NRL scientists focus on light ions for fast ignition of fusion fuels

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Scientists at the Naval Research Laboratory Plasma Physics Division demonstrate significant progress in the efficiency and cost effectiveness of light ions in the fast ignition of fusion targets. Light ions such as lithium or carbon are easier to produce technologically and the ion beam properties can be manipulated and tailored best to suit the necessary requirements for fast ignition.

The fast ignition concept has been conceived as an alternative to other approaches for nuclear fusion energy. In the fast ignitor scenario a high-energy particle beam, driven by an ultrashort pulse laser, is deposited into a pre-compressed deuterium-tritium (DT) fuel capsule and creates a 'hot spot' with temperature and density parameters suitable for ignition, approximately 10 kiloelectron volts (keV).

Initially, the easiest path for ignition was taken using electrons, but it was soon recognized that numerous problems such as instabilities exists. The next logical step was to use ions, more specifically, protons. Subsequent experiments demonstrated that protons could be accelerated to relevant energies with conversion efficiencies of 5 to 10 percent and they were proposed as an alternative to relativistic electrons. However, the number of protons required for fast ignition is in order of magnitude two times greater than that of light ions that have a conversion efficiency of laser energy into ions of up to 25 percent.

"Presently, all efforts in the direction of fast ignition focus entirely on protons, but this continues to be plagued by problems," said Dr. Jack

Davis. "Our research strongly indicates that the use of light ions, heavier than protons, in the lithium to aluminum range is a path in the right direction for ignition."

For ions of the appropriate range, the beam energy can be deposited directly in the fuel, with high efficiency. In general, ion beams offer the advantage of more localized energy deposition, improved beam focusing, straight line trajectory while traversing the DT fuel, maximum energy deposition at the end of their range and suppression of the various kinds of instabilities.

The Ion stopping power — the gradual energy loss of fast particles as they pass through matter — results in a quadratic increase in the required ion kinetic energy relative to atomic number, but a decreasing number of these ions is needed to deliver the fast ignition hot spot energy, translating into a decreased irradiated spot size on the coupling target. The ionization density (number of ions per unit of path length) produced by a fast charged particle along its track increases as the particle slows down. It eventually reaches a maximum called the Bragg peak close to the end of its trajectory. After that, the ionization density dwindles quickly to insignificance.

Other considerations such as tailoring the ion energy and angular distribution, which are responsible for ion beam focusing and energy density deposition in time and space, may turn out to be more important for the practical realization of the fast ignition.

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