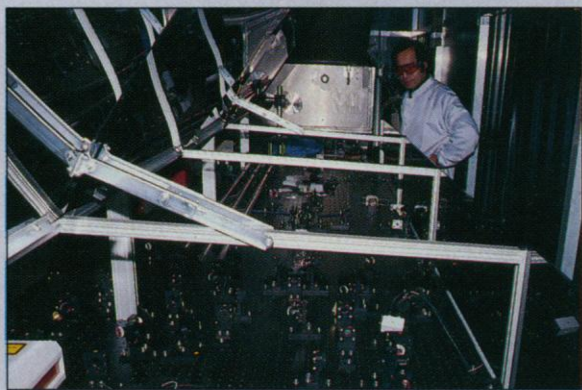
Meeting Takes Pulse of Laser Accelerators

LOUISVILLE, KENTUCKY—For the small band of physicists who hope to harness laser light to accelerate matter, a massive Japanese program to develop this and other applications of short-pulse lasers (see main text) comes at the right moment. In laboratories in the United States, Europe, and Japan, researchers are sharpening their picture of the interplay between laser light and ionized gases, or plasmas—phenomena that will be crucial to putting short-pulse lasers (SPLs) to use in practical devices such as accelerators. "A lot of the pieces are now in place to achieve the things that, a few years ago, were merely theoretical exercises," says Howard Milchberg, a physicist at the University of Maryland, College Park.

Milchberg was one of several dozen researchers who heard more about those pieces during an evening symposium, held here in November during a meeting of the American Physical Society's division of plasma physics, on SPLs and the electric fields they create in plasmas. The goal is to create particle accelerators hundreds of times more compact—and, ultimately, more powerful—than is possible with the best conventional technology, which uses radio-frequency (RF) cavities. Instead of "surfing" on the electric fields of RF waves in these cavities, the charged particles in SPL-based accelerators would accelerate in much shorter distances by riding on the much more intense electric fields that form, like waves behind a speedboat, in the wake of a laser pulse as it tears through a plasma.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Close quarters. KEK's Nakajima uses this small laser for experiments on an accelerator in an adjacent room at the University of Tokyo.

One important characteristic of the plasma, which affects propagation of the wake field, is its tendency to ring, like some fluid, electrified bell, at a frequency that increases with the plasma's density. Researchers know that high-performance wake field accelerators will have to use laser pulses shaped so that their light pressure excites plasma modes at precise resonances. Under those conditions, bunches of particles dropped into regions of the wake containing intense electric fields will accelerate uniformly, emerging more like a bag of sand than a handful thrown at the beach.

But the concept can also be used without such close attention to detail, according to Chris Clayton of the University of California, Los Angeles (UCLA), who described "a quick and dirty way to get [fast] electrons using the current technology." Clayton and co-workers—including UCLA's Chan Joshi and A. E. Dangor of Imperial College in London—used pulses that were much longer than needed to excite the optimum resonance. Plasma instabilities then eroded the pulse into a series of shorter pulses, and the resulting wake fields simply yanked electrons from the plasma and accelerated them to tens of millions of electron volts (eV). The method, Clayton thinks, might eventually be useful for making table-top electron sources in the billion-eV range for applications that don't require tight, single-energy bunches.

In more refined accelerator schemes, the total amount of acceleration will be limited by how far electrons can ride behind these intense laser pulses. In another talk, Kazuhisa Nakajima of the National Laboratory for High-Energy Physics in Tsukuba, Japan, reported preliminary evidence of pulses that remain tightly channeled over several centimeters rather than dispersing in a fraction of a millimeter, as tightly focused laser pulses ordinarily do in a vacuum or a normal gas. Although such an effect has been observed with "preformed" plasma channels created with a separate light pulse, the single-pulse, or "self-focusing," effect explored by Nakajima has remained elusive. Nakajima said he achieved the self-focusing in part by working at high gas pressures, and some researchers say they want more data to be sure of what's happening. "It's very hard to know what's going on" in the experiment, says Eric Esarey of the Naval Research Laboratory.

One possible technique for probing conditions around such a pulse was offered that evening by Michael Downer of the University of Texas, Austin, and presented elsewhere at the conference by a group at the École Polytechnique in France. Working with Austin colleagues Toshiki Tajima, Craig Siders, and others, Downer showed that the wake field structure could be probed with separate, less intense pulses of light that serve not as accelerators but as probes. These pulses propagate faster in areas where the density of plasma electrons is lower, allowing researchers to map out the shape of the roiling wake itself.

More powerful, multistage extensions of the idea, and practical applications such as table-top accelerators, will require a big boost in the overall efficiency of the laser system—the percentage of the power drawn from a source that ends up in accelerated particles—as well as a technique to synchronize a series of such devices, says Tajima, who organized the symposium. Still, he and his colleagues had heard enough to keep them talking late into the night, discussing how to harness the energy of a growing field.

–James Glanz

cations, thinks JAERI's time frame for these innovations—2 to 3 years for x-ray lasers, according to Iizumi—is "too optimistic." There is no guarantee that laser accelerators can even be built, he notes. But he adds, "I'm very excited about this initiative."

For now, Iizumi's first priority is to recruit topnotch researchers, including a director for the new center. Talks are under way with several overseas scientists, says Arisawa, although no agreements have been reached. Iizumi says it could take 5 years to reach the center's intended target of 200 scientists, who are expected to be working in new facilities at the Keihanna Science City near Osaka.

Still, many university researchers, both in Japan and abroad, wonder whether JAERI isn't rushing things. Maryland's Milchberg, for one, says JAERI's initial investment might be better spent on developing the underlying principles of laser accelerators and x-ray lasers. However, even its critics agree that, if JAERI's goal is to support a full-fledged program in compact lasers, the agency is doing the right thing by building up the necessary infrastructure. "In this country, the only crew that could do something like that would be Livermore," he says. Indeed, with JAERI poised to spend half a billion dollars over the next 5 years on compact lasers, the only thing about the program that's small may be what comes out of the lab.

–Dennis Normile