A Microphysics Model to Understand the Solid-to-Plasma Transition of Dielectric Ablator Materials for Direct-Drive Implosions

A. KAR, S. X. HU, and P. B. RADHA
University of Rochester, Laboratory for Laser Energetics

G. DUCHATEAU
Université de Bordeaux-CNRS-CEA, France

Summary

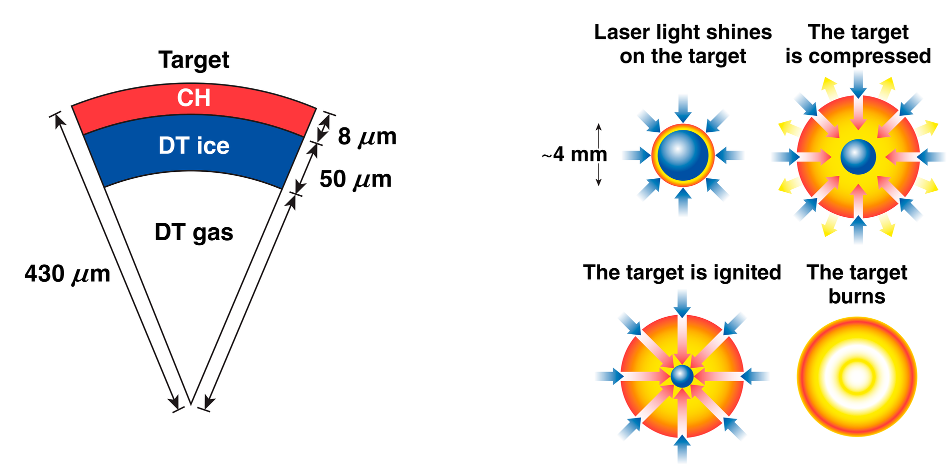
A model[1] to study the transition of polystyrene (CH) from the solid to plasma state has been developed and implemented into the 1-D hydrocode *LILAC*

- With this model, the critical surface formation takes place after the target has been irradiated and the laser-imprint mechanism has occurred
- The model includes multiphoton-ionization, recombination, and impact-ionization schemes that determine the free-electron density in the conduction band of the material
- By incorporating this model, the spatial profiles of the physical quantities such as pressure and mass density are observed to be different between the microphysics model and the original *ad hoc* mechanism in *LILAC*

A physics-based model to describe the initial plasma formation for plastic targets has been developed and implemented into a 1-D hydrocode.

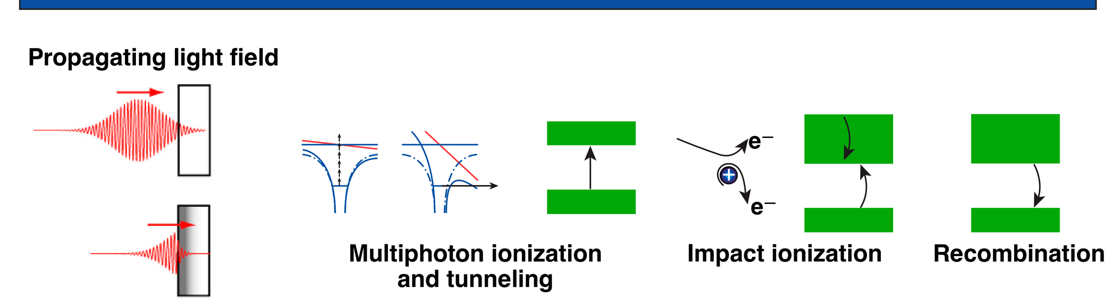
Motivation

Currently, the hydrodynamic codes avoid the detailed plasma-formation process



At present, the hydrocodes assume an initial plasma state or use the cold-start mechanism in an *ad hoc* mechanism and ignore the detailed plasma-formation process.

Multiphoton-ionization, impact-ionization, and recombination processes determine the free electron density in the valence band[1]

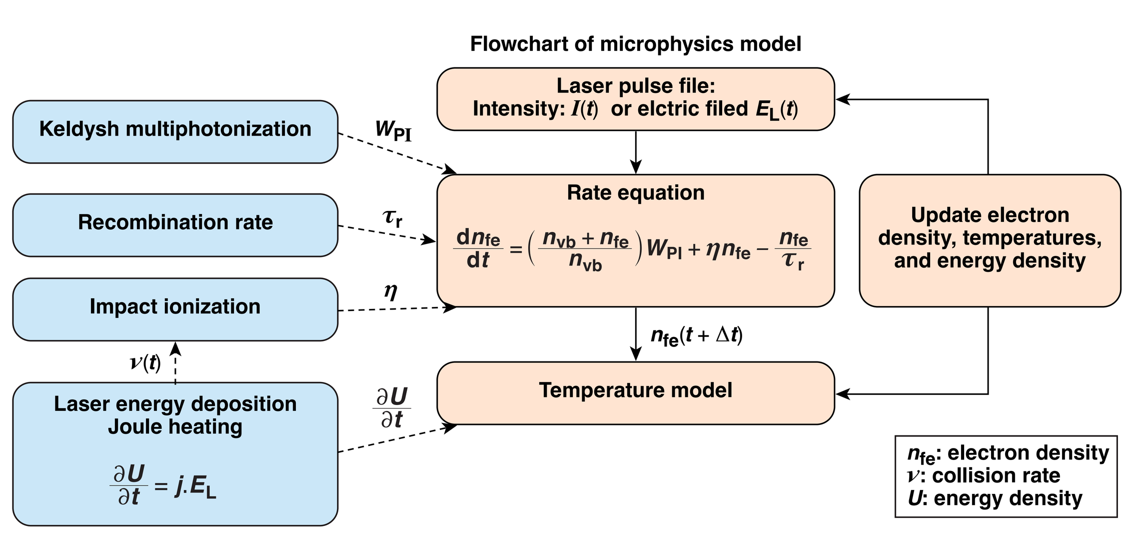


For CH:
Band-gap energy ~4.05 eV
UV light, λ = 351 nm, E = 3.53 eV
Critical density: 9×10^{21} cm^{-3}

Multiphoton ionization and impact ionization increase the electron density, but recombination decreases it.

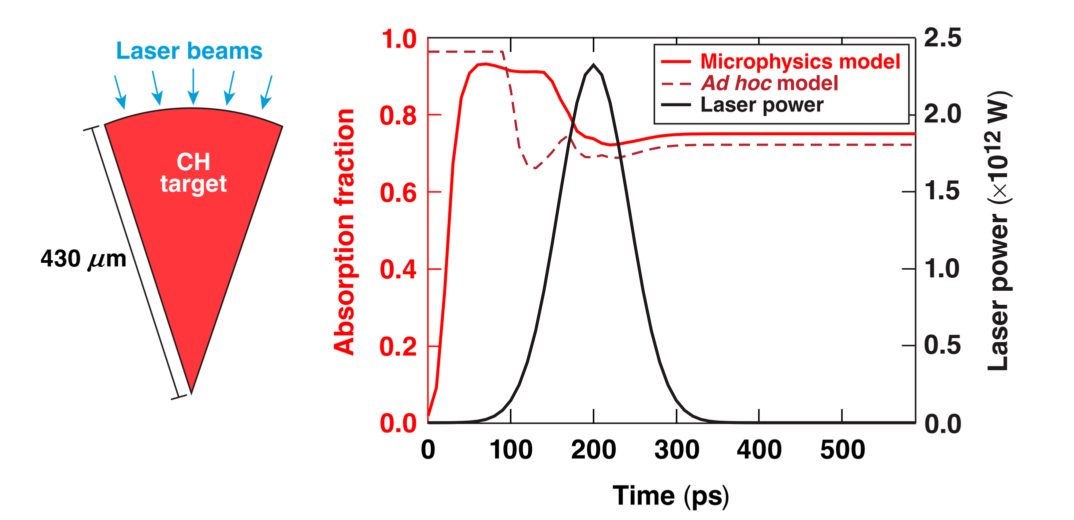
TC14875

The dynamics is governed by a rate equation that is coupled to the laser-deposition and the temperature models

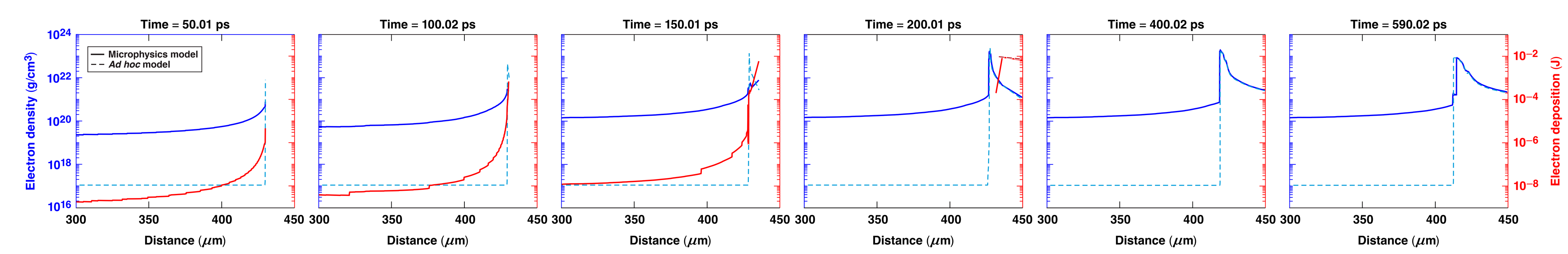


- Until the critical surface formation, the dynamics is governed by the microphysics model
- Beyond that, the inverse bremsstrahlung absorption is incorporated

Lower absorption in plastic is observed in the microphysics because of its transparency

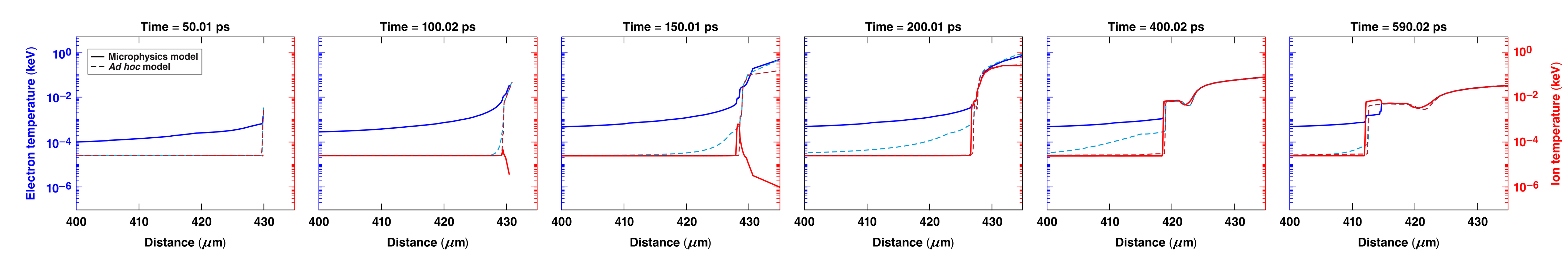


The critical surface formation takes place after the target has been irradiated and the laser-imprint mechanism has occurred



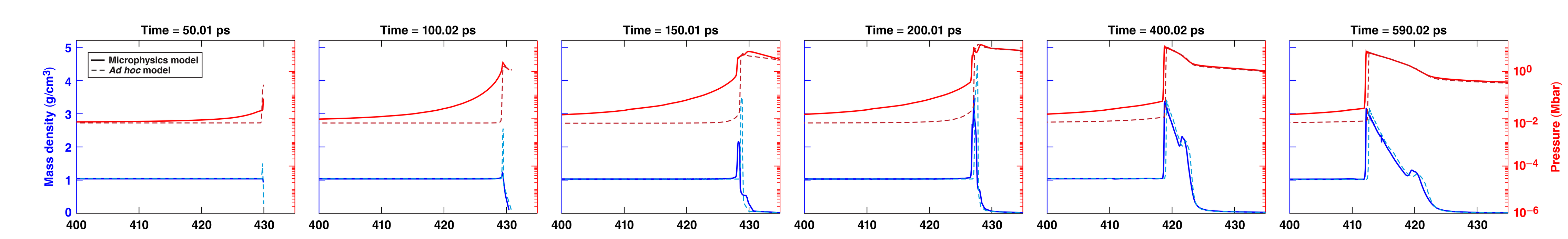
The electron density inside the plastic rises because of laser energy deposition.

The electron temperature inside the target observed in the microphysics model is higher than the *ad hoc* model



The temperature profiles in the ablation region between the two models are comparable.

Microphysics models predict decompression of the target ahead of the shock front because of shinethrough[2]



The target is decompressed because of a rise in the electron temperature inside the target.

Future Directions

A better understanding of the laser-imprint mechanism and shock-timing experiments is possible with the microphysics model

- Implementation of the microphysics model into 2-D or 3-D hydrocodes will provide a better understanding of the laser-imprint mechanism through an accurate estimation of the laser-absorption profiles
- The results of the microphysics model will help us to understand the results of shock-merger experiments better
- Future experiments are being planned to study this phenomena in detail

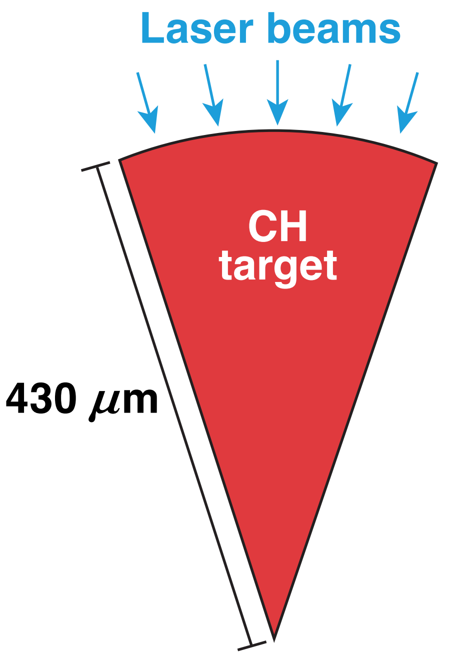
References

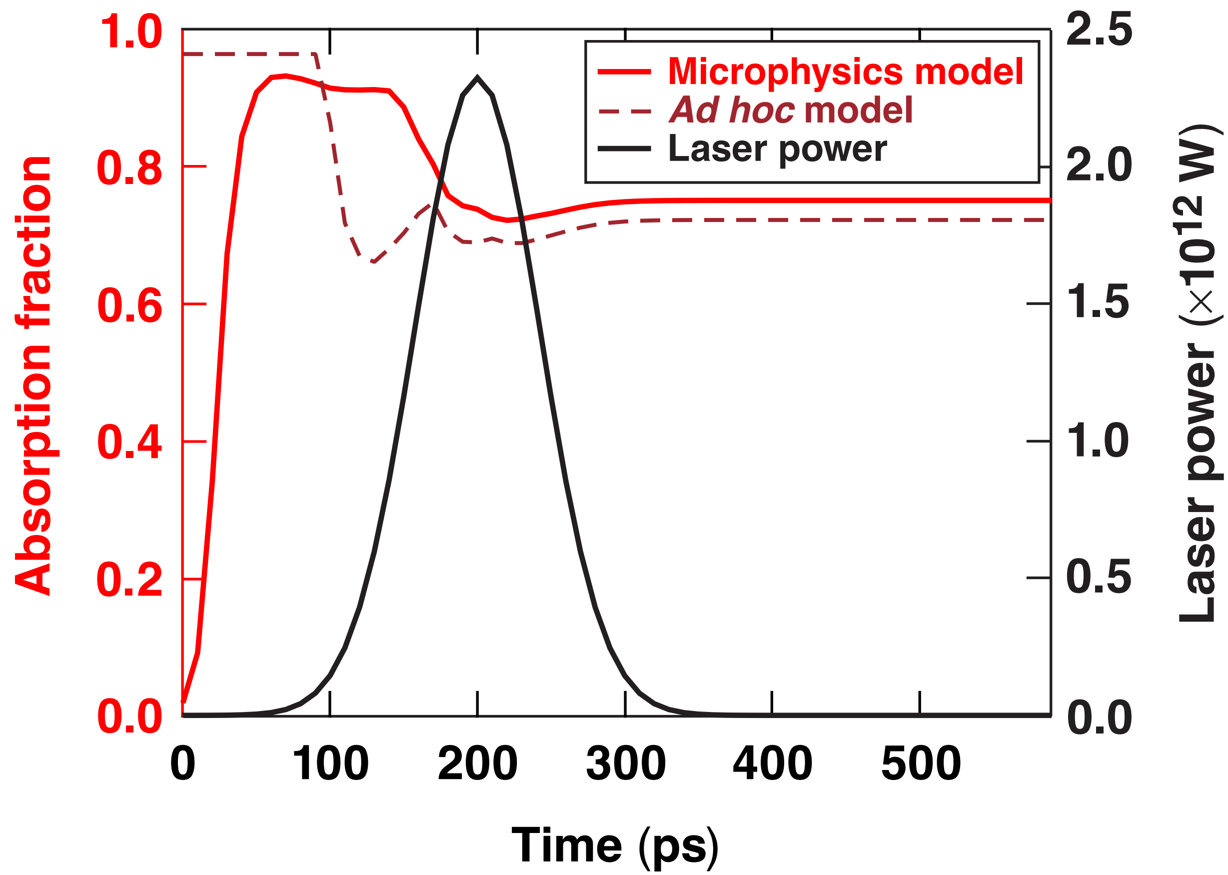
[1] "Modeling the Solid-to-Plasma Transition for Laser Imprinting in Direct-Drive Inertial Confinement Fusion," G. Duchateau, S. X. Hu, A. Pineau, A. Kar, B. Chimier, A. Casner, V. Tikhonchuk, V. N. Goncharov, P. B. Radha, and E. M. Campbell, submitted to Physical Review E.

[2] D. H. Edgell *et al.*, Phys. Plasmas 15, 092704 (2008).

UNIVERSITY of ROCHESTER

Lower absorption in plastic is observed in the microphysics because of its transparency

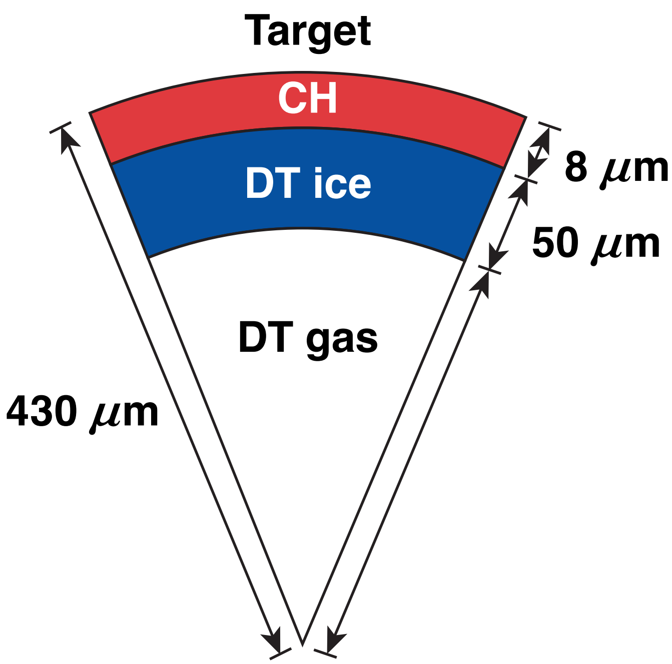


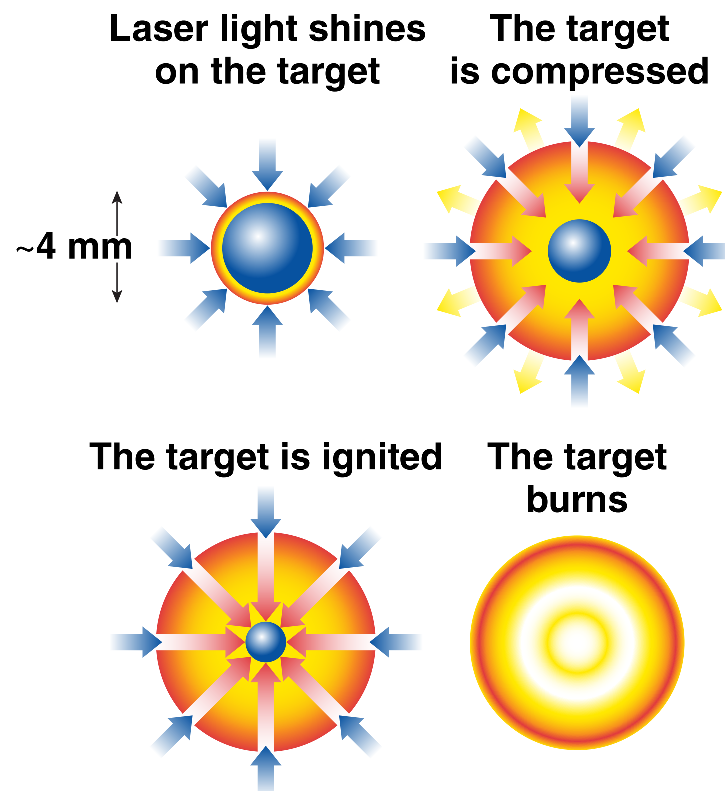


TC14845

Motivation

Currently, the hydrodynamic codes avoid the detailed plasma-formation process





At present, the hydrocodes assume an initial plasma state or use the cold-start mechanism in an *ad hoc* mechanism and ignore the detailed plasma-formation process.

TC14848a

Summary

A model[1] to study the transition of polystyrene (CH) from the solid to plasma state has been developed and implemented into the 1-D hydrocode *LILAC*

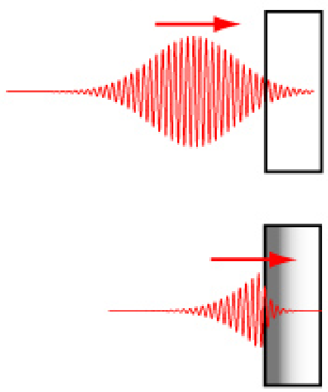
- **With this model, the critical surface formation takes place after the target has been irradiated and the laser-imprint mechanism has occurred**
- **The model includes multiphoton-ionization, recombination, and impact-ionization schemes that determine the free-electron density in the conduction band of the material**
- **By incorporating this model, the spatial profiles of the physical quantities such as pressure and mass density are observed to be different between the microphysics model and the original *ad hoc* mechanism in *LILAC***

A physics-based model to describe the initial plasma formation for plastic targets has been developed and implemented into a 1-D hydrocode.

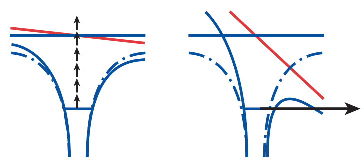
TC14873a

Multiphoton-ionization, impact-ionization, and recombination processes determine the free electron density in the valence band[1]

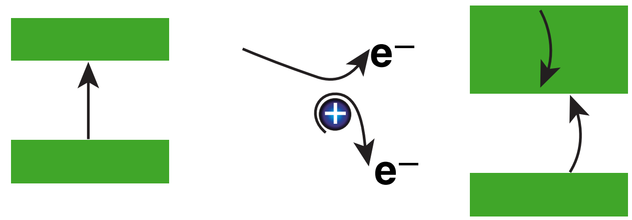
Propagating light field



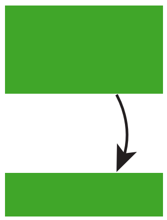
Pictorial representation of a laser pulse interaction with a solid



Multiphoton ionization and tunneling



Impact ionization



Recombination

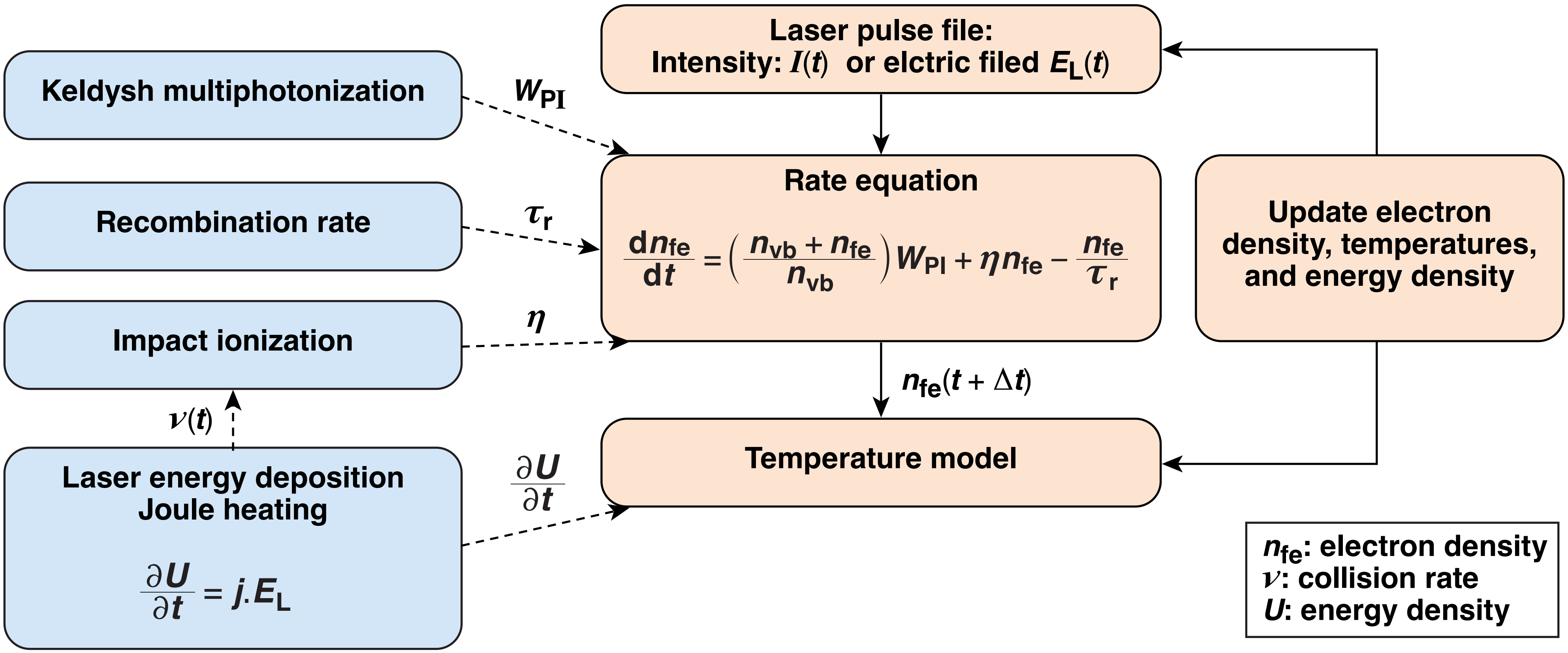
For CH:
Band-gap energy ~4.05 eV
UV light, λ = 351 nm, E = 3.53 eV
Critical density: 9×10^{21} cm^{-3}

Multiphoton ionization and impact ionization increase the electron density, but recombination decreases it.

TC14875

The dynamics is governed by a rate equation that is coupled to the laser-deposition and the temperature models

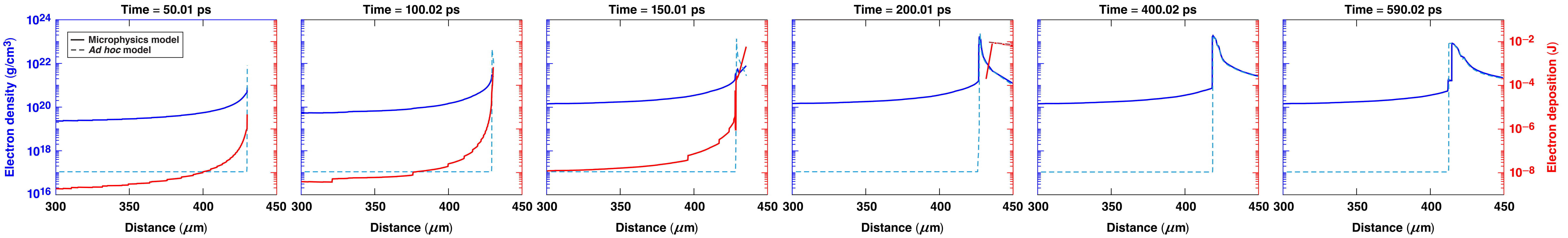
Flowchart of microphysics model



- Until the critical surface formation, the dynamics is governed by the microphysics model
- Beyond that, the inverse bremsstrahlung absorption is incorporated

TC14876

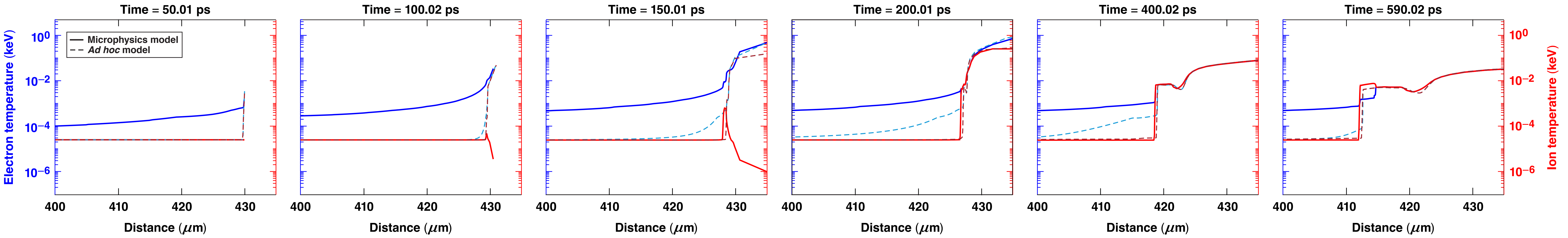
The critical surface formation takes place after the target has been irradiated and the laser-imprint mechanism has occurred



The electron density inside the plastic rises because of laser energy deposition.

TC14877b

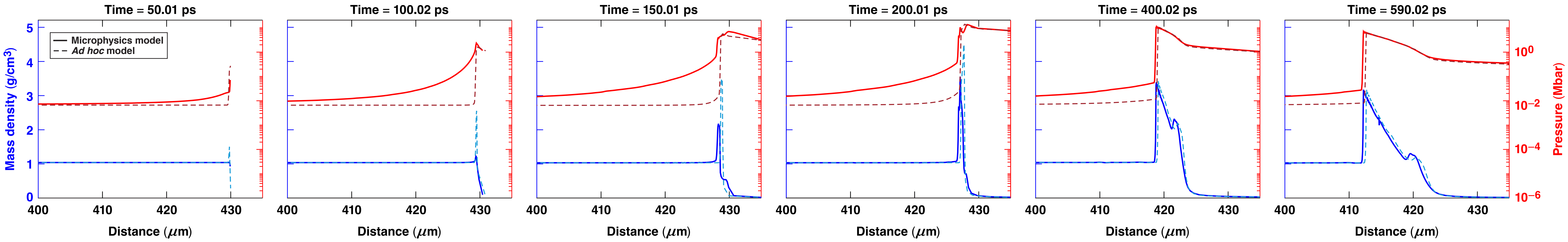
The electron temperature inside the target observed in the microphysics model is higher than the *ad hoc* model



The temperature profiles in the ablation region between the two models are comparable.

TC14878b

Microphysics models predict decompression of the target ahead of the shock front because of shinethrough[2]



The target is decompressed because of a rise in the electron temperature inside the target.

TC14879b

Future Directions

A better understanding of the laser-imprint mechanism and shock-timing experiments is possible with the microphysics model

- Implementation of the microphysics model into 2-D or 3-D hydrocodes will provide a better understanding of the laser-imprint mechanism through an accurate estimation of the laser-absorption profiles
- The results of the microphysics model will help us to understand the results of shock-merger experiments better
- Future experiments are being planned to study this phenomena in detail

TC14883

References

[1] "Modeling the Solid-to-Plasma Transition for Laser Imprinting in Direct-Drive Inertial Confinement Fusion," G. Duchateau, S. X. Hu, A. Pineau, A. Kar, B. Chimier, A. Casner, V. Tikhonchuk, V. N. Goncharov, P. B. Radha, and E. M. Campbell, submitted to Physical Review E.

[2] D. H. Edgell *et al.*, Phys. Plasmas 15, 092704 (2008).

TC14884