Magnetic Fusion Simulations at NERSC Advance Fusion Research

In pursuing the potential of fusion energy, experimentalists try to understand precisely what is going on inside the fusion plasma so they can tune the system to improve the conditions that would lead to a sustained reaction. If the temperature can be kept high enough and the energy contained, net power can be produced. But determining exactly what is happening inside a fusion plasma is very difficult experimentally. A conventional probe inserted into the hot plasma is likely to sputter and contaminate the plasma, leading to a loss of heat. Non-intrusive diagnostics only measure the edges of the plasma, requiring scientists to try to deduce the conditions and the magnetic field structures in the interior of the plasma.

Using supercomputers to create detailed simulations of fusion plasmas is another method for "seeing" what is happening inside the plasma.

By running the NIMROD fusion code on DOE's National Energy Research Scientific Computing Center's (NERSC) IBM supercomputer "Seaborg" at Lawrence Berkeley National Laboratory, scientists working on the Sustained Spheromak Physics Experiment (SSPX) at Lawrence Livermore National Laboratory have achieved simulations which are very close to the observed results from actual runs on SSPX. These results give the researchers confidence in the accuracy of the simulations and increased understanding of the physics in the spheromak.

A technician adjusts the high-voltage lines that initiate the plasma in the SSPX.

"These simulations are very important for supporting our experiments," said LLNL's Bruce Cohen, a member of the SSPX collaboration led by Carl Sovinec of the University of Wisconsin-Madison. "The experimental team has been upgrading the capacitor bank used to drive the reactor, and our simulations confirm how careful tuning of the current pulses can improve plasma performance, such as achieving higher temperatures."

Although the physical spheromak design is simple, its dynamo activity produces plasma behavior that is extremely complex and more difficult to predict and control than that found in tokamaks, the most common approach to magnetic fusion. The SSPX is a series of experiments designed to determine the spheromak's potential to efficiently create and confine hot fusion plasmas.

"How high a temperature you can achieve and how well you can hold that heat in the plasma are two of the key points on the short list of things you want to understand and optimize in a fusion device," Cohen said.

With recent changes to their code, the Wisconsin-LLNL collaboration has created simulations with temperature histories measured in milliseconds that are closer to the temperature histories observed in experiments. This follows the group's prior success in simulating the magnetics of the experiment.

"We really need supercomputer resources to do these kinds of simulations, which involve massive calculations," Cohen said. Although the simulations cover only four milliseconds in physical time, there are 105 time steps involved in the simulations. As a result, the group ran each of their simulations in 50 to 80 shifts of 10 to 12 hours each on Seaborg, consuming more than 30,000 processor hours in each complete simulation; and multiple simulations were needed.