

# Landau's spark plug: Switch-like heating of compressing plasma

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*A mechanism to build in switch-like heating or magnetic field generation in plasma under compression has been proposed.*

Compressing plasma in inertial confinement fusion (ICF) experiments has been pursued using a number of techniques, including laser implosion, magnetized liner implosion, and Z-pinches. The plasma is heated to thermonuclear temperatures as a result of the extreme compression, leading to nuclear fusion. What is not addressed in the context of compressing plasma, however, is the extent to which waves embedded in such plasmas can accomplish useful tasks. Interestingly, although no specific implementation is suggested yet for ICF plasmas, it turns out that energy stored in waves might be amplified by compression and released rapidly in the form of heat at a predetermined instant precisely when the heat might be needed. This prediction is presented at the APS this year and soon to be published in *Physical Review Letters*.

Just like the gas in an internal combustion engine is heated as it is compressed by a piston, so is plasma heated when it is compressed. When a wave is embedded in a plasma, mechanical compression ultimately leads both to heating of the plasma and amplification of the wave, so long as the wave travels much faster than the particles in the plasma. However, most of the explosive increase in heat and pressure in the cylinder of an engine is achieved at a precise instant (when the fuel is ignited at peak compression), allowing the engine to do the most work. Interestingly, while heating of the plasma makes the constituent particles travel faster, the compressed wave actually slows down in phase velocity as it grows in amplitude. When the phase velocity slows down enough so that it is moving at roughly the same speed as the fastest particles, the wave very quickly damps on those particles through a process called "Landau damping," suddenly releasing all of its energy in a switch-like manner and causing the resonant particles to speed up dramatically. Consequently, an abrupt increase in the heat and pressure of the plasma can be achieved at a desired instant using this stored wave energy, analogous to the release of chemical energy occurring during combustion of the compressed air-fuel mixture in the engine. Simulations have revealed this process in detail, as can be seen in the figure.

A hot region will tend to cool down as heat diffuses to colder regions nearby, which can, for instance, hinder the process of igniting a target in ICF. This method of concentrating some of the energy in the form of waves as the plasma compresses allows that energy to be confined locally and converted to thermal energy only at the moment when it is most useful. Additionally, this switch-like effect can also be used as a way to induce sudden bursts of electrical current in plasma. The authors hope the potentially large utility of such a simple

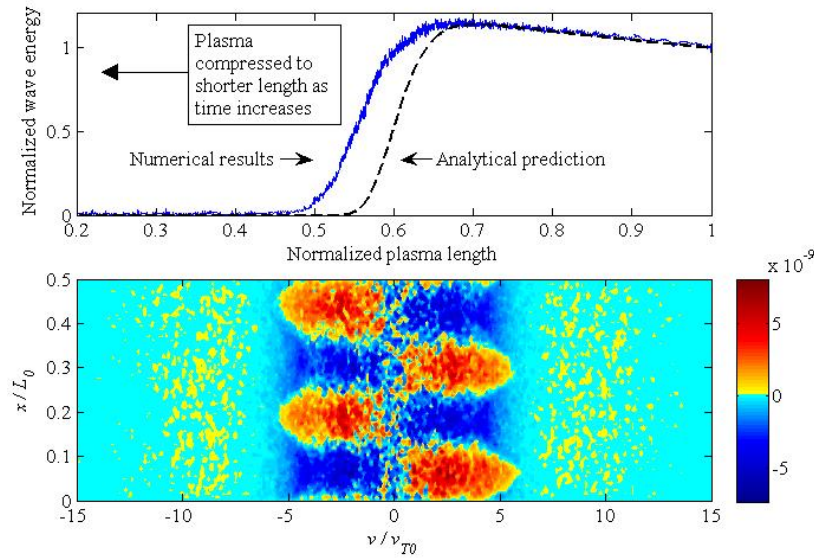


FIG. 1: Top - Wave energy in compressing plasma normalized to its initial energy according to numerical simulation (blue, solid line) and analytical model (black, dotted line). Bottom - snapshot, difference in electron density at various positions and velocities (normalized to initial system length,  $L_0$ , and electron thermal velocity,  $v_{T0}$ , respectively) between two similar compressed systems, one that had a wave and one that did not. Most wave energy is damped, though some periodic structure remains. Patches of particles (yellow) at high velocities indicative of switch-like heating.

phenomenon in plasma physics spurs a broader discussion within the field of many uses of waves in the context of compressing plasma.

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**Abstract TP9.00041**

**Controlling hot electrons by wave amplification and decay in compressing plasma**

Session TP9: Poster Session VII: Basic Plasma Physics

9:30AM-12:30PM, Thursday, November 11, 2010

Riverside West

**Abstract JP9.00064**

**Evolution of the bump-on-tail instability in compressing plasma**

Session JP9: Poster Session IV: Education and Outreach; Undergraduate and High School Research

2:00PM-5:00PM, Tuesday, November 9, 2010

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