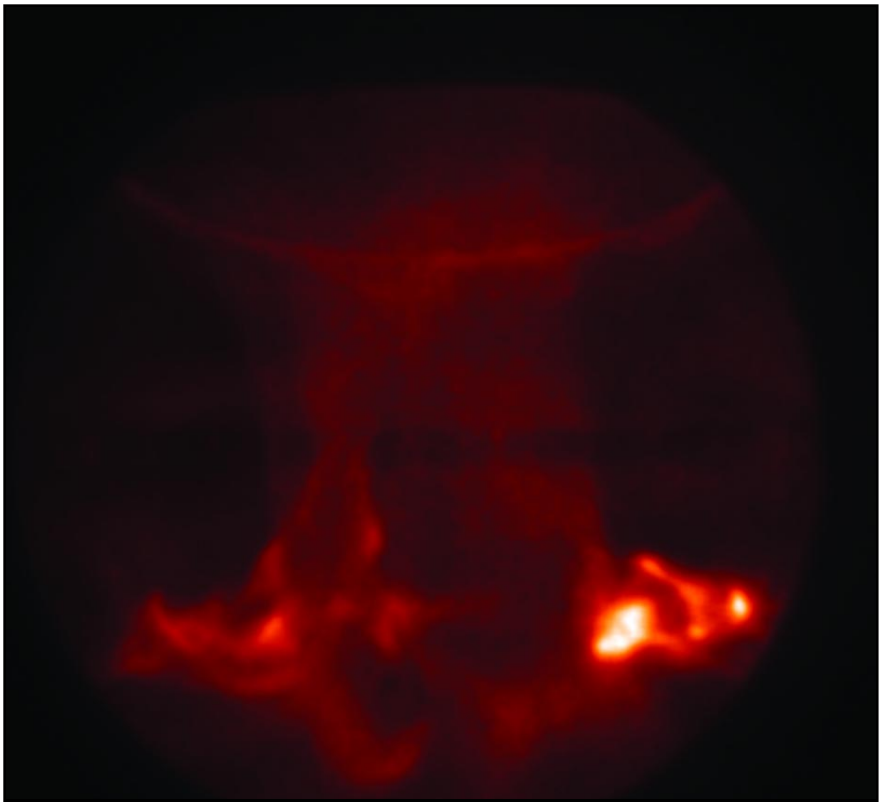
Camera Captures Spheromak Plasmas

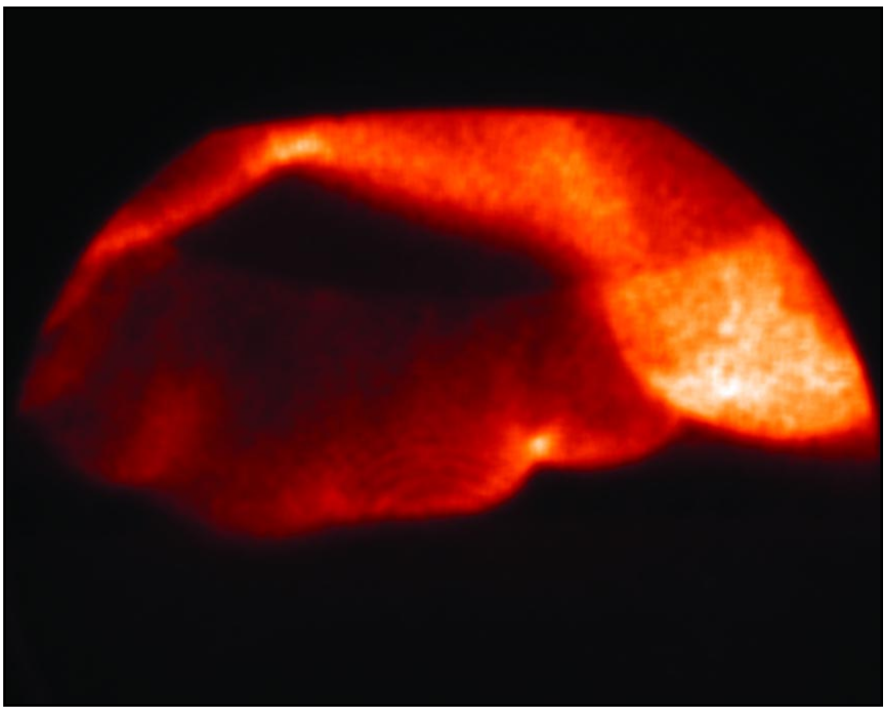
The promise of limitless, cheap and clean energy from thermonuclear fusion has been intriguing scientists for decades, and it is all the more enticing as we come to terms with the environmental hazards and limited supply of hydrocarbons.

Although a viable fusion reactor remains a dream, research in the field continues to mature, introducing novel plant designs. And imaging technology has a place in monitoring the performance of experimental prototypes of these designs.

First-generation reactors, whether based on magnetic confinement or on laser- or ion-driven inertial approaches, would compress deuterium and tritium into plasmas hotter than the center of the sun, producing helium-4 and neutrons. The process should release an estimated 3.4 $\times 10^{14}$ J/kg of fuel, some seven orders of magnitude greater than that from chemical reactions.

But bringing the theory into practice is no easy feat. "The basic problem with fusion plasmas is that the temperature at which fusion occurs is on the order of 100,000,000° and there is no material capable of sustaining such temperatures," said Carlos A. Romero-Talamás, a graduate student in Paul M. Bellan's plasma physics group at California Institute of Technology





Researchers at Lawrence Livermore National Laboratory are using the DiCam Pro high-speed intensified CCD camera from Cooke Corp. to image fusion plasmas in an experimental spheromak reactor.

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in Pasadena and a researcher with the sustained spheromak physics experiment at Lawrence Livermore National Laboratory in Livermore, Calif.

After funding was cut for more than a decade in favor of the doughnut-shaped tokamak, US scientists researching magnetic confinement are again studying the spheromak, which offers a potentially simpler and more economical design. “In spheromaks, magnetic fields are produced almost entirely by currents flowing within the plasma, and no expensive magnetic coil systems are needed,” Romero said.

Experiments are crucial in fusion research, he said, because the dynamics of the three-dimensional plasmas may be beyond the capabilities of computer simulation. In the Livermore study, the investigators monitor the density, temperature and turbulence of the plasmas, as well as the behavior of the magnetic fields, in the 1-m-diameter test device in order to develop an understanding of the essential physics.

Again, this is easier said than done. “The plasma moves extremely fast and is extremely short-lived,” Romero said. Although there is no need to synchronize the shutter and flash because the plasmas produce their own light, shutter speeds of 20 to 150 ns are necessary to capture the images in a typical experimental shot.

For the spheromak experiments, the researchers selected a high-speed 1280 × 1024-pixel intensified CCD camera with a shutter speed of 3 ns to 1000 s and a single-stage microchannel-plate intensifier. This is useful for imaging plasmas, which are very bright but also fleeting, making it challenging to collect enough photons to resolve the dynamics of the phenomena. The camera is a DiCam Pro from Cooke Corp.

Of course, fusion research does not live by one diagnostic modality alone, and the team employs several instruments to examine the plasmas at different stages of the 4-ms-long discharges. “Correlation of the images with other diagnostics (e.g., edge magnetic probes, voltage traces, H-alpha-line detectors, etc.) is also very useful,” he said, “and is helping to elucidate the physics of instabilities and other macroscopic changes.” □

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