Development of the hot spot residual kinetic energy diagnostics with the orthogonal 6-axis nTOF sightlines

Yuchi Wu[1], Zifeng Song[1], Bolun Chen[1], Qi Tang[1], Zhebin Wang[1], Yudong Pu[1]
[1] National Key Laboratory of Plasma Physics, Laser Fusion Research Center, CAEP
e-mail (speaker): wuyuchi@caep.cn

A high quality hot spot, with a high temperature and a high density, is crucial in the laser driven inertial confinement fusion (ICF). It is required that the driven energy should be transferred to the internal energy of the hot spot in a relatively high efficiency. However, the residual kinetic energy (RKE) of the hot spot always decreases the energy transferring efficiency rapidly, which may be induced by the driven energy unbalance, the non-uniformity of the fuel and shell, the diagnostic windows on the hohlraum and some other factors. It was once a major limitation in the path to the ignition on NIF.

At present, the fusion neutron emission spectra are the main path to diagnose the RKE. The bulk velocity of the hot spot will induce a slight shift of the neutron emission spectra, and the residual convergent kinetic energy will broaden the peak of the spectra. On NIF there are 5 sightlines of neutron time-of-flight (nTOF) spectrometers for the RKE diagnostics. For the other facilities with the fusion yield of lower than 1E15, the precision of the RKE diagnostics is a challenge. It is difficult to simultaneously measure the fusion reaction emitted neutron and gamma, which increases the uncertainty of the fusion bang-time. The neutron flight path is decreased to be about 10m, which decreases the precision of the nTOF measurement.

In this work, the authors proposed an orthogonal nTOF diagnostics with 6-axis nTOF sightlines. The two nTOF detectors in the opposite sightlines makes the measurement is independent with the fusion bang-time. The scintillators with a fast response are used. The temporal responses are calibrated by a pico-second UV laser. The machine learning methods are applied to determine the neutron arrival time. The precision of nTOF measurement is less than 50ps. And the precision of the bulk velocity diagnostic achieves to be less than 30km/s in the shots with yield of only about 1E13.

With the orthogonal nTOF diagnostics, the bulk velocity of the hot spot induced by the laser energy unbalance is obtained. A semi-empirical model of the fusion yield over calculation (YOC) with the laser energy unbalance is obtained. A scaling law of the YOC to the ratio of the hot spot velocity over the implosion velocity (v_{hs}/v_{imp}) is also deduced. The YOC decreases rapidly with the increase of the velocity ration. Furthermore, with the 6-axis nTOF measurement, the six apparent ion temperatures of the hot spot are diagnosed. According to the measured direction of the bulk velocity, the apparent temperature varies with the polar angle between the sightline and the velocity. The thermal ion temperature is diagnosed from the fitted temperature in the sight view of perpendicular to the velocity. In the following work, more physical relation between the RKE and the implosion degeneration will be studied in detail.