These following articles are from Aviation Week and Space Technology's Jan. 22, 2007 issue. The last few paragraphs from *HPM GETS CHEAP is what has influenced my sensor tech the most. I wonder what they have done in the last 6 years . . .*

HPM GETS

DAVID A. FULGHUM/WASHINGTON

Electronic warfare is becoming less a science of developing new technologies and more a process of sensor fusion, target networking and finding new ways to manipulate existing tools of the trade. A case in point—lasers and high-power microwave devices long have been eyed as competing directed-energy attack options. However, researchers are now combining the two to produce smaller, cheaper, more powerful, nonkinetic weapons. Electronic attack has taken a new path as well, shifting from covering enemy emissions with noise to finding, penetrating and exploiting enemy networks from low-power cell-phone networks to sophisticated air defense systems. The following articles explore some of those changes.

High-power microwave weapons may be on the verge of a high-speed turn toward the practical.

An advanced concept, pioneered by BAE Systems' researchers, uses light to multiply the speed and power at which HPM pulses—powerful enough to destroy enemy electronics—can be produced without the need for explosives or huge electrical generators.

Researchers predict leaps of 10-100 times in power output within two years. That advance could push the beam-weapon technology far beyond the 1-10-gigawatt limit of current tactical-size HPM devices. Long-standing industry estimates are that it would require a 100-gigawatt pulse for a few nanoseconds to disable a cruise missile at a useful range.

BAE Systems is not alone in the chase. Northrop Grumman and Raytheon are also building distributed array radars that can produce air-to-air and surface-to-air HPM weapons effects, contend longtime Pentagon radar specialists. In particular, the F-22, F-35, F/A-18E/F and newest F-15 radars are designed to accept modifications that would focus their beams to produce HPM energy spikes powerful enough to disable cruise, anti-aircraft, air-to-air and emitter-seeking missiles. Germany's Diehl is developing suitcase-size HPM devices that could be placed surreptitiously in a target building to damage electronics such as computers.

In addition, the U.S. military is giving classified briefings on the threat of HPM weapon technologies being developed in China and Russia. The Russians are believed to be developing radio-frequency microwave weapons for air defense, and the Chinese are developing HPM and electromagnetic pulse weapons for information warfare.

However, BAE Systems researchers claim they have made a singular leap in HPM weapons technology by combining the use of lasers and radar-like microwaves. Furthermore, the technology is scalable through the use of 4-in.-square arrays, each an integrated structure of dielectrics and electrical conductors. One hundred of them distributed over a square meter, for example, can generate up to 10 gigawatts of power, says Robert D'Amico, BAE Systems' director of advanced programs.

"We have shown everything we claimed with a laboratory testbed," says Oved Zucker, director of photonics programs for BAE Systems' advanced concepts facility here. "We are in the process of demonstrating total power substantially above 10 gigawatts, and we have plans to test [the system] further in an airborne mode.

"The power bandwidth product—how much power and how fast you manipulate it—is potentially the largest of any technology around. Having the bandwidth with larger power is where the money is," he says. There's no dearth of missions for HPM technology, including detecting and detonating improvised explosive devices, finding suicide bombers or hidden explosives, and attacking shoulder-fired anti-aircraft missiles.

There's also the appeal of weapons that can rob a foe of communications, power and mobility—while largely eliminating collateral damage to people and structures—which is a high priority for the U.S. military.

The development of HPM weapons has been hobbled for the last 30 years by seemingly intractable cost, size, beam-control and power-generation requirements. Tests of modified air-launched cruise missiles carrying devices to produce explosively generated spikes of energy were considered big disappointments in the early 1990s because of an inability to direct pulses and predict effects. New active electronically scanned array (AESA) radars can jam emitters or possibly cause damage to electronic components with focused beams. But power levels and ranges are limited by aperture size.

BAE Systems' photonically driven technology could open the way to much smaller and more powerful electronic jammers, nonkinetic beam weapons for cruise and anti-ship missile defenses, and stealth-detecting sensors.

"You could put a [sensor] system on

CHEAP

Light to boost destructive power and slash size of microwave weapons, sensors

a fighter-size aircraft that could generate enough power, with a 1-ft. resolution, to see stealthy objects at 100 mi." D'Amico says. "You can defeat stealth with enough power. If stealth takes the signature [of an aircraft or missile] down a factor of 10, you have to increase the [sensor's] power by a factor of 10." Most current fighter-size radars have less than a megawatt of peak power. Detecting stealth would require tens of gigawatts, which is now impossible in fighter-size packages.

What effects can HPM produce as an electronic warfare weapon?

"At one end, it can fry anything [electronic] that's out there," Zucker says. "The levels of EW extend from the sledgehammer to just making the [computer's] brain a little bit befuddled so it can't think for a moment. At a lower level, you can kill the detector of the other guy's radar as part of the suppression of enemy air defenses. You don't need much power because you're going after the most sensitive part. You're blinding the system."

The level below that is to momentarily stop electronics from functioning. A radar will try to defend itself by using a chain of circuits to "blink," and thereby shut out intruding signals. One method of exploitation is to do something during the blink. But if an intruding signal is fast enough, the radar can't react in time to keep out the invader.

"You can put energy in there and it won't be able to respond," Zucker says. "Another low-level effect is to make the computer skip bits so that it's not processing efficiently for the moment. All these games have to do with how much power [can be applied] and how fast."

BAE researchers envision HPM pulse weapons that are powerful enough to disable a tank, a missile, perhaps a helicopter or aircraft, but at the same time are small and light enough to function as part of a microwave radar sensor designed into the skin of an aircraft.

Alternatively, the HPM weapons could be scaled up to shipboard size—perhaps 100 sq. meters—to produce terawatt-size energy pulses. That's theoretically a large enough energy spike to stop another ship.

"You kill the brains by aiming at the bridge area because of all the computers and control systems there that run the ship," Zucker says.

This brute-strength scaling up of the technology involves installing a distributed array on the side of a ship. The elements would work together to form a large virtual antenna and then pull enough power from the ship's electric engines to concentrate a beam on vulnerable areas. From a few hundred yards, predictions are that the energy spike—focused in a beam several feet wide—could disable all the electrical equipment, including propulsion, leaving the ship a darkened, drifting hulk.

Researchers have some unusual techniques in mind for the associated antenna arrays.

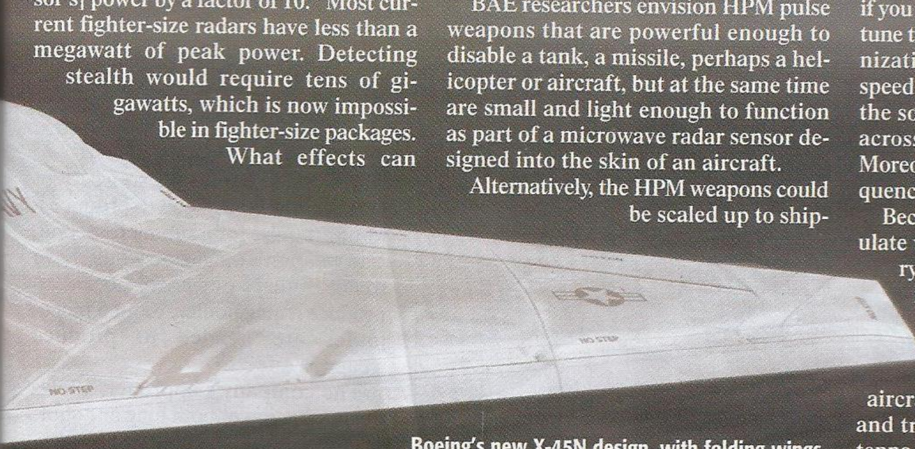
"We are integrating a large number of transverse electromagnetic [TEM] apertures," to produce the distributed transmitter arrays, he says. "To produce a large number of TEM antennas is sensible only if you can make each one sing to the same tune through this coherence [or synchronization] that comes from using [the speed of] light. That allows us to spread the source [of HPM pulse production] across the whole wing of an airplane. Moreover, TEM doesn't have a cutoff frequency, which gives us flexibility."

Because the high-speed switches modulate the HPM, they match the circuitry to the antenna. Composite skins for fuselages could have the conductors and switches built into them. At the moment, BAE is looking at new, 20-cm.-thick aircraft wings, tapered at the leading and trailing edges, with imbedded antenna structures instead of using a bolt-on system.

"That is my radiator, and it is a phased array," Zucker says. "It can be a radar, communications, receiver or HPM transmitter. The wing is the source with more gain than any aperture that's been available before. I don't have to pump the energy through wave guides. More area means more power and gain. Instead of megawatts, we're talking about gigawatts of peak power."

Researchers say the antennas, photoconductive switches and transformer blocks can be built into conformal skins for unmanned combat aircraft as well. Unmanned designs are favored initially because of the vagaries in distribution of HPM side lobes, the effects of HPM on humans, and the disturbances that energy spikes can create in fly-by-wire flight control systems.

Zucker also is designing fly-by-light flight control systems for UAVs. With fly by light, actuators are triggered by simple blobs of light that can't be disrupted by spikes of electrical energy produced by the aircraft's payload.



BOEING CONCEPT

Boeing's new X-45N design, with folding wings, represents the class of aircraft expected to carry high-power microwave weapons. However, that means HPM has to be manufactured in a small, cheap package with lower power requirements.

Then Add Light

How BAE Systems researchers are adding power and reducing the size of HPM weapons

DAVID A. FULGHUM/WASHINGTON

Melding lasers and high-power microwaves is part of a new formula for creating more powerful, operationally flexible, directed-energy weapon designs.

The shift in technology is considered comparable to the change from vacuum tubes to transistors in the 1960s. For example, today, a 10-gigawatt high-power microwave (HPM) system—the power needed to produce weapons effects at tactically effective ranges—is about the size of a house. However, a joule of laser light could generate that same 10 gigawatts of HPM in a far smaller package.

"The technology is cheap enough that you could put it on disposable platforms," says Oved Zucker, director of photonics programs for BAE Systems' advanced concepts facility here. "Very early on, we looked at cruise missile applications. Making the pieces is dirt cheap, but only in volumes of hundreds of thousands."

The basic building blocks of the HPM-generating technology use the integrated combination of extremely fast photoconductive switches (that can carry 9,000 volts and 30,000 amps with picoseconds of rise time and coherence); thin-film transmission lines; diode-pumped yttrium-aluminum-garnet (YAG) lasers as the light source; specialized transformers, and powerful new lithium-ion batteries to provide basic DC power to generate, transform and match HPM pulses.

BAE SYSTEMS

A photoconductive switch developed by BAE Systems—out of focus to avoid revealing details—uses laser-generated photons to switch electronic flow in an HPM weapon at the highest possible speed, enabling large power increases.

"Think of it in terms of a transistor that can [manipulate] 100 times the voltage and current, but with the same fast switching speed," Zucker says. "We do it by manipulating the carriers inside the silicon semiconductor with light. The YAG-based laser is the same wavelength as silicon, which is a marriage made in heaven. We create the carriers in situ, so we can produce huge current—30,000 amperes instead of the 30 from a transistor."

The basic unit being tested by BAE Systems is a 4 X 4-in. block of integrated electrical conductors and dielectrics with linear photoconductors attached to generate submicrosecond pulses timed to within a few picoseconds, says Robert D'Amico, BAE Systems' director of advanced programs. The timing is crucial for synchronizing distributed pulses so that they can be combined into a single pulse destructive enough to damage enemy electronics. A test unit has produced 30 megawatts of HPM during demonstrations. It is expected to reach 100 megawatts before development is complete, and has demonstrated hundreds of megawatts of power when several units are combined.

"It's tempting to say the switch is the key part of the HPM system," Zucker says. The company has made a multimillion-dollar investment in a semiconductor foundry in nearby Manassas, Va., that can develop customized semiconductors. "But the secret is in designing a switch and a pulse-generating system that will work together. Essentially, we're switching a capacitor in the theoretically fastest possible way. The trick is to use light to switch the circuit at very high speed so that the power does not degrade the speed, and vice versa."

Photoconductive, silicon-based switches are embedded in thin films. Photons from the laser hit the photoconductive switch, which generates electrons there by switching the thin-film transmission lines at the fastest possible speed and power.

For a 100-kilojoule source, researchers say they need to produce a terawatt pulse for a submicrosecond. The weapon's magazine would have to accumulate power for 10 sec. to produce a megajoule. About 5 megajoules are needed to produce weapons effects.

The company's approach allows the production of both long and short pulses of HPM. "With a short pulse, it puts out high power—gigawatts—but low energy—tens or hundreds of joules," says D'Amico. "With long-pulse HPM, the product is even higher power (terawatts) and high energy (megajoules)."

"The magazine produces energy constantly, and you pack it in small packages and lob them," Zucker says. "The bigger the lumps, the slower the rates." On board an aircraft capable of generating an extra 500 kw. of power, "your magazine is infinite."

New-generation batteries also can aid the new technology. One-shot cruise missile applications were developed and tested in the early 1990s for HPM use against ground targets employing explosive generators. But in the last five years, batteries have been developed that can produce 12% of the energy of explosives, but at a much greater efficiency, and the batteries allow multiple shots—even during a single, one-way cruise missile mission. In particular, BAE Systems has been working with SAFT researchers, who have been increasing power densities by a factor of 10-100 with lithium ion batteries.

The low prime power voltage (less than 10 kilovolts) can be converted by the light-sensitive switches to a 40-60-kilovolt output. The battery-provided direct current can be converted to HPM in a single power conditioning stage with an efficiency of 50%. That wildly outperforms traditional four-stage conditioning, which achieves about 1% efficiency.

In place of an electrical or explosive generator, for niche applications, the batteries can provide both electrical energy to the microwave source and the laser, D'Amico says. Laser advances, instead of competing with HPM, are helping propel cheap weapons development.

"Diode pumping of YAG is now a mature laser technology," Zucker says. "A diode-pumped laser should give you a joule per pulse. You can think about making HPM at three kilohertz. That's incredible power. Yet, a YAG laser that can generate that, with all the bells and whistles, is about 6 in. square.

"Because we are synthesizing the pulses cycle by cycle, we can space and modulate them to a level we want," he says. "Microwaves at different wavelengths have different penetration. We can generate quite a variety."

For generating HPM pulses, the primary requirement is for a lot of power in a specific frequency in a relatively short pulse—less than 100 nanosec. Most electronics are narrowband, so an HPM frequency may be needed that's high enough to slip through the cracks in protective structures and to disable any missile. Sometimes the need is for a wideband pulse, for example, to jam or otherwise electronically attack ultra-wideband radar.