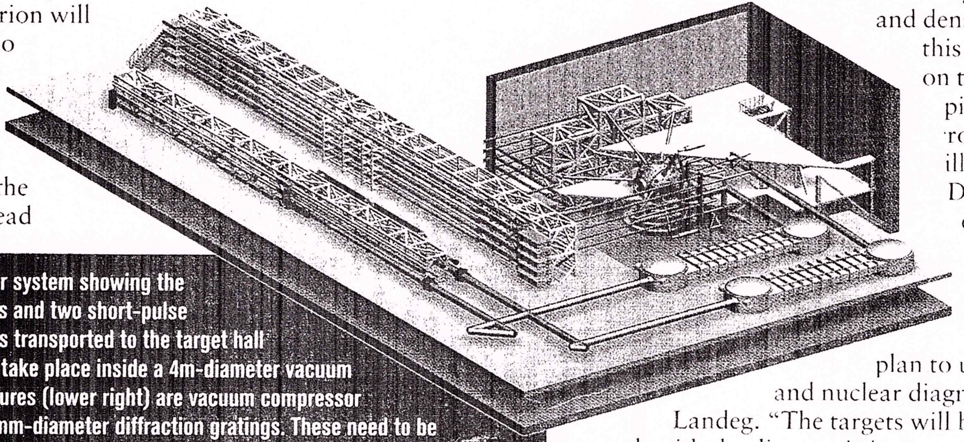
Target practice

The multi-million-pound Orion laser project aims to unlock some of the secrets of plasma physics, writes *Lee Hibbert*

As the long-standing home of the Atomic Weapons Establishment, the quiet village of Aldermaston in Berkshire is inextricably linked to the defence industry. That reputation will be bolstered further with the construction of an incredible £100 million laser project which will be used to generate extreme states of matter. The Orion facility will use extremely high-powered glass lasers to replicate conditions found at the centre of the sun or at the heart of a nuclear detonation, albeit on a minute scale. Its construction will push AWE forward to become the world leader in this type of research.



Model of the Orion laser system showing the 10 long-pulse beamlines and two short-pulse beamlines. Laser light is transported to the target hall where the experiments take place inside a 4m-diameter vacuum vessel. The large structures (lower right) are vacuum compressor chambers housing 600mm-diameter diffraction gratings. These need to be aligned to within 1 micro-radian. The ground floor (not shown in detail) houses the pulsed power system used to energise the laser

Aldermaston has had a laser test facility for more than 25 years. But the so-called Helen (High Energy Laser Embodying Neodymium) facility is reaching the end of its working life. According to Daryl Landeg, head of plasma physics at AWE, Orion will allow his team to do more sophisticated experiments, as part of Aldermaston's role as a safe home for the UK's nuclear warhead stockpile in the test ban era. "The new facility will allow us to perform world-class plasma physics research," he says. "It will enable us to undertake experiments at much higher temperatures and densities. Orion will also be used by the wider academic community on projects in areas such as fusion energy and astrophysics."

Research into laser plasma physics is essential to maintain the UK's nuclear warheads. AWE staff need a better understanding of the processes that occur during a nuclear explosion. There is a key requirement for fundamental data about materials to be obtained under comparable temperature and pressures. The data will be used to confirm theoretical understanding and validate computational models.

To simulate conditions in a nuclear warhead requires high temperatures and high densities to be achieved simultaneously. Orion will compress the target material using the pressure generated by its 10 long-pulse beams and then heat the target almost instantaneously with its petawatt beams. Then the materials will enter a plasma state which simulates conditions found in an operating nuclear warhead.

Orion will use neodymium-doped glass as the active lasing medium. This is the same technology as used on nearly all the world's large lasers including the US National Ignition Facility and France's Laser MegaJoule. A specialised technique, chirped pulse amplification, creates ultra-short-pulse laser beams.

The laser energy is generated in the infrared, but frequency converted to blue or green light using non-linear optics. The higher frequency light couples more efficiently to the laser targets. The facility will produce five times the amount of energy as AWE's existing laser, but 20 times the power. It will create the high temperatures and densities by focusing this energy in a vacuum on to tiny targets – pically less than 1mm ross – in 1,000 illionth of a second. Data is gathered by diagnostic instruments, which will monitor Orion's target chamber. "We plan to use optical, X-ray and nuclear diagnostics," says Landeg. "The targets will be in a vacuum vessel, with the diagnostic instrumentation around the outside, resembling a porcupine. We will be capable of doing several hundred laser firings each year."

As for safety, the obvious hazards are high voltages and intense laser light. These hazards are managed by containing them in special rooms and excluding people. The laser glass is activated by xenon flash tubes similar to those used in photography, but on a larger scale, and the tubes are driven by a high-voltage capacitor bank. When ultra-intense laser light interacts with material it can generate X-rays. So there is a concrete shield around the experiment hall. "We have decades of experience and none of these tests pose a hazard outside the facility," insists Landeg.

The laser will be housed in a building 100m long by 60m across. Its construction is posing challenges. "The optical componentry needs to be precisely located and aligned, which will involve micro-radian adjustments. The facility needs an extremely stable platform, so the foundation has to deal with the smallest vibrations. We are doing tests equivalent to firing a laser and hitting a 10p piece from a distance of 24km. So the mountings and components need to be very stable."

Photons and protons

When it is completed in 2010, Orion will employ 150 researchers and engineers. "The laser facility will deliver real advancements," says Landeg. "We are interested in how photons are transported through the plasma and just how compressible the plamas are. Theoretical models do not all necessarily agree. We need experimental data. The short-pulse laser will also generate proton and electron beams in a novel way. There is a lot of fundamental science to understand."