Theory for time resolved temperature measurements using x-ray scattering

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A precise characterization of the ion and electron temperatures at stagnation and during the burn phase of a deuterium-tritium inertial confinement pellet is essential for the understanding and modelling of α-particle stopping and electron-ion energy transfer in the pellet and thus for the optimization of fusion energy production.

We explore the theoretical possibilities to measure the evolution of temperatures shortly before and after ignition by x-ray scattering or by diffraction of x-rays or electrons. The principle of detailed balance not only applies to plasmons of electrons but also to ion acoustic modes, giving, in principle, direct and model independent access to electron and ion temperatures. Further, small angle x-ray scattering for sufficiently homogeneous systems might enable access to the compressibility and thus temperature via an equation of state. Also, elastic scattering is visible in the Rayleigh peak and an ion temperature can be extracted using a theory for the structure of dense matter. Finally, dopants and the broadening of the K or L shell lines might be used to determine the temperature. We will give an overview of these methods and their limitations from a theoretical point of view as well as considerations concerning the transition from full non-equilibrium to two-temperature systems and finally to full equilibration.