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Study on Optical Measurement System for Temperature Evaluation of Sample Toward Generation of Warm Dense Matter using Intense Pulsed Power Generator

大強度パルスパワー発生装置を用いた Warm Dense Matter 生成に向けた試料温度評価のための光学計測系の検討

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To generate warm dense matter (WDM) state with inertial confinement fusion implosion process, an intense pulsed power generator is implemented to the isochoric heating. For the temperature evaluation with wavelength, an optical measurement system with a spectroscope mounted on a streak camera is used. To estimate the requirements for temporal resolution and wavelength resolution, the emission intensity is calculated with a measured input power. The peak wavelength shift is obtained around 10 nm each temporal resolution of 1 ns. It indicates that the estimated resolutions are enough to evaluate the time evolution of temperature with wavelength.

1. Introduction

In order to investigate the properties of the warm dense matter (WDM) in inertial confinement fusion (ICF), the evaluation method for the WDM with isochoric heating [1,2] on the implosion timescale using an intense pulsed power generator ETIGO-II (~1 TW, ~50 ns) [3] has been considered [4]. The WDM region is in density from 10^{21} to 10^{24} cm^{-3} and for temperature varying from 10^3 to 10^5 K. The WDM is complex regime, because of unclear theoretical model, and lacked experimental evaluations. Foamed metal such as a pusher and a radiator is considered as structural materials in the fuel pellet [5]. Properties in WDM should be clear to design the ICF fuel pellet.

We studied the measurements of the internal energy and the temperature for the estimation on a specific heat at constant volume of the WDM. In this study, an optical measurement system with a spectroscope (Hamamatsu Photonics: C11119-01) mounted on a streak camera (Hamamatsu Photonics: C7700-01) is considered the temperature evaluation of a foamed metal sample.

2. Study on Optical Measurement System for Temperature Evaluation of Sample

To obtain the time evolution of temperature with a wavelength, the spectroscope and the streak camera are used. To estimate the requirements for a temporal resolution and a wavelength resolution of the optical measurement system, the emission intensity is estimated from numerical simulation [6,7] with a measured input power.

Figure 1 shows a concept of the experimental setup. Foamed copper is used as a sample, which is packed into a hollow sapphire capillary (∅5 mm × 5 mm). The density of the foamed copper sample is

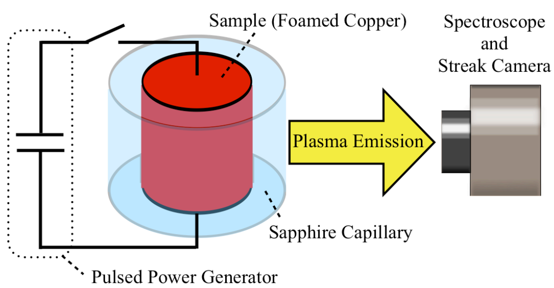

Fig. 1 Concept of experimental model.

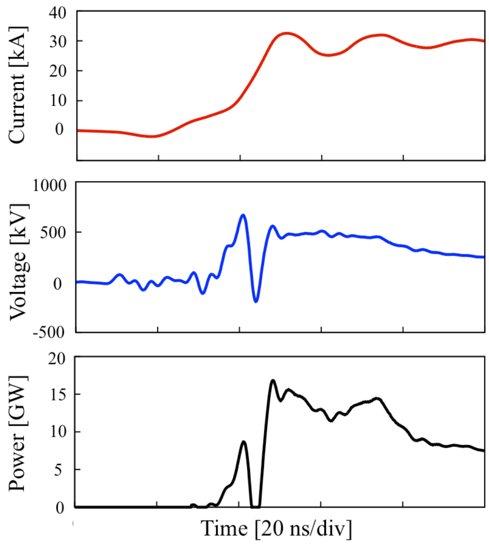

Fig. 2 Current and voltage waveforms and input power into the sample. The starting time to calculate the power is defined as 10% of peak current.

0.1 times the solid density (8960 kg/m^3). The temperature of the sample is increased due to Joule heating with intense pulsed power discharge.

To determine the feasibility of generating WDM state using ETIGO-II, the input power was measured [4]. Figure 2 shows current and voltage waveforms and input power into the sample.

Figure 3 shows the temperature of the sample as a function of time. The temperature of the sample is estimated with the measured power and the conventional thermodynamic properties [8, 9]. The achievable temperature of sample is estimated ~10000 K in several-10 ns.

To estimate the requirements for the temporal and the wavelength resolutions, the time evolution of emission intensity is estimated from numerical simulation [6,7]. Figure 4 shows the emission intensity as a function of time at wavelengths between 400 and 750 nm, which is corresponded with the time evolution of the temperature as shown in Fig. 3. The temporal resolution and the wavelength interval are defined as 1 ns and 10 nm, respectively. Squared points in the figure indicate the peak emission intensity. The wavelength of peak emission intensity shifts from 750 nm to 400 nm during 22 ns. The peak shift is obtained over 10 nm up to 18 ns. From above estimations, total sweep time of streak camera and the wavelength resolution of spectroscope are required to 100 ns and 5 nm with the equipment specification. It indicates that the temporal resolution of 1 ns and the wavelength resolution 10 nm are enough to evaluate the temperature of the sample with wavelength.

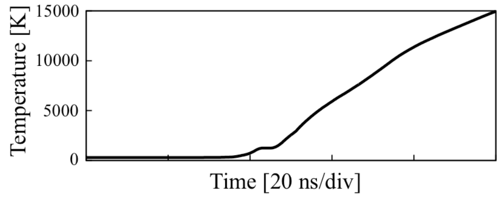

Fig. 3 Time evolution of the sample temperature.

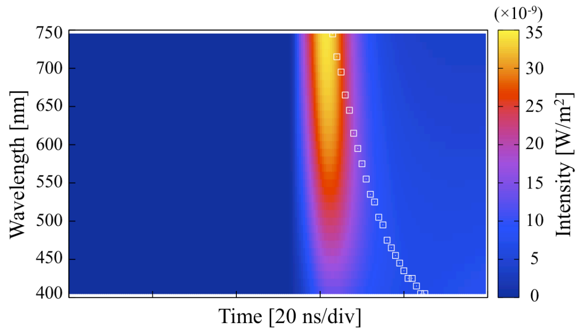

Fig. 4 Emission intensity as a function of time at wavelengths between 400 and 750 nm. Squared points indicate the peak emission intensity.

3. Conclusion

Requirements for resolution of optical measurement system are estimated for the temperature evaluation of WDM in ICF. The temporal resolution and the wavelength resolution are estimated to 1 ns and 10 nm from the wavelength of emission intensity. It means that the temperature evaluation of the sample using the considering system is measured.

Acknowledgments

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