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Experimental determination of the thermal, turbulent, and rotational ion motion, and magnetic field profiles in imploding plasmas

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We review new developments that made possible measurements of basic parameters in high-energy-density (HED) plasmas. The ion temperature plays a key role in determining the fusion rates and the electron-heating rate that often controls the radiation emission. However, its experimental measurement was lacking, since both the emission Doppler broadening and neutron spectra only yield the total ion kinetic energy. We describe various approaches in the last decade for studying the ion motion, in particular novel ones that allowed for determining the ion temperature and bringing up the finding that much of the ion kinetic energy at Z-pinch stagnations can be stored in non-thermal (probably turbulent) motion; also allowing for the determination of the non-thermal-motion dissipation time into ion heating. The magnetic-field (MF) distribution plays a key role in MF-driven HED plasmas. Recent spectroscopic observations in imploding- plasma systems will be reviewed, including the spatial evolution of the MF in Z-pinch plasmas, yielding unanticipated profiles of the MF field near stagnation. Applied or self-generated MF may lead to plasma rotation that affects the plasma dynamics; the diagnostics of rotation as a function of space and time will also be presented. Such observations have significant implications on the established concepts of implosion dynamics and provide challenges for model and code validation. While much of the recent results were obtained with university-scale systems, suggestions for applying these diagnostic developments in large-scale programs, and estimates of the ion temperatures in higher-power implosions, will be discussed.