Science Afternoon at NIST: Focus on Infrared Energy

with Dr. Joe Rice of the Sensors Science Division (Joseph.Rice@nist.gov)

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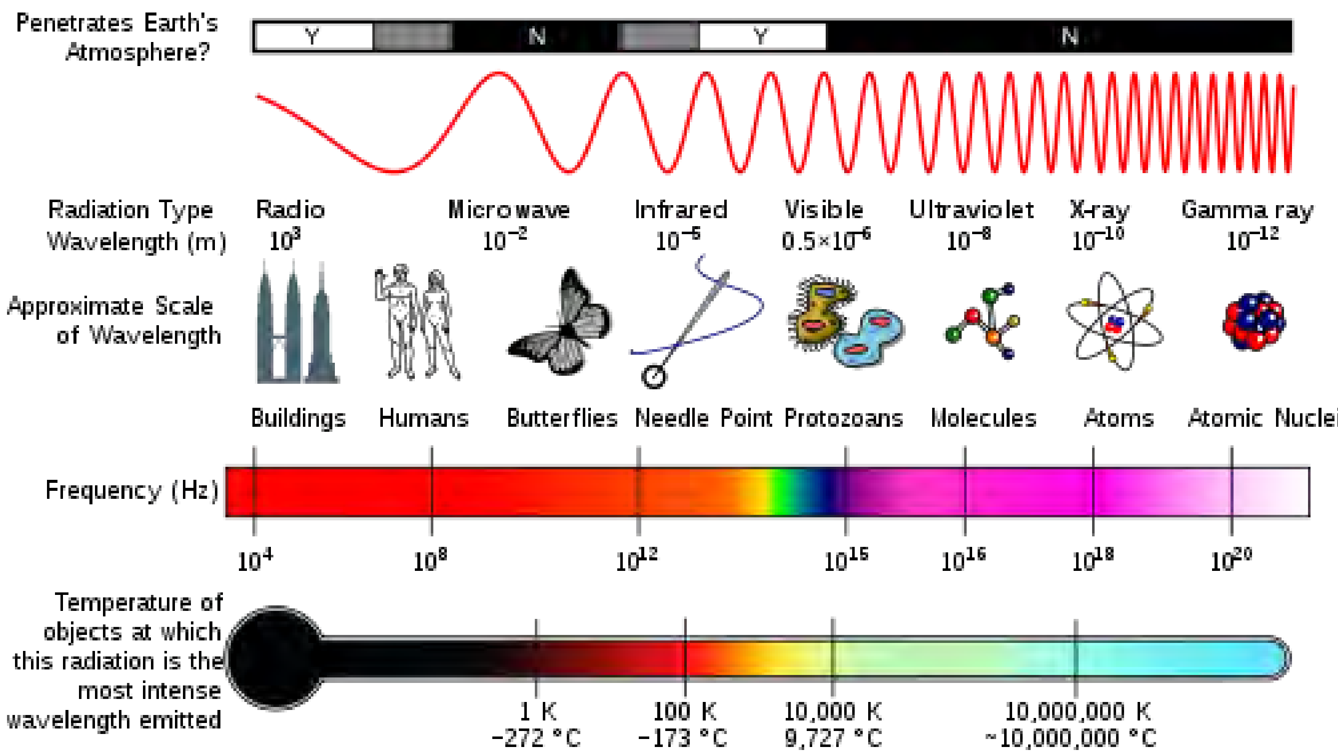
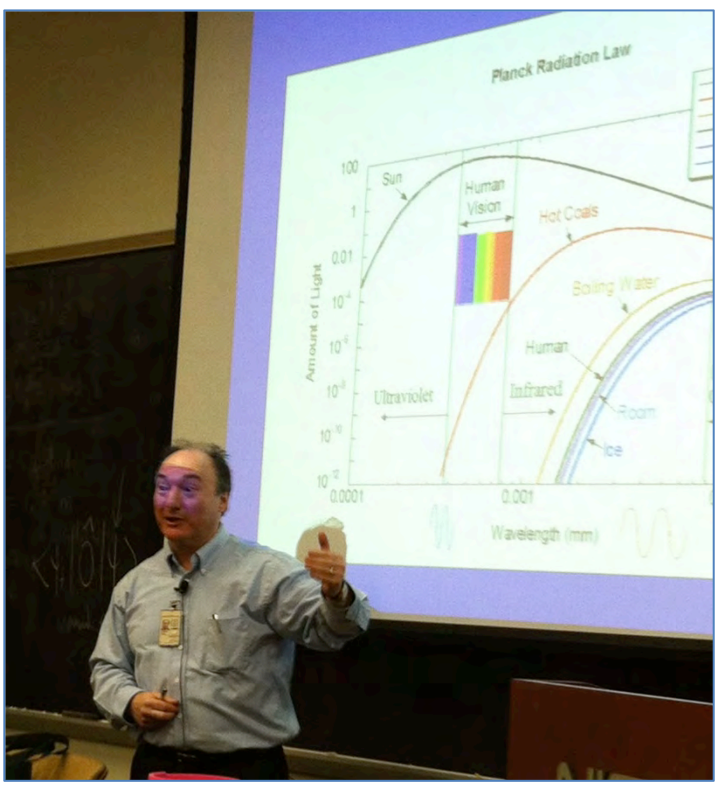
Teachers came to NIST to learn about infrared energy and how it applies to them and especially their students, and to learn about NIST work in the area. Infrared energy is on the electromagnetic spectrum just beyond visible red light and is composed of wavelengths longer than visible light.



from http://en.wikipedia.org/wiki/Electromagnetic_spectrum

Light is a transverse wave, not a longitudinal wave, and if you're really skilled you can indicate polarity by making a circular transverse wave. Either a slinky or a rope can be used to demonstrate the waves, although a longitudinal wave is best demonstrated with a slinky. (This oversized slinky came from rainbow magic spring)



Joe talks about how the amount of light an object emits is dependent on the composition of the object and the wavelength. Note how many "hot" objects emit the greatest amount of "light" (invisible to us) in the infrared range. That light is invisible to our eyes, yet with special detectors we can see it.

Teachers are given infrared thermometers that detect the surface temperature of an object – and quickly begin to use them to check the temperature of objects around them. Since this thermometer measures infrared energy from a large invisible cone extending out from the detector, it's better to move it as close as possible to the object you're measuring. That's why the ear thermometers commonly used in doctors' offices are actually inserted in the ear. Lisa tests this by measuring the temperature in her mouth. She does not have to say, "Aaah".

Julie starts to measure the temperature of multiple objects all around her. A question is raised as to the correct terminology: are we measuring the infrared energy of the object or the temperature or the heat? Joe's answer: the IR thermometer measures IR energy and based on its calibration (hopefully traceable to NIST), converts that measurement to a temperature reading.

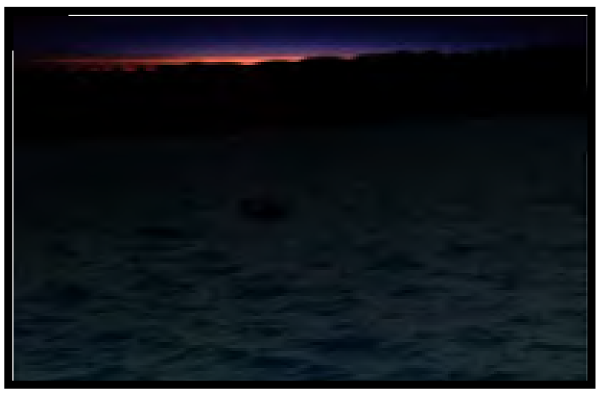
Jonathon asks an interesting question about the heat lamps used to keep French fries at McDonalds warm. Infrared energy, right? Sorta, Joe says, but convection and conduction are also involved since there's air in the system.

And how does the IR thermometer the teachers received compare to the IR camera? The basic difference is that the IR camera is made of an array of 320 x 240 detectors, while the IR thermometer only has a single detector. The IR camera has enough detectors so it can build a picture based on the temperatures observed by each of the many detectors, whereas the thermometer can only report a single temperature.

With Infrared Cameras. We Can See…

Through smoke:

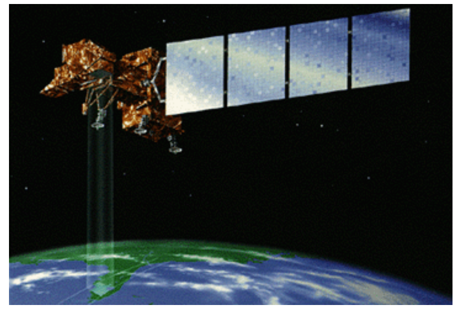
At night:



Regular Visible Camera Infrared Camera

Joe points out some of the more common uses of IR cameras today: search and rescue such as in fires, searching for bad guys at night, and looking for heat loss in buildings. Interesting fact: IR works in fires because the wavelength of IR is greater than the size of the smoke particles so the IR camera doesn't even "see" the smoke. Unfortunately, glass does stop IR so firefighters have to break the glass so they can look through the smoke for signs of life.

Infrared Cameras on Space Satellites



- Scientists and Engineers at NASA and similar places use Infrared Cameras to monitor Earth's weather and climate
  - -Ocean and Land temperatures
  - -Atmospheric and Cloud
  - -Health of plants

Goes Weather Satellite

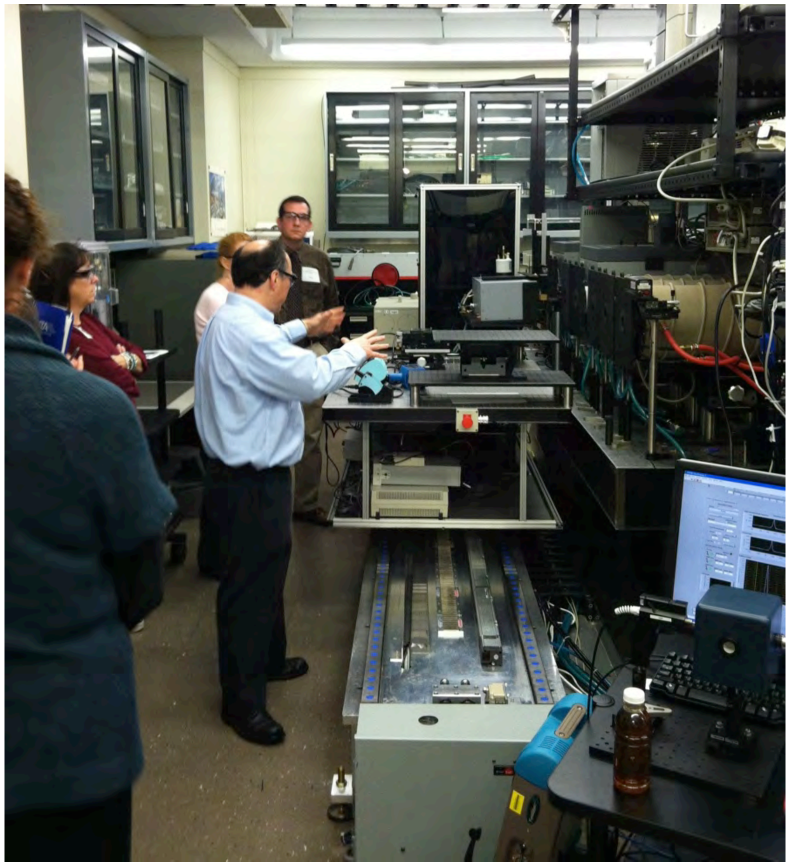
Calibration
(this is what I help with)
Infrared Image

imagers.gsfc.nasa.gov/ems/infrared.html

Joe's work at NIST in part involves calibration of systems used for IR detection, from those on earth to those on satellites. A teacher in Florida, Erica Corey, points out that satellites have been tracking the effects of the Gulf oil spill and changes in vegetation from before and after can be detected, based on the IR signal. Then it's off to the lab we go to see the equipment used, with teachers investigating with the IR camera along the way.

Joe brought along an "inexpensive," only ~$2000, IR camera and allows the teachers to use it to investigate the world around them. One thing they quickly discover is the importance of the surface in the measurement – reflection makes a big difference! Since IR is a wave, reflections of IR may cause confusing and erroneous readings; another example of the importance of understanding what the measurement is trying to teach you. For example, pointing the camera at the sky gave a reading of ~20 C, which was primarily due to the light reflected from the clouds. If the clouds weren't there and the camera was pointed at the sky the temperature would be much lower, close to the temperature of outer space!

Lisa notices that the residual heat from a handprint is visible using the IR camera – discussion of development of a forensics investigation ensues! (If you look closely you can see someone holding the IR camera reflected in the glass.)



In the lab Joe points out the movable stage where detectors and sources are placed so they can be compared to standards and calibrated.

Lynda uses the IR camera to detect the source of the greatest amount of heat.

Using her infrared thermometer, Carolyn attempts to do the same thing – but it's much harder due to the imprecision of the device, and the way it gathers information from a large cone extending out from the detector. With the IR thermometer you really have to get right close to the source…

… as Joe demonstrates (don't try this at home).

Teachers learn about the different sources and the importance of the matte black cavity. To be accurate there should be no reflection and all the light should be absorbed. In this case the emissivity of the material would be 100%.

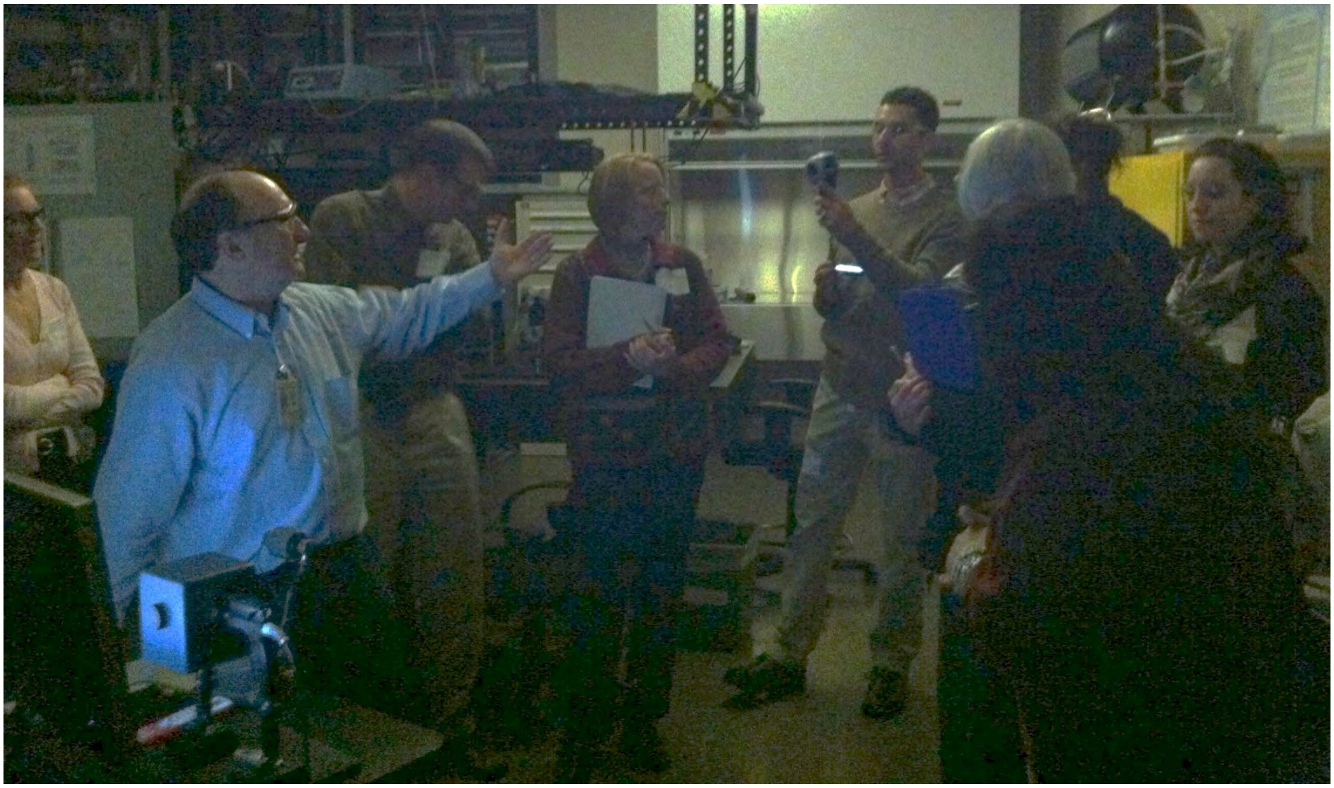
Questions arise about the ability of the IR camera to detect the cool liquid in the plastic bottle. Will the measurement be thrown off by the reflectivity of the plastic? Jonathon checks it out. The reflective surface of the plastic does make a difference but this camera has been set to assume the material measured has an emissivity of 0.95 to account for an estimated ~5% reflectivity in order to try to correct for this. That correction is based on an assumption, since in this case we do not know the actual reflectance (We could do the additional work to actually measure it, but we have not in this case)

Checking out the ability of the IR camera to detect latent heat – teachers wonder how long the heat lasts after the source has been removed?

And does the surface make a difference? Yes, based on the heat transfer capabilities of the materials.

How well does the IR thermometer work to measure heat leftover after a source has been removed. Not nearly as well as the IR camera but may work well enough for development of a classroom activity!

On to the spectrometer for further investigation of IR sources. Julie wonders about the source of some of the peaks…



… and the answer becomes clear once the lights are turned off and the peaks disappear. Note Jonathon holding the IR camera in the background – no change in what he sees even with the lights off.

Keeping the lights off to avoid the background light signal, Joe, with Matt's assistance, measures the signal from a remote control. Turns out that all the functions on the remote control utilize the same wavelength, 947 nm. How does that control anything, teachers wonder? Joe speculates that although the same wavelength is used a sequence of pulses, sorta like Morse code, enables control of all the functions.

Then Chris tests the reflected IR of healthy green leaves contrasted with brown leaves – and yes, there is a subtle difference!

Teachers head out continuing discussion of the tour and everything they learned, looking forward to using all of this in the classroom.