KSU Physics Education Group Visual Quantum Mechanics
Infrared Detection Exploration

http://web.phys.ksu.edu/vqm/tutorials/re/repg1.html

Introduction and Equipment:

In this activity you will perform a series of experiments to build a model of material which converts low-energy infrared light into higher energy visible light.
You may obtain a small card containing this material from Radio Shack (part #267-1099). You will also need a TV or VCR remote control and an infrared lamp. The lamp should emit most of its energy in the form in the non-visible infrared portion of the spectrum. When it is on, the lamp should be a deep red color. These lamps are available at most hardware stores. (See Figure 1.) "Heat Lamps" which produce a white light will not work.

Figure 1: The best heat lamp is similar to this one.

Finally, you will need a very small amount of colored transparent plastic. This material is available at office supply stores. You may also be able to cut pieces from plastic packages. You must be able to see at least one color transmitted through the plastic. In this experiment you will need to use red, green and blue colored plastics.

Preparation:

In this activity you will use a remote control such as the one used for a TV or VCR. To start this activity you should learn a little about how the remote control communicates with the TV or VCR. In order to do this, complete these activities and answer the following questions.

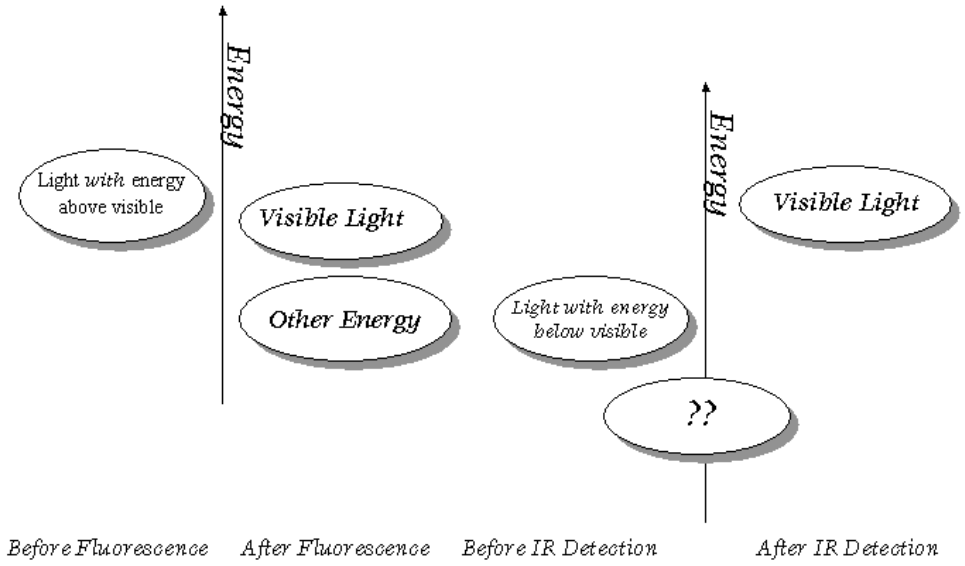
1. Most remote controls have a plastic section that is dark but different from the black plastic section that covers the rest of the remote. The signal leaves the remote through this section. Cover this part of the remote control. Does the TV still respond?
2. Usually you can find the place where the signal is recieved. It will have dark material covering it. Does the TV respond when it is covered?
3. Will the TV respond if someone stands between the remote control and the TV? Try several positions.
4. Can the TV be controlled if the signal is transmitted through glass and bounced off a mirror?
5. Based on these results, describe how the signal coming from the remote is similar and different from visible light.

The answers to these questions indicate that a signal is coming out of the remote control which behaves as light does. No light is visible when you activate the remote. However, the remote is sending out a low-energy light signal to communicate with the TV. Most remote controls emit infrared (IR) light, which has an energy that is less than 1.6 eV. When the remote is activated, pulses of infrared light leave the remote control. When this light is received by the device, it is interpreted and the TV, VCR, or CD player responds.

"Seeing" Infrared

Large amounts of infrared light may be detected as heat. The heat you feel from a fireplace, sunlight, or the ground are all sources of infrared light. The eyes of some living creatures, like the rattlesnake, are sensitive

to infrared light. Thus, they see very small temperature variations in their environment. However, the amount of infrared light coming from a remote conrol is very small, so we do not feel any heat.
Sometimes remote controls fail to function correctly. The first check that is made by repair people is to see if the remote control is emitting infrared light. Of course, the repair people cannot see infrared light and carrying around rattlesnakes is considered impractical.
Fortunately, a small material enables them to "see" indirectly the infrared light. This IR detecting material converts infrared signals to visible light. At first the process may seem similar to fluorescence because it is converting light of one energy to light of another energy. However, IR detection is different from fluorescence in one very important way. In fluorescence a solid emits a lower energy than it absorbs; the rest of the energy goes to other forms. In IR detection, the material is emitting *higher* energy than it absorbs. This process is described graphically below.



The difference between fluorescence and infrared detection is in the changes in the energy of photons. We have included a question mark because you do not yet know how the energy changes in the IR detection process.

Exploring the IR Detector

To begin your investigations, use either a remote control or an LED which emits infrared light. Expose the card with the IR detecting material to a room light for a few minutes. Then activate the remote or increase the voltage on the LED. Describe what you see coming from the material.
Continue to expose the material to IR light for about one minute. Record any changes in the light emissions.
In a darkened room, expose the IR detector to an infrared lamp. This lamp emits very little visible light an a large amount of infrared light. The room should not have any light, save that coming from the IR lamp.
Once you have exposed the card to intense IR be careful to keep it out of visible light. Then, hold the infrared detector card close to the activated remote control for about 10 seconds. Record your observations.
Now, allow some room light to fall on the card. Then, in a dark room expose the card to IR light from a remote control. Describe what happens.
Leave the IR light from the remote control on. Does the light from the card decrease with time.

IR Detections and Color of the Visible Light

Expose the detecting material to the intense heat lamp again in an dark room. Before exposing the material to visible light, cover one-half of the detecting material with the colored transparent plastic. While holding this transparency in place, expose the IR card to visible light.

Return to the dark. Then, activate the remote control and describe the results. Repeat the experiment until you have results for, at least, red, green, and blue transparencies. Summerize your results and conclusions.

Summary of Experiments

From your observations:

1. Speculate about other sources of energy that might be involved in the emission of visible light from the card. Explain your conclusions using your observations.
2. Speculate why the light emitted by the card decreases after a period of time in the dark room even though the IR light from the remote control is kept on it.

Summary

The IR detector card, like the fluorescent and phosphorescent materials, consists of solids with impurity atoms. An energy band model can explain the observed properties of the card. Try to develop an energy band diagram the could explain the properties of the IR detector card.
Sketch your prediction and identify the energy bands of the materials and the energy or energies absorbed by the card (along with their sources) as well as the energy emitted by the card.
In the next activity, you will use a computer program to construct a model that explains the operation of the IR detector card:

Introduction

In the previous activity you completed several experiments using infrared detection material. Each of the experiments was directed toward understanding how the material can absorb infrared light and then emit higher energy visible light. In this activity you will work with a computer program that uses energy bands to create a model of the IR detecting material. By changing variables in the program you will be able to see how the model explains each of the observations in the previous activity. This activity can be found here:

http://phys.educ.ksu.edu/vqm/index.html

Energy Bands in IR Detecting Material

A figure of the IR detector card will appear on the left part of the screen and an energy scale will appear of the right part of the screen.
Notice that the energy scale contains a black set of horizontal lines located at -5eV. These lines represent the valence band of the IR detection material.
Create an Excited State Band (conduction band). A set of gray horizontal lines representing the excited state band appears next to the energy scale.
Click on the 'Create Impurity State Band' button. A set of gray horizontal lines appears in the energy gap.
The material that makes up the IR detector card consists of many solid atoms, including some impurities. Interactions occur among solid atoms that are relatively close together. Electrons bound to these atoms have allowable energies that are in both excited and ground state bands. The impurities create additional allowable energies in the impurity state band.
The program begins with a simulated IR detection material that is similar to material that has been exposed to an intense IR source. So, it must be exposed to some visible light before it will function. The Input Spectrum represents the source of this visible light.