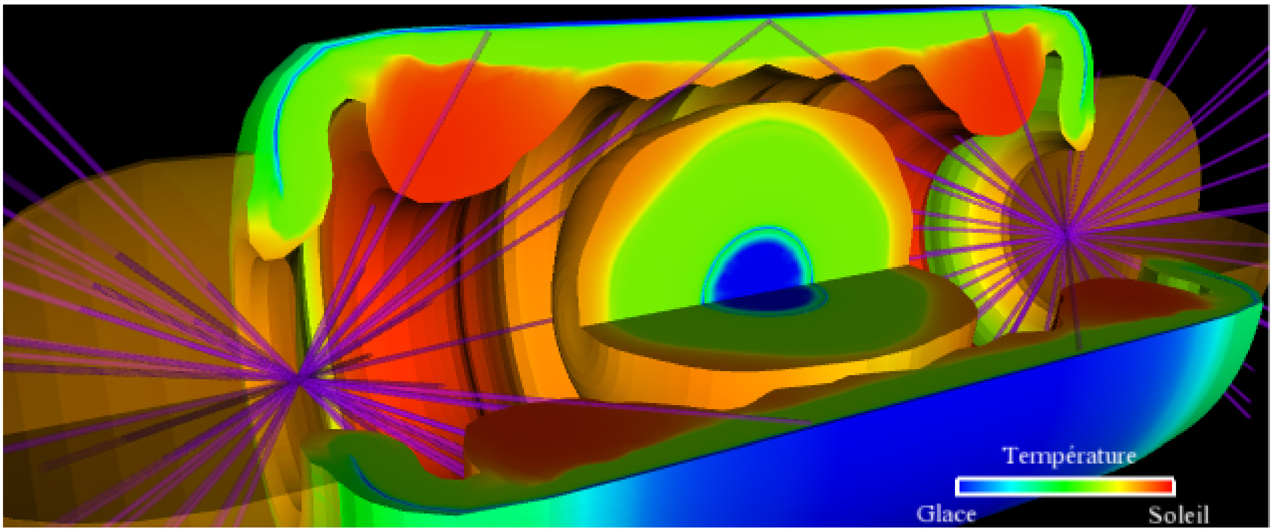
Simulation of a fusion experiment performed on the Megajoule Laser

The Megajoule Laser (LMJ) is a key component of the Simulation programme, intended to ensure the continuation of effective deterrence after the comprehensive ending of nuclear testing. It will also make it possible to validate physical models under temperature and pressure conditions which are currently inaccessible in the laboratory.

Experimental description

Nuclear fusion is a process where two atomic nuclei combine to form one heavier nucleus. The fusion of the two lighter nuclei releases enormous quantities of energy. To attain the fusion conditions, laser beams must be directed at a target which consists of a metallic cylinder at the centre of which is placed a spherical capsule. Inside a plastic shell, this microcapsule holds the fuel, an atomic mixture of Deuterium and Tritium, two of the isotopes of hydrogen. Several tens of milligrams of deuterium and tritium are present in the form of a solidified shell at very low temperature, containing a gaseous phase.
The microcapsule has a radius similar to the thickness of a one euro-cent coin. The gold cavity has a length similar to the diameter of the same coin. And yet, up to 240 laser beams must enter and carefully cross the distance between the two plastic windows at its ends.



The experiment starts with an implosion phase of the microcapsule. To cause the deuterium and tritium to fuse, the mixture must be taken to enormously high temperatures and densities.
To achieve this, the metallic cavity is heated by laser beams playing the role of an oven. Under the effect of the laser, the gold walls produce high-frequency electromagnetic radiation - x-rays - roughly comparable to a thermal bath of between 2 and 3 million degrees. This almost uniform x-ray radiation around the microcapsule heats the outer layer of the shell which evaporates abruptly. By reaction, the rest of the microcapsule is set in motion and moves towards the centre. This mechanism is called the "rocket effect" by analogy with the acceleration of a rocket by the violent expulsion of gases from its reaction engine. This compression gradually concentrates the fusible mixture at the centre of the microcapsule until temperature conditions are attained which are favourable to ignite the combustion. Locally, the matter is taken to several tens of millions of degrees, i.e. the temperature level encountered at the centre of the sun. Ignition, that is to say commencement of the fusion reactions, occurs in a small central volume, known as the hotspot, which has dimensions comparable to the cross-section of a hair. It is produced around nineteen billionths of a second after the start of the experiment.

This is now the start of the combustion phase. The laser, which delivered the energy to produce the implosion, can now be switched off.
All of this occurs in several tenths of 1 billionth of a second. The hotspot will play the role of a match. The entire fusible mixture very rapidly attains the ignition conditions. Combustion, which propagates throughout the microcapsule, generates an abrupt release of energy and, locally, temperatures that are 100 times higher than at the centre of the sun. By the end of the experiment, the energy that has been produced by the fusion reactions will be around 10 times greater than the energy initially delivered by the laser.

Numerical simulation can be used to evaluate the characteristics of the laser and the targets, and their requirements, and to improve understanding of experiments which take place under extreme conditions.

For further details, see: http://www-lmj.cea.fr/html/cea.htm