spills. Japanese experts have been at the forefront of efforts to tackle this problem. In 2000, the Japanese government commissioned the floating "Landysh" ("Lily of the Valley") facility in Bolshoi Kamen Bay, near Vladivostok, to dispose of such waste.

Military secrets revealed

Russia's reluctance to divulge data hampered the Landysh project early on. "Getting technical information was always a problem, because everything is considered secret," says Jim Stephens, an engineer at Crown Agents, a U.K. firm contracted by the Japanese government to manage its Russian sub programs. The information was coughed up eventually. "Although they knew they needed us, there was huge distrust," he says.

The key question now is whether Western experts will win more access to sensitive sites. Russian officials have long opposed visits by foreigners to military facilities, contending that it has sufficient expertise to carry out dismantlement on its own. But Western governments that are paying substantial sums for these programs have long pushed for more accountability. Russia's own contributions are paltry by comparison. Minatom has budgeted \$204 million in 2003 to stabilize thousands of sites across the country that pose potential proliferation threats. Only \$70 million of that is earmarked for dismantlement—a mere down payment on a "huge job" that could end up costing close to \$4 billion, says Akhunov.

Disputes over access and liability, for example, have impeded Japan's decade-long, \$170 million assistance program at the Zvezda shipyard near Vladivostok, where 41 general-purpose subs await dismantlement. For many years, "the Russian side did not admit access to the location at all," which also serves as the base for the Landysh project, says Toshiyuki Kawakami of the Japan-Russia Committee for Co-operation on Reducing Nuclear Weapons. In a high-profile snub last November, Yoshitaka Sindo, Japan's parliamentary secretary for foreign affairs, was refused entry to Zvezda. However, Kawakami says, "after controversial negotiations" the Russians relented, enabling Japan to reaffirm its commitment to submarine cleanup in a June agreement to speed up stalled programs.

A similar thaw is taking place in the northwest. "The Russians are much more willing to open up access to us now," says Torbjorn Norendal, special adviser on nuclear safety at the Norwegian Ministry of Foreign Affairs. He points to a recent Minatom decision to allow Norwegian inspectors into Andreeva Bay, where Norway had funded projects to help create safer environments for cleanup workers. "We told them more money would follow once access was granted," Norendal says. Since November, a Norwegian contractor has had monthly access. One big hurdle was overcome last May, when Russia and several partner countries and organizations signed the Multilateral Nuclear Environmental Program for Russia, which clarifies tax and liability issues surrounding nonproliferation activities. With donors now writing checks, the accord provides legal assurances for €1.8 billion worth of proposed projects.

"Working with Minatom is getting easier," says Eduard Avdonin, deputy director of Minatom's International Center for Environmental Safety. He points to recent successes such as improved Western access at Andreeva, an international conference in Vladivostok last fall on the ecological threats posed by mothballed nuclear submarines, and joint research on the ecological impacts of ocean-dumping radioactive materials.

Nowhere is the recent glasnost more evident than at Zvezdochka. "Back in 1993 when American advisers first came here, we realized that we had a vast amount in common. Now other countries are getting involved too," says Frolov. When the shipyard finishes these two Victor class submarines, it hopes to turn its shears to three more, if it wins a contract for the job from Canada and Italy. "As soon as the funding is secure, we'll get them out of the water and the world will be that much safer," Frolov says. But scores more decommissioned and deteriorating nuclear subs would still be waiting in line.

–PAUL WEBSTER

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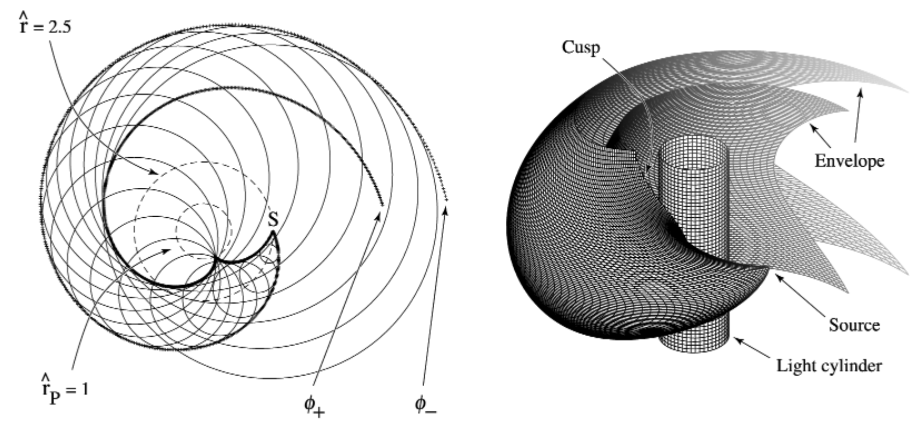
Physics

Money Spinner or Loopy Idea?

A tabletop synchrotron claimed to generate unusual radiation could transform communications and radar systems. But critics say it is based on flawed science

BRISTOL, U.K.—After the Turweston Aerodrome in Northampton shuts down for the night, three physicists wheel onto the runway a 2-meter-long device and jack it up on a scissor lift. They flip a switch and the machine emits radio waves that they pick up with an antenna down the runway. They rotate and tilt the device at a variety of angles, noting the radiation intensity, then move the antenna farther away and repeat the experiment. The trio—John Singleton of Los Alamos National Laboratory in New Mexico, Houshang Ardavan of the University of Cambridge, and Arzhang Ardavan of the University of Oxford—leave before dawn and return in the evening. Odd nocturnal activity, perhaps, but the researchers are chasing a dream: to circumvent the hallowed inverse square law, which holds that radiation intensity falls off in proportion to the square of the distance.

Others say they're chasing a phantom. If the team's machine—called a polarization synchrotron because it rotates a polarization pattern much like a conventional synchrotron rotates charged particles—does indeed emit radiation that defies the inverse square law, it would shake the physics community and possibly spur radical design alterations for all sorts of devices that generate electromagnetic radiation. "This machine opens up a new way of emitting radio waves," Singleton claims. Antennas powered by miniature polarization synchrotrons would require less power or transmit farther—perhaps, for ex-



To dizzying effect. According to their model of how the polarization synchrotron emits radiation, the Los Alamos–Oxford team claims that spherical wavefronts spiral away from the machine (point source S, *left*).

CREDIT: J. SINGLETON/LANL

ample, allowing mobile phones to communicate directly with satellites without the need for relay stations.

The bold claims are stirring consternation and anticipation. It's "nonsense," says Antony Hewish of the University of Cambridge, who shared the 1974 Nobel Prize in physics for the discovery of pulsars. The physics, he says, "is simply wrong. … The radiation from such a device must be conventional." Others disagree. "I've no doubt that what they've modeled is correct," says John Ffowcs Williams, a professor of acoustical engineering at the University of Cambridge. However, he says, whether the machine works according to the model is another question.

If the polarization synchrotron seems otherworldly, so are its theoretical underpinnings: a controversial hypothesis for how pulsars—rapidly spinning neutron stars—emit radio waves in regular, coherent pulses. The conventional view is that such pulses result from clusters of electrons and positrons that move along the magnetic field lines of pulsars at nearly light speed, shedding electromagnetic radiation in the direction they are moving. Like a lighthouse, this beam moves as the pulsar rotates, producing the pulses observed on Earth.

In a 1998 paper in *Physical Review E*, Houshang Ardavan, a mathematician and astrophysicist and Arzhang's father, offered a new interpretation. Ardavan argued that the telltale beam is generated when a pulsar's magnetic field polarizes the electrons and positive ions that make up the plasma surrounding the star. As the magnetic field sweeps around, so too does the polarized region of plasma. Far enough away from the pulsar, the polarization pattern moves faster than light, Ardavan asserts, although the particles themselves, of course, do not surpass light speed. "Imagine spinning a flashlight on a turntable; get far enough away and the beam [representing the pulsar's field] sweeps past you faster than the speed of light," says Singleton. "We don't break relativity or any laws of electromagnetism."

According to Ardavan, because each point within the rotating polarization pattern exceeds light speed, the wavefronts emanating from a point bunch up behind it. The interference among wavefronts reinforces the emission along spiraling trajectories that the researchers call "cusps"; these increase in diameter as the radiation streaks away from the pulsar (see diagram). Ardavan contends that these cusps are what form a pulsar's directed beam.

Father and son discussed the idea, and Arzhang, a postdoctoral researcher in Singleton's laboratory at the time, realized that their experimentation in high-frequency electronics could be used to test Houshang's ideas. They got hold of a piece of alumina—a dielectric, or nonconducting, material in

Ready for takeoff. Preparing a test of the synchrotron at Turweston Aerodrome.

CREDIT: ALE NARDUZZO

which an applied electric field displaces charge but does not induce a current—and milled it into a gently curving arc. Next, they fitted this with a series of electrodes to polarize it, in other words to shift the positively charged aluminum ions with respect to negatively charged oxygen ions in the alumina. They varied the voltage across each electrode sinusoidally and introduced a slight delay between electrodes. Although no charge moved between electrodes, the polarization pattern varied like a sine wave from one electrode to the next. By carefully selecting the voltage frequency and time delay between electrodes, the pattern, they claim, can be ramped up beyond light speed.

Because radiation from a conventional source spreads out in all directions, at any given distance from the source it impinges on the inside of an imaginary sphere. The surface area, and hence the degree of spreading, is proportional to the square of the radius from the source—the basis for the inverse square law. But the Ardavans and Singleton argue that the polarization synchrotron, like Houshang's pulsars, generates radiation cusps that alter this equation. Essentially, rather than spreading out over a sphere, the radiation spreads out over the circumference of one turn of a cusp. Although each cusp is formed from wavelets that obey the inverse square law, the cusp's geometry dictates that radiation intensity falls off in proportion to r rather than r^2, they argue in a paper submitted to the *Journal of the Optical Society of America A*.

Based on experiments carried out at Turweston since May, Singleton and company now claim to have evidence that radiation from their synchrotron, as Ardavan predicted, bunches up in cusps and falls off in intensity accordingly. The team members have tested the device to distances of up to 900 meters, and they say they have mapped the three-dimensional shape of the emission, confirming that it is a curved beam that could only have been generated by a superluminal source.

Critics are unconvinced. Over limited distances, notes theoretical physicist John Hannay of the University of Bristol, conventional antenna dishes or laser beams can focus radiation in particular directions such that its intensity falls off more slowly than $1/r^2$. But even a highly focused beam begins to disperse such that beyond a certain distance, inverse square is the rule of law. "The acid test in physics is experiment," adds Hewish. "They should just point the thing towards Oxford from a great distance and see if they pick up anything from their machine. To my mind 1000 meters is nothing. They need more like 50 miles [80 km]."

Singleton claims a long-distance experiment that provides meaningful results is not feasible, as it would require numerous measurements at various distances from Turweston, often on private property. More important, he says, are their measurements showing how cusp shape and position evolve with distance. Singleton doubts whether further data could satisfy the critics. "There are so many conceptual barriers," he says. The device "appears to go against several of the things that we were taught as undergraduates."

Singleton and his team have not let the skepticism prevent them from attempting to capitalize on their invention. They are setting up a company, Oxbridge Pulsar Sources, and drumming up seed money. Besides offering a way to improve antennas, the cusp's unusual shape would make it difficult to trace radiation to its source—an obvious improvement for defense radar systems, Singleton says.

They also plan to test their hypothesis that the superluminal polarization pattern will produce radiation in a wide range of frequencies—including the difficult-to-generate terahertz band, which is well suited to skin and breast cancer diagnosis. In another article in press in the *Journal of the Optical Society of America A*, the researchers lay out the theoretical groundwork for how their device should emit a broad band of frequencies simultaneously.

Nevertheless, some superluminal luminaries doubt that the synchrotron will perform as advertised. "I do not believe it will work," says Vitaly Ginzburg, an expert on superluminal charge patterns at the Lebedev Physics Institute in Moscow. "But that is different from saying it is impossible."

–EDWIN CARTLIDGE

Edwin Cartlidge is news editor of *Physics World*. With reporting by Richard Stone.