NIST Summer Institute for Middle School Science Teachers
Day 6: July 16, 2012

We spent the entire day at the NIST Center for Neutron Research, one of only four facilities of its kind in the United States. In addition to the research done by the NIST scientists, researchers come from all over the world to use neutrons in experiments to probe matter, such as materials used for hydrogen storage or more mundane issues such as the emulsification of salad dressing. Dan Neumann, a physicist at NCNR, welcomed the teachers.

Juscelino Leao gave an exciting talk about the importance of neutrons in scientific research. Juscelino's teaching style benefits from his seven years in the middle school classroom.

Teachers are ready for a demonstration of the fission reaction simulated by the mousetraps with ping pong balls on them.

How much fun! Look at the anticipation on the teachers' faces!

And look at the change in expression during…

… and after it's over. To compare the energy released by the mousetraps to the energy of the neutron source Juscelino used the LabQuest dual range force sensor. The NCNR produces 20 MWatts of power and it would take 8 x 10^7 mousetraps to do that much work! And the reactor works 24 hours/day for 38 day cycles with 10 days off, while the mousetraps took about 3 s: lots more mousetraps needed!

There is a mock-up of the reactor and Juscelino shows the different parts. Here's he's shown removing the core, with the rods shown in grey.

Mo and her notebook of drawings illustrating the scattering that provides information about the material bombarded by neutrons.

Efrain Rodriguez talked about the different methods of crystal formation and how they're important in the use of neutrons. Here Monica examines a sample of open formation crystals made from holmium that appear pink in fluorescent light but yellow in white light.

Teachers prepare to make alum crystals, with the help of NCNRs Nina Verdal, starting by dissolving lots of alum in hot water….

… then tying a seed crystal onto a string….

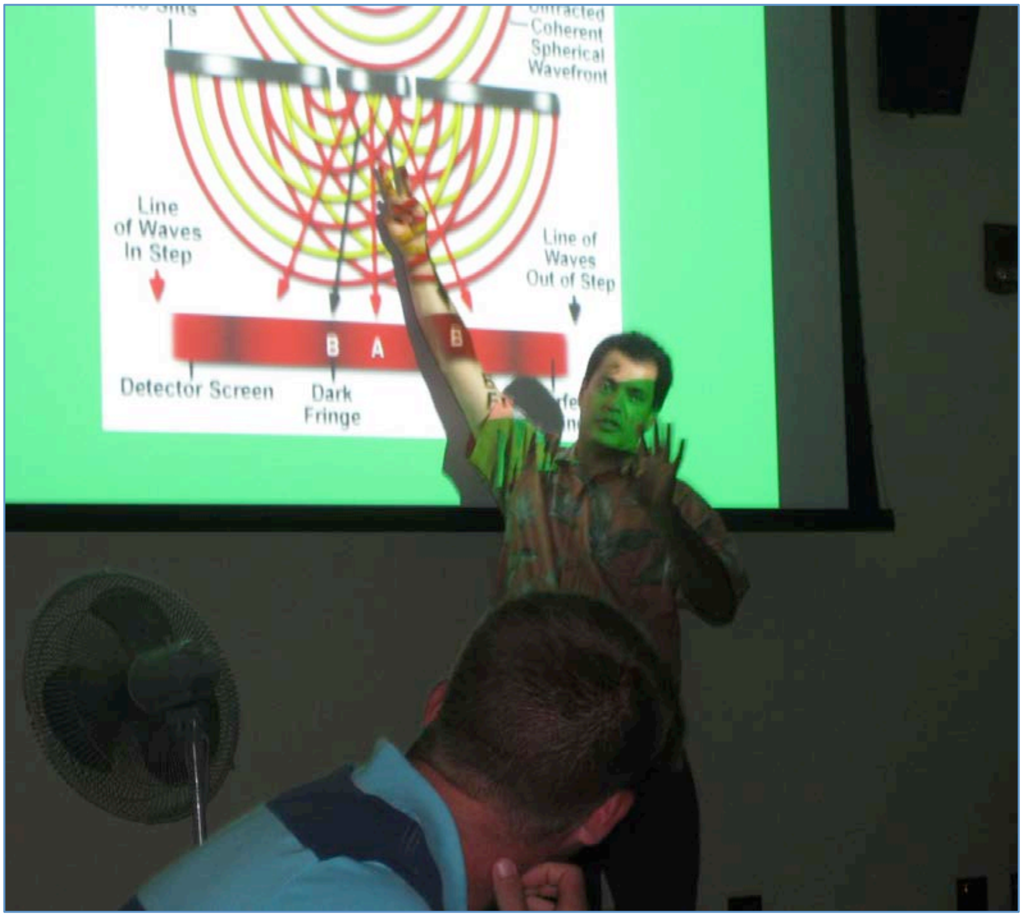

… and putting it into the saturated solution, not touching the bottom or sides of the jar.

Then it's off to share lunch with NCNR scientists. Julie Borchers and Jessica learn about each other's work.

Randy and Postdoc Mike Dimitriou

Jerrin and Daniel Pratt

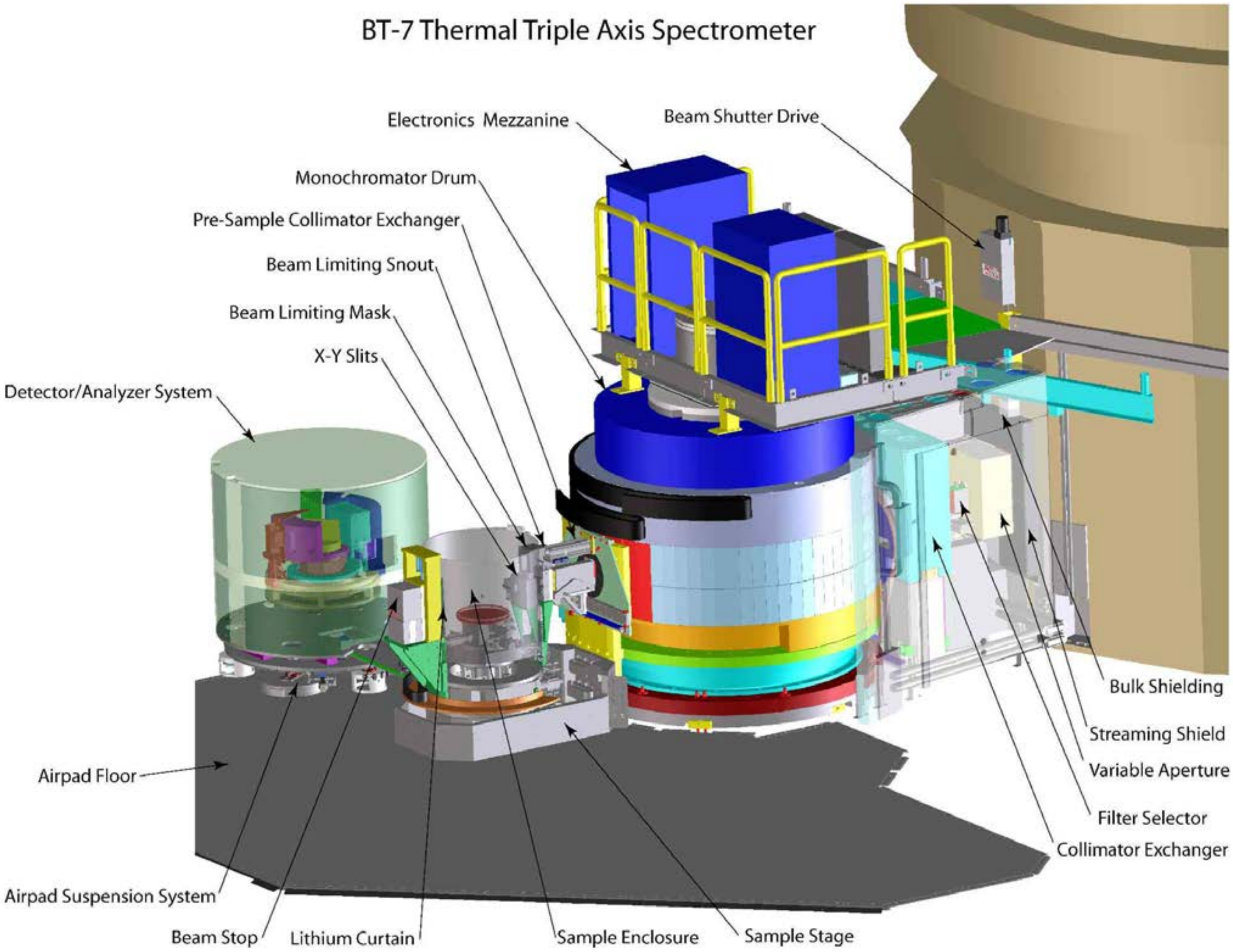
Karen and Cherry with Ken Qian



After lunch Juscelino talked about how diffraction enables determination of the structure of materials.


How is the diffraction pattern of a single crystal different from that of a crystal? Juscelineo illustrates by spinning a diffraction pattern which produces rings of brightness and darkness representing constructive and destructive interference.

Here's a picture from our tour of the guide hall in front of the Spin Echo instrument with Antonio Faraone. With Spin Echo one can look at microscopic properties on the range of nm and study things like soap and how it does its job on oil and dirt. Bilayer membranes in cells as well as proteins have also been investigated. Different information is gained from changing the angle between the two parts of the instrument; although the magnets weigh tons the pneumatic system – sorta like air hockey – allows for simple control and movement. Why couldn't we see that system demonstrated? Because Antonio has an experiment going, that's why!



We also visited the triple axis spectrometer which was pioneered by Bertram Brockhouse in the late 1950's to investigate inelastic (energy non-conserving) excitations using neutron scattering, and his work culminated in a Nobel prize in physics in 1994. During an experiment, neutrons come from the reactor with a distribution of energies and first hit a monochromator to fix the energy to a specific value, much in the way that visible light can be monochromated from white to a specific color. Next, neutrons hit the sample, and their velocity can increase, decrease, or stay the same as a result of the interaction, and energy changes are discriminated using an energy analyzer. Finally, the known-energy neutrons are detected and the data can be examined by a scientist to check a hypothesis. Scientists have used the triple axis spectrometer to investigate the way atoms and magnetism move in materials, such as in superconductors that are used in MRI for health care. (Thanks to Daniel Pajerowski for the explanation!) Image taken from http://www.ncnr.nist.gov/instruments/bt7_new/

Here the tour is in front of the small angle neutron scattering (SANS) instrument where they have studied materials such as a stable explosive to determine the cause of its stability, and carbon nanotubes dispersed throughout a polymer to determine how much of the nanotubes are necessary to provide the desired properties. That blue rectangle in the foreground is one of the beam lines transporting neutrons from the source to an instrument. As the sign says, when this picture was taken the beam in this line was off – probably because Jeff Lynn was working on the instrument.

A group photo at the Disk Chopper Spectrometer, which is used to pulse neutrons and produce them with a certain amount of energy. It's been used to study hydrogen storage, polymers, and methane release, among other things. Sure wish Dave could've been with us today!

We began the day with a talk by Becky Hill and Erica Butts on the use of DNA for human identification.

Cherry and Karen examine the capillaries used to separate DNA in capillary electrophoresis. This differs from gel electrophoresis (which the teachers will see demonstrated in the lab) by the precision possible. Gel electrophoresis is a more qualitative technique used to check that the DNA amplification worked, while capillary electrophoresis can separate DNA at the level of individual base pairs.

Becky Hill and Cherry discuss aspects of forensic science at NIST.

Erica Butts and Loryn talk about Erica's job at NIST and how she came to work here.

Becky using a multi-channel pipet to load eight wells of a flash gel at once!

While in the other lab with the other half of the teachers is Jenny McDaniel who works with RNA and gene expression measurements. In this photo teachers watch closely as Jenny talks about the different pipets and the choice of the correct one for the job: stay in the middle of the range of the pipet for the best accuracy.

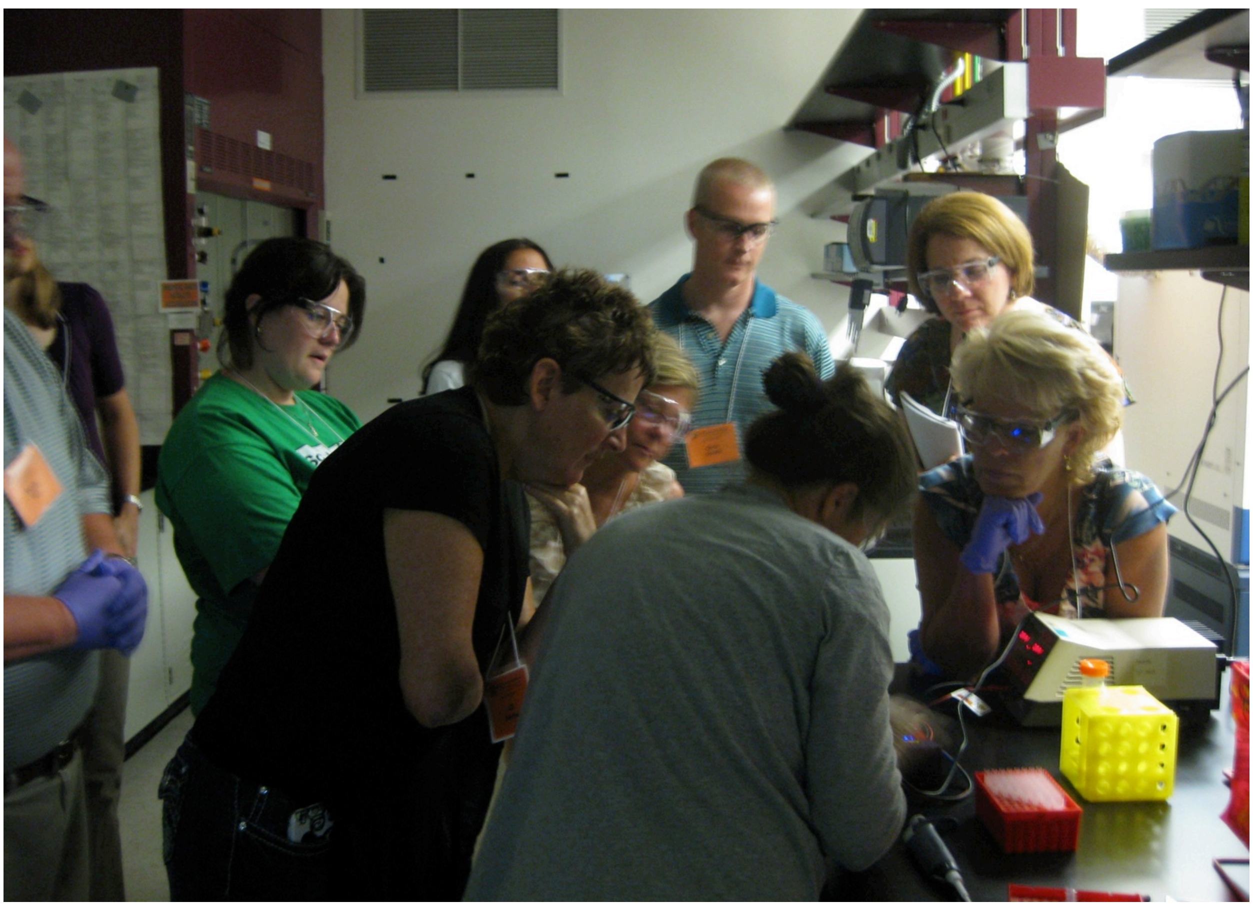
Teachers don gloves – primarily to protect the sample from them rather than protect them from the sample! – and transfer a small amount of amplified DNA to the well in the flash gel. Flash gel? It's called that because it separates the DNA right before your very eyes in seven minutes! In this picture Jill is transferring the sample while Loryn looks on.

Loryn pipets the next sample…

…. and then it's Karen's turn.

Randy tries his hand at pipetting…

…as does Jerrin.



Teachers examine the separation of the DNA under the fluorescent light. It worked!

Jenny and Jill

Jenny and Loryn

Jenny and Lisa

Then it's back to Lecture Room A to explore electrophoresis on our own using kits and 9V batteries. Not a flash gel but at least the technology is in the classroom. Dana Schneider, a MCPS teacher who participated in the 2011 NIST Summer Institute and is currently at NIST in the Research Experience for Teachers program, gave teachers hints on her use of electrophoresis in the classroom.

While some of the teachers are practicing their pipetting skills (here's Laurie using the micropipette that Dana brought in)…

… others are listening to Betsy Steel talk about her experience this summer in the Research Experience for Teachers program.

After a bit the gel has finished running and Jill, Mandy, and Lauren examine it on the light box.

Dave teaches Madi, who hasn't had biology yet, how electrophoresis works.

After lunch teachers split up, some to attend the Forensics Colloquium and some to go to the Temperature and Humidity Group to learn about NIST's work in temperature. Greg Strouse starts off with a discussion of why measurement of temperature is important.

Then teachers move to the lab with several stations manned by Greg Strouse, Dawn Cross, Michal Chojnacky, Karen Garrity, and Wyatt Miller. Here Michal talks about her work with the Centers for Disease Control (CDC) determining the proper temperature for vaccine storage in refrigerators and the lab she developed for teachers.

At Dawn's station teachers put dry ice in a glove, tie it off and see what happens. They also pour soapy water over dry ice, adding food coloring for entertainment. Good clean fun!

At Wyatt's station teachers use their LabQuest to measure the steam point of water. Is it 100° C?

Karen Garrity leads the teachers in an investigation of the effect of salt on the freezing point of water.


Then it's back to the conference room to make ice cream with liquid nitrogen – a perfect use of the super cold liquid especially on this hot day! Look at the fog on the table caused by condensing water vapor – so cool!

NIST Summer Institute for Middle School Science Teachers
Day 8: July 18, 2012

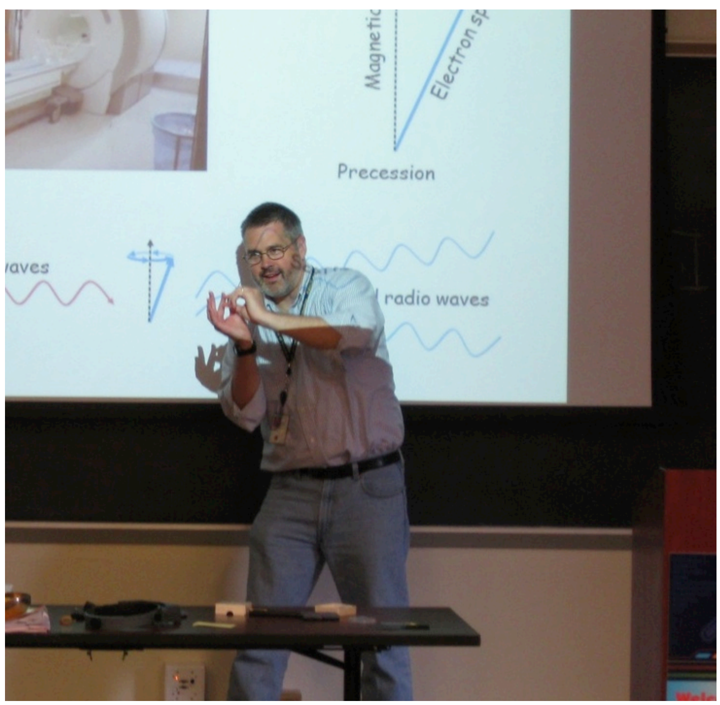
We started off with Cherry Willoughby explaining how she uses the polydensity demo in the classroom. The bottle has two different kinds of beads with slightly different densities that remain in the middle of the bottle unless it is shaken. Then one set of beads goes to the top of the liquid and the other set goes to the bottom. The trick is the use of a saltwater and alcohol mixture. When the mixture is allowed to sit it separates and both kinds of beads are at a density in between that of the more dense salt water and less dense alcohol. When the mixture is shaken, the salt water and alcohol mix together to produce a solution that is more dense than one set of beads (so the beads float to the top) and less dense than the second set of beads (so they sink to the bottom). As the mixture of salt water and alcohol gradually separates, both sets of beads return to the middle.

Ryan Fitzgerald, a physicist in the Ionizing Radiation Division, led the teachers in a measurement of temperature activity. He was more interested in the philosophy of measurement than the actual temperatures measured. Ryan asked the teachers to put the wooden and aluminum blocks on their forehead to see which one feels the coldest. In typical middle school fashion, some teachers complied and others didn't!

Then teachers had to design an experiment to test the temperature of the two blocks with their LabQuest and temperature probe. Here Damisha, Eric, and Lisa discuss their strategy.

Loryn, Laura, and Frank monitor the temperature of each cube one-by-one. After the class had completed the exercise, most groups found that the aluminum block was warmer than the wooden block! What is going on here? In the ensuing discussion several factors arise that may have resulted in this observation including heat transferred from the hand holding the block – is the temperature of the probe really measuring the temperature of the block? What is really being measured? What does the date tell us? In this inquiry experiment teachers are encouraged to look beyond the basic facts of the data and ask what the measurement is trying to tell you. Doing so may lead to an update of a mental model and more experiments. One thing Jill noticed: by sensing the temperature the person doing the measurement can't help but affect it!

Then teachers observed the melting rate of ice on a metal block vs. a wooden block – amazing to see the effect of the rapid heat transfer causing the ice to melt before our very eyes! If the first lesson of the day on temperature transfer was successful then students may more easily understand why the ice melted on the metal block faster than on the wooden block.



Bob McMichael, a Physicist in the Electron Physics Group, followed with a highly interactive presentation and series of activities designed to explain how he measures magnetic forces at the nanoscale with his ferromagnetic resonance force microscope. His work is applied in the electronics industry with the idea that the alignment of tiny magnets can serve as stable computer memory. Bob's work is to develop measurement techniques to make the magnets on computer chips behave as we desire – although at this point we're spending more time learning how they behave. First the understanding, then the control.

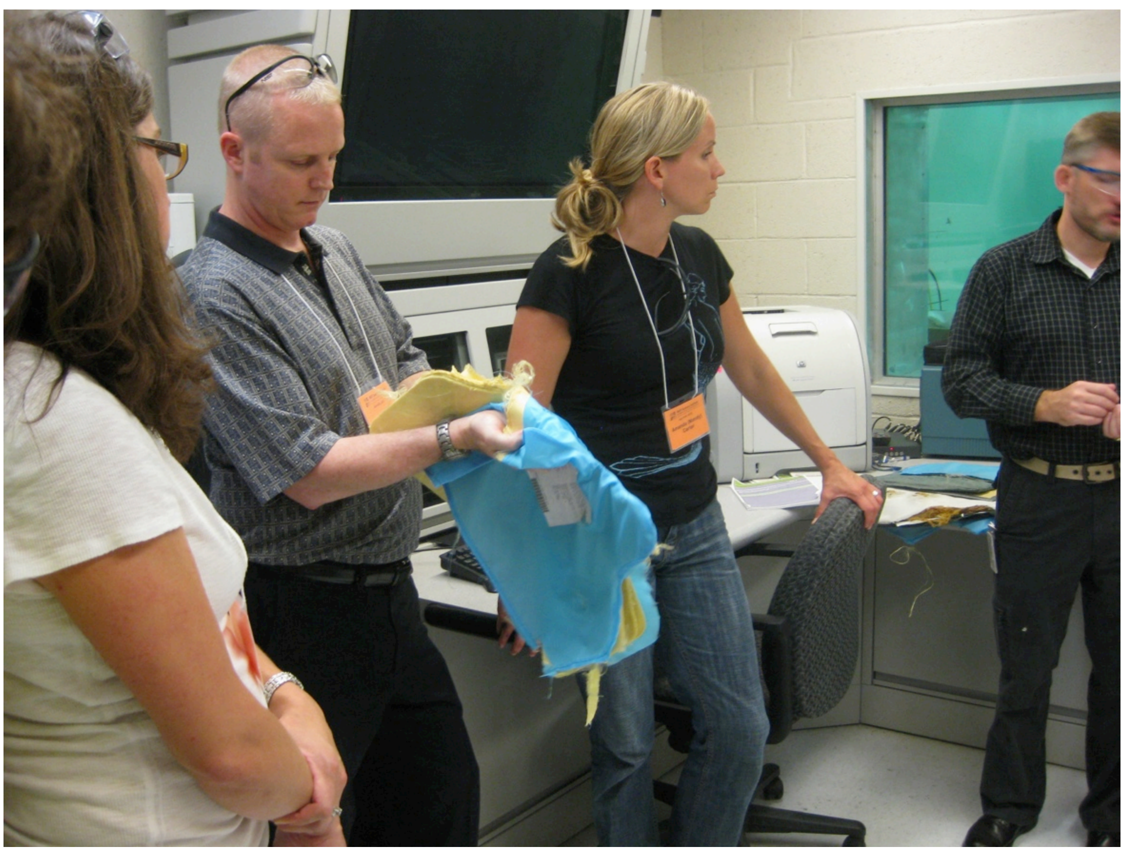
Teachers test magnetic force microscopes using a cantilever made from a strip of a refrigerator magnet. Pulling it in one direction on the magnet and then rotating the magnet 90 degrees, one can learn about the magnetic fields of the magnet.

Then teachers are given a puzzle: a magnet to figure out using their magnetic force microscope the arrangement of magnetic field: is it parallel or perpendicular? Dave and Kelly try to puzzle it out.

Loryn, Jill, Laura, and Frank work together on a pair of magnets to determine the arrangement of the magnetic fields.

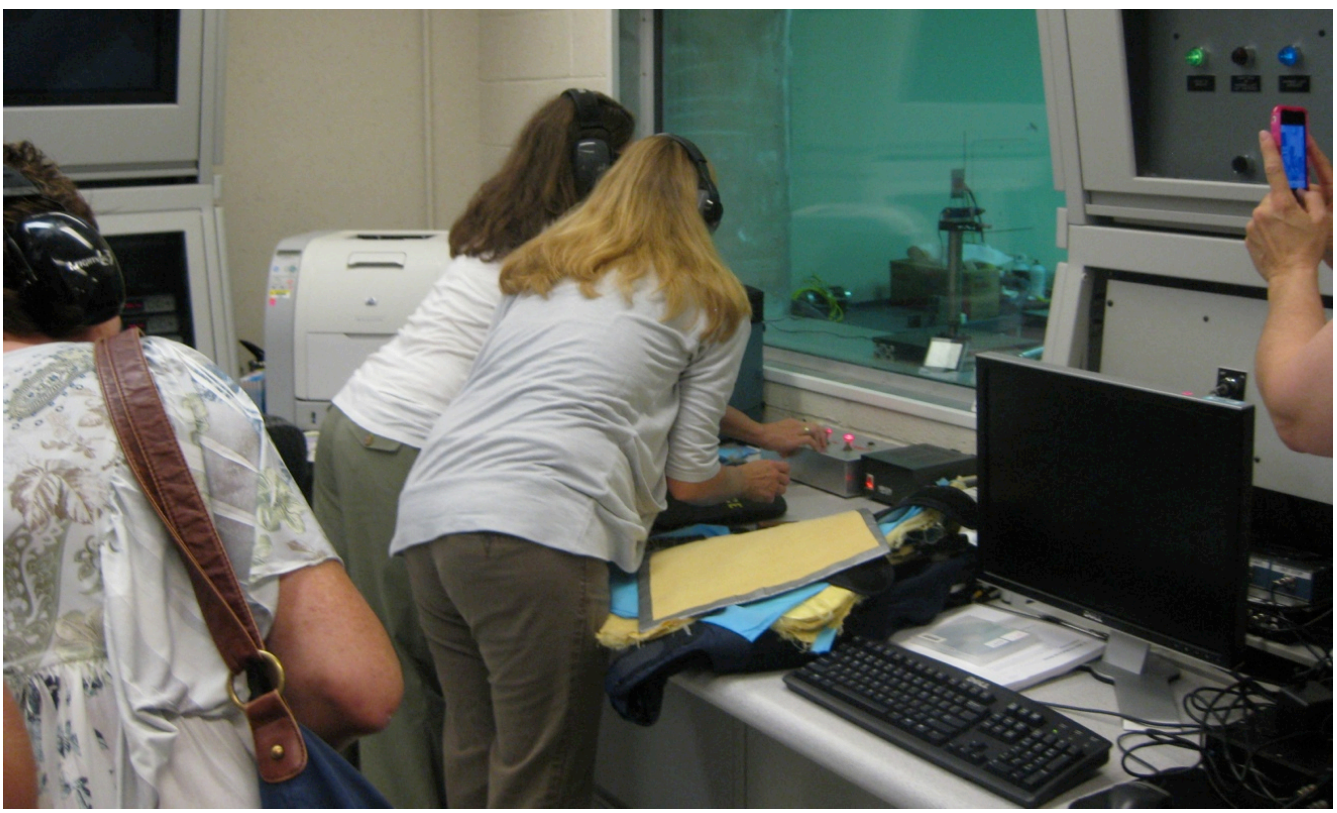
Finally, an easier way to see the magnetic fields of the magnet: use the green film impregnated with iron flake in oil. As Kelly, Monica, and Karen show Mary, it's perfectly clear that the refrigerator magnet is made up of lines of magnets with opposite poles. I see it!

Bob works with Mo and Mandy to see the interference fringes on two pieces of glass, caused by the reflection and interference of light, which illustrates how an optical fiber detects cantilever forces in Bob's magnetic force microscope.



Next teachers are off to visit the Ballistics Testing Facility (or the Million Pound Force Machine, which was shown in the Day 2 photojournal), where materials used in bullet-resistant clothing are tested. Here Chris examines the material in a bullet-resistant vest.

In the firing chamber Mike Riley shows teachers the gun used that can be modified to hold many different kinds of bullets, and the mock up of a human body made of clay.



Laura prepares to fire the gun with Amanda Forster's help…

…. and then teachers go back into the firing chamber to assess the damage.

Summer Undergraduate Research Fellows (SURF students) join the teachers for lunch.

Students talked about their work at NIST, their backgrounds, their middle school experience etc.

After lunch it was off to the Engineering Lab to see Clarissa Ferraris who has worked with cement – or is it concrete? – for her entire working life. Cement is the powder and concrete is the combination of cement, water, and other ingredients like rocks and salt and sugar. Salt and sugar? Yes, salt to accelerate the setting process and sugar to slow it down.

Clarissa set teachers up to do an activity making cement paste. No specific instructions, just mix things together and see what happens…

…and happen something does! Someone's mixture gets warm! As Clarissa guides the teachers they realize that it's an exothermic reaction and chemistry is occurring!

No worries for those whose mixture doesn't heat up immediately; slow-set ~~cement~~ concrete is very useful in some situations such as when the material needs to be transferred to the work site.

Back in Lecture Room A, Mary does her best to give away some books and spur discussion on how teachers will use what they're learning in the classroom. Randy easily earns a book by giving Mary a copy of the Horry County curriculum.

The last event of the day is a lecture and activities led by chemist Ken Pratt on the perils of pH paper. Teachers test the pH of various solutions and buffers with pH paper and compare the observed pH with the expected pH. The buffering actions of the indicator dye (contained in the pH paper) on the solution moving up the paper mean that for the most dilute solutions there just aren't enough OH- or H+ ions, relative to the number of molecules of dye in the paper, to produce the expected color change – an example of the measuring tool affecting the measurement!

NIST Summer Institute for Middle School Science Teachers
Day 9: July 19, 2012

We started with a quick chemistry lesson on strong and weak acids by Madi, who has just finished high school chemistry and tutors fellow students. Way to go, Madi, for teaching these concepts in a way we understand!

Sarah Munro, a bioengineer, and John Heddleston, a biologist turned physicist, came to teach teachers about the latest biology innovations including next-gen sequencing. First there was a basic lesson on the ideas behind the central dogma of biology: DNA→RNA→protein.

Mandy, Mo, and Loryn volunteer to play the DNA Mycomuncher game…

… while in the middle of the room Laura, Jessica, and Jerrin are discussing how they use the Newton's cradle.

Then it's back to the Mycomuncher and translation from RNA to protein. After gaining a basic understanding of the lesson, teachers break into teams to build their own set.

Here Mandy and Laurie are assisted by Autumn Downey, a microbiologist in the Biochemical Science Division. Perhaps she can help them figure out what a mycomuncher is!

Monica, Mary, Kelly, and Dave form an efficient team – even if Mary keeps wandering off!

Miki Tanase comes by early to collect Mo and Jessica and take them to the Nanofab Clean Room where they will dress up like bunnies! Why? Primarily to protect the samples they will work on.

Although the task appears daunting, Cherry works with her team to conquer the challenge and end up with a complete set of the DNA puzzle.

Karen and Loryn work out a strategy for applying the stickers representing DNA, RNA, or proteins.

Teachers labor in their groups until ~11AM when a NIST scientist of their choice comes by to pick them up. Returning for lunch, they find Jamie Ging in the room sharing his undergraduate work using titanium dioxide nanoparticles in a format designed to clean the environment when painted on walls as they degrade organic materials such as bacteria. A solution to sick building syndrome!


After lunch teachers continue building their DNA puzzles. Here Eric and Damisha find a working groove.

Judy Prozonic of the NIST Safety Office comes by to lead a discussion on safety in the middle school science classroom. Here Damisha describes an accident that occurred in her classroom.

While teachers continue to work on their DNA puzzles…

…there is much obvious interest in the issue of safety in the science lab. Conditions vary from state to state and even from school to school in the same county. Efforts such as the use of contracts and ongoing awareness are a good way to increase lab safety locally.

The day ends with teachers attending Nobel Prize winner Bill Phillips presentation on Time, Einstein & Coolest Stuff in the Universe. Here's the abstract:

Description: At the beginning of the 20th century Einstein changed the way we think about time. At the beginning of the 21st century Einstein's thinking is shaping one of the key scientific and technological wonders of contemporary life: atomic clocks, the best timekeepers ever made. Such super-accurate clocks are essential to industry, commerce, and science; they are the heart of the Global Positioning System (GPS), which guides cars, airplanes, and hikers to their destinations. Today, atomic clocks are still being improved, using atoms cooled to incredibly low temperatures. Atomic gases reach temperatures less than a billionth of a degree above Absolute Zero. Super-cold atoms are at the heart of Primary Clocks accurate to better than a second in 100 million years. Such atoms also use, and allow tests of, some of Einstein's strangest predictions. This will be a lively multimedia presentation, including experimental demonstrations and down-to-earth explorations about some of today's most exciting science.

Wow!

NIST Summer Institute for Middle School Science Teachers
Day 10: July 20, 2012

On the last day of the NIST Summer Institute, John Gillaspy, an atomic physicist, spoke on The Magic of Science/ The Science of Magic. Using simple magic tricks and other science toys, many of which were given to the teachers, John made analogies and connections to his work with the Electron Beam Ion Trap (EBIT).

Teachers watched intently as John performed tricks such as the pom pom pole in which connections between seemingly separate objects affect each other, analogous to quantum entanglement. John explained quantum entanglement as when two objects that were once close to each other but are now separated behave as if they were still connected even though there's no obvious or visible connection between them. Einstein called this "spooky action at a distance" and didn't believe it could really happen, although quantum mechanics predicts it. Turns out quantum entanglement does really happen, under certain conditions.

Another example was squaring the circle in which John took a square made of flat pieces of metal attached to each other. After talking about possible ways of making a circle including cutting the pieces in half and then in half again and again to eventually approximate a circle, John mentioned that scientific discoveries often result from people changing the way they're thinking, and trying totally new perspectives. And then with a quick twist, John turned the square into a circle, with the flat sections of the metal at a 90-degree angle to its previous figure. This is analogous to the "thinking outside the box," perspective. For example, to produce the highly charged ions John uses – with as many as 72 electrons removed from atoms such as Bismuth – requires superhot temperatures (on the order of 100,000,000 K) – which are produced by cooling down the apparatus to only a few degrees above absolute zero!

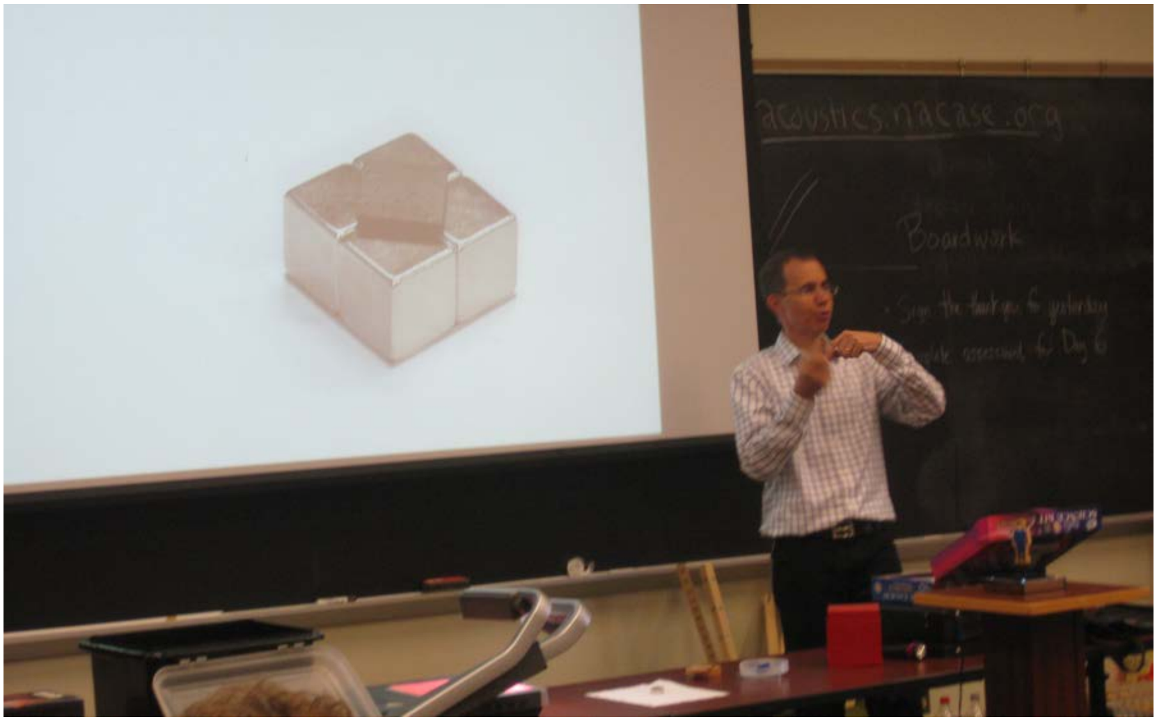

Teachers from past Summer Institutes were invited to attend the presentation and listened with rapt attention.

Halfway through the presentation there was a break for a tour of the EBIT lab. Safety cautions: don't touch anything, pay attention to where you're walking, and don't freak out if a drop of water falls on your head – it's due to condensation on the cooling lines.

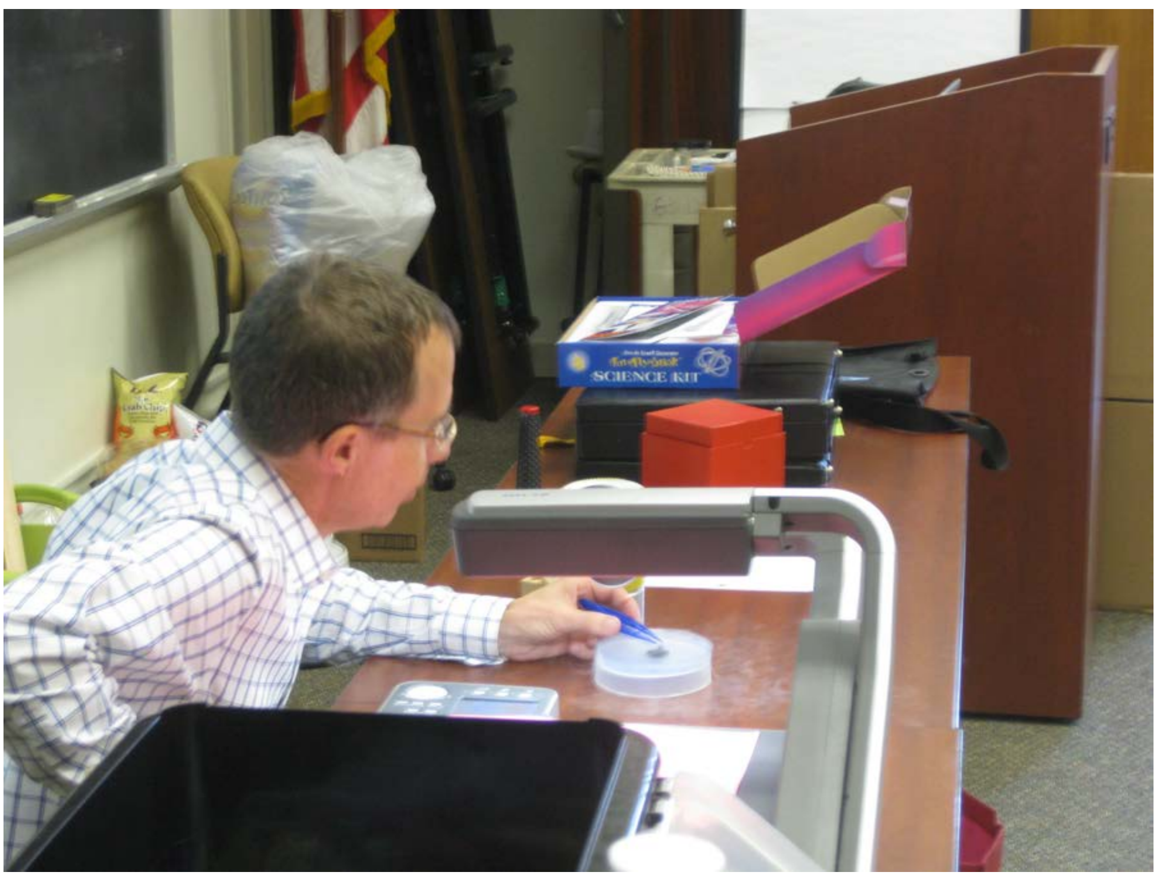
The NIST EBIT has been around for about 20 years and various postdocs and other scientists have attached instruments onto it in different places. For example, Josh Pomeroy, who met with teachers in the one-on-one is measuring the effect highly charged ions have on surfaces. Another of John's collaborators chose a different career path and is now a high school science teacher!

Then it's back to the classroom where John talked about levitation, which contrary to popular belief can't be sustained with permanent magnets – unless you are constantly moving them around or spinning one of them. One place where magnetic levitation is used is in the spinning disk in the power meters outside our houses. It's not fully levitated —needs "the pencil" to keep it from falling sideways, but it goes a long way towards reducing friction. (By the way, the calibration for these is traceable to NIST.)

A better way to levitate something is using active feedback stabilization: when the levitated object starts to wobble and become destabilized a mechanism senses the change and modifies the magnetic field in response. Of course, this only works with magnetic objects, so how to levitate non-magnetic objects?



Turns out that due to the spin and circulation of electrons inside atoms, all objects can have at least a weak response to magnetic fields; they're diamagnetic. Graphite, the floating black rectangle shown levitated above, is the strongest diamagnetic substance at room temperature. To illustrate this effect to their students, teachers are given magnets and a piece of graphite.



Another way to levitate is with superconducting materials, which must be cooled with liquid nitrogen. This superconducting material is made of yttrium barium copper oxide. Note the fog on the table produced by the liquid nitrogen – it's at 77K or -321 °F.

Teachers come closer to see the effect.

Another way to levitate something is by using the repulsive effects of many electrons. Here John uses a miniature Van de Graaff generator to levitate and control an aluminized piece of mylar as teachers look on in delight. In his lab, John uses a beam of electrons to aid in the trapping of highly charged ions.

The Electron Beam Ion Trap (EBIT) is in some sense a "souped up" plasma ball. With the plasma ball that teachers will receive, John demonstrates how the flow of electrons can be used to excite the material inside a fluorescent light bulb. In John's lab a much more intense electron beam is used to produce, trap, and excite highly charged ions. Experiments in the EBIT lab produce atomic data that is needed for the development of new technologies to improve the quality of life. These same experiments can sometimes also be used to test our fundamental understanding of nature and reveal new knowledge about the limits of reality.

"I believe that the key to producing the next generation of outstanding scientists is simply having good teachers who both know and love science. All the rest is just extra." Dr. John Gillaspy, July 20, 2012

Thanks, John, for increasing our understanding and renewing our love of science. What a wonderful finale to the 2012 NIST Summer Institute for Middle School Science Teachers!