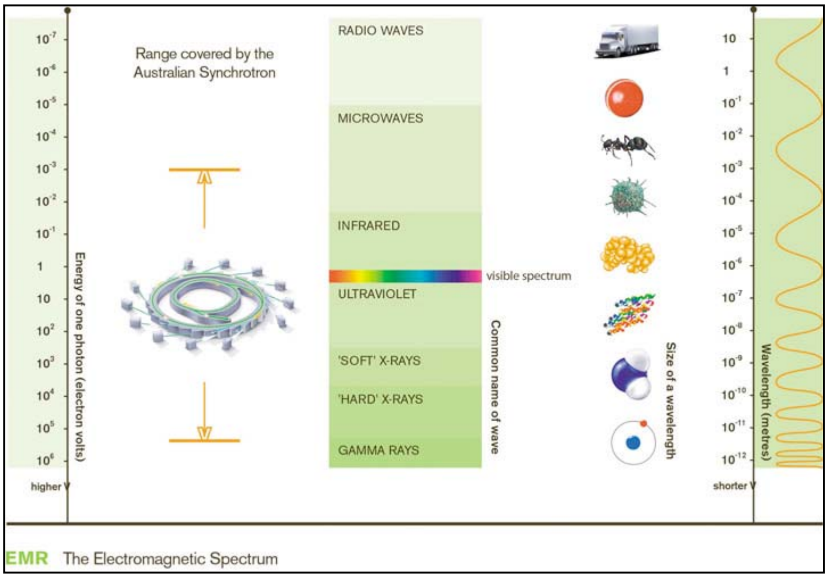
4.4 Building a beamline

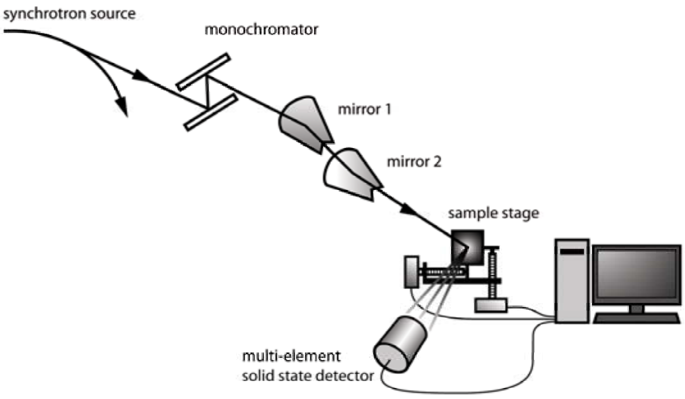
Background

Synchrotron radiation includes wavelengths of electromagnetic radiation from infrared to hard X-ray regions of the spectrum.



Where the Australian Synchrotron fits into the electromagnetic spectrum
Image courtesy: Australian Synchrotron, State of Victoria

To gather useful data, scientists select wavelengths appropriate to the experiment they are conducting and block the rest from interacting with the sample. The process involves directing electromagnetic radiation from the synchrotron down a **beamline**. The electromagnetic radiation selected then passes through a **monochromator** where the desired wavelengths are selected and then focused onto the sample.



The Image courtesy: DUIT Multimedia

The interaction of the selected electromagnetic radiation with the sample provides information about the material that the scientist is seeking. The monochromators used are either gratings or crystals, they diffract and wavelength select the electromagnetic radiation or prisms to refract the light. These are used so a single frequency can be selected. Filters (slits) are then used to select the monochromatic (single frequency) of electromagnetic radiation required.

Your challenge

You and your group are to construct a monochromatic beamline from a polychromatic light source and focus that light on a point where a sample of matter is to be analysed. Your beamline must be able to select a particular frequency of light required for this experiment.

Materials

Light sources – any polychromatic light source can be used. Here are some suggestions:

- Hodson light boxes
- overhead projector
- torch
- microscope light
- sun light
- laser light

You will also need:

- prisms (right angle or sixty degree), diffraction gratings or pieces of a CD
- cardboard (to make slit filters)
- a range of coloured paper including white
- scissors or knives
- sticky tape
- mirrors for directing light

Step 1 – selecting your materials

Select:

- a light source
- a prism
- diffraction grating or a piece of CD
- cardboard
- paper
- scissors or knives
- sticky tape
- mirror for directing light

1. What light source did you choose and what properties does the light from your source have?

Step 2 – creating the spectrum

Holding your prism or grating in front of the light, try to produce a spectrum that sharply defines the colours of the rainbow. You may have to work out how to limit the amount of light you use from your source. You will have to explore how and where to hold the prism to get the sharpest image. Use the mirrors to get the beam positioned where you want it. You may also have to explore where and onto what surface your spectrum is projected.

2. How far away from your light source does your prism have to be?

3. What happens when you move the prism closer?

4. What happens when you move the prism farther away?

5. Estimate the angle at which your prism is held relative to the direction of the rays of light.

6. How does changing the angle affect your spectrum?

7. What are you directing your spectrum onto?

8. Does the distance of the ‘sample’ to the light source affect your spectrum? If so, how?

9. What is the distance of the ‘sample’ from the prism?

10. Does the material of the ‘sample’ itself affect the spectrum (colour, size, etc)?

Step 3 – Selecting a wavelength

Now that you have managed to project a nice sharp spectrum onto your 'sample', you need to install your 'selector'. Choose something from the material provided that will be able to block out all of the light that you don't need. Cut a hole or slit in that material. The slit/hole should be designed to only allow one colour of light through to shine onto your 'sample'. You will have to figure out how and where to place your selector to get the best results.

11. What material did you choose for your selector?

12. Why did you choose this particular material?

13. How did you cut your opening for your selector?

14. Did you have to change the shape or size of that opening? Why or why not?

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

16. Explain how you chose your selector position.

17. Draw a scale diagram of your beamline (like the one provided in the background information).

My scale is: ....

Step 4 – demonstration

Demonstrate to your teacher and/or class that your beamline is able to select individual colours of light and share any ideas you or your group feel are relevant to the class.

Step 5 - questions

Now that you have successfully built a beamline capable of selecting wavelengths of light within a visible colour range, it is time to reflect on what worked for you and why.

18. What kind of light source would work best? Why?

19. Do you think a different kind or shape of prism would work better?

20. What suggestions would you make regarding the environment this beamline will be used in? (For example: should the room be light or dark; what kind of structure should hold the light source, the prism, the sample; how clean does the area need to be; etc)

21. How did you determine the location of each component of your beamline?

22. Why do those distances work best?

23. What advice would you have for the designers of the research beamline?

24. What type of selector should be used and how should it be constructed?

25. What things should the designers be careful of when they build their own beamline?

26. Could the group using the laser light get a spectrum of colours? Why/why not?

27. Explain how you might use your beamline to select an infrared frequency to examine a sample?

Real beamline problems

What did your group find the most difficult problem to solve in getting a monochromatic beam of light of sufficient intensity on your sample? Explain in some detail.

Guess what all research scientists have the most difficulty with?

Can you solve this code?