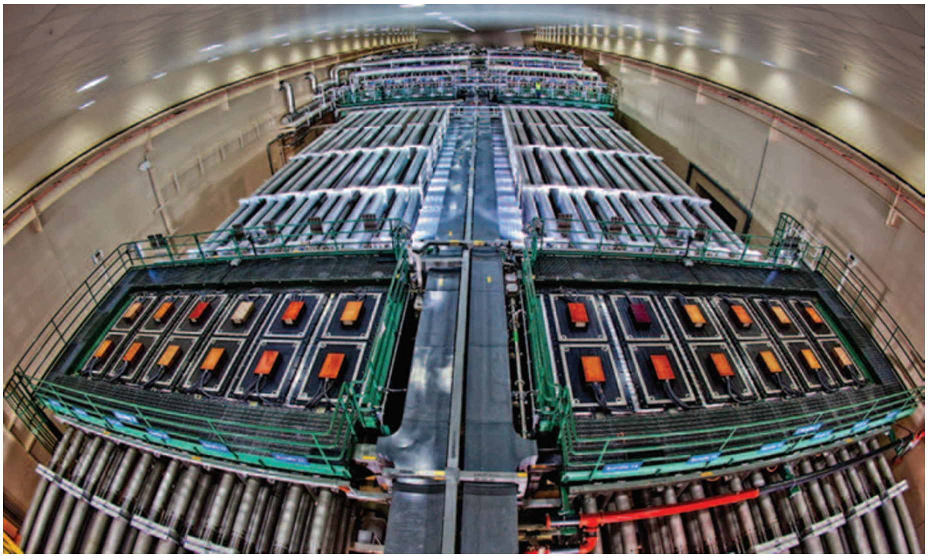
Laser fusion on the horizon

Could 2012 be the year that laser fusion becomes a reality? Progress at the National Ignition Facility in the USA certainly gives cause for optimism.

The achievement of laser-based fusion now seems to be a near-term realistic goal rather than a distant dream, following the latest news from the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory (LLNL) in California, USA.

Researchers at the NIF have just reported that the facility can finally operate at its design specifications, firing all 192 laser beams in unison to deliver an incredible 1.875 MJ of energy in 23 billionths of a second[1].

The milestone shot, which took place on 15 March 2012, means that the NIF is now the world's first 2 MJ ultraviolet laser, capable of generating 100 times more energy than any other laser in operation. More importantly, this result suggests that the elusive goal of igniting a fusion reaction in a compressed hydrogen-isotope fuel pellet could soon be within reach.


LLNL

Although researchers at the NIF have demonstrated similar energies using just one or four beams, this is the first time that such an energy has been achieved by firing all 192 beams simultaneously — a capability that is essential for ensuring the symmetric implosion required for fusion to take place.

This result sets the stage for a series of full-power experiments over the coming months. Excitement at the facility is now mounting, with some experts believing that laser-based ignition of a fusion reaction could be reported before the end of 2012. Success would not only represent a long-awaited and important scientific achievement, but also bring vindication for a long, expensive and much-criticized project that was plagued with problems in its early stages[2].

The NIF is currently firing around 40 shots per month, and experiments with ignition-type targets containing frozen hydrogen, which first started in September 2010, are ongoing.

Over the past 16 months, researchers at the facility have improved the quality of target capsule implosions by a factor of 100 (indicated by the number of neutrons produced) and have demonstrated symmetric implosions repeatedly at high degrees of compression while avoiding significant instabilities.

"Getting the implosion of fusion fuel exactly right to trigger ignition requires control of the laser, laser plasma interactions and hydrodynamic instabilities," explained Ed Moses, director of the NIF. "Over the past few weeks we have made continuing progress by improving the target implosion performance and overcoming physical challenges as they arise."

Moses says that they have managed to reduce the hundreds of different experimental factors involved down to four key variables — implosion velocity, central hot spot shape, fuel adiabat and mix — which can be controlled through the shape of the laser pulse and the materials and geometry of the target.

Researchers at the NIF are interested in the dynamic behaviour of the highly compressed hydrogen fuel, and are therefore currently investigating the pressure, mix and velocity late in the implosion process.

This news means that the NIF is now twice as energetic as it was three years ago, when 1 MJ operation was achieved in March 2009. Moses told *Nature Photonics* that the new level of performance is largely due to increases in the laser-induced damage threshold of critical optical components. The fused-silica optics located just before the target chamber are particularly vulnerable to laser-induced damage. Finishing processes during the fabrication of these components can introduce microscopic defects on the surface of the silica that act as damage precursors. The use of improved fabrication processes and acid-based etching has reduced the number of precursors, microfractures and chemical impurities on the surfaces of the optics, thereby providing higher damage thresholds.

Moses was candid when asked whether ignition is likely to be reported in 2012. He said that although recent experiments continue to show improvements in target performance and that everything is "proceeding according to plan", it is not possible to predict with certainty when ignition will be achieved. "We are encouraged by our progress, and this science exploration will continue whether or not we have achieved ignition by the end of the year," he said.

The NIF is also turning out to be useful for experiments in other areas of physics. In December 2011, a team of scientists from the University of California Berkeley, Princeton University and LLNL used a 20 ns, 750 kJ pulse from 176 beams at the NIF to compress a diamond sample to a record pressure of 50 Mbar. Their intention was to replicate the conditions at the centre of a planet much larger than Earth. Pressures at the core of planets can reach values ranging from 3.5 Mbar (Earth), 8 Mbar (Neptune) and 30 Mbar (extra-solar planets), to 40 Mbar (Saturn) and 70 Mbar (Jupiter)[3]. ❐

References

1. http://lasers.llnl.gov
2. *Nature Photon.* **3,** 177 (2009).
3. www.llnl.gov/news/aroundthelab/2011/Dec/ATL-120911_nif.html