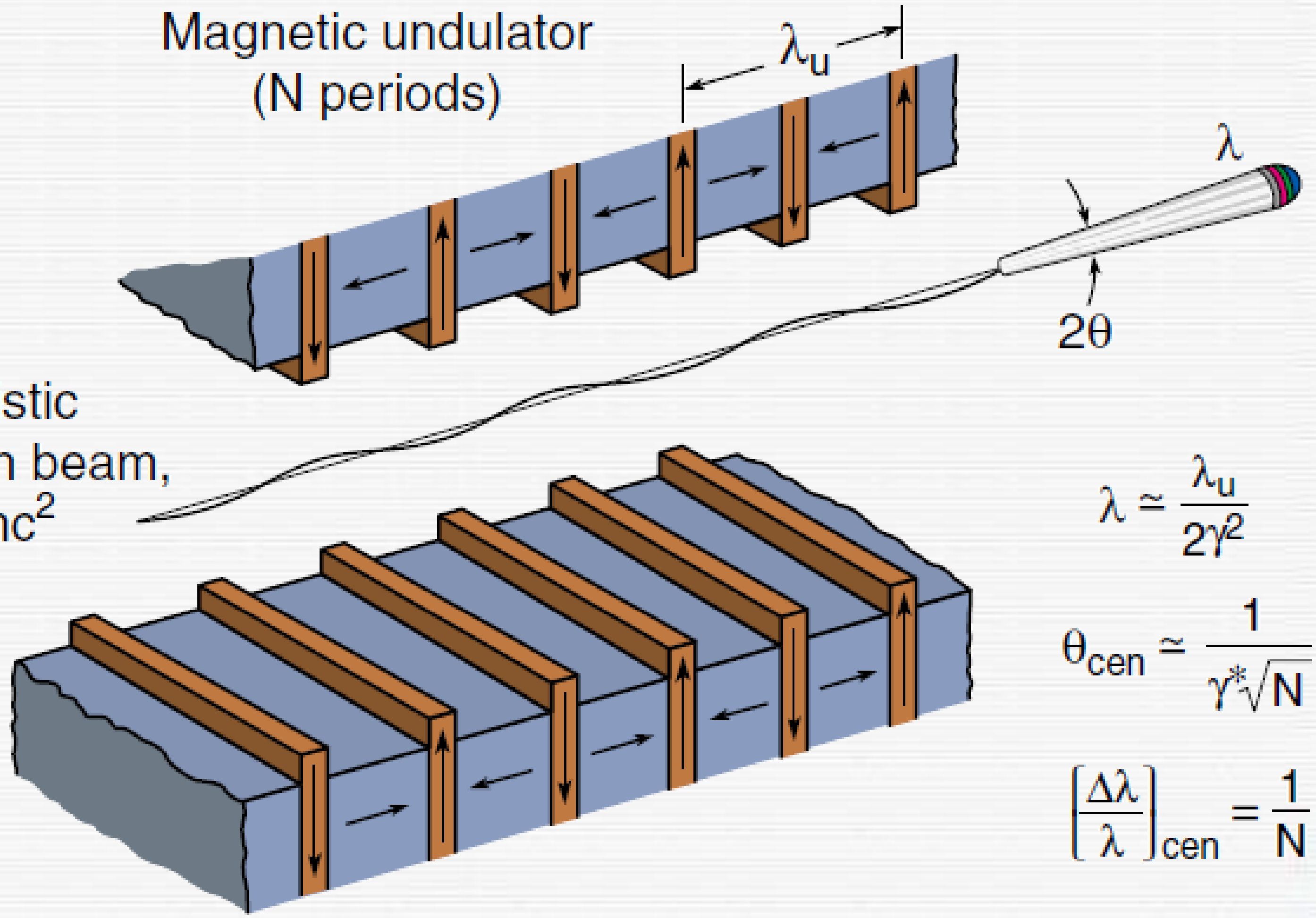
Three Forms of Synchrotron Radiation



Modern Synchrotron Radiation Facility

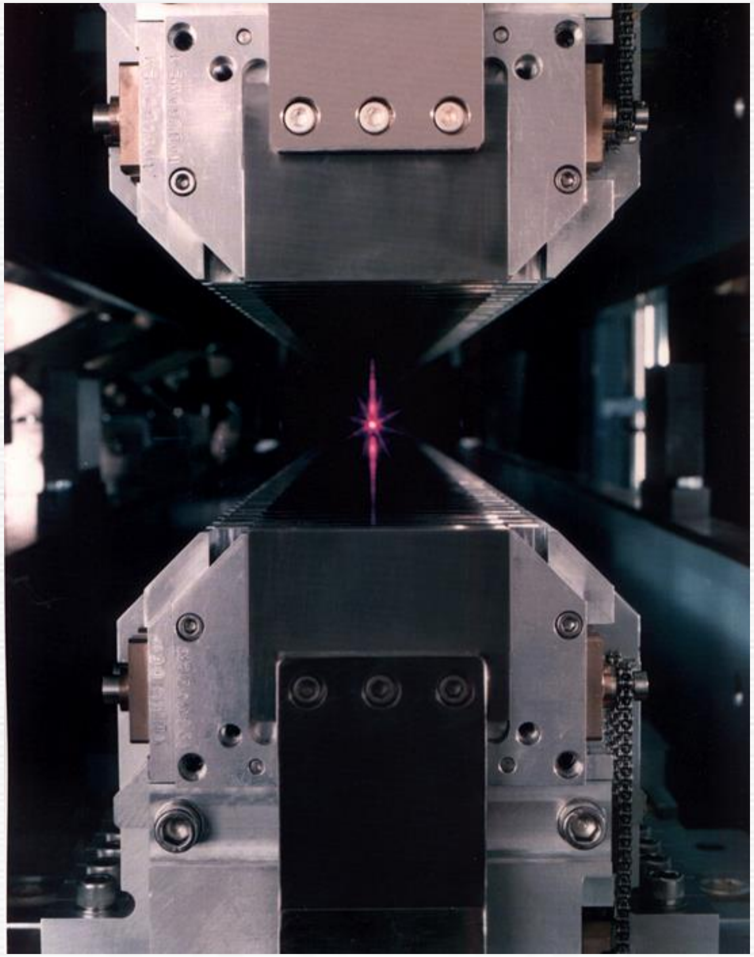


Undulator Radiation and Periodic Magnet Structure

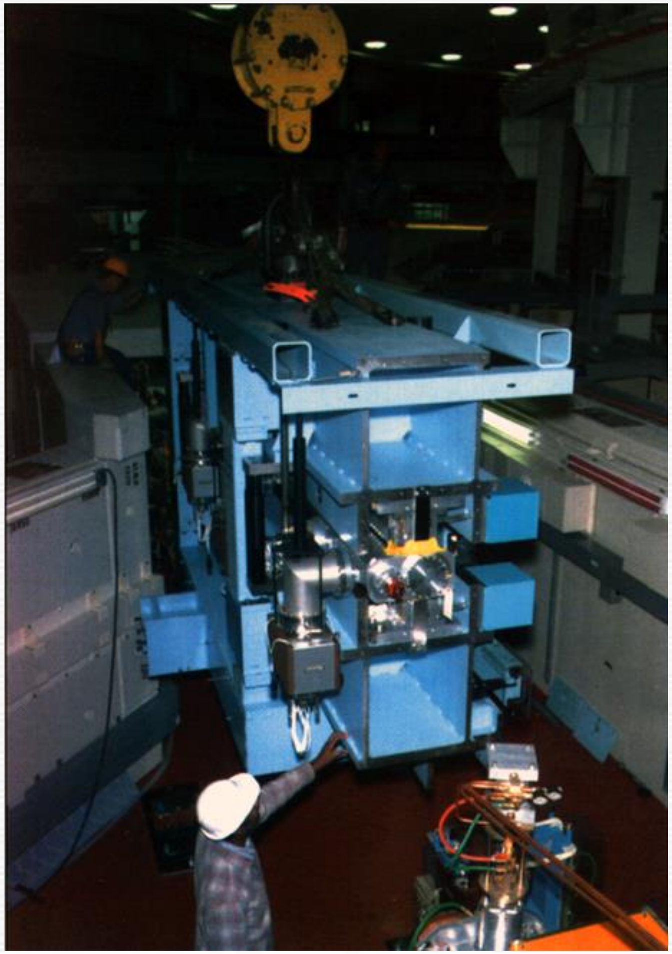


Narrow Cone Undulator Radiation, Generated by Relativistic Electrons Traversing a Periodic Magnet Structure

Undulator



ALS U5 undulator, beamline 7.0, N = 89, λu = 50 mm



ALS Beamline 9.0 (May 1994), N = 55, λu = 80 mm

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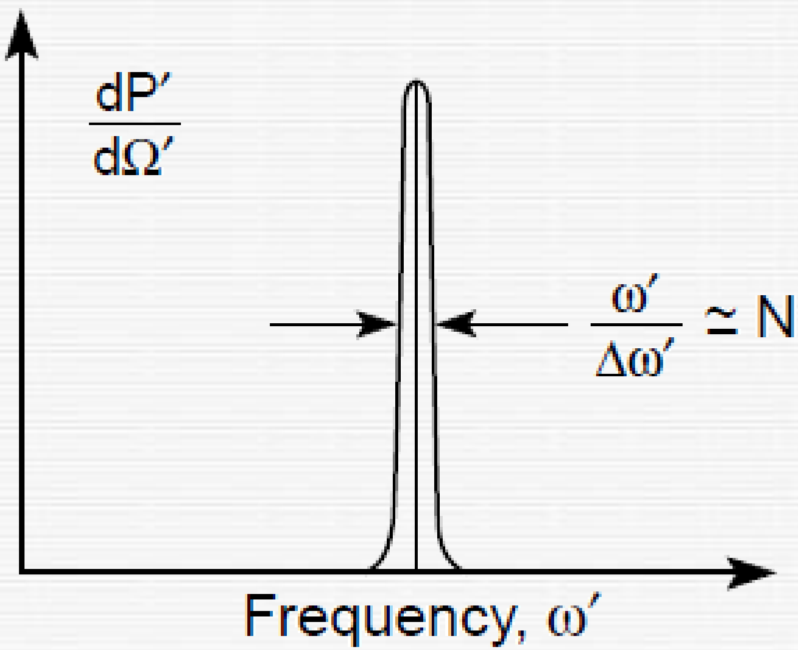
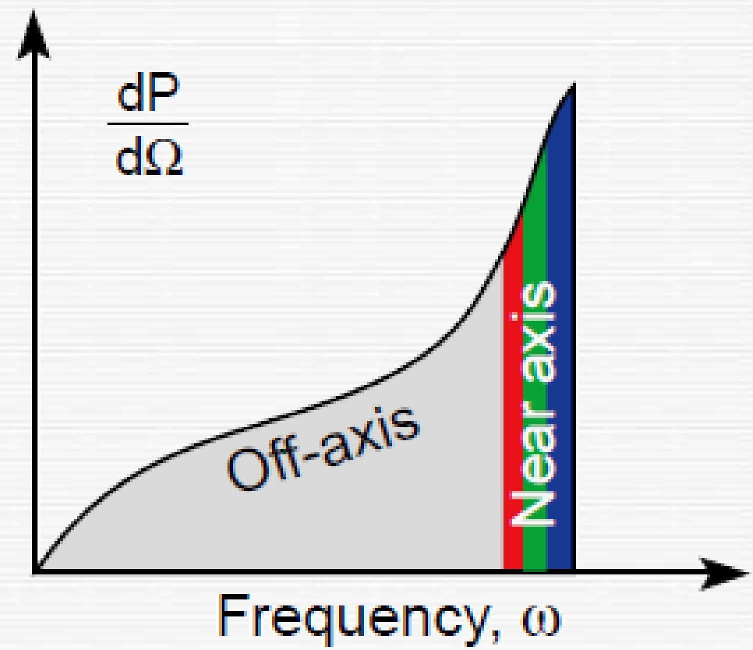
The Undulator Radiation Spectrum in Two Frames of Reference

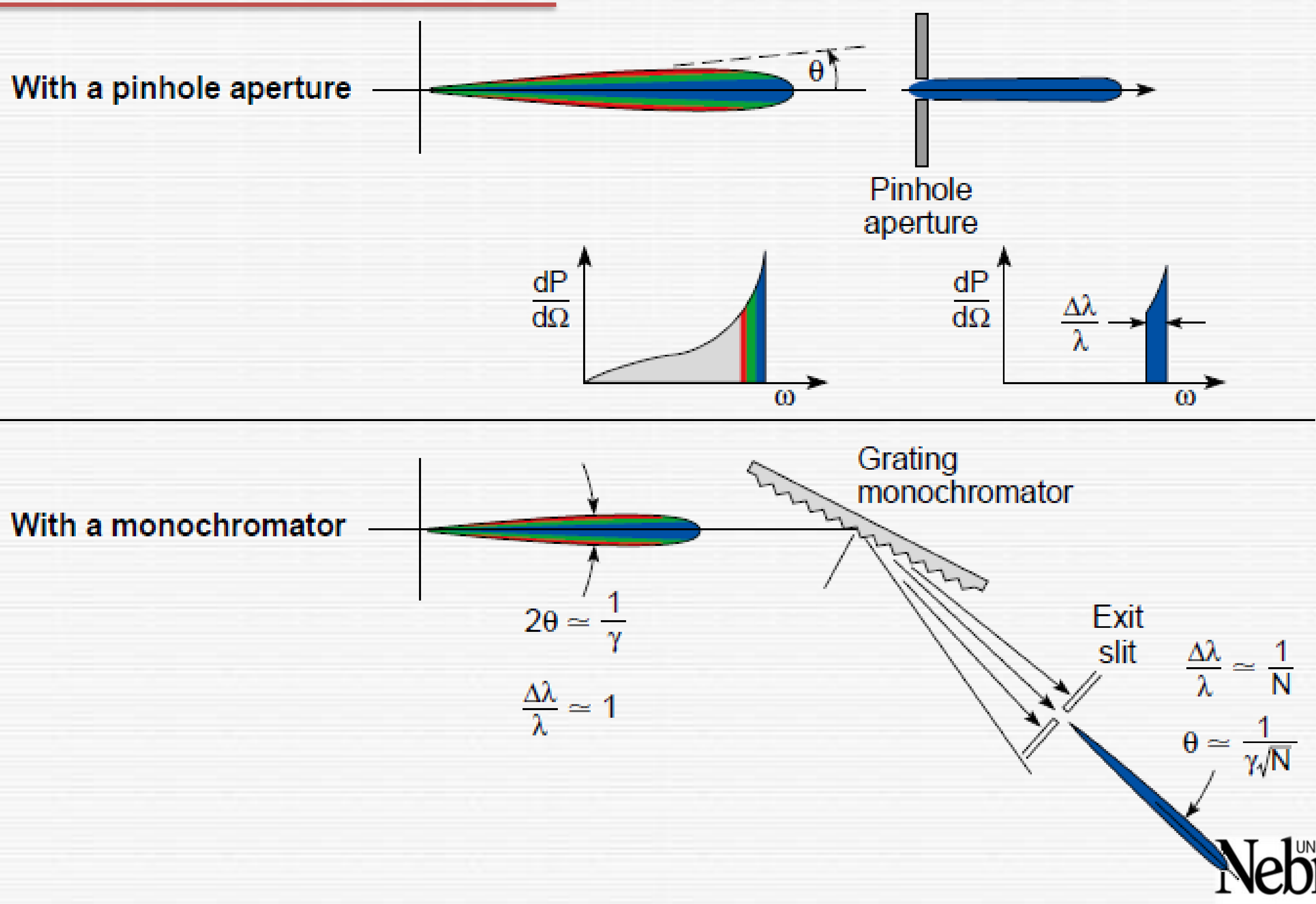




Execution of N electron oscillations produces a transform-limited spectral bandwidth, $\Delta\omega'/\omega' = 1/N$.

The Doppler frequency shift has a strong angle dependence, leading to lower photon energies off-axis.

The Narrow (1/N) Spectral Bandwidth of Undulator Radiation Can be Recovered in Two Ways



Summary

Synchrotron radiation can provide:

- Spectrally continuous (Bending Magnet/Wiggler)
- quasi-monochromatic (Undulator)
- Linearly or circularly polarized

This is the end.

Thank you for your time!

Synchrotron