

(CHAMP). Emitting bursts of RF energy as it flies by structures, the prototype missile has been shown to disable computers and communications electronics that are pervasive in today's weapons-guidance and air-defense systems. The CHAMP system is capable of irradiating multiple targets per missile and is sufficiently mature that it could be deployed on cruise missiles in two or three years, says Mark Gunzinger, a senior fellow at the Center for Strategic and Budgetary Assessments. With an RF weapon, "I would have a pretty powerful capability to disrupt enemy air defenses," he says. He notes that a B-52 can carry 24 cruise missiles. The air force, however, hasn't initiated an acquisition process.

The air force and the army have developed separate versions of a third type of directed-energy weapon, known as an active denial system. The truck-mounted ADS emits a diffuse millimeter-wave beam that penetrates human skin to a depth of 0.4 mm; it causes intense pain but no lasting harm. According to the army, the ADS could be used for crowd control and for security at military installations, ports, embassies, checkpoints, and other facilities.

Challenges ahead

Among the challenges that laser weapons developers face as power levels are scaled up is dealing with the generated heat. "These solid-state [fiber] lasers are pumped with diodes that create heat, and that heat needs to be managed," De Fatta explains. Cooling is especially problematic for land-based mobile lasers, given the need to fit the required equipment onto a truck. It's also difficult to pack sufficient power on the vehicle; De Fatta says the solution will require advanced battery, generator, and hybrid electric technologies. In his remarks at the Marshall Institute event, Meyer said that current laser technology has an electrical efficiency of 30% at best, and

significant technological advances will be needed to improve on that.

Moisture, dust, and atmospheric turbulence resulting from shifting weather conditions can cause the air over long distances to act like a lens, diffusing and shifting the laser beam. The challenge is particularly great at sea, due to thermal gradients between the water and air. Adaptive optics are used to compensate and maintain power on the target, says Morrison. DARPA's Excalibur system uses an ultrafast optimization algorithm to help correct for atmospheric turbulence.

Because laser weapons can only engage a single target at a time, their effectiveness against a saturation attack is not assured, notes a Congressional Research Service report. That limitation could be overcome by putting more than one laser on a ship. Adversaries could also take countermeasures, such as adding shielding to UAVs.

An additional challenge for the RF weapon is that the damage it produces isn't visible. "In the eyes of the warfighter, unless I can see an effect, I have a disbelief that the effect really took place," Meyer said during the Marshall Institute discussion. Panelist Ronald O'Rourke, a naval affairs specialist with the Congressional Research Service, said that more generally, directed-energy weapons "may face barriers because they are unfamiliar and people don't know about their potential and advantages."

Spending on solid-state laser weapons across DOD totals \$355 million this year, which is about the cost of three F-35 fighter aircraft, says Gunzinger. Given what he calls the game-changing nature of laser weapons, he says he believes that's too little. But De Fatta disagrees: "We are adequately funded for the program we currently have. I don't want to rush to failure. So if I had an infinite source of funds, it wouldn't change the program much." **David Kramer**

Particle physicists brainstorm long-term collider options

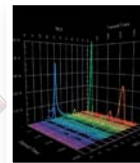
Even as the US high-energy physics community is working to keep a world-class program for the next 10 years (see story on page 18), its counterparts in Europe and China are revving up discussions for longer-term projects—circular colliders 50 to 100 km in circumference that might be built in the coming decades.

The Institute of High Energy Physics (IHEP) in Beijing and CERN near Geneva have similar visions: Each might start with an electron-positron machine—perhaps 240 GeV in China and higher in Europe—and then convert to a proton-proton facility with center-of-mass collisions up to 100 TeV, about seven times as high as planned

HIDEN

ANALYTICAL

QGA



Mass Spectrometers for Gas Analysis

- ▶ Fast data acquisition > 500 measurements/sec
- ▶ Fast response time to 150 ms
- ▶ Species molecular weight range to 200, 300 or 500 amu. Up to 1000 amu for specialist applications
- ▶ Multiple gases & vapors



SIMS WORKSTATION

Mass Spectrometers for Surface Analysis

- ▶ Unrivalled performance for depth profile & interface analysis
- ▶ SNMS uniquely offers quantitative surface analysis
- ▶ Static & dynamic SIMS
- ▶ FIB-SIMS
- ▶ Low cost of ownership



for further details of Hiden Analytical products contact:

HidenAnalytical.com

E info@hideninc.com

T +1 734 542 6666

for the next stages of the Large Hadron Collider (LHC).

The China high-energy physics community, says IHEP director Yifang Wang, is looking for a successor to the 240-m Beijing Electron Positron Collider. For now, he says, “we are focusing on a 50-km ring as the lower limit for creating a Higgs factory.” A possible location has been scoped out in Qinhuangdao, some 300 km east of Beijing. Wang lists money, manpower, and technology as the top challenges. Export controls could also put a monkey wrench into importing crucial know-how.

In February IHEP launched the Center for Future High Energy Physics to attract students into the field, garner support among scientists for a future collider in China, and show the Chinese government that the local and global physics communities are behind the idea.

Nima Arkani-Hamed, a theoretical physicist at the Institute for Advanced Study in Princeton, New Jersey, is director of the new center. “I became convinced that they [in China] are serious, and there is a nonzero chance of it happening. This project is something you can be guaranteed to be world leader in if you build it.” Proponents hope that the promise of prestige could persuade China to invest new money into the field—and that such a project could move faster and cheaper in China than elsewhere. “It’s good for China, and it’s good for physics,” says Arkani-Hamed.

CERN scientists have their eye on a 100-TeV proton-proton collider that would go under Lake Geneva so as to exploit the existing CERN infrastructure. “What 100-TeV center of mass would give you is lots of high-energy collisions,” says John Ellis of King’s College London. “If you go much below that, you won’t open up as much phase space for new physics.” Areas of discovery might include dark matter, supersymmetry, and the origin of the matter-antimatter asymmetry in the universe.

A future circular electron-positron collider would scientifically overlap the design-ready International Linear Collider (ILC), which Japan is considering hosting (see *PHYSICS TODAY*, March 2013, page 23). High-energy physicists are divided as to whether the two projects would interfere with each other’s going forward. Results from the upcoming higher-energy and higher-luminosity stages of the LHC could determine future directions. “But in any circumstance I can imagine,” says Arkani-Hamed, “these [high-energy



The opening ceremony of the Center for Future High Energy Physics in Beijing attracted many scientists, including (from left) Nima Arkani-Hamed of the Institute for Advanced Study in Princeton, New Jersey, the center’s founding director; Hesheng Chen, former director of the Institute of High Energy Physics in Beijing; David Gross, director emeritus of the Kavli Institute for Theoretical Physics at the University of California, Santa Barbara; and IHEP director Yifang Wang.

circular] machines are going to be a necessary step.”

In China, the plan is to prepare a proposal for R&D funding by the end of this year. In Europe, where money and personnel are currently wrapped up with the LHC, scientists aim to include a circular collider in the next European Strategy for Particle Physics, on which work begins in 2018. The two teams

are cooperating and generally concur that at most one 100-km-scale collider would go ahead. The IHEP scientists are taking RMB 20 billion (\$3.2 billion) as a preliminary cap for their electron collider. For a 100-TeV hadron machine, says Ellis, “it’s premature to estimate. Everyone has in mind 10 billion of your favorite currency unit.”

Toni Feder

How much will it cost to destroy stockpiled US plutonium?

Lawmakers reject the Obama administration’s plan to suspend construction of a South Carolina plant for fabricating mixed-oxide nuclear fuel.

Mixing plutonium with an inert material—“downblending” it—and entombing it at the Waste Isolation Pilot Plant (WIPP) repository near Carlsbad, New Mexico, is the cheapest way to dispose of the surplus US fissile material. So says a recently released report from the US Department of Energy’s National Nuclear Security Administration (NNSA).

The report lists five options for how the US could meet the terms of a 2011 agreement with Russia. Under those terms, the two nations each agreed to permanently get rid of 34 metric tons of plutonium. In its fiscal year 2015 budget request, the Obama administration said that it intends to mothball a half-finished plant being built to transform the US plutonium into mixed-oxide (MOX) fuel for commercial nuclear re-

actors while it explores potentially less costly routes for disposal over the next 12–18 months (see *PHYSICS TODAY*, May 2014, page 18). The plant’s construction cost, estimated in 2007 at \$4.8 billion, has ballooned to \$8.7 billion.

The NNSA report estimates that combining the plutonium with materials to inhibit reuse and storing the mixture permanently underground would come to \$8.8 billion over the lifetime of the operation. By comparison, the projected lifetime expenditures for converting the plutonium to MOX fuel would be \$25.2 billion. The estimates include both capital and operational expenses, plus costs for preparing the plutonium metal. They do not include funds already spent. The downblending option was based on the assumption that the geological repository