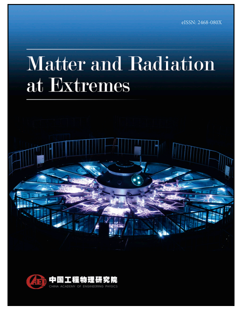
Accepted Manuscript



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PII: S2468-080X(17)30106-1

DOI: 10.1016/j.mre.2018.06.001

Reference: MRE 89

To appear in: *Matter and Radiation at Extremes*

Received Date: 11 October 2017

Revised Date: 6 May 2018

Accepted Date: 15 June 2018

Numerical studies on the radiation uniformity of Z-pinch dynamic hohlraum

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Abstract

Radiation uniformity is important for Z-pinch dynamic hohlraum driven fusion. In order to understand the radiation uniformity of Z-pinch dynamic hohlraum, the code MULTI-2D with a new developed magnetic field package is employed to investigate the related physical processes on Julong-I facility with drive current about 7~8 MA. Numerical simulations suggest that Z-pinch dynamic hohlraum with radiation temperature more than 100 eV can be created on Julong-I facility. Although some X-rays can escape out of the hohlraum from Z-pinch plasma and electrodes, the radiation field near the foam center is quite uniform after a transition time. For the load parameters used in this paper, the transition time for the thermal wave transports from r =1 mm to r = 0 mm is about 2.0 ns. Implosion of a testing pellet driven by cylindrical dynamic hohlraum shows that symmetrical implosion is hard to achieve due to the relatively slow propagation speed of thermal wave and the compression of cylindrical shock in the foam. With the help of quasi-spherical implosion, the hohlraum radiation uniformity and corresponding pellet implosion symmetry can be significantly improved thanks to the shape modulation of thermal wave front and shock wave front.

Keywords*: Z-pinch, Dynamic hohlraum, Radiation uniformity, Shock wave, Thermal wave*

PACS Codes: *52.58.Lq; 52.59.Qy; 52.65.Kj*

1 Introduction

Typical inertial confinement fusion (ICF) schemes involve symmetrical implosions of a fuel-filled capsule or tube driven by laser beams [1],[2], ion beams [3], or Z-pinches [4]. Z-pinches are regarded as promising approaches for ICF because of the capability to convert electrical energy into X-ray radiation energy with high efficiency. In the experiments conducted on Z machine located at Sandia National Laboratories, X-ray output as high as 200 TW and 1.8 MJ was produced, with a conversion efficiency from electrical energy to X-ray energy up to 15% [5]. In the past decades, Z-pinch dynamic hohlraum has been used to drive DD pellets on the 20 MA Z machine [6], [7], achieving a thermonuclear neutron yield up to 3.1×10^{11}. In the design of next generation Z-pinch facilities, dynamic hohlraum is considered as one of the two candidate loads [8].

A typical Z-pinch dynamic hohlraum is composed of a tungsten wire array and a low density plastic foam. When the high speed tungsten plasma accelerated by Lorentz force is impacting onto the plastic foam, a radiating shock traveling towards the axis is launched, emitting intense X-rays. The X-rays are trapped by the imploding plasma and electrodes, thus a Z-pinch dynamic hohlraum is created. As in the concept of laser driven hohlraum [1], the X-ray radiation inside the Z-pinch dynamic hohlraum can also be used to implode a pellet to fusion conditions.

However, there are some issues to be considered carefully, apart from the effects of magnetic Rayleigh-Taylor instability. First, the spherical pellet will be compressed by the cylindrical shock launched by the collision of the wire arrays and the plastic foam, unless the pellet can be imploded to fusion conditions before the arrival of the shock. Second, some people worry about the radiation uniformity in the Z-pinch dynamic hohlraum, which is a requirement for the symmetrical pellet implosion. This is because that X-rays are emitted by the cylindrical plasma and can escape from the hohlraum from the relatively cool electrode plates.

For Z machine with peak drive current about 20 MA, there have been some 2D integrated