Building a Beamline

Background: The National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory (BNL) is a user facility open to industry, academia and local high school student teams. The purpose of the NSLS-II is for basic and applied research in biology and medicine, materials and chemical sciences, geosciences and environmental sciences, and nanoscience. It is composed of an electron storage ring that produces extremely bright x-ray beams.

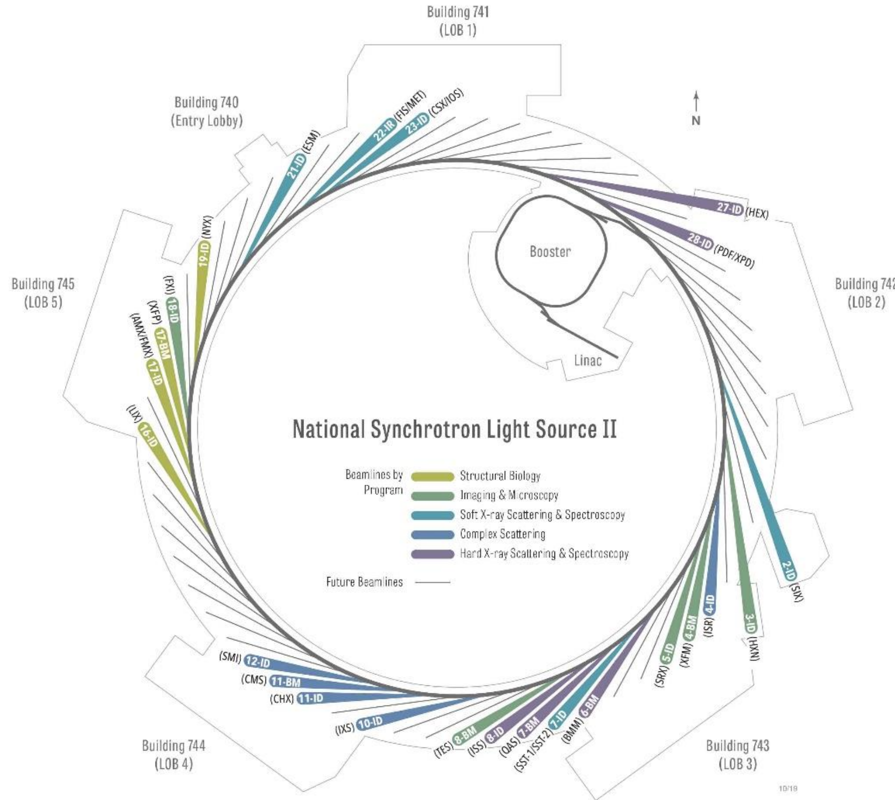
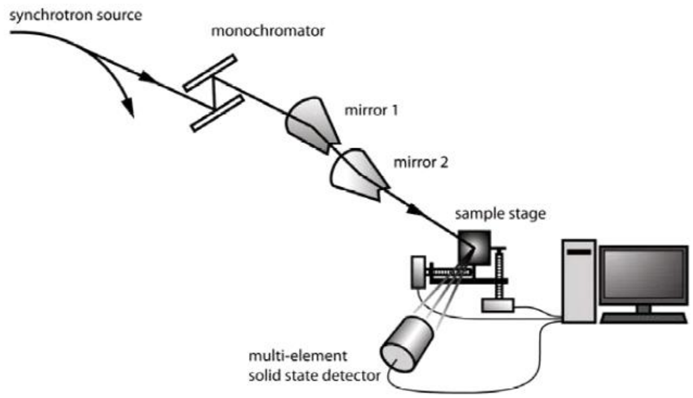


Image credit: NSLS-II

To gather data, scientists select appropriate wavelengths of light for their experiment and block the rest from reaching their sample. This is done by sending the electromagnetic radiation (light) down the beamline. As it travels down the beamline, the light goes through the monochromator where it narrows down to the desired wavelength. After that, the light can be focused on the sample for analysis. The interaction of the electromagnetic radiation with the sample can provide scientists with more detailed information.



Sample beamline
Image courtesy of DUIT multimedia

Objective:
To create a model of a real-life NSLS-II beamline from a polychromatic light source
To critique the behavior of a monochromatic beamline
Vocabulary: synchrotron, monochromator, polychromatic light, wavelength, beamline

Materials:
Many of the materials for this activity can be substituted with other materials. We have provided the list of required materials and items that can be used in their place.
-*Light source* (polychromatic light can be found in Hodson light boxes, overhead projector, flashlight, sun light, laser light, or smartphone flashlight)
-*Prism* (traditional prism including right angle or sixty degree, diffraction gratings, pieces of a CD)
-convex/concave lens (lens from glasses)
-*mirrors for directing light*
-*Colored paper*
-*cardboard*
-*scissors*
-*sticky tape or binder clips*
-*white index card* (white paper, white cardboard, white cardstock)

Procedure:
Step 1: Select your materials.
What light source did you choose?

Step 2: Create a spectrum of light. Hold the prism in front of the light, adjust the prism until you can produce a spectrum of light that defines the colors of the rainbow onto the white index card. Try to get the sharpest image possible from the light source/prism combination. Some things to considers:
How far away from your light source does your prism have to be?
What happens when you move the prism closer or farther away?
Does changing the angle of the prism change the spectrum?
Does the distance of the white index paper (representing a sample) affect the spectrum being produced?

Step 3: Selecting a wavelength. The next step is to isolate a specific wavelength of light onto the white index card. Choose something from the materials list that will block out the unnecessary light. Cut a small hole or slit in the material. This hole should only allow one color of light to shine through. You may need to adjust the selector to get the best results. Some things to consider:

Did you have to change the shape or size of that opening? Describe any changes you made.

How far away from your prism have you located your selector?

Step 4: Refine the light. Focus the light to one single point using a lens.

Predict which lens created the most focused beam of light.

Which lens will focus the light?

Try out this procedure with a different light source. Does it behave in the same way? If so, how? Share challenges that you think a real beamline scientists might face?

Tips: Use the sticky tape or binder clips to hold down the different pieces of the beamline as you complete each step.

Lesson Resources:

This lesson was adapted from the Synchrotron Investigations student activity from the Australia School Innovation in Science, Technology and Mathematics.

The Diamond Light Source created a simulation that describes the stages the electrons move through from the LINAC to the experimental floor.