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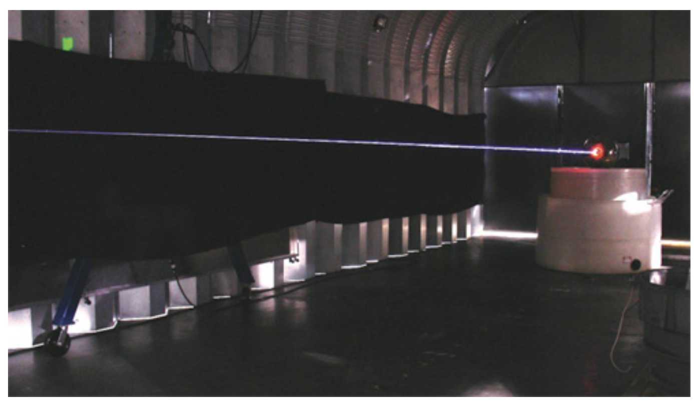
To Boldly Go (Again)

David Schneider

Transport yourself back to the early 1960s, before the now-famous television series *Star Trek* first aired. At that time, only wild-eyed visionaries would have dared imagine that people of the 23rd century would be taking in the world on gargantuan flat-panel video screens, talking to one another across the width of the planet using wireless, flip-top communication devices and instantly accessing obscure bits of information by making simple queries to their computers. Yet today these scenes are commonplace. So it is fitting that two new high-tech devices also have eerie similarities with fictional technology first presented on that venerable science-fiction series. Remember how *Enterprise* landing parties always carried "phasers," weapons that could conveniently be set on "stun" when less-than-deadly force was needed? And do you recall the invisible doors that mysteriously kept air in the ship's shuttle bay from whooshing rapidly out into space? Such marvels are now reality—or almost.



Ionatron's prototype weapon uses laser light to ionize the air and channel a high-voltage electric discharge, which could be adjusted to disable a person without killing. Ionatron

The phaser look-alikes expected to be appearing soon are similar in principle to equipment that law-enforcement officers have long been able to purchase from an Arizona company named, appropriately enough, Taser International. Taser guns fire two small darts, each trailing fine wires. After these projectiles strike their target, this nonlethal weapon uses the newly established electrical conduits to give the person caught in the crosshairs an electric shock, which disables without killing. The newer generation of stun weapons will dispense with the clumsy darts and wires entirely. In their place, they will use lasers to generate conductive channels of ionized air—raylike beams of plasma—through which an electric shock can be administered.

This general strategy, having a laser induce ionization and thus allow for the conduction of electricity, has for decades been the Holy Grail of scientists and engineers seeking to control lightning. They have longed to be able to generate a conductive path between a thundercloud and the ground, which could harmlessly drain off the buildup of charge that otherwise might strike a sensitive facility, say an electric-power substation or an airport control tower. A less ambitious goal is to create a shorter "laser lightning rod" that could be deployed at the flip of a switch. The main hitch early on was that ordinary lasers do too good a job at inducing ionization, which then makes the air opaque to the light beam. But more promising results have been achieved using lasers that emit extremely short pulses. Last December, for example, Roland Ackermann of Université Lyon 1 in France and 15 colleagues reported in the journal *Applied Physics Letters* their success in ionizing a path in air that served to channel an artificial electric discharge. This recent experiment is notable because it was carried out under conditions of simulated rain. The length of the laboratory discharge was only about a meter, so this technology has a ways to go before it can be used to control real lightning bolts. But the same principles are now being apply in a phaser-like way.

Just as Ackermann's paper was being published, an Arizona company named Ionatron demonstrated the use of laser-guided electric discharges in something it calls a "portal denial system," which can be set up in a corridor and switched on to prevent intruders from passing through. Three beams in this system create a virtual electric fence that spans the width of a hallway. Steve McCahon, Ionatron's executive vice president for technology and engineering, explains that the company's system demonstrated nonlethal levels of deterrence but "that doesn't mean you couldn't turn it up."

Are guns next? According to the boldly written claim on its Web site, "Ionatron intends to use our compact, non-lethal LIPC [laser-induced plasma-channel] technology to replace guns as the weapon of choice in close-range defense." McCahon confirms that "the thrust is extending range." Exactly how much range Ionatron has been able to achieve with such a weapon is being kept secret. And it's unclear whether the sophisticated lasers needed could ever be made very small. Still, it seems reasonable to anticipate that in the not-so-distant future, military or law-enforcement officers might be caught uttering the phrase "phasers on stun" in all seriousness.

Similar physical principles are behind a second *Star Trek*-like technology now coming into use, something called the "plasma window," which is the brainchild of Ady Hershcovitch, a physicist at Brookhaven National Laboratory. Hershcovitch conceived of the plasma window to serve in electron-beam welding, a technique used to fashion metal welds that are narrower and deeper than what can be accomplished with conventional tools.

The chief drawback of this technique is that the electrons used for welding must be accelerated in a vacuum (just like, for example, the electrons that light up the front of a television picture tube). Hence the objects being welded together must normally be placed within a sealed chamber from which the air has been extracted. With that constraint, one cannot make welds to, say, the deck of a battleship. Even for small work pieces, pumping down the vacuum chamber each time an object is inserted is time-consuming, making this form of welding rather costly.

To get around this difficulty, some have tried a variation of electron-beam welding that has the electrons accelerated in vacuum but the welding done at atmospheric pressure. Such systems rely on bulky, energy-hungry vacuum pumps to maintain the pressure differential between the source of electrons and the work piece. So they are awkward and costly to operate. What is more, the electron beam has a troubling tendency to spread out once it passes into the air, negating the fundamental advantage of electron-beam welding in the first place. Last May, Hershcovitch and colleagues at Acceleron, a company in Connecticut licensing his invention, described in the journal *Physics of Plasmas* how to sidestep these problems, making electron-beam welding that much more practical.

The trick is to send the electrons out of the welder through a window that is made up of nothing more than an electric discharge channeled through a length of ionized gas—that is, a plasma. The temperature of the plasma is searing (about 15,000 kelvins), so it can counterbalance atmospheric pressure even though its density is only two percent of normal air. The low-density plasma offers little resistance to speeding electrons passing through it, making it the perfect window for an electron-beam welder.

Hershcovitch had this idea more than a decade ago, but only recently did he realize that a plasma window could also counteract the nagging tendency for the electron beam to spread out as it moves through the air. The reason is that the electrical current used to heat the plasma sets up a sizable magnetic field, one that exerts a radial force on the electrons in the beam. As chance would have it, Hershcovitch initially had the polarity of this current set in such a way that the magnetic field inside the plasma window made the electron beam spread out more than usual. But he soon realized what was going on. After asking himself, "How stupid can I be?," Hershcovitch reversed the polarity of the current and was delighted to discover that his plasma window acted to focus the beam tightly, thus circumventing the second roadblock to electron-beam welding in air. Hershcovitch notes modestly that this is a good example of a common principle: "It's better to be lucky than to be smart."

Phaser-like weapons and ethereal vacuum windows will surely not be the last *Star Trek* technologies to come to life. What's next? Myself, I'm looking forward to those anti-gravity handles: Hand trucks are such a pain to use on stairs.—*David Schneider*