However, water usually coexists with the unwanted microorganisms and greatly absorbs microwave energy in the range of 10–300 GHz. That happens to be the typical vibrational frequency range of the capsids (protective protein shells) of viruses. Thus it is extremely difficult to transfer microwave excitation energy to the vibrational energy of viruses—and similarly to bacteria—without heating up the surrounding water molecules.

Tsen's method targets the capsids and can inactivate the unwanted viruses while leaving sensitive materials like mammalian cells unharmed. The FSL coherently excites vibrations with large amplitude on the capsids through the impulsive stimulated Raman scattering process.

By tuning the FSL to just the right pulse or spectral width, combined with high enough intensity, the user can create resonant vibrations strong enough to break the weak links on the capsids; the damage to the capsids ultimately causes it to disintegrate. Tsen likens the effect to giving a child a push on a swing. "If the pushing force is constant, then the maximum amplitude is achieved when the force is applied for one-quarter of a cycle of the swing," he explains. "Thus a window exists for pulse width that can be used for selectivity."

The difference in size between viruses, bacteria, and mammalian cells is another critical factor. A virus typically measures 0.01 micron, compared with 0.1 micron for bacteria and 1 micron for mammalian cells. Because of the corresponding difference in surface area, more water molecules surround the mammalian cells than surround viruses or bacteria. The result is a dampening effect that minimizes the strength of the vibrations of the cells much more than it does for viruses or bacteria. According to Tsen, this offers a partial explanation of why it takes much larger laser intensity to damage cells.

To date, Tsen has successfully demonstrated the technique on the tobacco mosaic virus, the M13 virus, and the *Escherichia coli* bacterium. Atomic force microscopy images of irradiated M13 viruses indicate that his technique does indeed destroy viruses by damaging the capsids. However, bacteria have a very different structure—lipid bilayers rather than capsids—and Tsen has yet to perform AFM imaging on the laser-irradiated bacteria to determine whether the same process, disintegration of the protein coat, is responsible for their inactivation.

Much development work must be done to bring such a system into clinical use, but Tsen believes the first likely application of his technique might be to kill any virus and bacteria tainting the blood stored in blood banks. He is currently testing his technique on HIV and hepatitis viruses.

All in all, femtosecond lasers are shaping into an important enabling technology for promising breakthroughs in biology and medicine. Davison, for one, anticipates even more new applications in other market sectors as such systems continue to become smaller, cheaper, and easier to use. "It's always been an incredibly versatile light," he says of the FSL. "It's just been trapped in big room-sized devices until now."

Jennifer Ouellette

With Domenici's departure, DOE labs to lose their top Hill advocate

No successor is apparent for "St. Pete," who showered funding and new programs on the labs.

Many lawmakers will be retiring when Congress adjourns at the end of this year, but none will be missed more by the Department of Energy (DOE) and its national laboratories than Pete Domenici (R-NM).

The veteran senator, often referred to within the laboratory system as "St. Pete," cited his diagnosis of a rare degenerative brain disease in announcing this past summer that he wouldn't seek a seventh term in 2008.

"Almost everyone in the national lab system owes an enormous debt to Senator Domenici for caring about all of the science that is done at the labs," said Bruce Tarter, former director of Lawrence Livermore National Laboratory. "At the moment, he's almost irreplaceable."

"He was much more than the savior of Los Alamos," echoed former Los Alamos director Siegfried Hecker. "He was the patron saint for science and technology in the US."

Unparalleled influence

A combination of seniority, key committee chairmanships, forceful personality, political horse-trading skills, and what many who have known him describe as a genuine interest in DOE's programs have given Domenici a degree of influence over the department and its labs that is unparalleled for a decade or more. While a few other lawmakers, notably former House Science Committee chairman George E. Brown Jr, also have been ardent science backers, none were as well-situated as Domenici to provide for the labs. Since the mid-1990s the senator either has chaired or held the ranking minority member position on the Committee on Appropriations subpanel that funds DOE. As its chairman, he authored the Senate's versions of the annual energy and water development spending bills for fiscal years 1996 through 2007 (with the exception of FY 2002 and FY 2003 when Democrats briefly seized control of the Senate). Domenici has used his position to unabashedly shower funding on the labs—always ensuring that New Mexico's own Los Alamos and Sandia laboratories got first dibs.

Although his clout has diminished with this year's Democratic takeover of Congress, the clubby culture of Appropriations provides that the minority's needs and requests will be considered in near-bipartisan fashion. Domenici remains the senior minority member of the panel, a post he also holds on the full Committee on Energy and Natural Resources, the panel with jurisdiction over all of DOE's nonweapons programs. Fellow New Mexican Jeff Bingaman (D) now wields the gavel there.

No state is more dependent on federal research laboratories and dollars than sparsely populated and economically challenged New Mexico. But while Domenici's ability to secure more funding for his home-state labs is legendary, the largesse spilled over to the rest of the lab system, and DOE's science programs, as well.

"Everyone says he was the patron saint of the New Mexico labs, but in supporting them, he supported all parts of DOE," said William Madia, who just retired as the overseer of the four nonweapons DOE labs managed by Battelle Memorial Institute. "It was the rising tide [that] lifts all boats."

Backed genome project

Few lawmakers have the enthusiasm for science that Domenici displayed on his frequent visits to the labs, noted Tarter. "You would see visible excitement," particularly when the senator was reviewing biological research activities, he said.

Indeed, Domenici has been credited with providing the political backing for

DOE to initiate the Human Genome Project in the late 1980s, when the biomedical research establishment at the National Institutes of Health scoffed at the notion of sequencing the entire 3 billion base pairs of DNA. Hecker recalled how as a rookie in 1986 he had approached Domenici with the idea for the project. Although the senator liked the idea, he insisted on first hearing from the pharmaceutical industry and academia before throwing his support behind it. "It was a great act of statesmanship for him to bring in the other communities," Hecker said.

Domenici

James Decker, the long-serving ex-deputy director of DOE's Office of Science, pointed out that Domenici also was behind the initiation of an ongoing DOE research program on the health effects of low-dose radiation.

Domenici also stood up for the Laboratory Directed Research and Development program, which allocates 6% of each laboratory's budget for R&D programs of the director's choosing. A periodic target of budget hawks over the years, LDRD is deemed essential for maintaining the scientific health of the labs, Decker asserted.

The Battelle-run labs, which include Oak Ridge, Pacific Northwest, Idaho, and Brookhaven, have benefited from Domenici's support for nuclear nonproliferation R&D and from the funding he doled out to establish multiple "nanoscience centers," Madia said. The senator's backing for Oak Ridge's Spallation Neutron Source scientific user facility was "invaluable" to its completion, he said. Common to each of the programs are the significant roles that New Mexico's labs, particularly Los Alamos, played in them.

Seen as parochial

But one former Appropriations staffer who worked with Domenici maintained that the senator's support for the labs and DOE science extended only as far as his home state. The staffer, who declined to be named, said he hadn't met a lawmaker during his 35 years on Capitol Hill who "was as strongly parochial—mired and bogged down in his own backyard" as Domenici, "even when it was not necessarily the right policy for the country as a whole." He pointed to the long-stalled Yucca Mountain nuclear waste repository project, which Domenici, despite his staunch support for nuclear power, did little to advance.

Domenici did ensure that the budget for the nuclear weapons program remained stable throughout the ongoing period in which no warheads are being built and no new design efforts begun. But his strong backing of DOE's science-based Stockpile Stewardship program, which is supposed to validate the viability and safety of the existing nuclear stockpile without nuclear testing, didn't prevent him from threatening to kill one of its key elements, the National Ignition Facility, as the cost of the 192-beam laser ballooned from $1 billion to $4 billion. Hecker said he was once asked directly by Domenici whether he should try to terminate NIF. He advised against it.

"It was a lot harder for us to get the more controversial projects through," Tarter admitted when asked about NIF, "but they're still on track."

Hecker credited Domenici with writing legislation to spur commercialization of technologies from the labs and for initiating multiple programs designed to secure nuclear weapons materials and find new jobs for former weapons scientists in the former Soviet Union. There, too, the benefits to New Mexico's labs and economy were obvious.

"I always considered him to be an incredibly dedicated statesman who also knew how to take care of his constituents," Hecker said.

A blow to labs

But whether he was motivated by statesmanship or parochialism, the loss of an advocate of Domenici's stature does not bode well for the labs in the coming years. Although a handful of lawmakers, including Livermore's local representative Ellen Tauscher (D-CA), are broadly supportive of the labs and their programs, Tarter lamented, "No one is logarithmically within the same range" of influence as Domenici. Bingaman, though also a strong supporter of the labs and science generally, lacks the critical seat on Appropriations and has "a different personal style," as Hecker diplomatically put it. Scandal-tainted Larry Craig (R-ID), an Appropriations member from a state with a significant DOE lab presence, was in line to succeed Domenici as ranking member on the energy committee until announcing he won't seek reelection in 2008.

Madia called Domenici's position at the apex of energy and DOE budgetary policy a "singularity," and his retirement will be a "huge loss" for the labs.

"We haven't seen any strong leaders emerge with the same sort of long-term understanding of science."

"It will be difficult times for Los Alamos, New Mexico, and DOE," Hecker said. Domenici's retirement comes at a time when the labs already are "under enormous siege and fighting for their survival." Currently undergoing painful downsizings and preoccupied with day-to-day management crises, the weapons labs haven't had the opportunity to develop the long-term vision and strategy they need to justify their continuation in the post-cold war era, he said.

"[Domenici] was able to buy the labs some time to allow them to regenerate. The immediate impact of his departure," Hecker said, "will be to not buy [the labs] more time."

David Kramer

Early start for experiments at Homestake underground lab

South Dakota has taken the initiative to begin installing a variety of experiments in the 8000-foot-deep mine this year—long before the federal government can make its final decision.

Four months after choosing the disused Homestake gold mine in South Dakota as the site for the proposed Deep Underground Science and Engineering Laboratory (see PHYSICS TODAY, August 2007, page 34), NSF convened a "town meeting" in Washington, DC, in November to introduce a broad range of prospective DUSEL users to the facility's site-specific conceptual design and its scientific potential. For experiments in nuclear, particle, and astrophysics, the primary attraction of laboratory space deep underground is the reduction—by many orders of magnitude—of the inescapable flux of cosmic-ray muons that can swamp delicate signals.

Lesko

Led by Kevin Lesko (University of California, Berkeley), the team that championed the Homestake proposal has now been funded for the next three years to prepare a detailed engineering design for DUSEL. That effort must, of course, take account of the first group of major experiments that will be chosen from among competing proposals during the design phase. But the start of full-scale construction of the $500 million DUSEL facility has to await approval from the funding agencies and ultimately from Congress. That's unlikely to happen before 2011.

Starting with SUSEL

But the state of South Dakota, which has a considerable stake in the enterprise, is not sitting idly by, waiting for Washington to decide. Funded by a $70 million gift from South Dakota banker and philanthropist T. Denny Sanford and by appropriations of some $45 million from its legislature plus a modest congressional earmark, the state hopes to jump-start DUSEL with its own Sanford Underground Science and Engineering Laboratory. Part of the impetus for SUSEL is the specter of inexorably rising ground water in the 8000-foot (2400 m) mine—the deepest in North America—since the pumps were shut off when the 126-year-old mine ceased operation in 2003. If nothing is done, by the end of February the water will reach the cavern at the 4850-foot (1480 m) level that for 37 years hosted the detector with which Raymond Davis discovered the shortfall of neutrinos from the Sun and won a Nobel Prize (see PHYSICS TODAY, December 2002, page 16).

"We expect pumping to recommence in January," says newly appointed SUSEL director Jose Alonso, "and we hope to begin preparing the 4850-foot level for reoccupation by April." SUSEL has initiated an Early Implementation Program (EIP) under which moderate-scale experiments in a variety of fields will be invited to get started in suitably refurbished parts of the mine as early as this year. The EIP foresees the possibility of significant scientific and engineering results by 2009. "That certainly couldn't hurt DUSEL's prospects," says Lesko.

In November 2005, almost two years before NSF chose Homestake from among competing sites, the South Dakota Science and Technology Authority invited letters of interest from prospective Homestake experimenters. It then put together a program advisory committee, chaired by physicist Frank Sciulli (Columbia University) and geologist Derek Elsworth (Pennsylvania State University) to vet some 85 letters. From among the proposals it deemed good candidates or the Homestake facility, the committee in its May 2006 report took special note of those that seemed suitable for the EIP.

SUSEL

Alonso

Now that Homestake has won the site competition, Alonso and his SUSEL colleagues have been in conversation with those EIP candidates. Some have, in the meantime, opted to accept invitations from existing underground labs like the 6800-foot-deep Sudbury Neutrino Observatory in Ontario. But from those conversations have emerged a number of prospective EIP projects that already have funding and could move expeditiously into the 4850-foot cavern and shallower levels at Homestake.

EIP candidates

A list of nine such proposals was presented at the November town meeting. Four were particle-physics experiments. Among them is LUX, a collaboration led by Rick Gaitskell (Brown University) and Tom Shutt (Case Western Reserve University) that has already begun building a large liquid-xenon dark-matter detector to follow up on the pioneering XENON10 experiment carried out at the Gran Sasso laboratory in Italy (see PHYSICS TODAY, August 2007, page 16). Another is Majorana, a collaboration, headed by John Wilkerson (University of Washington) and Steven Elliott (Los Alamos National Laboratory), that would look for nuclear double-beta decay that emits no neutrinos. The existence of such a decay mode would mean that the neutrino, unlike the charged leptons, is a Majorana particle—a lepton that's its own antiparticle.

Also on the EIP list is a proposal by a seismological collaboration headed by Steven Glaser (UC Berkeley) and Bill Roggenthen (South Dakota School of Mines and Technology) to create a unique large-volume seismic observatory that extends throughout the mine from instruments at the surface all the way down to probes at 8000 feet.

Then there is a planned undertaking, led by Sookie Bang (SDSM&T) and Mark Conrad (Lawrence Berkeley National Laboratory), to extensively sample material during early excavation for the purpose of establishing baselines for future experiments in geology, biology, chemistry, and hydrology. And two projects on the EIP list are regarded as essential precursors for future large-scale experiments at DUSEL: A collaboration headed by