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Stagnation and Interpenetration of Laser-Created Colliding Plasmas

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KMS Fusion
Ann Harbor, MI 48106

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KMS Fusion

Abstract

A KMS laser experiment collides Aluminum (Al) and Magnesium (Mg) plasmas. The measurements include electron density, time and space resolved Ly-alpha and He-alpha lines of Al and Mg, and x-ray images. These measurements were analyzed with a hydrodynamic code, LASNEX, and a special two-fluid code OFIS[1]. The results strongly suggest that at early times, the Al interpenetrates the counterstreaming Mg and deposits in the dense Mg region. At late times, the Al plasma stagnates against the Mg plasma.

Experiment

Two opposing disks, one Mg and one with a 1 to 2-micron thick 125-micron diameter dot of Al mounted on CH, were irradiated with 100 J of 0.53 micron light from the KMS CHROMA laser (figs. 1 and 2). The disks were separated by 400 microns, the pulse length was 0.7 to 1.3 ns, and the laser intensity was 0.5 to 1.0 * 10^{14} W/cm2. The disks were arranged so that the expanding Al plasma collided with the expanding Mg plasma in order to see the extent to which the plasmas interpenetrated each other. The experiment was monitored by x-ray pinhole cameras, an x-ray framing spectrograph, and holographic interferometry to measure electron density.

Pinhole images, shown in fig. 3, show x-ray emission reulting from the plasma collision. A gated spectrograph with an imaging slit clearly shows the Ly-alpha and He-alpha lines from H-like and He-like Al and Mg (fig. 4). Midplane ion temperatures of 10 to 20 KeV were calculated from the spectral line widths (fig. 5). The He-alpha to Ly-alpha line ratios imply that the electron temperatures increase towards the midplane to a maximum of 700 to 800 eV (fig. 6).

In this poster session we concentrate on the variation of He-alpha and Ly-alpha Al lines with distance from the Al target at 640 ps, 1060 ps and 1270 ps (fig. 7). Most of the emission comes from the initial position of the Al target. At 640 ps, one can see a prominent bump in both He-alpha and Ly-alpha emission about 50 microns from the initial Mg surface. At later times, this bump disappears and instead we see emission from the midplane, where the Al and Mg plasmas would stagnate against each other. These features are explained, at least qualitatively, by interpenetration at early times and stagnation at later times.

Modeling the Experiment

We modeled the experiment with two codes: LASNEX, which has much of the detailed physics but can only model stagnation, and OFIS, which can model both stagnation and interpenetration but lacks electron and ion conduction, radiation transport, and the process of laser absorption. Both two-dimensional and one-dimensional LASNEX simulations show that the plasmas begin to stagnate at 400 ps. Al line emission peaks strongly in the stagnation region, and as expected in a one-fluid code, no Al line emission is seen beyond the midplane. In this poster session, we concentrate on the results of OFIS because of its ability to model both the case of stagnation and the case of interpenetration.

OFIS is a one-dimensional two-fluid code that allows two electron temperatures and an ion temperature but has no laser absorption, radiation transport, electron conduction or ion conduction[1]. It assumes an ideal equation of state. In our simulation, two disks of pure Al separated by 600 microns expand due to a 0.145% 800 eV electron component in a 10 eV background. These parameters were selected to match the experimental value of 800 eV electron temperature and an electron density of about $7*10^{20}$ /cc observed 100 microns from the midplane at 800 ps (fig. 8).

Figure 9 shows the electron and ion density profiles in the case of stagnation. In the code, the ionization has been set to 11.5, so that the electron density is just 11.5 times the ion density. Figure 10 shows the electron and ion density profiles in the case of interpenetration. The electron density is symmetric about the midplane, and is similar to what is seen in the case of stagnation except that the density spikes near the midplane are gone. The ion densities are similar to the case of stagnation within 150 microns of the initial location of the Al. However, in the case of interpenetration, no midplane density spike appears except at late times, when the plasmas are stagnating against each other. At 650 ps, a prominant density spike appears near the opposite plate. This spike arises from the Al plasma that penetrates the opposing stream and deposits in the dense material of the opposite plate.

The output from OFIS, consisting of electron and ion densities and temperatures as a function of time, were run through DSP, a spectroscopy postprocessor developed by C.Keane, R.Lee and J.Grandy[2]. DSP calculates the Al populations for 10 H-like levels, 19 He-like levels, 25 Li-like levels, and 11 other ionization states based on non-LTE rate equations. It then calculates the opacities and emissivities in up to 2000 photon bins based on the level populations. Figures 11 and 12 show the spatial variation of emission in the He-alpha and Ly-alpha lines in the case of stagnation and interpenetration, respectively. As expected, in the case of stagnation, a big spike in emission comes from the stagnation region near the midplane with no emission beyond that. In the case of interpenetration, at t = 650 ps there is a strong spike in emission coming from the opposite plate that becomes less prominant at later times. At 950 ps, one can see increased emission coming from stagnation at the midplane. These figures are to be compared with figure 7, which shows the experimental results.

Discussion and Conclusions

The details of how the interpenetrating ions are slowed down and captured in the dense counterstreaming plasma are not done correctly. Thus the calculations of level populations and line emission from the ions as they stagnate and termalize are qualitative at best. As can be seen in figure 13, the Al ions are mostly fully stripped as they interpenetrate the opposing stream of ions. As they slow down and thermalize, both the colder electron temperature and the higher electron density they encounter decrease the ionization state of the Al ions and they emit He-alpha and Ly-alpha lines. Evidence of this is seen in the experiment. We conclude that our experiment and calculations strongly suggests that at early times, the Al plasma penetrates the counterstreaming Mg plasma and deposits in the dense regions. At late times, the Al plasma stagnates against the Mg plasma. We are now improving our codes, and hope to do an improved interpenetrating experiment on the NOVA laser.

References

1. R.Berger, J.R.Albritton, and C.J.Randall, "Stopping and Thermalization of Interpenetrating Plasma Streams", 1986 Laser Program Annual Report, Lawrence Livermore National Laboratory, pp. 2-41 to 2-49.
2. C.J.Keane, R.W.Lee, and J.P. Grandy, "Detailed K-shell Spectroscopy Postprocessor (DSP)", International Workshop on the Radiative Properties of Hot Dense Matter, Sarasota, Florida, Oct. 22-26, 1990.

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LLNL

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Thirty-Second Annual Meeting of the Division of Plasma Physics, Cincinnati Ohio

Nov 12 1990

Significant contributions were made by

- <u>Experimenters</u>
  - R. Bosch, G. Busch, G. Charatis, B. Failor, E. Gabl
- <u>Theory and Modeling</u>
  - N. Delamater, J. Albritton, R. Kaufmann, C. Keane, Y. Lee, S. Pollaine, R. Berger
- <u>Data Acquisition and Reduction</u>
  - Chroma Laser and Diagnostic Groups

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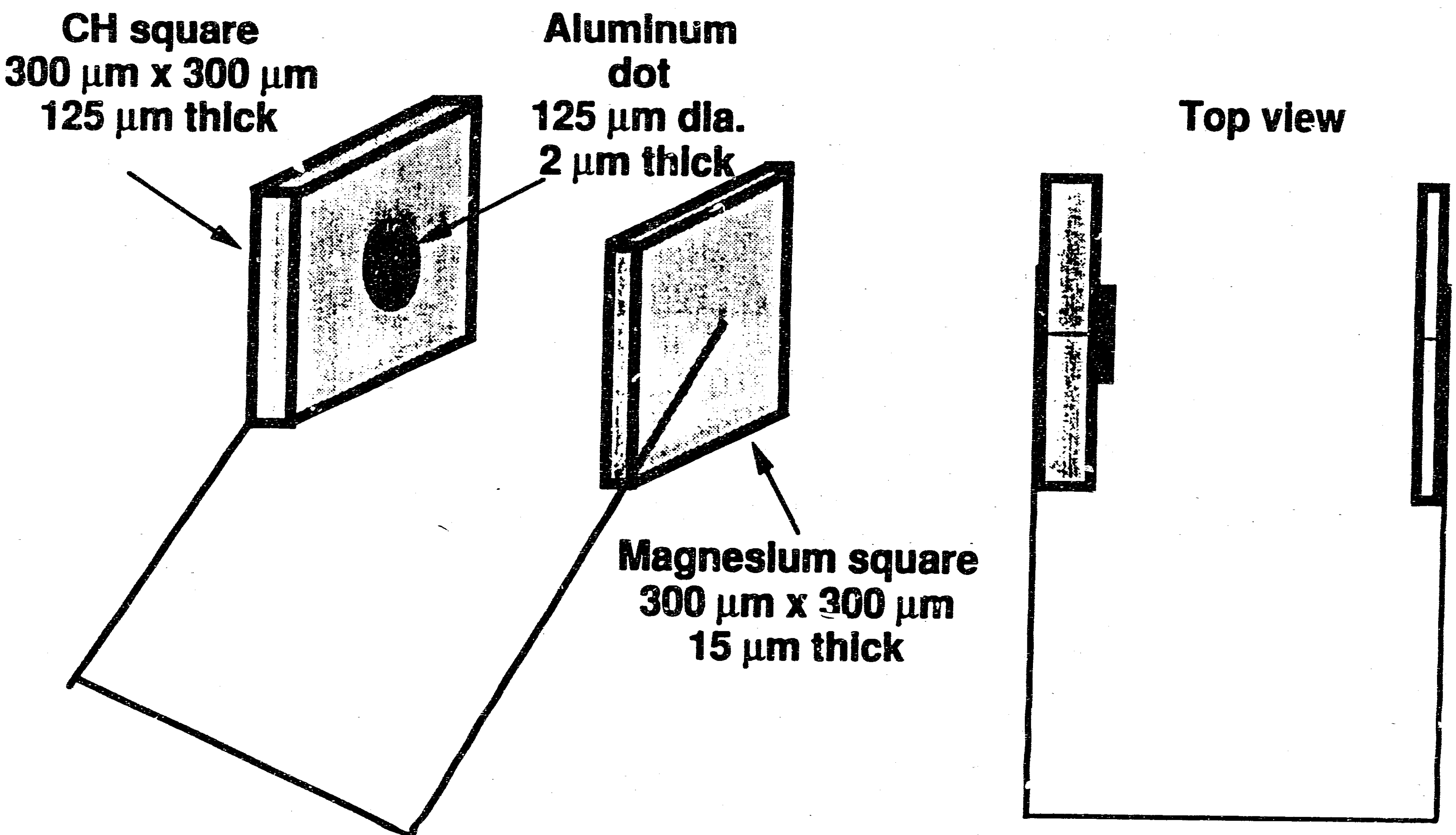
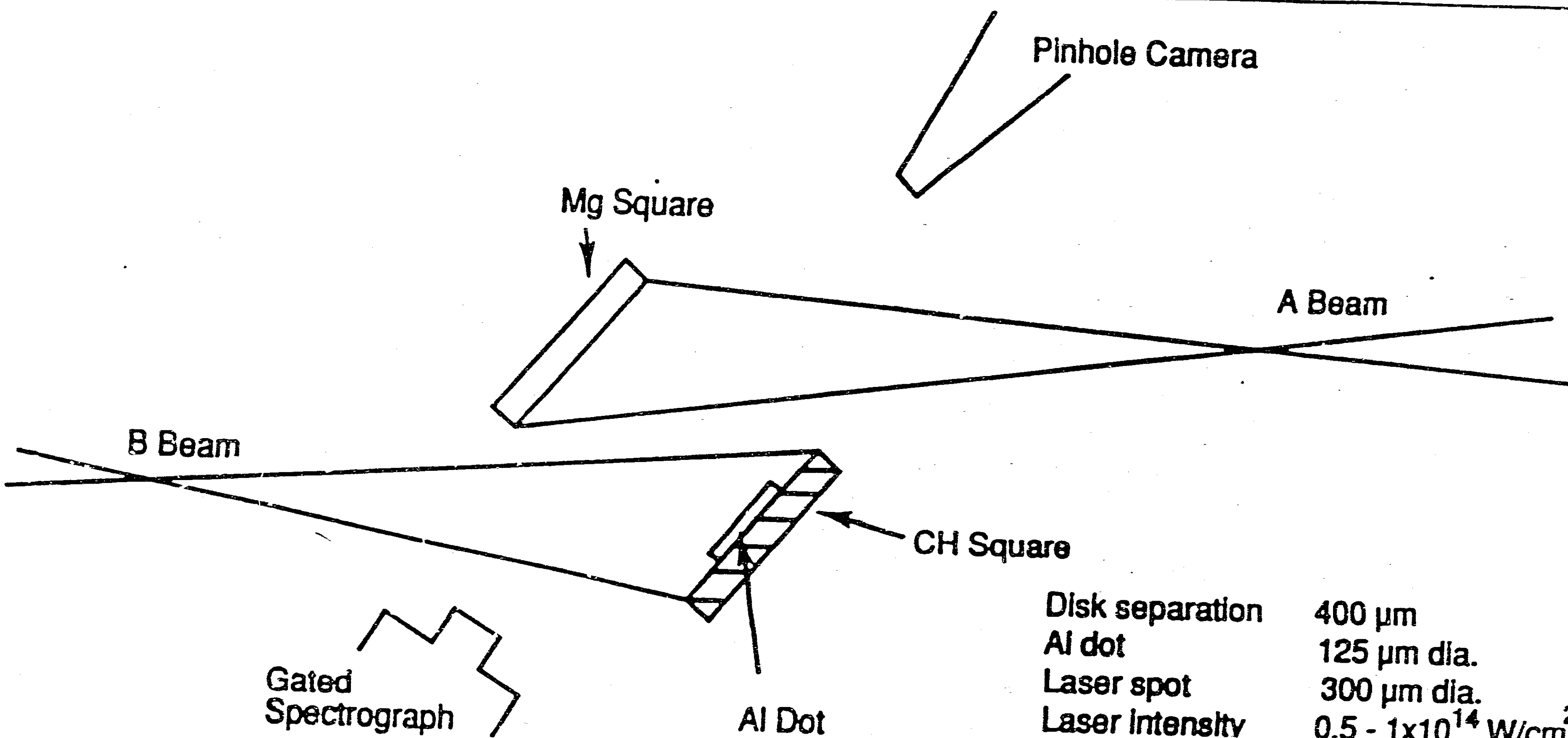
Abstract

A KMS laser experiment collides Aluminum (Al) and Magnesium (Mg) plasmas. The measurements include electron density, time and space resolved Ly-alpha and He-alpha lines of Al and Mg, and x-ray images. These measurements were analyzed with a hydrodynamic code, LASNEX, and a special two-fluid code OFIS[1]. The results strongly suggest that at early times, the Al interpenetrates the counterstreaming Mg and deposits in the dense Mg region. At late times, the Al plasma stagnates against the Mg plasma.

The primary Collisionality targets were double arm targets



Opposing disks were irradiated at λ=0.53 μm using the CHROMA laser



Disk separation	400 μm
Al dot	125 μm dia.
Laser spot	300 μm dia.
Laser intensity	0.5 - 1×10^{14} W/cm^2
Pulse length	0.7 - 1.3 ns

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Collisionality diagnostics

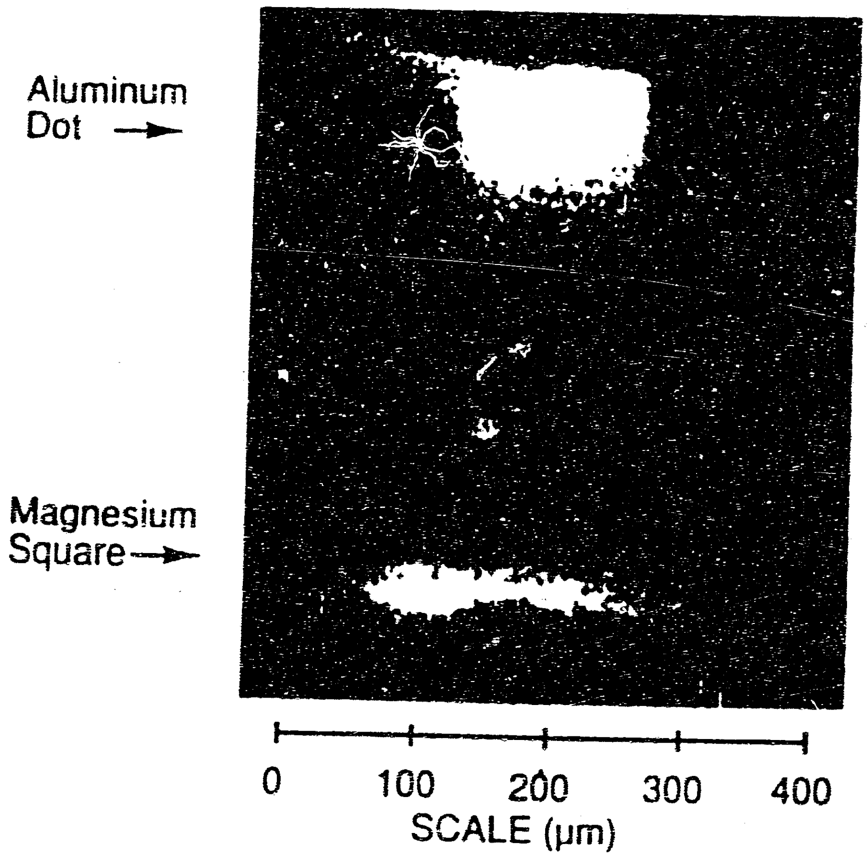
Laser:

- energy on target
- pulse shape

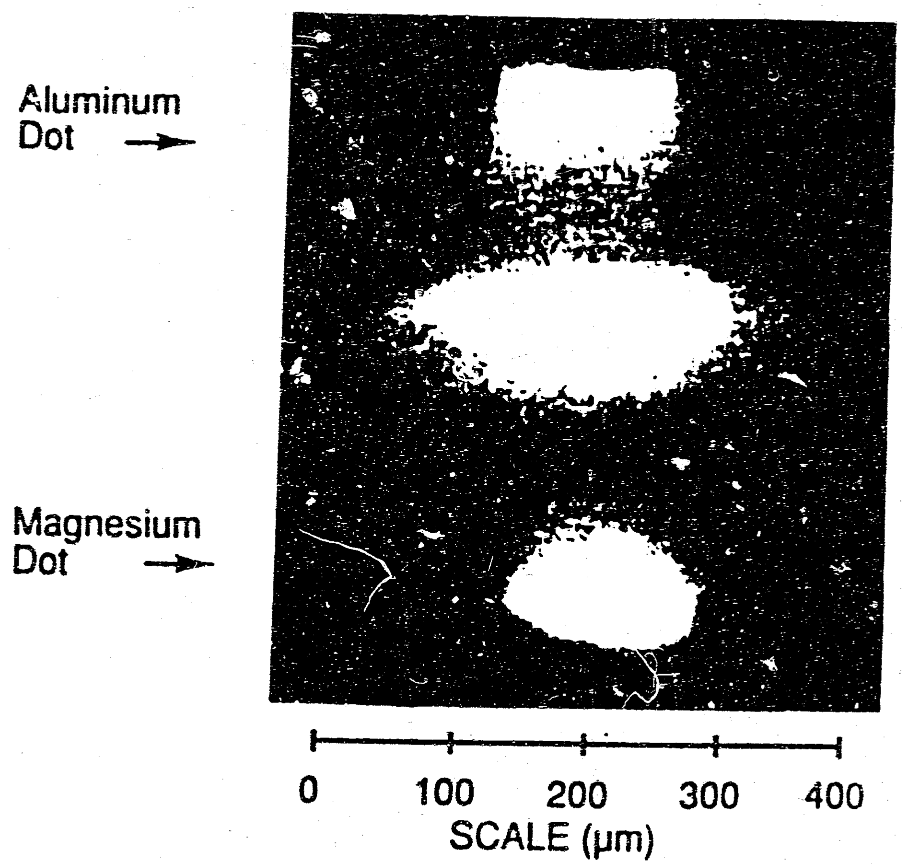
Target:

- x-ray pinhole cameras
- x-ray framing spectrograph
- holographic interferometry

Pinhole images show x-ray emission resulting from plasma collision

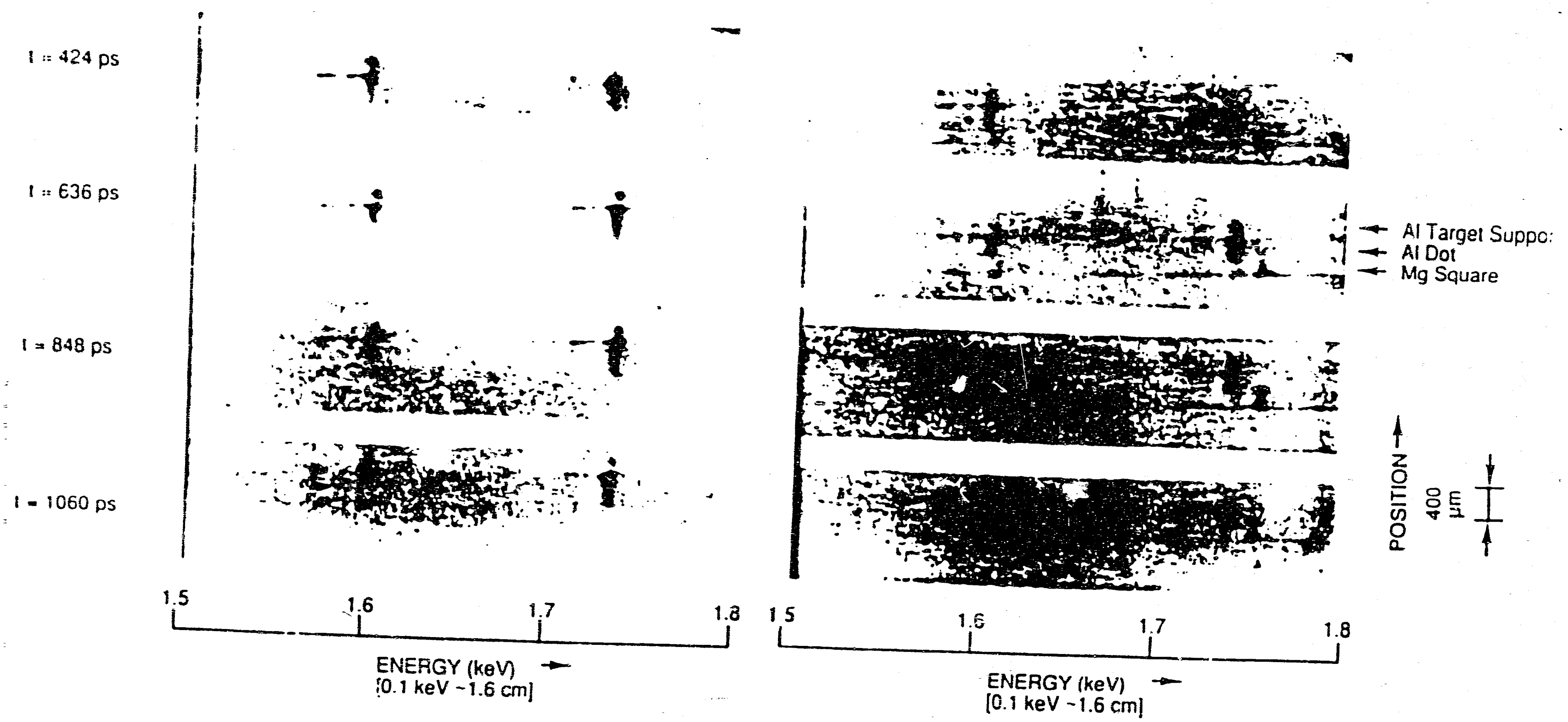


aluminum target illuminated



both targets illuminated

Colliding plasmas were observed using a gated spectrograph with imaging slit

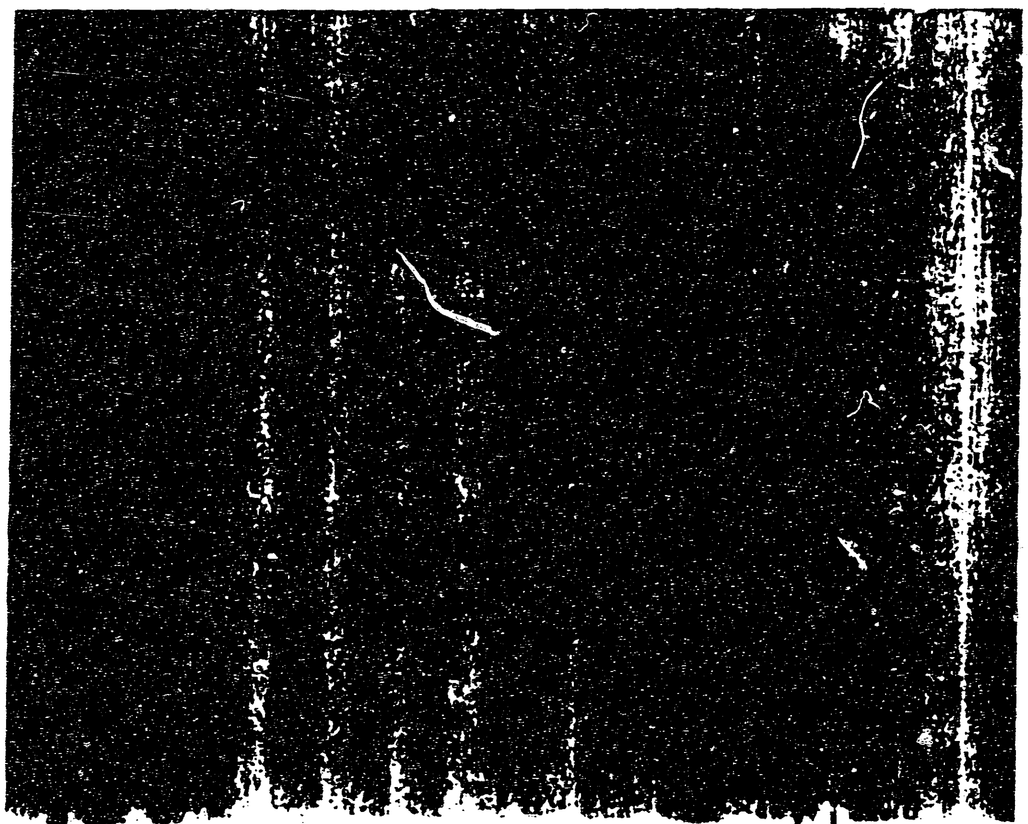


aluminum target illuminated

both targets illuminated

The spatially resolved Ly_α and He_α emission from Al shows the interpenetration and stagnation

100 ps Framewidth.



Laser pulse = 1.3 ns

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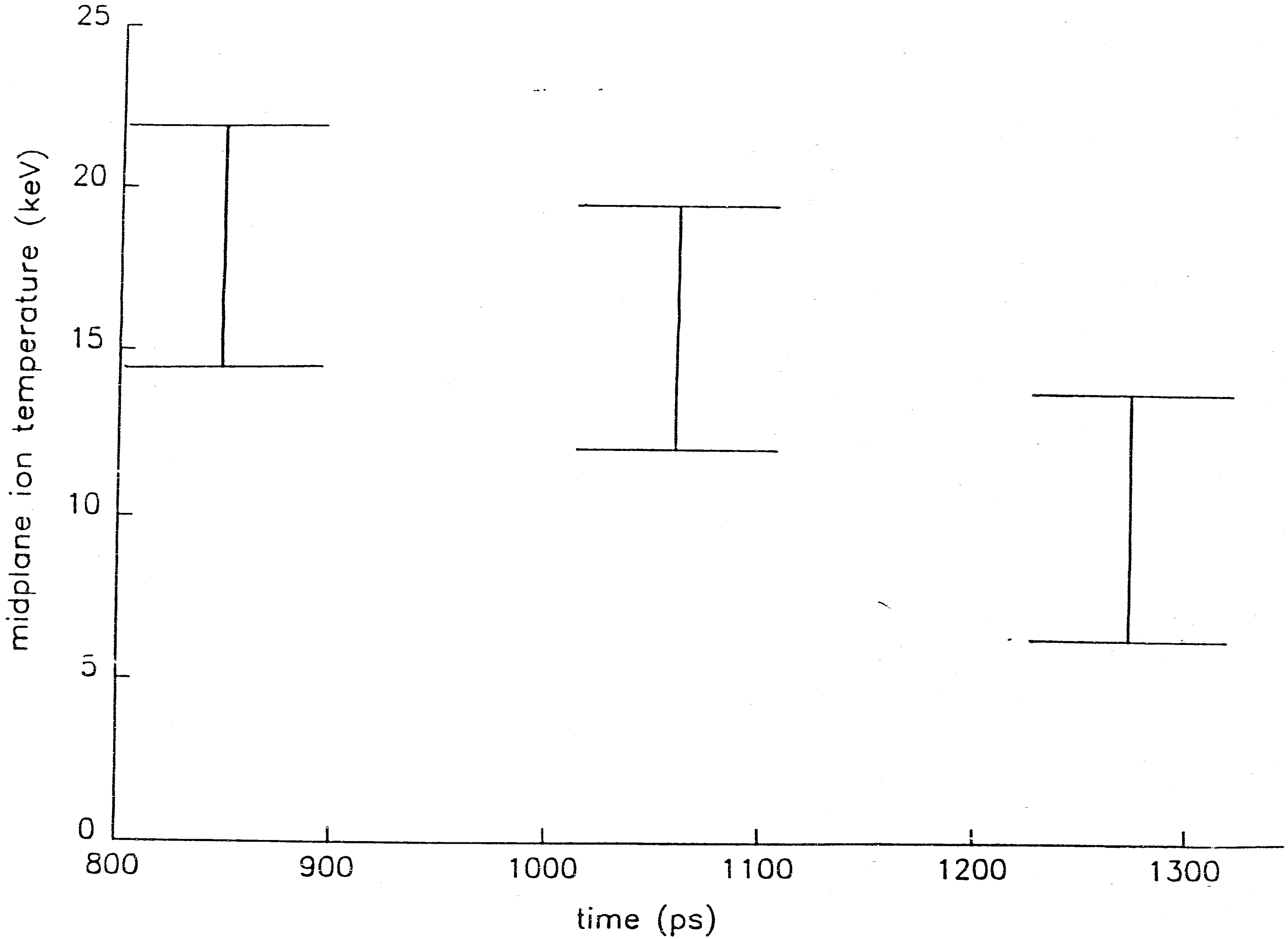
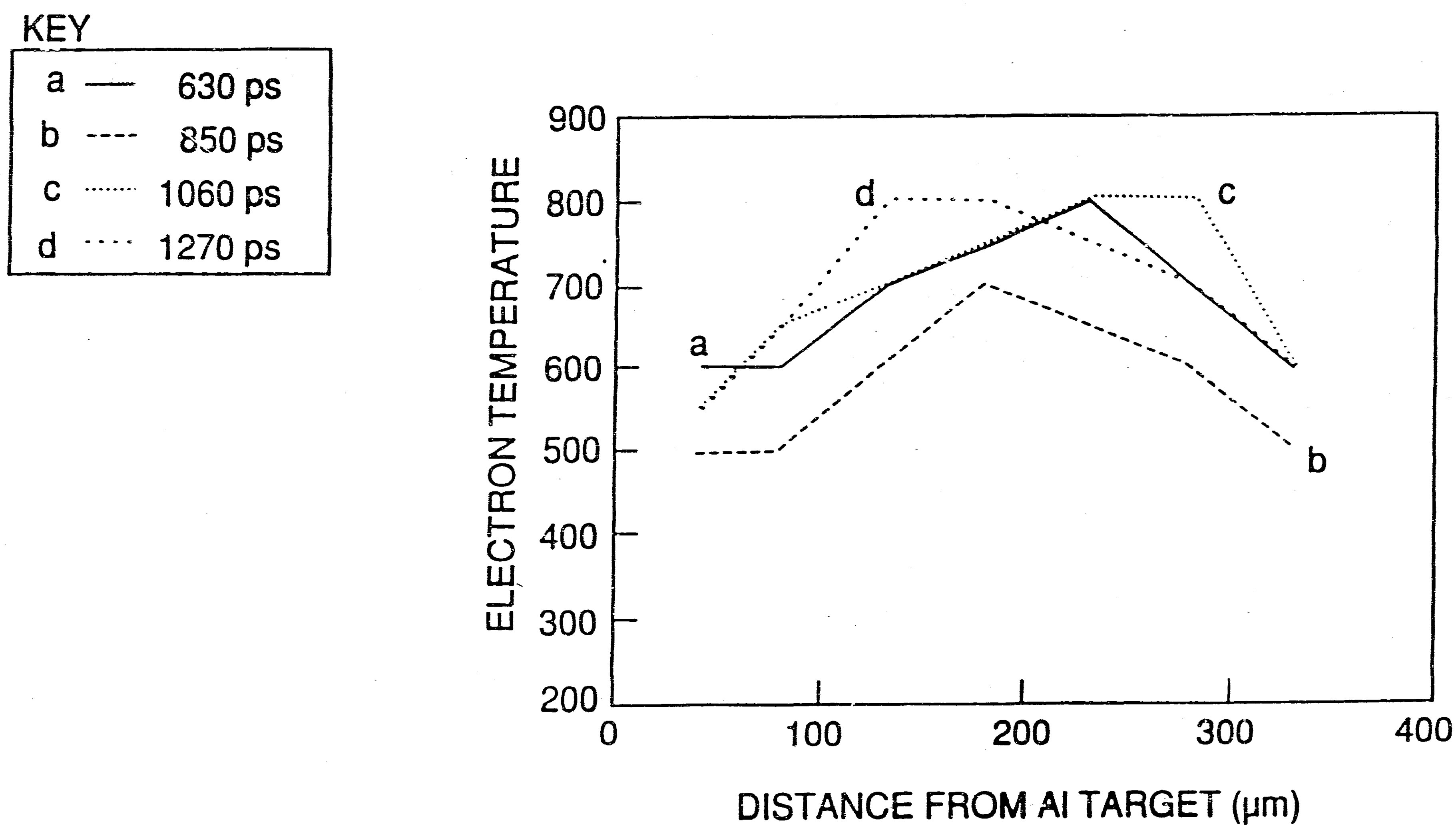
Midplane ion temperature was calculated from spectral line width



The He_α to Ly_α line ratio indicates the plasma electron temperature is increasing near the midplane



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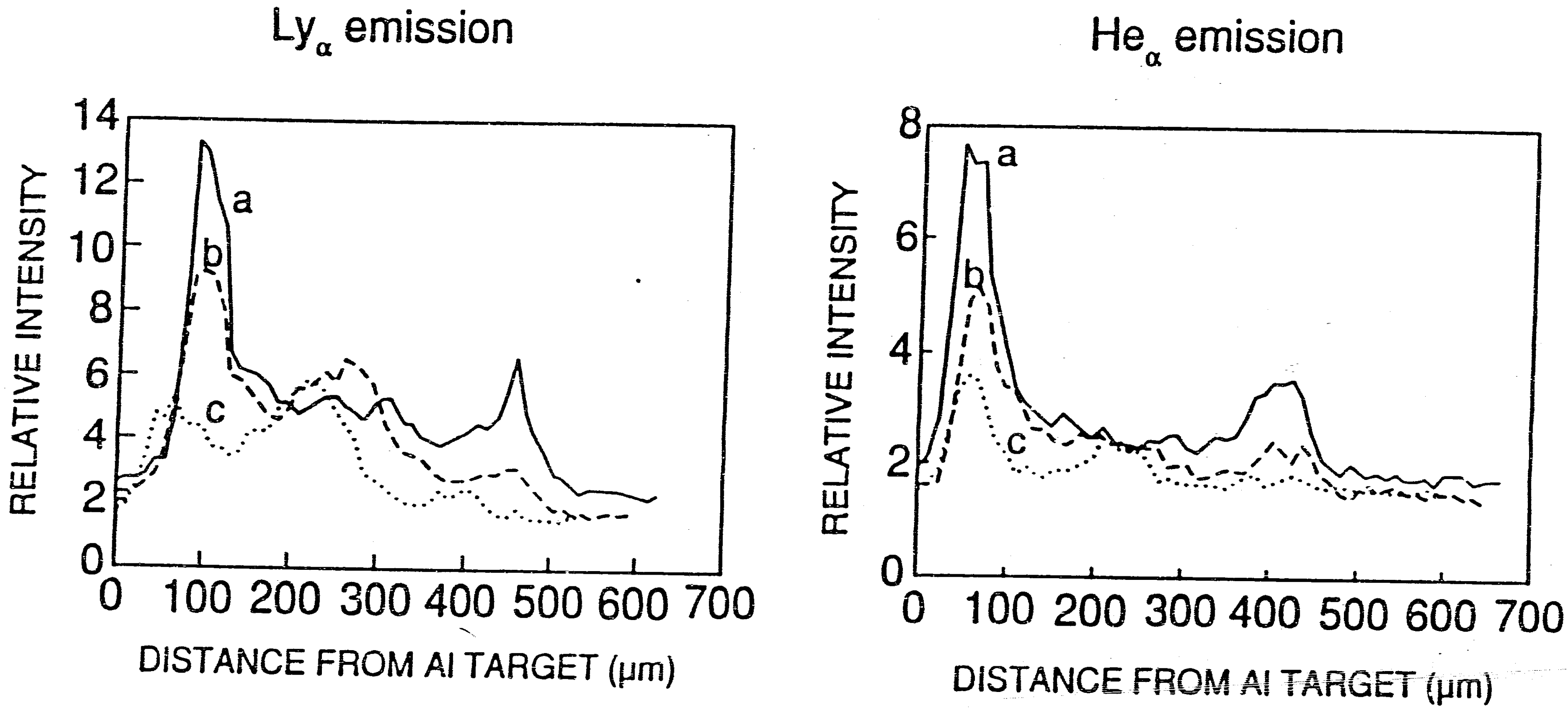
The He_α and Ly_α emission differ in their variation with distance from the target surface



Key

(a) ——	640 ps
(b) - - -	1060 ps
(c) ·····	1270 ps

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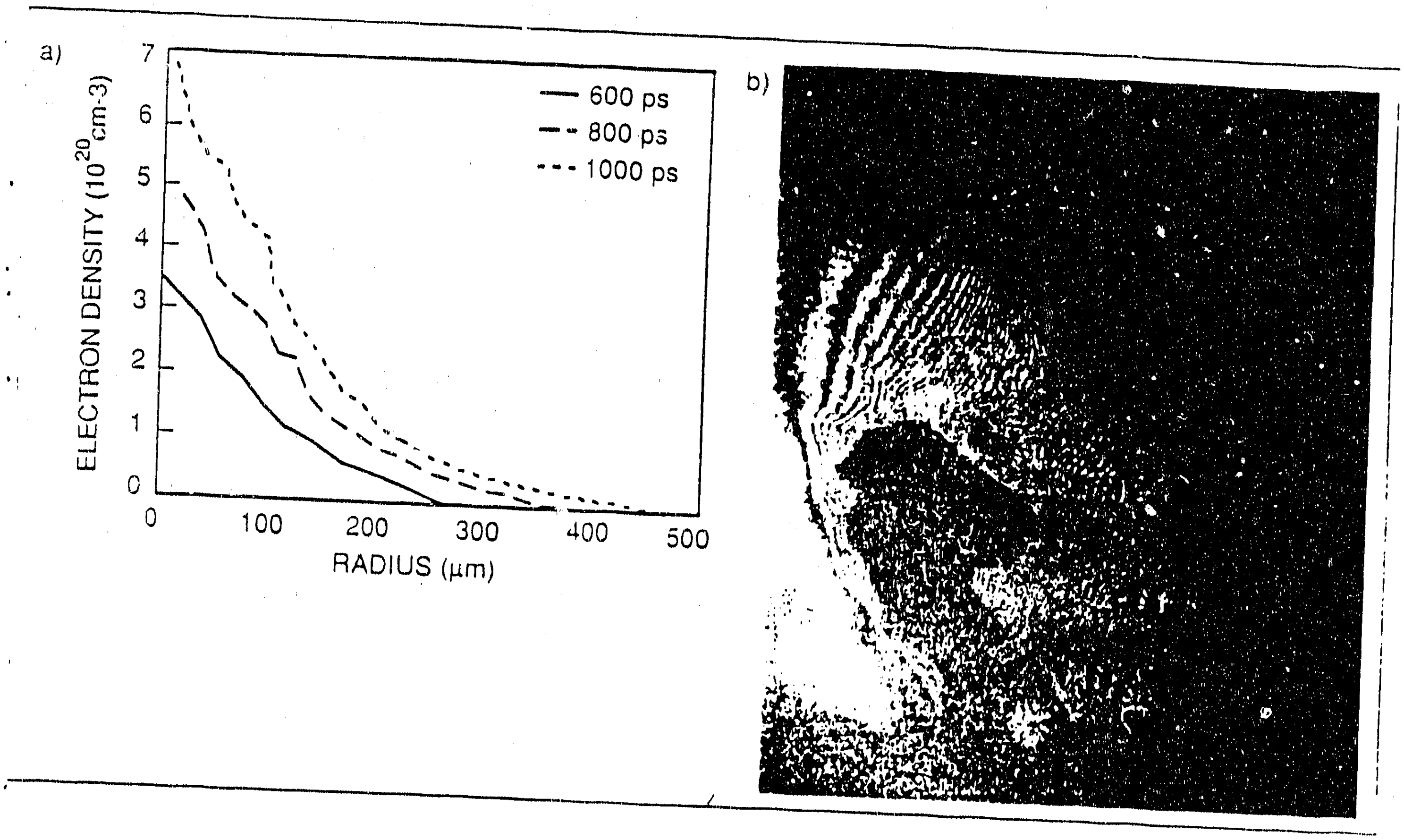
The electron density is about 7×10^{20} /cc in the midplane at 1000 ps.



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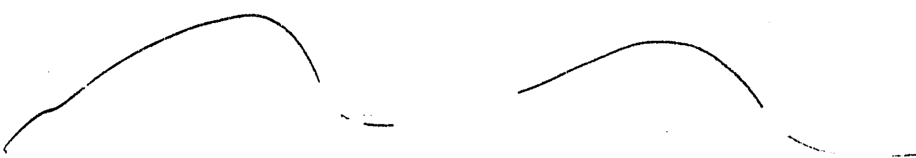

Electron and Ion density profiles show a spike due to stagnation at the midplane

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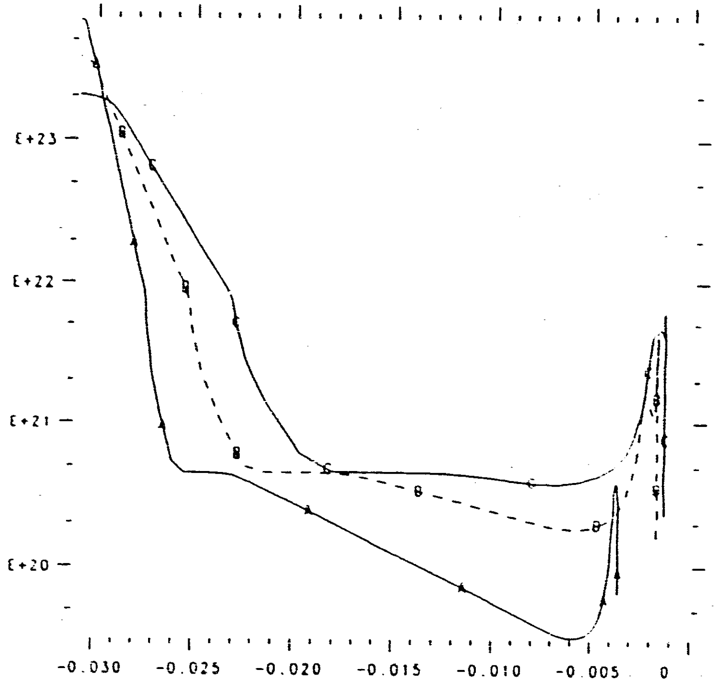
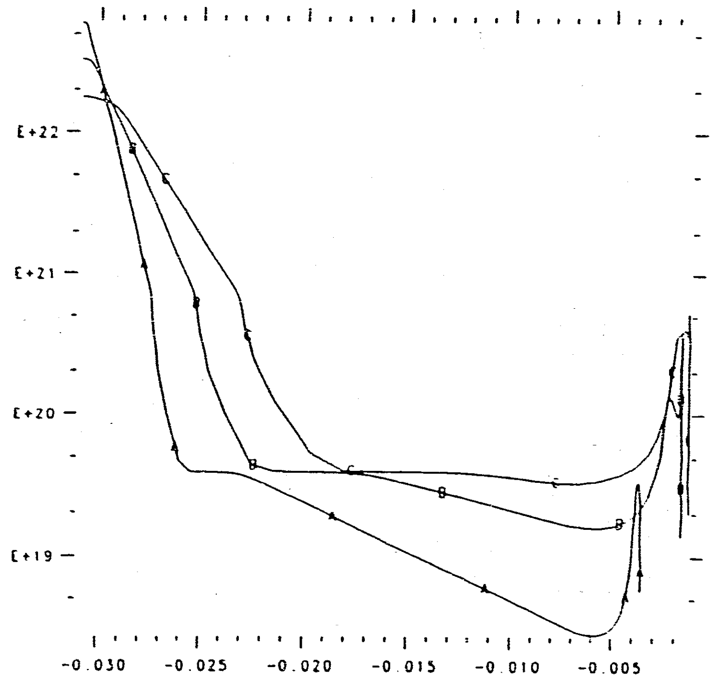


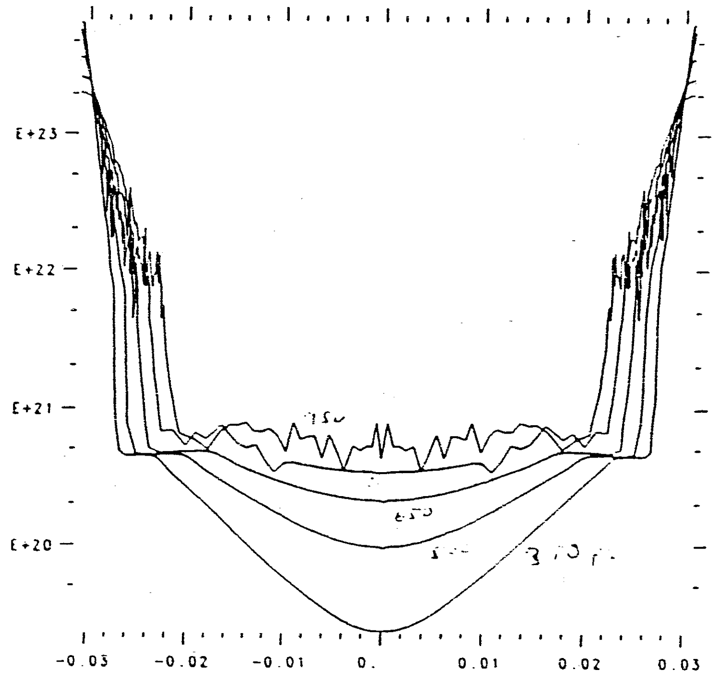
A: polxfa. t = 350 ps. eden
B: polxfa. t = 650 ps. eden
C: polxfa. t = 950 ps. eden



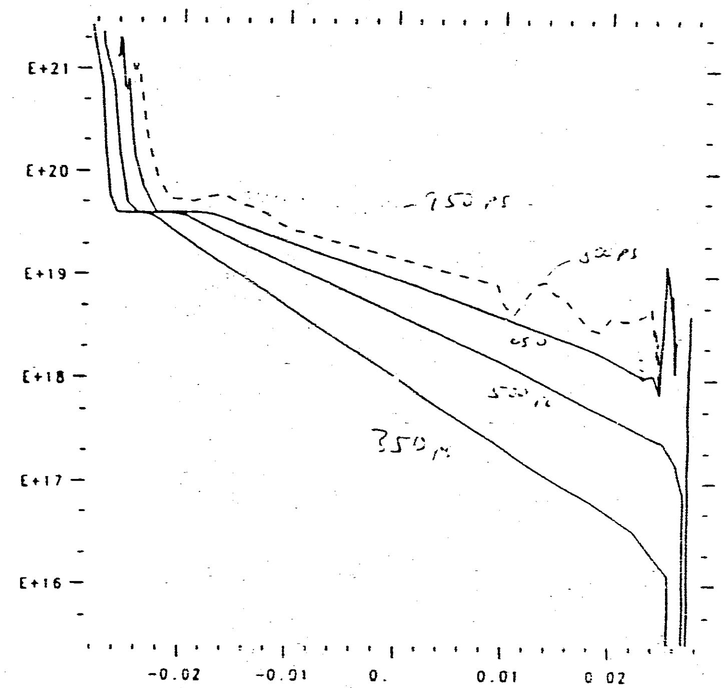
A: polxfa. t = 350 ps. ion d
B: polxfa. t = 650 ps. ion d
C: polxfc. t = 950 ps. ion d

Ion densities in interpenetrating plasmas show evidence of stagnation at the midplane only at late times

Conv

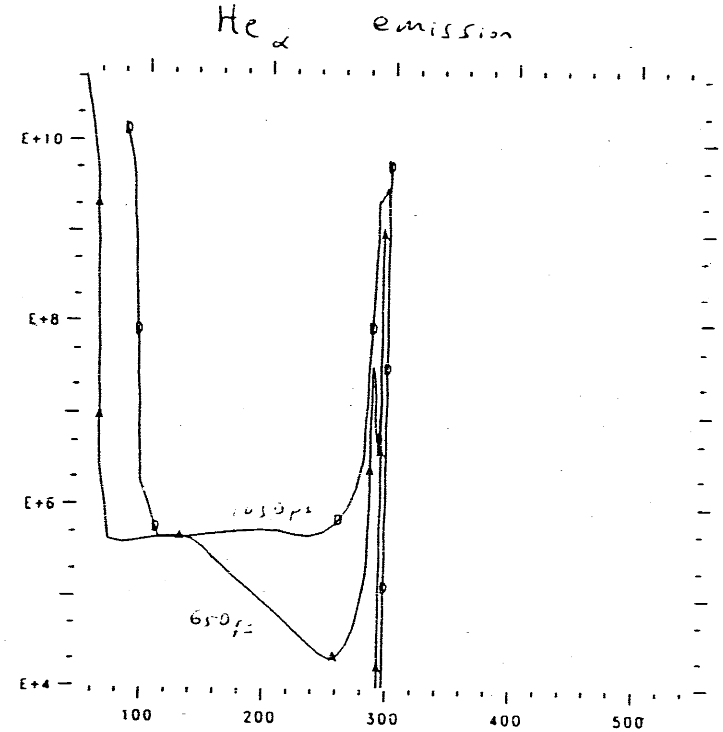


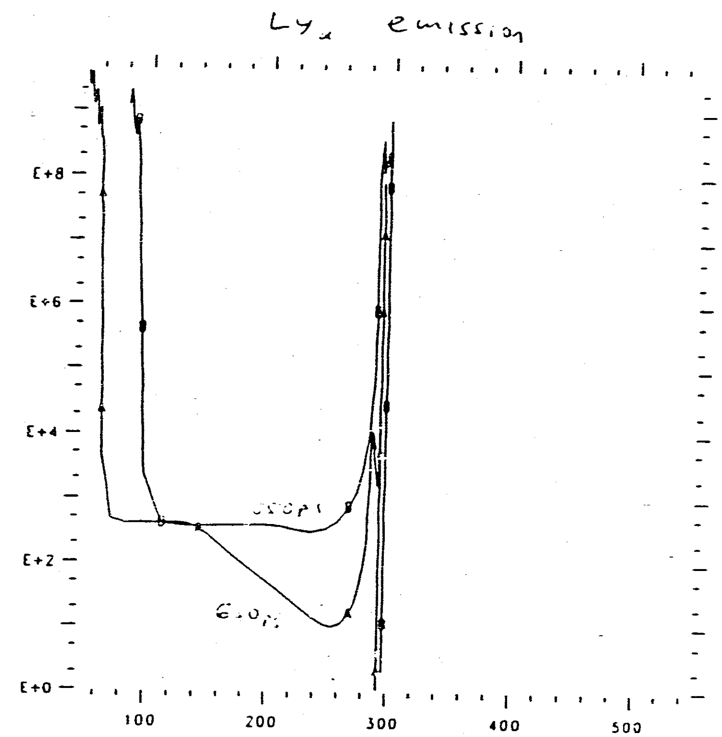
Electron Density



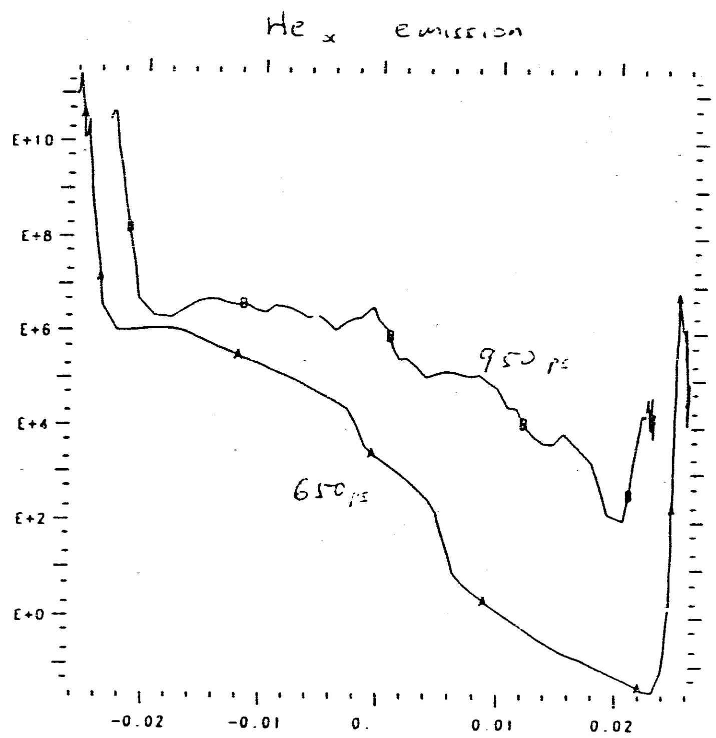
Ion Density

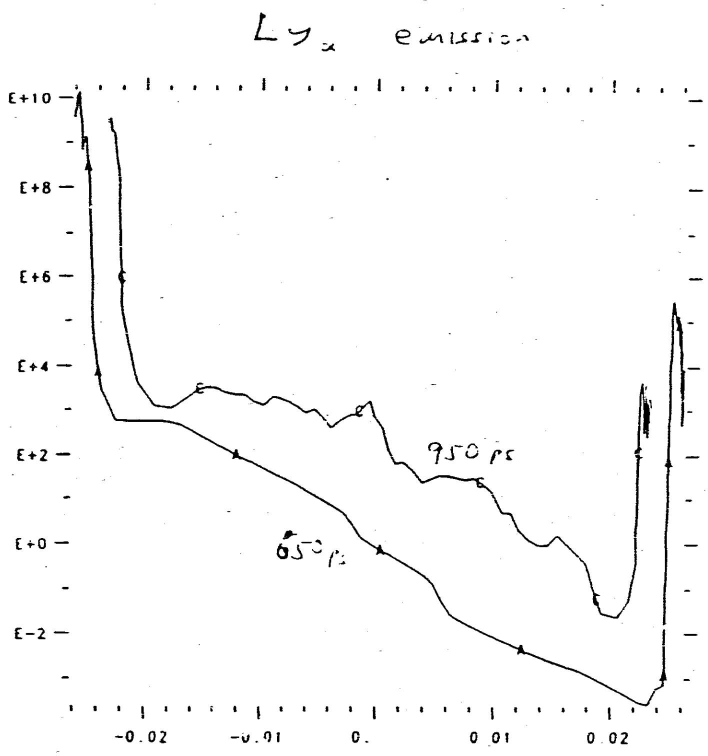
Al line emission peaks strongly in the midplane if stagnation is enforced





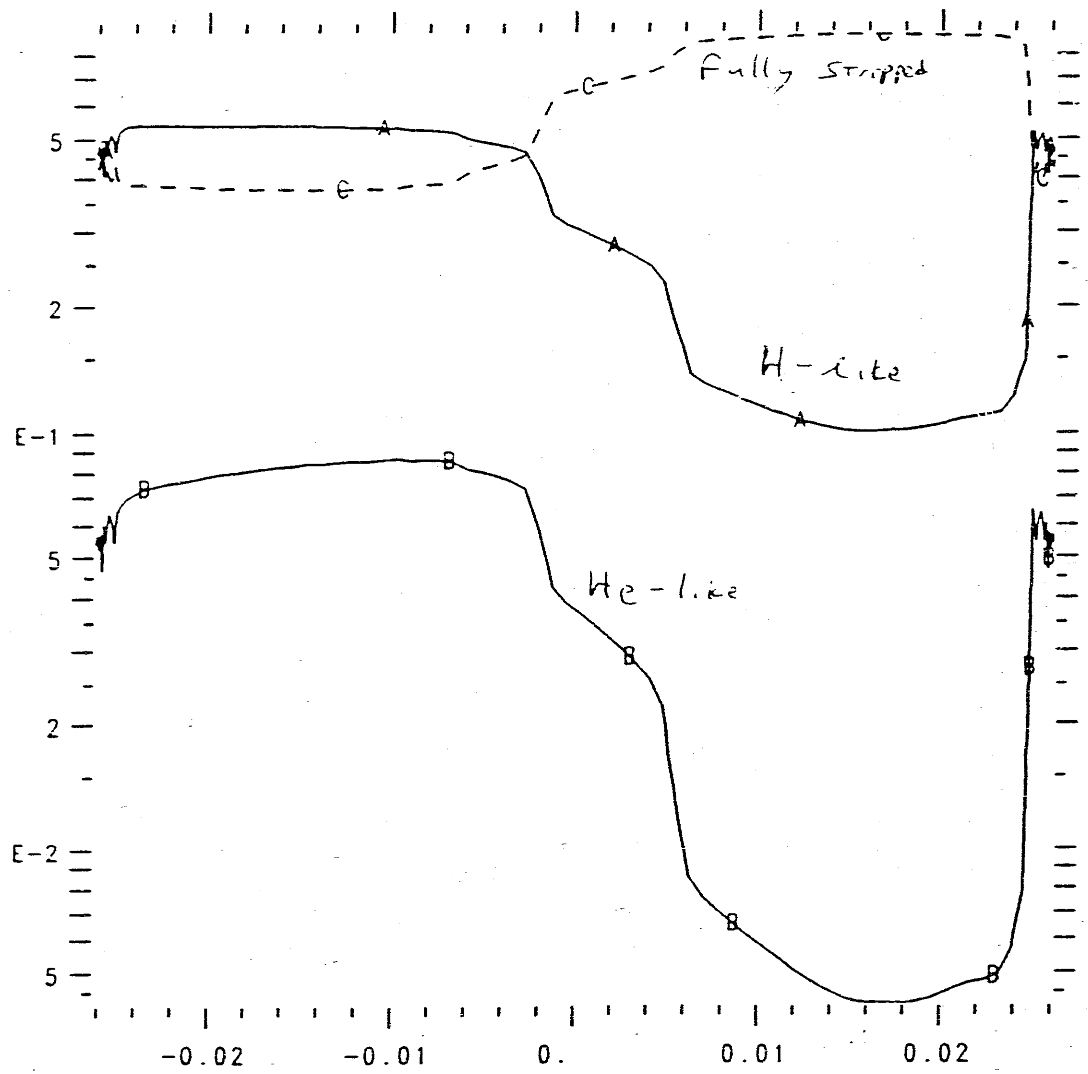
Al line emission shows strong emission at opposite plate, where ions are thermalized in the dense material





Al ions are mostly fully stripped as they stream through the opposing plasma.

ilevl



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