

bers at research universities who want to improve their undergraduate teaching skills. About 40 participants from 20 research universities attend the week-long program each year.

Gates is one of nine members on a technical advisory panel formed by the AAU to guide its initiative. Each member is considered an expert on undergraduate STEM teaching, the association said in a news release. Other physicists on the panel include Noah Finkelstein, associate professor at Colorado, and Cornell professor Peter LePage.

YouTube and whiz-bang

Gates says he prepares lectures in presentation software, but then often turns to the blackboard if a set of equations in his presentation elicits questions. He's found "amazing resources at YouTube"; repurposing videos he finds there, he creates "a little snippet of something that you can insert into a QuickTime movie, for incorporating in the lecture. There's a whole new way of teaching that many of us are starting to embrace, not just because of the call for increased efficacy of our teaching but also because of the evolution of information technology."

Gates credits fellow Maryland professor Edward (Joe) Reddish, a pioneer of physics education research, with introducing him to novel pedagogies more than a decade ago. He says he agreed to try out courses that Reddish had developed on what set apart students who learned physics well from those who didn't.

Bassam Shakhshiri, a University of Wisconsin chemistry professor, is known for his efforts at popularizing

science; one such effort includes the annual whiz-bang public show "Once upon a Christmas cheery, in the lab of Shakhshiri." When teaching, he asks his students to submit a weekly one-page paper reflecting on what they learned during the previous week. When his initial appeal brought responses from just 1 in 10 students, he began offering them a small reward, amounting to 1% of their grade, if they complied. Participation shot up to 80%. "That's engagement," he says.

In Wieman's view, the common denominator to the new pedagogy is "getting students to practice thinking like experts in the subject." He says, "Rather than the student just sitting there passively listening, you are giving them a task, a question, things to solve, that really force them to think." Instead of memorizing long lists, students should be thinking about whether certain effective concepts can be applied to solve a particular problem.

The OSTP is now completing an inventory, ordered by Congress last year, of federal STEM education programs. Preliminary results have identified 252 STEM programs at 13 federal agencies, with combined spending of \$3.5 billion annually. About \$2.5 billion of that is devoted to STEM education generally, and the remaining funds go to train individuals for agency-specific missions, such as National Institutes of Health programs for new biomedical researchers. The complete results and analysis of the inventory are to be released later this fall and should help shape a strategic STEM education plan that OSTP is scheduled to deliver to Congress in January.

David Kramer

Taking the pulse of magnet labs

As fields get stronger and electronics improve, demand for pulsed magnets is growing; the newest lab is in China.

Two magnet labs achieved new highs in pulsed-field strengths this past summer. In June the Dresden High Magnetic Field Laboratory (HLD) in Germany created a 91.4-tesla field. That was topped in August by the Los Alamos branch of the National High Magnetic Field Laboratory (NHMFL), with 97.4 T; in the coming months Los Alamos National Laboratory expects to boost the highest field it offers users from 85 T to 92 T.

"The first 100-T projects were advertised 20 years ago," says Oliver Portugall, technical director of the National

Pulsed Magnetic Field Laboratory in Toulouse, France. "But somehow nobody was capable of getting much beyond 70 T or 80 T until recently. A 5-T increase is quite significant. Higher fields open new horizons for fundamental research."

At the Toulouse lab, the maximum field is 70 T, but "we are currently upgrading our installation in order to keep up with Dresden and Los Alamos," says Portugall. His lab, he adds, "has the unique possibility to combine high magnetic fields with advanced photon and neutron sources."

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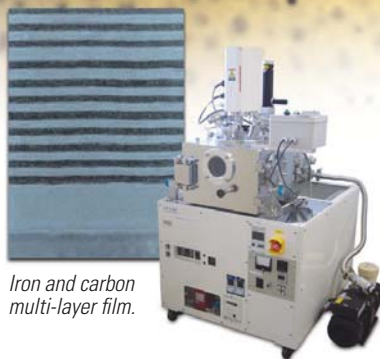
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issues and events

"In the 1980s I don't think there was any pulsed-magnet user facility," says NHMFL director Gregory Boebinger. The number of papers in *Physical Review Letters* that were based on work using pulsed magnetic fields started to grow in the 1980s and 1990s, he says. "Now, if you look at the most prestigious journals, the distribution of publications from research using DC and pulsed magnets is about even. That's new in the last decade." Among the advantages of pulsed-field magnets are that they can be much stronger than DC magnets and they are much cheaper to build and run.

Extreme conditions

When applied to materials, magnetic fields couple to both electron spins and electron orbital motions. Spin splitting of electron energy levels is proportional to the gyromagnetic ratio of the material and to the magnetic field; deviations provide information about electron-exchange interactions and internal magnetic fields. Orbital splitting, the formation of Landau levels due to the quantization of the electrons' cyclotron motion, is inversely proportional to the effective mass of the material and proportional to the magnetic field. Landau levels can reveal the shape of the Fermi surface, the energy-momentum relationship for the highest-energy electrons in a metal.

"Applying a magnetic field gives you a knob to tune, and [it] sometimes tunes the strengths of interactions," says Junichiro Kono, a physicist at Rice University who has worked at several of the big magnet labs. "It's also a way to go to extreme conditions, where the electron kinetic energy is quenched due to magnetic confinement. It's like freezing the motion of electrons. Unexpected things can happen in ultrahigh magnetic fields." In his research, Kono applies high magnetic fields to low-dimensional systems such as nanotubes and graphene. High fields are also used to study the electronic properties of metals, semiconductors, superconductors, and other materials.

For high-temperature superconductors, says Suchitra Sebastian of the UK's University of Cambridge, "the basic million-dollar questions are, Why are they superconducting? What is the glue that holds electrons together in Cooper pairs?" High magnetic fields are crucial to weaken superconductivity and reveal the underlying behavior of unpaired conducting electrons, she says. A strong applied magnetic field "is almost like a magnifying lens to help see the signal the electrons are tracing." Higher fields also allow more of the doping phase dia-



This nondestructive magnet at Los Alamos National Laboratory last summer achieved a record pulse of 97.4 T. The lab plans to offer 92-T pulses to users soon.

gram to be probed. Sebastian has used the 85-T magnet at Los Alamos to study underdoped yttrium barium copper oxide, and she looks forward to doing experiments at higher fields: "We really don't know what we will see. Every time we go up, we get new information. And a lot of times we have had to change our thinking."

Steady, spike, or bust

Pulsed fields are more difficult to work with than static ones. They typically have a duration of milliseconds, and the recovery time for a subsequent pulse is up to two hours, depending on the peak field strength. In recent years advances in electronics have broadened the scope of measurements possible with pulsed fields; for example, some nuclear magnetic resonance (NMR) experiments can now be done with the shorter-duration pulses. As a rule, heat capacity measurements, swept-angle measurements, and experiments that require a long acquisition time or a homogenous field, such as most NMR and electron spin resonance measurements, are best suited to static fields.

Even with their increasing popularity, pulsed magnets won't put static ones out of business, says Boebinger. Currently the strongest static magnet is 45 T, at NHMFL's site in Tallahassee, Florida. Scientists there are working on the conceptual design for a DC 60-T hybrid resistive-superconducting magnet. The price tag is "more than \$50 million," Boebinger says. For its full suite of eight DC magnets, the Tallahassee NHMFL site spends about \$4 million annually on electricity.

By contrast, replacing one of Los Alamos's 65-T workhorse pulsed mag-



China's Wuhan National High Magnetic Field Center is the newest high-field pulsed magnet lab.

nets would cost about \$60 000, estimates Boebinger. A new set of inner coils for the 85-T magnet comes to some \$125 000; the coils have to be replaced roughly every 200 shots due to stress on materials. Energy costs for pulsed magnets are “negligible,” says HLD director Jochen Wosnitza. “A full charge of our capacitor bank costs about €2 [\$2.70].” Pulses cost up to \$1000 per shot, including “capital investment, energy, people’s time,” adds Toulouse’s Portugal.

A third magnet category produces destructive pulses. They are typically in the 100- to 1000-T range and last for microseconds. The pulse destroys the magnet and, above 300 T, the sample as well. One hot area of research using destructive magnetic fields is organic conductors, Portugal says. “They often have low mobility of electrons. At low-field ranges, we are not able to resolve [important effects]—they are washed out by scattering. So we may need 200 T or so.” But for most problems, the weaker, longer-lasting nondestructive fields are sufficient, he says. “Milliseconds is an eternity, and the electronic system will be in equilibrium during the pulse.”

Cranking up the field

Jacking up the field strength is mainly a matter of dropping the magnet bore diameter. Dresden reached its peak field by going from a 20-mm bore to a 16-mm one. And the 10-T jump to 97.4 T in Los Alamos’s multicoil magnet was made possible by reducing the bore from 15 mm to 10 mm. The other keys to raising the Los Alamos magnetic field strength were tweaking the winding of its inner magnet, improving the magnet’s structural reinforcement, and increasing the applied energy to crank the field in the experiment’s outer magnets from 37 T to 39 T, says magnet engineer Chuck Swenson. Nondestructive magnets, he says, are limited by “materials

and the cleverness of engineering design.” Multicircuit magnets reduce heating and make it easier to evenly distribute stress over the magnet materials.

Having reached 97.4 T, says Boebinger, “our engineers are talking about 110 T. We are limited by funding.” The materials that go into the magnets are expensive, he says, giving as an example a nanocomposite of copper and niobium that costs roughly \$475/kg. “We need to use the nanocomposites because of how strong the pressure of the field is on the materials—at 85 T it’s about 30 times the pressure at the bottom of the ocean. The pressure tries to explode the magnet materials.”

At Los Alamos, the outer magnets are driven by a \$30 million power generator—a relic from a nuclear power plant that was first brought to the lab for a plasma fusion experiment—and the inner magnet uses a capacitor bank. The Dresden lab—which opened to users in 2007—sports the world’s largest capacitor bank. Each power method has its advantages and disadvantages, say the researchers. “The competition between the US and European labs has fostered the development of better magnets and improved measuring techniques,” says Wosnitza. “High-field science has experienced a boost during the last years.”

Higher fields, more labs

In addition to Los Alamos, Dresden, and Toulouse, the top pulsed magnet labs include the International Mega-Gauss Science Laboratory in Tokyo. That lab specializes in long pulses, up to 10 s in duration, and in destructive pulses up to 1000 T. The Japanese lab’s peak nondestructive field is 70 T, but like the other labs, it’s aiming for 100 T.

Quickly catching up with the more established pulsed-field labs is the Wuhan National High Magnetic Field Center in central China. It was founded

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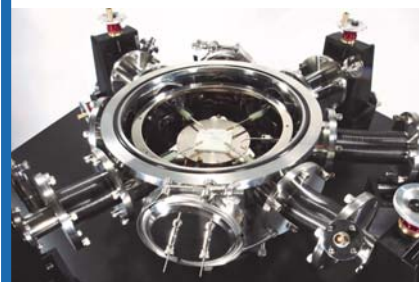
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in 2008 and is scheduled to open to users in 2013. The CNY180 million (roughly \$28 million) Wuhan lab at Huazhong University of Science and Technology is the first major scientific facility in China to be under the auspices of a university rather than the Chinese Academy of Sciences. A sister lab in Hefei that focuses on static magnets is comparable to centers in Tallahassee; Tsukuba, Japan; Grenoble, France; and Nijmegen, the Netherlands.

Liang Li, the director of the Wuhan lab, earlier worked in Europe and the US and designed pulsed magnets at the NHMFL. So far, 7 of 11 planned experimental stations at Wuhan are ready; they are outfitted with low-temperature cryostats, lasers, and other instruments. Li says the Chinese lab has achieved 78.8 T and plans to test its first dual-stage magnet this month. "We will get as high as we can, hopefully to 85 T."

Toni Feder

Weather data gap is forecast as satellite is delayed

A new polar-orbiting satellite is only a temporary fix for a more durable spacecraft that has been starved of funding.

As the launch of a next-generation polar-orbiting satellite is pushed back by budget cuts, the likelihood grows that the National Oceanic and Atmospheric Administration's weather forecasts will become significantly degraded in about five years. Polar orbiters supply 80% of the observational data, such as atmospheric soundings—measurements of a variety of physical characteristics such as pressure, wind speed, and water vapor content—that are entered into the numerical weather-prediction models, NOAA deputy administrator Kathryn Sullivan told the House Committee on Science, Space, and Technology during a 23 September hearing. A gap in observational data is likely beginning in 2016, she warned, when an orbiter scheduled for launch last month (after *PHYSICS TODAY* went to press) is expected to reach the end of its design life.

A permanent new polar-orbiting spacecraft, originally scheduled for launch late in 2016, would offer enhanced observational data. But the new orbiter, the Joint Polar Satellite System (JPSS), is almost certain to be delayed if Congress leaves funding for the program at its fiscal year 2011 level, as expected. Lawmakers supplied just \$382 million of the \$1 billion the Obama administration requested for the JPSS last year. The White House submitted an identical budget request for FY 2012, and Congress appears poised to continue funding at last year's level.

An experimental precursor satellite was due to be launched on 27 October. Built to try out several of the new JPSS instruments, it will also provide observational data for NOAA models. But engineers at NASA, which is managing

construction of the experimental satellite known as the National Polar-Orbiting Operational Environmental Satellite System Preparatory Project (NPP), have estimated its life at just five years. Although Sullivan acknowledged that satellites often operate well beyond their design lives, she said that a gap in observations is a "near certainty" when the NPP stops working. In that event, only a single polar orbiter operated by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) will remain aloft. David Powner of the Government Accountability Office told the committee that even in the most optimistic scenario, the JPSS satellite won't be transmitting quality data until 2017, because necessary testing and calibration in orbit can take 6–18 months.

Pointing fingers

"To date, the federal government has spent over \$6 billion on the ... JPSS programs, and the only thing we have to show for it is a modified research satellite," said Representative Paul Broun (R-GA), chairman of the Science Committee's investigations and oversight subcommittee, at the September hearing. "The JPSS program is the ultimate example of a runaway government program that has over promised, is over budget, and has underperformed," declared Rep. Andy Harris (R-MD). But Sullivan blamed Congress for the program's woes. "NOAA and NASA have concluded that the lack of adequate funds is the major challenge to achieving JPSS mission success," she told the panel.

Right now, the US and EUMETSAT satellites are complementary. Both are

in sun-synchronous orbit; NOAA's observes conditions at 1:30 pm local time and the European spacecraft assesses morning conditions. Each orbits 14 times a day and passes over the entire surface of the globe twice. NOAA receives fresh data for its models every six hours. The afternoon measurements capture conditions in the warm and more energetic atmosphere, Sullivan said, whereas a quiescent atmosphere is seen in the morning orbit.

Although the US Department of Defense operates two other polar orbiters, they are in early morning orbits and serve very different forecasting needs, Sullivan said. "They're looking for minutes-to-hours tactical forecasting, clouds, dust—are we launching or not launching an operation now," she told the President's Council of Advisors on Science and Technology on 16 September. The US, she added, "will make every effort to take advantage of" relevant data from other nations' polar-orbiting satellites, including one Japan is expected to launch soon. The private sector has expressed no interest in supplying NOAA with the high-precision atmospheric sounding data that are "the lifeblood of weather forecasting," she noted.

To illustrate the importance of having two polar-orbiting satellites, NOAA ran its forecast models several times using archived data from only one of the satellites in the days preceding the record-setting February 2010 East Coast snowstorm. The results were compared with actual forecasts, which had accurately predicted the locations and depths of snowfall five days before the event. With input from just one orbiter, however, the models underforecasted snow depths by 10 inches, Sullivan said. The data from two satellites also have

An artist's rendering of the interim polar-orbiting weather satellite scheduled for launch late last month.

