Numerical Simulations on the Formation Proces s of Z-pinch Dynamic Hohlruams

Xiaojian Shu,
Delong Xiao, Ning Ding, Shunkai Sun, Chuang Xue,Yang Zhang

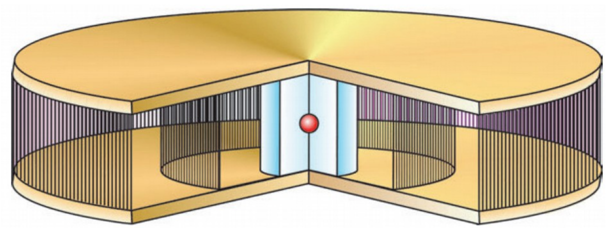
E-mail: shu_xiaojian@iapcm.ac.cn
Institute of Applied Physics and Computational Mathematics

Outline

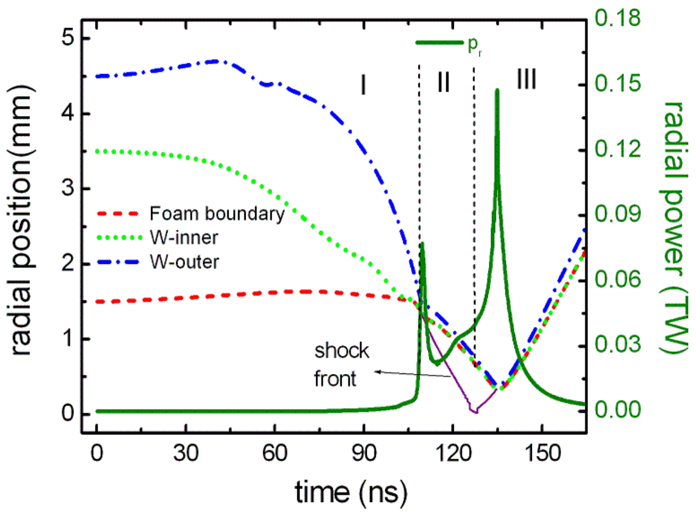
- **Background and motivation**
- **Formation and optimization of dynamic hohlraum**
  - **characteristics of dynamic hohlraum**
  - **change wire-array and converter parameters**
  - **two types of DH experiments**
- **Conclusions and future works**

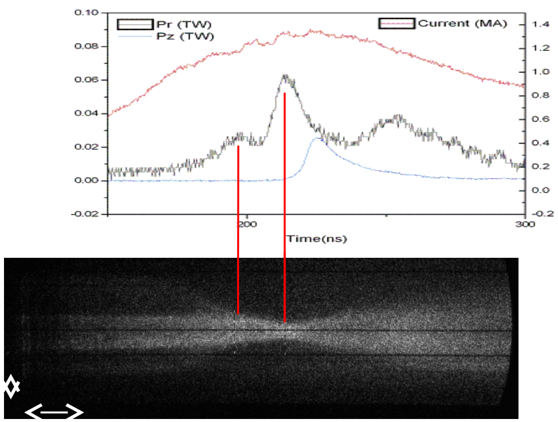
Backgroud

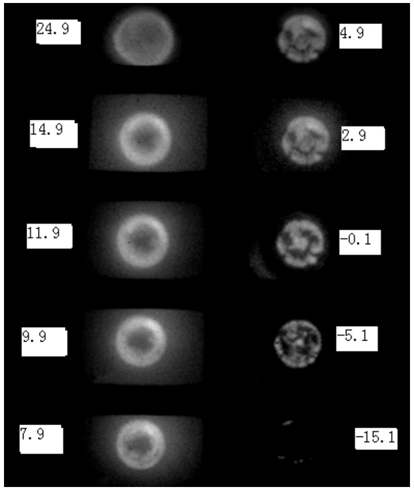
- Z-pinch driven dynamic hohlraum(DH) is an efficient configuration to gain high radiation temperature hohlraum, and can be used to drive inertial confinement fusion(ICF)
- The physics of light wire-array Z-pinch implosion and its interaction with heavy foam converter is well understood in the past years by simulations and experiments conducted on the "Qiangguang I" facility



T. A. Mehlhorn, et al., Plasma Phys.& Control. Fusion **45**, A325(2003)



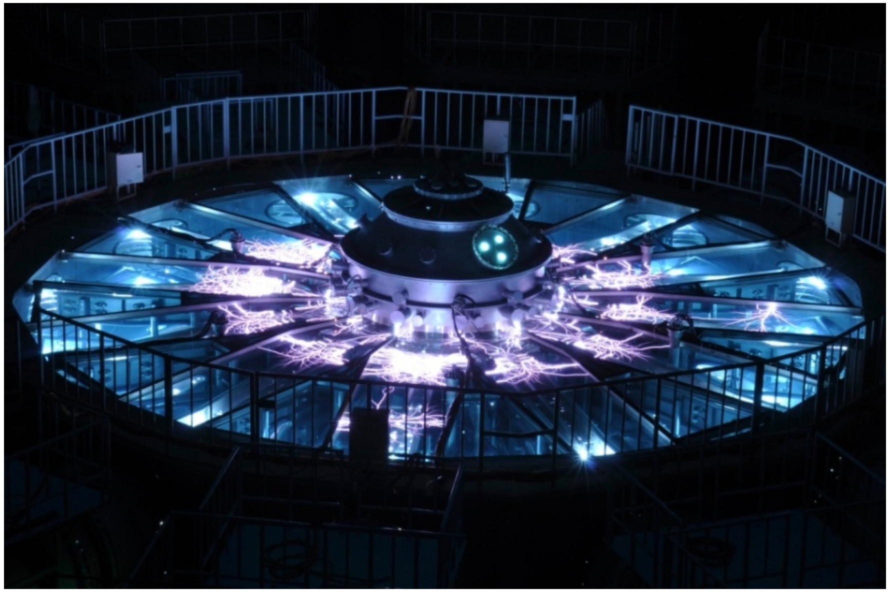




Motivation

- Currently, the most powerful pulsed power generator in China, "Julong I" faciltiy, has been constructed at the Institute of Fluid Physics, CAEP
- The peak drive current of a typical wire-array is about 7~8MA

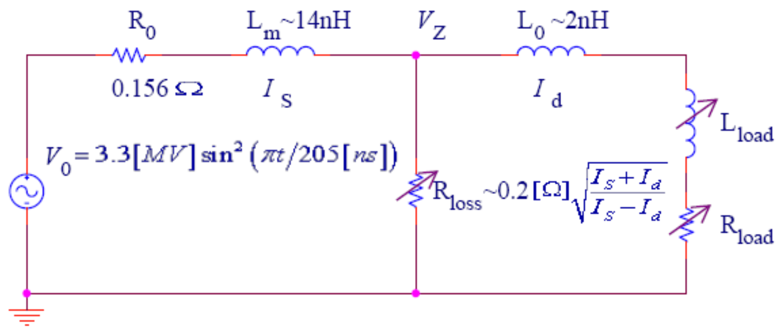
- What's the key physics of dynamic hohlraums on the ~8MA "Julong I" faciltiy?
- And how to optimize the dynamic hohlraum radiation on the facility?



peak current 7~8MA
rise time(10%~90%) 60~70ns
~3MJ energy while 65kV charged

Models

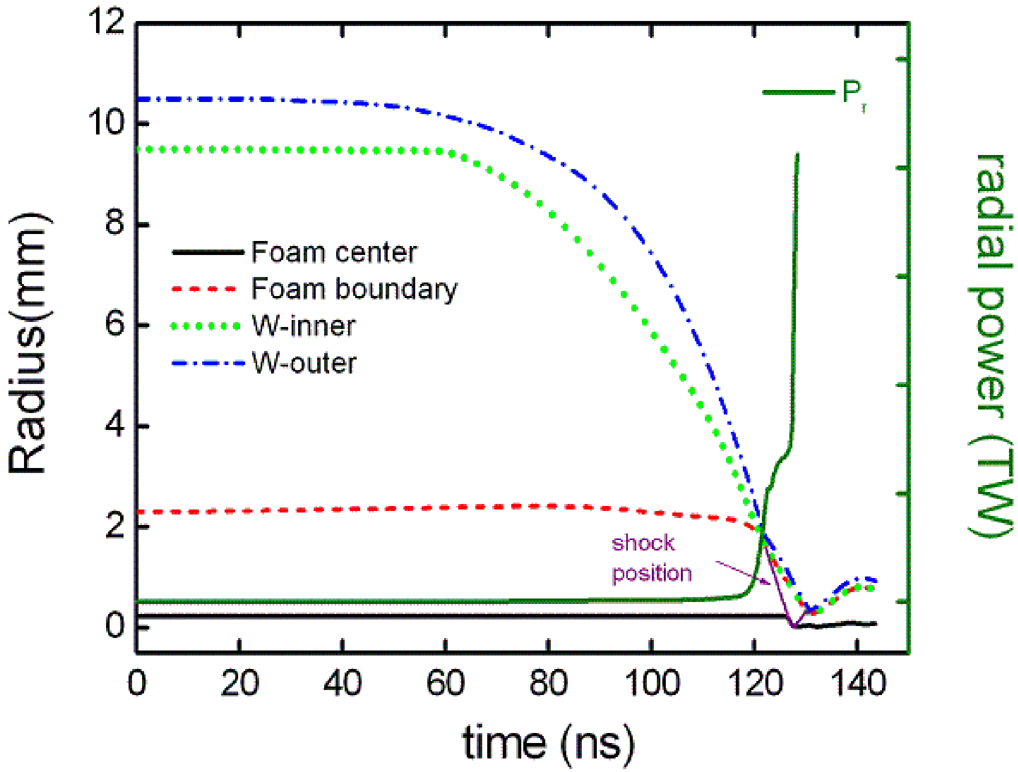
- Use the zork model to calculate the dirve current



- An one-dimensional MHD code with multi-frequency diffusion is used to calculate the implosion dynamics of dynamic hohlraum
- Wire-array and foam converter are varied to explore the relative optimization of dynamic hohlraum radiation

- Tungsten Wire-array is assumed as a thin plasma shell with an intitial temperature of 1eV
- And form converter is uniformly distributed with an initial temperature of 1000K

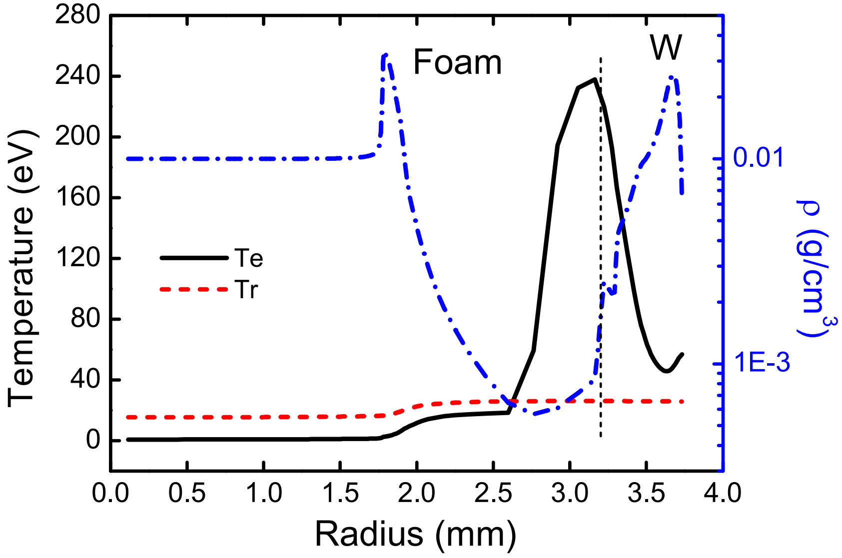
Overall implosion dynamics

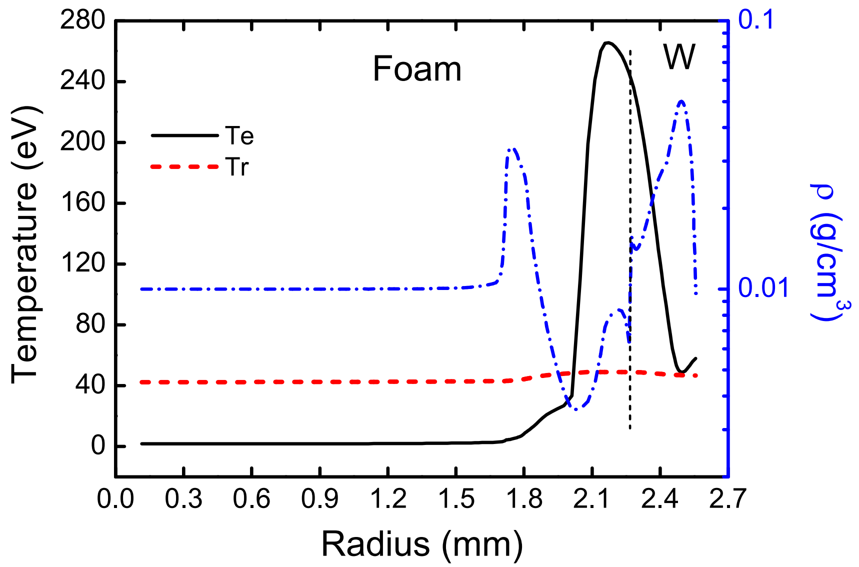


- Three stages can be divided to describe the implosion dynamics of wire-array Z-pinch with embedded foam converter

- acceleration of the wire-array plasma
- collison of the wire-array plasma with the foam converter and the formation of dynamic hohlraums
- stagnation

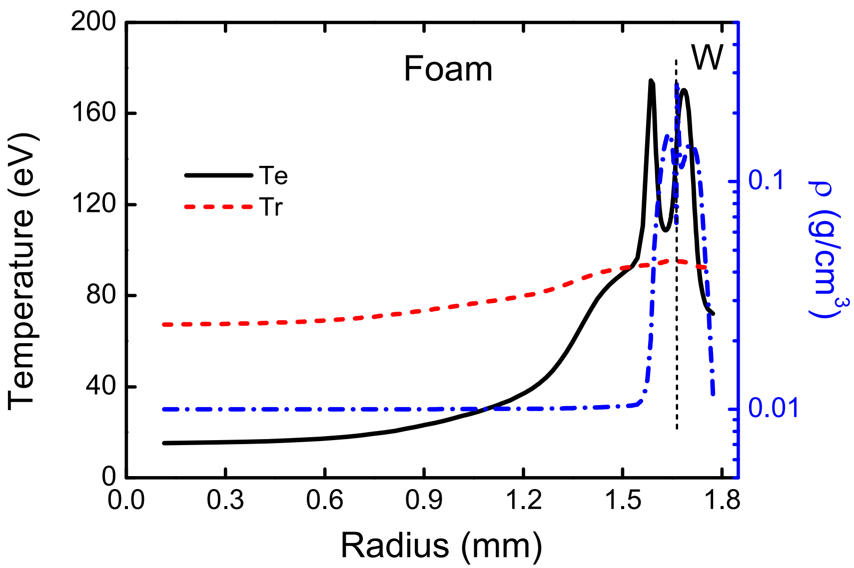
acceleration and impaction

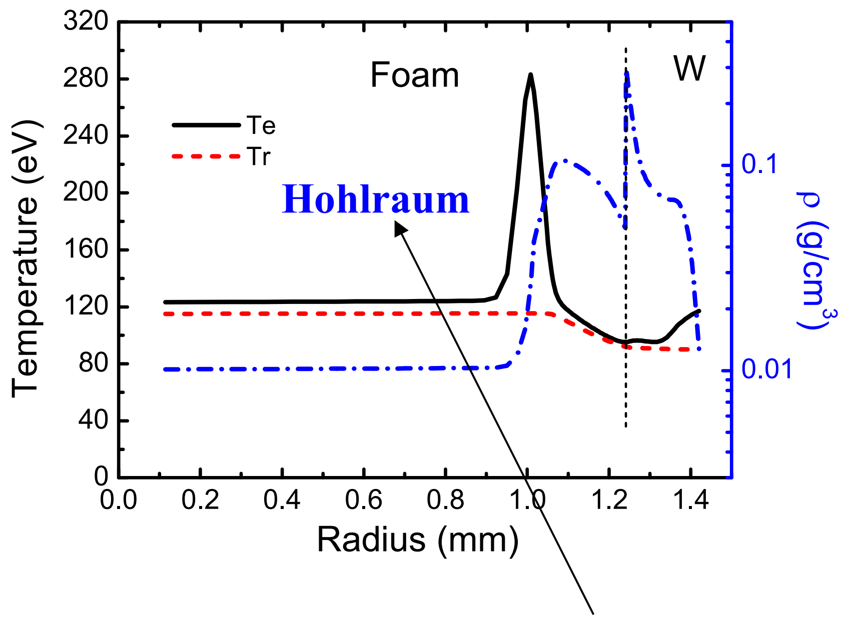




- During the acceleration of the bulk tungsten plasma, only weak energy conversion takes places near the surface of the converter plasma, and the magnetic field slightly diffuses into the surface of the converter plasma.
- While the bulk tungsten plasma impacts onto the foam converter, strong energy thermalization takes places to produce a high pressure layer, and a strong radiative shock is launched

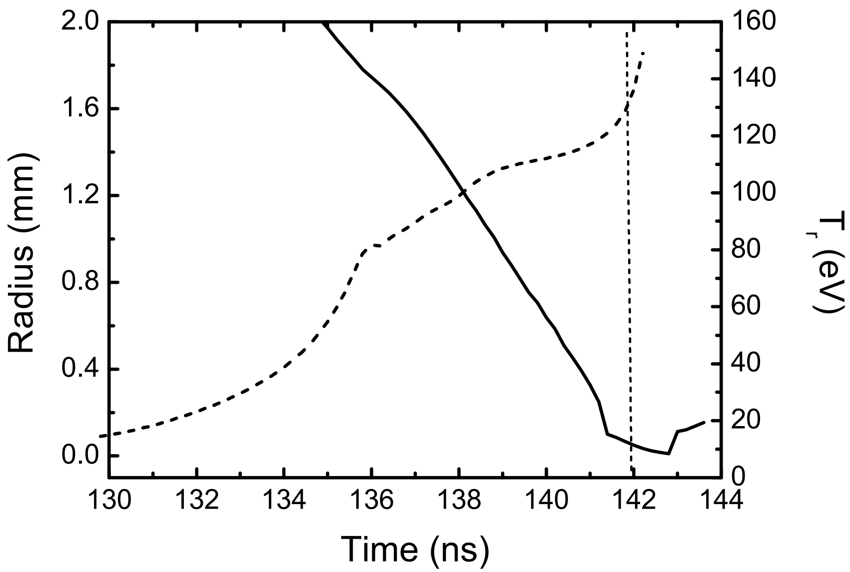
shock propagation and DH formation

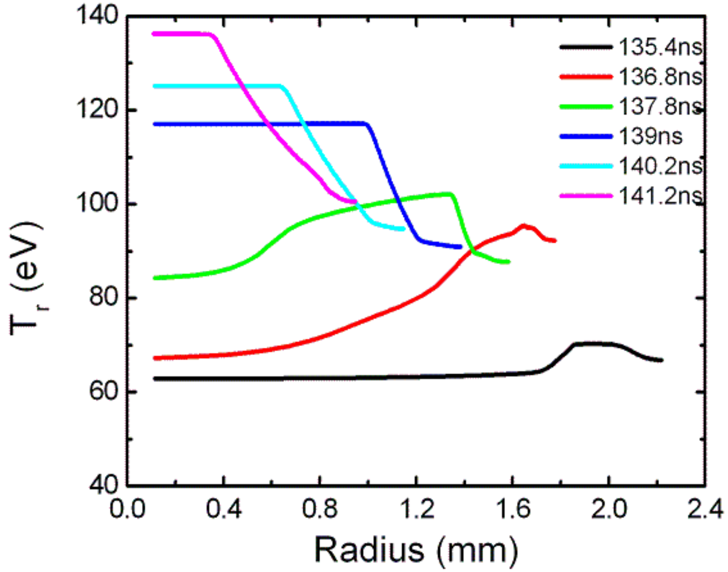




- High temperature radiation transfers supersonically in the low density foam converter plasma
- Thus, in the interior of the shock front, a dynamic hohlraum is formed, in which the radiation temperature is relatively high and the matter is weakly disturbed

characteristics of dynamic hohlraum





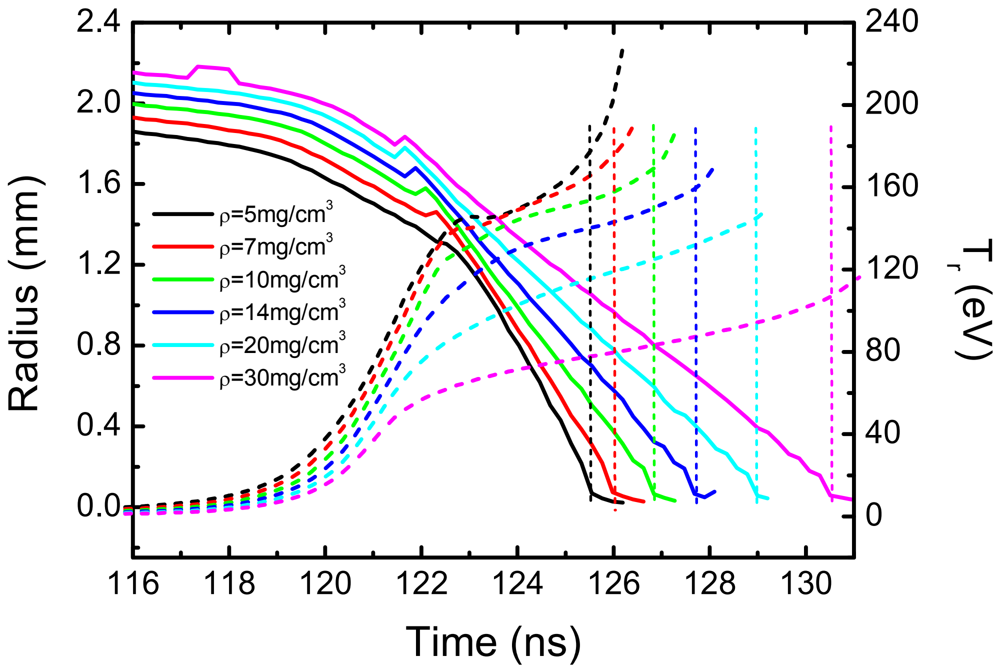
- As the shock front propagates to the axis, the hohlraum temperature is slightly increased due to cylindrical convergence
- The radiation in the hohlraum is relatively uniform

Optimizing DH---change mass ratio:parameter

load num.	height mm	array radius mm	wire diameter mm	wire number	foam radius mm	foam density mg/cm^3	array/foam mass ratio
1	15.0	10.0	7.0	168	2.3	5.0	1.5
2	15.0	10.0	7.0	168	2.3	7.0	1.07
3	15.0	10.0	7.0	168	2.3	10.0	0.75
4	15.0	10.0	7.0	168	2.3	14.0	0.54
5	15.0	10.0	7.0	168	2.3	20.0	0.38
6	15.0	10.0	7.0	168	2.3	30.0	0.25

- Parameters of wire-arrays are fixed
- Radius of the foam converter is fixed
- To increase the mass density of the foam converter to decrease the array/foam mass ratio

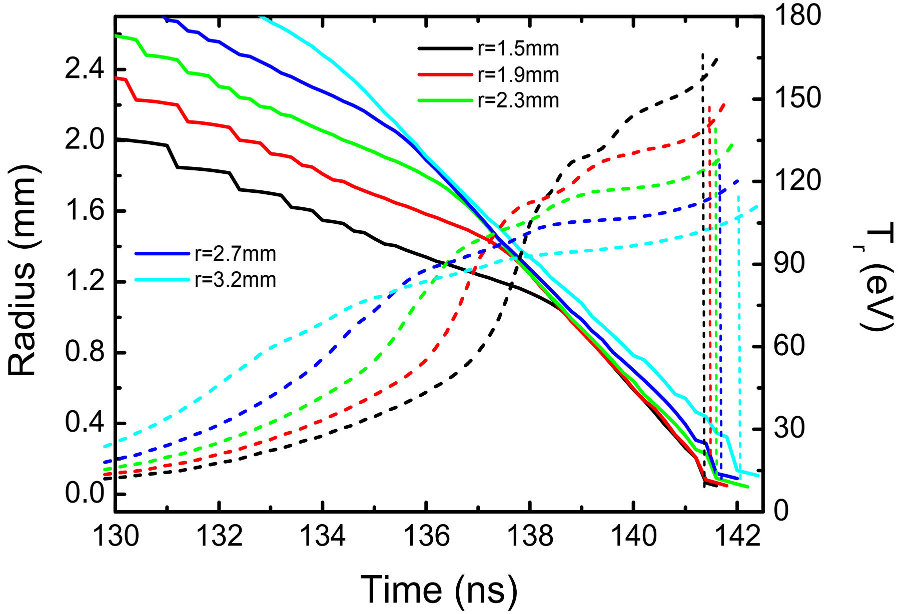
Optimizing DH---change mass ratio:shock and T_r



- As the foam density is increased, the shock velocity and the hohlraum temperature is decreased. However, the time duration of hohlraum radiation(before the shock arrives at the axis) is increased
- It is noted the simulation results change silightly when the ratio is about 1.
- We choose the load parameter with the mass ratio 0.75 as a relatively optimized selection

Optimizing DH---change the radius ratio

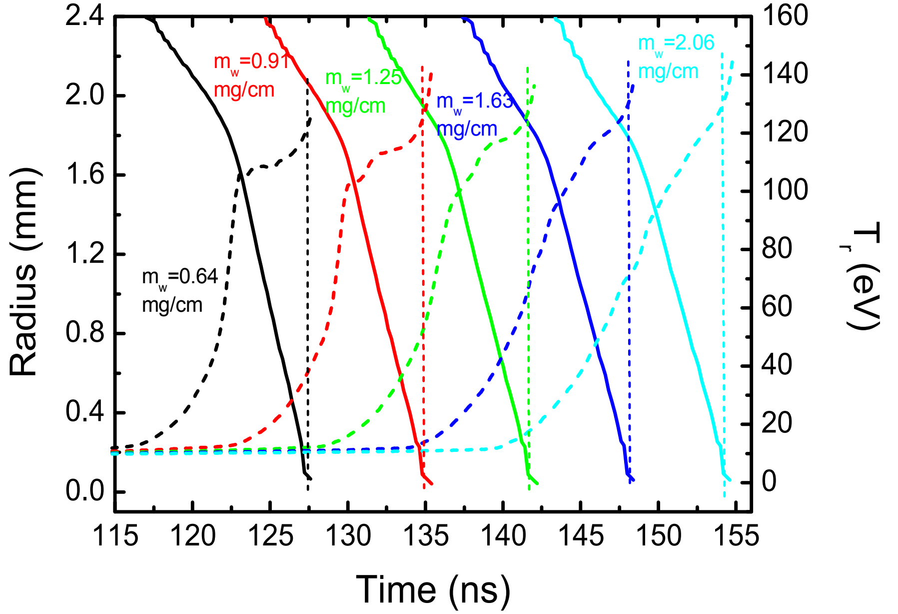
load num.	array mass mg/cm	foam radius mm	foam density mg/cm³	array/foam mass ratio
1	1.25	1.5	23.5	0.75
2	1.25	1.9	14.7	0.75
3	1.25	2.3	10.0	0.75
4	1.25	2.7	7.3	0.75
5	1.25	3.2	5.2	0.75



- The wire-array parameters and the mass of the converter are fixed
- As the radius is increased, the array/foam radius ratio is decreased
- As the radius ratio is increased, the shock velocity change slightly. However, The peak hohlraum temperature is decreased, and the time duration is increased.

Optimizing DH---change the load mass

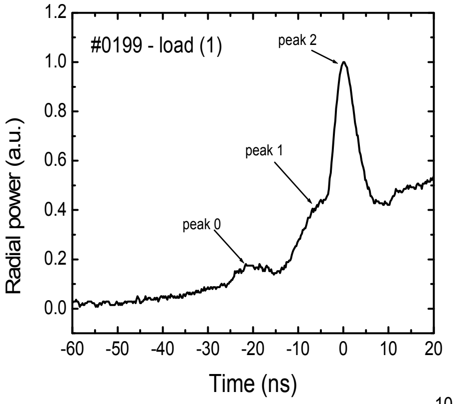
load num.	array mass mg/cm	foam radius mm	foam density mg/cm3	array/foam mass ratio
1	0.64	2.3	5.1	0.75
2	0.92	2.3	7.3	0.75
3	1.25	2.3	10.0	0.75
4	1.63	2.3	13.1	0.75
5	2.06	2.3	16.5	0.75

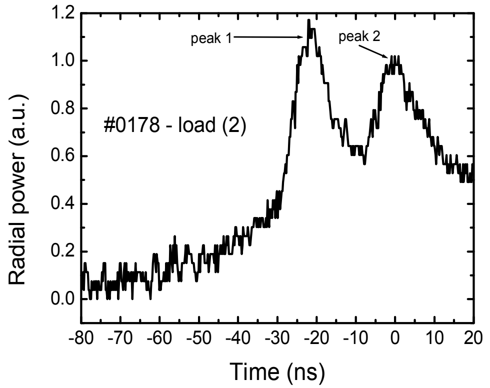


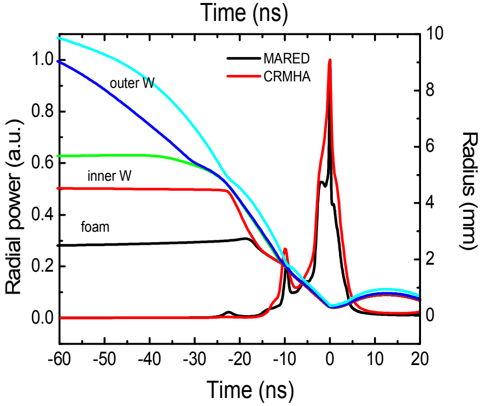
- The ratios of array/foam mass and radius are fixed
- When the load mass is very low, the hohraum temperature is also low and the time duration is short.
- When the load mass is very high, the hohlraum will be remarkably decreased
- We therefore can choose load (3) as a optimized design in experiments.

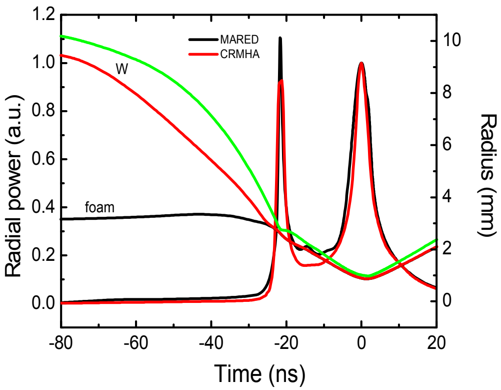
Two kinds of DH experiments on the "Julong I"

load num.	height mm	array radius mm	wire diameter mm	wire number	foam radius mm	foam density mg/cm3	array/foam mass ratio	shots
(1)	15.0	10.0/5.0	6.0/6.0	168/84	2.3	10.0	0.83	0199,0200,0201,0203
(2)	15.0	10.0	7.0	168	3.0	15.0	0.29	0178,0179,0180



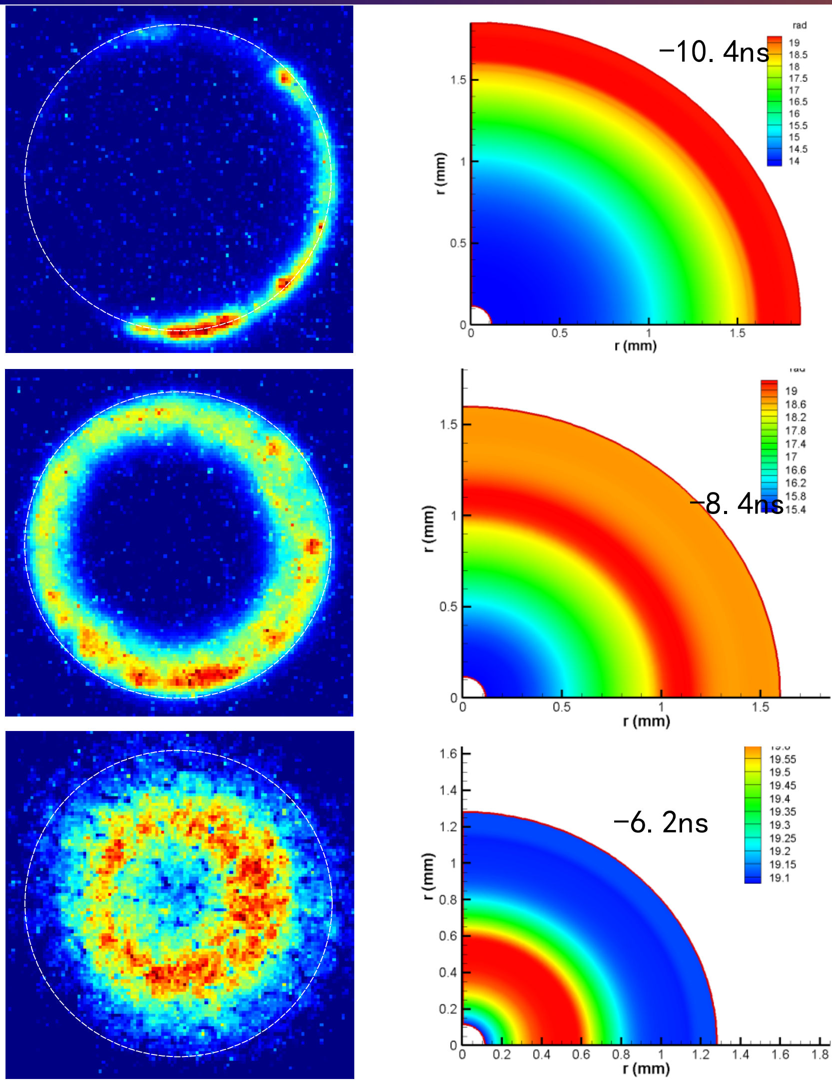


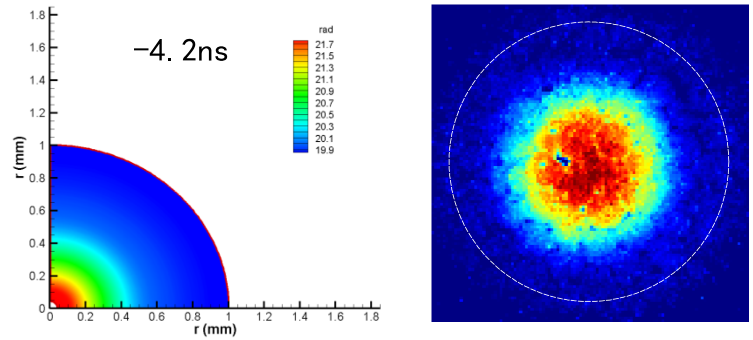




- load (1): relativleiy optimized load parameters for DH experiments
- load (2): low array/foam mass ratio to show the propagation of the radiating shock
- Experimental and simulation results present similar characteristics of radial radiation power

radiation distribution of load (1)---#0203

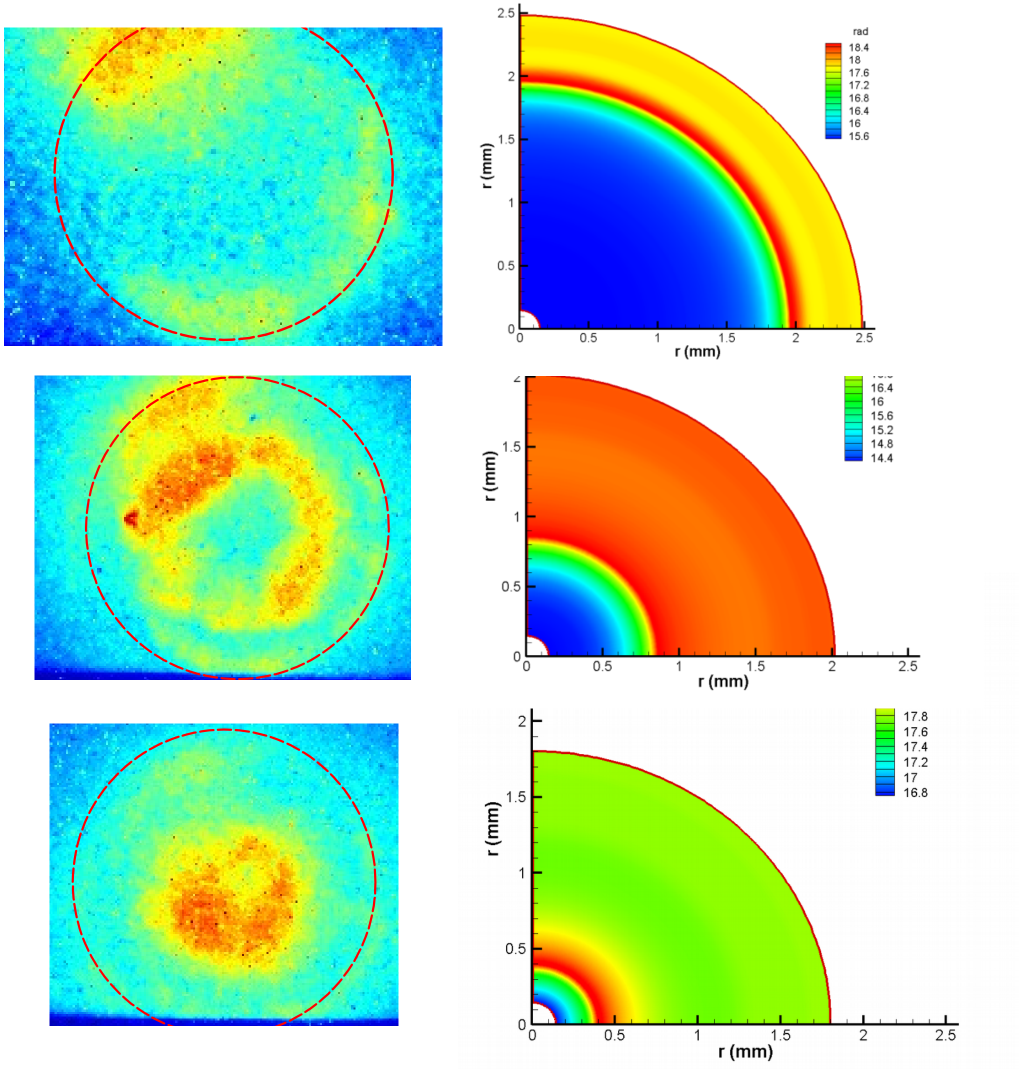




- for load (1), the radiation tmperature is higher than 100eV
- When the bulk tungsten plasma impacts onto the converter, the surface of the converter emits significantly.
- And this strong radiation emission can quickly transfers into the interior of the foam converter
- And in the interior of the shock front, the rdiation is relatively uniform.
- Just from the x-ray image, the shock front is hardly distinguised

experiment simulation

shock propgaation of load (2)---#0180



experiment

simulation

- For load (2), the radiation tmperature is much lower than 100eV
- And the gradient of the radiation is similar to that of the shock front.
- So we can approximately use the largest gradient of the radiation image as the position of the shock front.
- In this shot, the single wire-array is used. In nested wire-array expemriments, the shock ring is largely improved.

Summary

1) Conclusions

- The formaion processes and key issues of optimizing dynamic hohlraums are numerically explored for the "Julong I" facility DH experiments
- Several parameters, such as the array/foam mass ratio and the array/foam radius ratio can be used to optimize the dynamic hohraum radiation. Our simulation results show qualitative agreement with recent DH experiment on the "Julong I" facility

2) Future works

- futher investigation of DH, effect of a high density cover.
- corresponding expriments on the "JuLong I" facility.

Thanks for your attention！