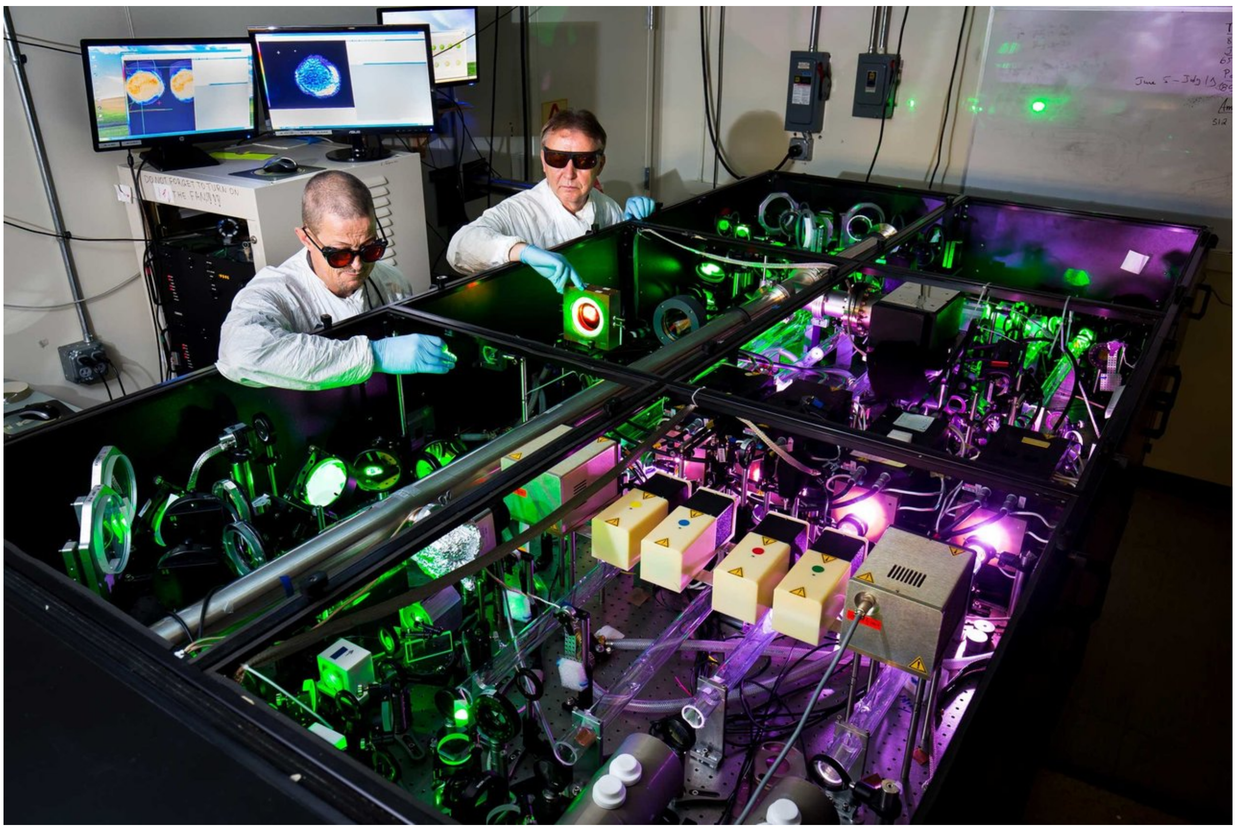
Doubling the power of the world's most intense laser

October 17 2017, by Contact Katherine Mcalpine



The HERCULES laser holds the Guinness World Records certificate for highest intensity focused laser, and it is about to get more powerful and intense with a $2M upgrade from the National Science Foundation. Credit: Joseph Xu, Michigan Engineering

The most intense laser in the world is about to get a power upgrade with

$2 million from the National Science Foundation.

With more laser energy to focus, researchers at the University of Michigan and collaborators from around the world can make better tabletop devices that produce particle and X-ray beams for medical and national security applications—and also explore mysteries in astrophysics and the quantum realm.

The power of the HERCULES laser comes from a series of five embedded "pump" lasers that amplify ultrashort pulses of light. To upgrade the power of HERCULES from 300 trillion watts, or terawatts (TW), to 500 or even 1,000 TW, the researchers will replace the final three of those pump lasers.

If HERCULES can achieve 1,000 TW, it would once again be among the most powerful lasers in the U.S. Regardless, the bump in power will up the ante on its intensity record—currently 20 sextillion (2x1022) watts per centimeter squared. The improved HERCULES should be able to double or even triple that intensity.

A decade ago, when engineers at Michigan first built HERCULES, the commercial pump lasers the system relies on couldn't reach the ambitious 300 TW—record-breaking at the time—that the researchers had in mind. They had to build their own pump lasers. Now, driven by a demand from international projects seeking power levels north of 10,000 TW, commercial pump lasers can outstrip the homemade versions that run in HERCULES today. This new technology is what will push HERCULES to higher power and intensity than ever before.

"This upgrade enables a wide variety of different experiments," said Karl Krushelnick, U-M professor of nuclear engineering and radiological science and director of the Center for Ultrafast Optical Science, which houses HERCULES. "There are these exciting applications, and it also opens up a new regime at the very frontier of plasma physics, where quantum phenomena start to play an important role."

This is what researchers have to look forward to:

- Tabletop accelerators: Conventional particle accelerators are often hundreds of yards long, but laser light can power the acceleration of particles and produce other high-energy beams such as X-rays in just a few square yards or less. In the future, laser-driven particle accelerators may help reveal new physics or drive ultra-compact X-ray lasers. Particle and X-ray beams can also be used to determine the presence of nuclear materials in shipping containers arriving at ports. They are used for medical treatments such as radiation therapy.
- X-rays that differentiate among soft tissues: High-energy X-ray beams emitted by laser accelerators could enable advanced X-ray imaging that can find the boundaries between soft tissues—as opposed to conventional X-rays, which are best at picking out dense materials like bone. When the X-rays from a laser accelerator travel through different materials, their waves get out of sync to different degrees, and this can distinguish between a lung and a heart, for example. This method of measuring would be cheaper and offer faster results than an MRI.
- Gamma ray bursts—astrophysical mysteries: How are flares of powerful electromagnetic radiation that last for no longer than a few seconds produced in space? One theory holds that very strong magnetic fields, near black holes for instance, may be breaking apart. When the magnetic field lines come back together they can accelerate particles that release these powerful bursts of electromagnetic energy in the form of gamma rays. By using the HERCULES laser in the lab, the team can create strong magnetic fields on microscopic scales that can break apart and reconnect in the same way, shedding light on whether this is

really the mechanism behind gamma ray bursts.

- Questions in strong field quantum electrodynamics: Quantum electrodynamics—the quantum description of light and its interactions with matter—hasn't been adequately tested in some extreme situations. For example, when electric fields are strong enough, the phenomenon of "boiling the vacuum" is predicted occur: matter and antimatter can spontaneously appear from nothing. Electric fields this strong may be found in neutron star atmospheres, for example. The upgraded HERCULES laser can simulate these environments by accelerating electrons to near the speed of light, so that—from the vantage point of the electrons—the fields are strong enough to generate particles from the vacuum. By looking at how the electrons behave, researchers can deduce whether the predictions of quantum electrodynamics are accurate.

Krushelnick anticipates that the expanded capabilities of HERCULES will enable researchers at U-M who specialize in these areas to do experiments that were previously impossible. In addition, HERCULES powers experiments for researchers around the U.S. and abroad, so the upgrade will make it more valuable as a national scientific resource.

Provided by University of Michigan

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