frontiers in Physics

EDITORIAL
published: 15 January 2021
doi: 10.3389/fphy.2020.625164

Editorial: Non-Local Thermodynamic Equilibrium (NLTE) Hydrogen–Boron Fusion

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Keywords: proton–boron fusion, non-local thermodynamic equilibrium, laser plasma, clean energy, alpha particle

OPEN ACCESS

Edited and reviewed by:
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Specialty section:
This article was submitted to Interdisciplinary Physics, a section of the journal Frontiers in Physics

Received: *02 November 2020*
Accepted: *11 November 2020*
Published: *15 January 2021*

Citation:
Eliezer S, Hora H, Martinez Val JM, Belloni F and Nissim N (2021) Editorial: Non-Local Thermodynamic Equilibrium (NLTE) Hydrogen–Boron Fusion. Front. Phys. 8:625164. doi: 10.3389/fphy.2020.625164

Editorial on the Research Topic

Non-Local Thermodynamic Equilibrium (NLTE) Hydrogen-Boron Fusion

The HB^{11} reaction creating 3 α particles was attractive from the beginning of research in terrestrial fusion energy applications because no neutrons are produced in this case. However, the reactivity $<\sigma v>$ (σ is the fusion cross section and v is the relative velocity between reacting species) of HB^{11} fuel at temperatures of 20 keV is five orders of magnitude less than that of deuterium–tritium (DT) fuel. The $<\sigma v>$ of HB^{11} at about 600 keV reaches a rate comparable to that of DT at 20 keV. The 600 keV temperature is extremely high for a laboratory reactor. This seems to be the main reason why the HB^{11} clean fusion was neglected on the road to achieve a clean and safe solution to the energy problem, while most of research and development was done for DT fusion.

Recently, in a series of publications, it has been suggested that for the HB^{11} case, we do not need to reach a local thermal equilibrium (LTE) at such a high temperature before fusion becoming viable. Thanks to the development of lasers, we can effectively accelerate protons in a plasma, inducing the HB^{11} interaction at its maximum cross section, at about 600 keV center-of-mass energy. In addition, the reaction yield might increase significantly without reaching extremely high temperatures because of a further non-LTE (NLTE) effect. Indeed, it has also been suggested that the avalanche or chain reactions based on suprathermal ions energized by elastic scattering with the α′s may play an important role in increasing the yield of fusion reactions.

The controlled nuclear fusion reactor suffers from the need of thermal pressures at the temperatures of hundreds of million Celsius requested for ignition. Frontiers is publishing five articles about proton–boron nuclear fusion in the NLTE regime. In the following five articles, research is done to check the physics principles for the novel idea that a fusion reactor can be achieved by nonthermal conditions without the need for heating up to temperatures as high as in the center of our Sun.

These articles are as follows:

1) Margarone et al. report the measurements of energetic α-particles produced *via* proton–boron fusion at the Institute of Laser Engineering of the University of Osaka. The reaction was induced by the short pulse of a high-intensity, high-energy, PW-class laser. The laser pulse was focused onto a thin plastic foil to generate a proton beam which impinged onto a boron–nitride (BN) target to produce the α particles. The α particles with energies in the range 8–10 MeV have a flux of about 5×10^9 sr^{-1}.

2) Kovacs et al. have used a KrF laser with 700 fs pulse duration and a temporal contrast of 12 orders of magnitude to measure plasma velocities above $5 \times 10^5\,\mathrm{ms}^{-1}$. In these experiments, the laser pulse had an irradiance higher than $10^{18}\,\mathrm{W\ cm}^{-2}$ and interacted with the surface of boron and gold targets. Brunel absorption and ponderomotive effects are shown to play an important role in the observed phenomena.
3) The article by Krása and Klír is related to the difference between thermal and nonthermal pressures at laser–plasma interaction. This is an important contribution to the interpretation that the highly increased neutron yield by a factor ten thousand as measured earlier with ps CPA pulses indicates nonthermal reaction conditions.
4) The article by Eliezer et al. is focused on a basically new scheme for HB11 fusion by high-power lasers or by accelerators where a proton beam is created, which then interacts with a gas medium or a low temperature plasma. This configuration shows that a nonsolid density plasma can also provide conditions different from thermal equilibrium for HB^{11} fusion. The mitigation of the stopping power with an external electric field is analyzed.
5) The article by Consoli et al. presents a comprehensive summary of the rather complicate diagnostics of the HB^{11} fusion reaction, at both low and high projectile energy.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.