Laser and particle beam interaction with ionized matter and perspectives for fusion energy

Dieter HH Hoffmann¹,²

¹Xi’an Jiaotong University, School of Science, Xi’an, China
²Technical University Darmstadt

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兰州重离子加速器
国家实验室
（1991年国家计委批准成立）

IMP Lanzhou

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Hefei Synchrotron

Institute of Applied Nuclear Physics

HIAF
Programme

- Energy loss of Ions in Plasma
- Laboratory Astrophysics
- Proton Boron Fusion
- Outlook
First Experimental Evidence for the Significant Contribution of Projectile Excited States to the Stopping of Slow Helium Ions in Hydrogen Plasma

Yong-Tao Zhao, Yan-Ning Zhang, Bin He, Rui Cheng, Chun-Lei Liu, Xian-Ming Zhou, Jie-Ru Ren, A. A. Golubev, and 霍迪
Energy Loss Calculation

\[ S = \sum_i P(i)S(i) = \sum_i [P(i)S_b(i)n_b + P(i)S_f(i)n_f] \]

\[ S_f = \frac{e^2}{\pi v_p^2} \int_0^\infty \frac{dk}{k} |Z_p - \rho(k)|^2 \int_{-kv_p}^{kv_p} d\omega \omega \text{Im} \left( -\frac{1}{\varepsilon(k,\omega)} \right) \]

\[ \Delta E = \int S dx \]
Benchmark Experiment to Prove the Role of Projectile Excited States Upon the Ion Stopping in Plasmas
Anomalous stopping of laser-accelerated intense proton beam in dense ionized matter

Jieru Ren, Zhigang Deng, Wei Qi, Benzheng Chen, Bubo Ma, Xing Wang, Shuai Yin1, Jianhua Feng, Wei Liu, Zhongfeng Xu, 霍迪, Shaoyi Wang, Quanping Fan, Bo Cui, Shukai He, Zhurong Cao, Zongqing Zhao, Leifeng Cao, Yuqiu Gu, Shaoping Zhu, Rui Cheng, Xianming Zhou, Guoqing Xiao, Hongwei Zhao, Yihang Zhang, Zhe Zhang, Yutong Li, Dong Wu, Weimin Zhou & Yongtao Zhao
Laboratory Observation of C and O Emission Lines of White Dwarf H1504+65-like atmosphere model

Bubo Ma, Jieru Ren, Zhigang Deng, Wei Qi, 霍迪, Shangyi Wang, Rui Cheng, Quanping Fan, Yong Chen, Yongtao Zhao
Experiment set up at the XG-III laser facility of Laser Fusion Research Center in Mianyang
02. Experimental Set up

- **Laser**: ns-150J, 2ns, 100μm, 532nm;
- **Target**: Hohlraum diameter-1mm, C₉H₁₆O₈ foam, density- 2mg/cc,
- **Detector**: TGS \ PH \ XRD \ FGS

The high resolution flat grating spectrometer (FGS) is used to plasma diagnostic.
Plasma generation and diagnostic

Well characterized plasma target and X-ray diode diagnostics

The XRD signals indicate that the effective heating time of the Hohlraum X rays is about 6ns
Plasma diagnostic

plasma temperature diagnostic (Flat-field grating spectrometer)

The Boltzmann plot of the spectral-lines indicated the foam plasma temperature is \( \sim 17 \text{eV} \)

According to FLYCHK, The average ionization degree is about \( C^{3.8+}H^{0.98+}O^{4.5+} \), \( n_e=4\times10^{20} \text{ cm}^{-3} \)
Identification and comparison in 10-13nm

- Consistent O VI position with the strongest intensity

The identified Ne lines may contain the contribution of O V. Two O V lines predicted by the model at 11.910 nm and 12.461 nm are observed.
A plasma sample with a similar temperature and composition ratio as the white dwarf was created in the laboratory.

Our result filled the gap of white dwarf in the 14-80 nm and provides support for the line identifications and model benchmark.

Our method of creating a well-defined, long-living uniform plasma sample will also be applied in laboratory astrophysics in the future to study a broader range of cosmic conditions.
Energy from Nuclear Fusion and the p11B Project

霍迪  Dieter HH Hoffmann
on behalf of p11B project team of

Xi’An Jiaotong University, School of Physics, Xi’An, China
PI: Yongtao Zhao
Hebei Key Laboratory of Compact Fusion, Langfang 065001, China

ENN Science and Technology Development Co., Ltd., Langfang 065001, China
CSO: Martin Peng

Institute of Modern Physics, CAS, Lanzhou, China
PI: Rui Cheng
Shanghai Inst. Of Applied Nucl. Phys., Shanghai, China
PI: Guoqiang Zhang
The p11B fusion project

Boron: $10.811 \text{ g/mol}$, $Z = 5$

$^{11}\text{B} \approx 80\%$  $^{10}\text{B} \approx 20$

$\rho = 2.34 \text{ g/cm}^3$;
Melting point 2349 K
Cost per kg about 2200€

$650 \text{ mg} \cdot \text{kg}^{-1}$ ($\text{LD}_{50}$, Rats, oral)
Simulated r-abundance normalized to solar

R-process simulation for Boron by Bowen Jiang (GSI)  
28.07.2021

<table>
<thead>
<tr>
<th>Element</th>
<th>Simulated r-abundance</th>
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<tr>
<td>B</td>
<td>5.101980e-09</td>
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<td>Ba</td>
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<td>3.304903e-10</td>
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Neutron Star Merger (figure from Wikipedia)
The p11B Fusion Reaction at $E_o = 612 \text{ keV}$
New Measurements of Cross sections

High Voltage Platform and Beamline at XJTU

Yang Li VIII-1 May 30th, ICMRE 2019
We need data on:

H11B fusion cross section up to 6 MeV

Boron Plasma opacity

EOS of Boron

Energy loss of Alpha particles in burning H11B plasma