dims, allowing matter to fall inward again.

Yet another group envisioned a kind of astrophysical hurricane, with the clouds circling the core, and it is that picture that the latest results support. By measuring Doppler shifts of some of the clouds' emission lines to get their velocities, then comparing the velocities with the positions indicated by the time delays, the team was able to distinguish their overall movement. According to preliminary analyses, the clouds appear to be orbiting the central engine like planets around the sun. "I think this alone tells us that gravity is the most important force acting on the gas," says Peterson—and he's made a rough calculation indicating that the gravity at work is that of a black hole weighing in at about 20 million solar masses.

What's next for reverberation mapping? That question worries even the researchers who are most enthusiastic about the method. Astronomers would like to see whether NGC 5548 is a typical case by extending the technique to other AGNs and to distant quasars—and mapping them in greater detail as well. But doing so would demand observations still more intensive than the past long campaign, perhaps even a dedicated space instrument that could monitor an AGN or quasar continuously. "What depresses me," says Peterson, "is how hard it will be to do much better in the future."

–John Travis

PHYSICS

Tuning Up an Electromagnetic Accordion

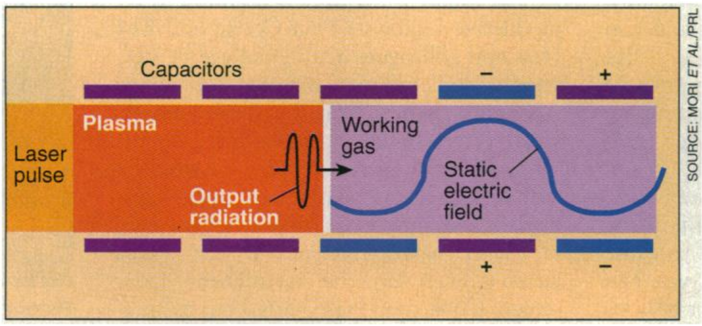
As those who love the polka can attest, it's not easy to master the accordion. But imagine how much tougher it would be if the leather bellows were swapped for an undulating electric field, the pressure from a musician's arms for a jolt from a short-pulse laser, and the sound for a burst of radiation. That's just the transformation that University of California, Los Angeles (UCLA), physicist Warren Mori and his colleagues have carried out. Yet he and his colleagues expect sweet music. As the laser pulse races through the electric field, says Thomas Katsouleas of the University of Southern California (USC), it should "accordion up" the field structure to produce a pulse of infrared light or microwaves that can be tuned as precisely as any musical note.

Some of this music could be particularly sweet in the fields of radar, communications, and materials science, and that is one reason for the excitement over the scheme, unveiled earlier this year in *Physical Review Letters*. More recently, Mori and his colleagues John Dawson at UCLA, Katsouleas, and C. H. Lai at USC have built a working version of the electromagnetic accordion and coaxed the first "sounds" from it: short bursts of radio waves.

The group is now trying to extend its range to shorter wavelengths and pulse lengths. If they succeed, the strategy "could be much simpler" than existing techniques for creating short pulses of tunable radiation, says California Institute of Technology physicist Richard Savage. As a bonus, says Dawson, the device could provide insight into conditions near supernovae, where processes much like the electromagnetic accordion may be at work.

On Earth, the method relies on two venerable tools of physics—relativity theory and plasma physics—along with a new one, short-pulse lasers, which briefly generate light at intensities of billions of watts. When photons from such a laser slam into a low-pressure gas, they ionize it to create a plasma. By aiming the laser through a gallery of capacitors that carry alternating electrical biases, Mori and his colleagues can create a sharp ionization front—a boundary between plasma and normal gas—racing at nearly the speed of light through the sinusoidal electric field created by the capacitors.

That's where relativity theory comes in.



Squeeze box. A traveling ionization front, generated by a laser, compresses a stationary electric field to produce a pulse of radiation.

Imagine riding along with the ionization front; in this moving frame of reference, according to relativity theory, stationary features appear compressed in the direction of motion. As a result, the onrushing electric field appears foreshortened—accordioned up. As the foreshortened wave strikes the moving boundary of the plasma, part of it is reflected, while the rest passes into the plasma. Just as light slows in passing from air to water, the transmitted wave slows by an amount that depends on the density of the plasma.

Because of this slowing—which corresponds to a kick toward the front's direction of motion—the electromagnetic wave now looks foreshortened even to an observer at rest. In the simplest case, the laboratory observer sees a compressed electromagnetic pulse following the ionization front. "The output is an analog of what you start with, but scrunched up," says Katsouleas. At the end of the capacitor array, a glass barrier stops the ionization front, but the scrunched wave continues as a pulse of radiation.

In the preliminary experiments, the scheme generated output wavelengths as short as 1 centimeter, in the radio spectrum. But the real action would come if the team can manage to fine-tune the setup to produce coherent infrared radiation at wavelengths of from 10 to 100 microns—frequencies off-limits for ordinary lasers but much prized for studying semiconductors' electronic structure. To get to that range, Mori and colleagues need to boost the pressure of the gas filling the device (which would increase the "scrunching factor") and tinker with the capacitor array. So far, however, contamination problems have prevented the accordion from playing a song this high-pitched.

Simply by shortening the array, meanwhile, Mori and his colleagues believe they can shorten the pulses almost arbitrarily, until they contain only a few wavelengths of radiation. At microwave frequencies, such short pulses could give radar "a better feel for sharp objects," says Mori, yielding clearer images of their shape. Inscribed with a specific pattern of frequencies, such pulses could also carry coded military communications, easy to pick out of a background of jamming frequencies.

Dawson hopes for a more esoteric payoff as well: insight into the behavior of the turbulent gases surrounding supernovae. The x-rays and ultraviolet light from an exploding star can send ionization fronts plowing through the surrounding gases. Like the laboratory fronts, these should shift the frequency of an ambient electromagnetic field—in this case a field generated not by capacitors but by the cosmic microwave background, the afterglow of the big bang. Detected from Earth, the shifts should act as "frequency signatures" of magnetic fields, density, and other conditions in supernova atmospheres, says Dawson. And by trying to reproduce the frequency shifts in the laboratory, he thinks, astrophysicists could test their interpretations.

If such hopes pan out, many more physicists may decide that the relativistic accordion is just the instrument they always wanted to play.

–James Glanz

James Glanz is a science writer in Chicago.