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Exploring the late evolution of a Rayleigh-Taylor unstable system – an experimental insight on turbulence

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Instabilities and turbulence are ubiquitous in hydrodynamic and related flows, such as in magneto-hydrodynamics. One of the simplest instabilities, the Rayleigh-Taylor instability (RTI), plays a major role in high energy density physics at many different scales, from microscopic, in inertial confinement fusion, to astrophysical ones. The study of RTI is still an active research field due to the non-linear behavior observed at late time, where it can lead to the appearance of a turbulent flow. Such flows, which are characterized by their chaotic behavior, redistribute the energy inside the system. In astrophysics, this is believed to influence the star formation rate including the destabilization of cosmic filaments. The study of turbulence in high energy density is limited mainly to simulations as experiments are usually restricted due to the limited spatial resolution of the diagnostics.

In this talk, we will show experimental results relative to turbulence, which were obtained on the Japanese x-ray free electron laser SACLA[1]. This experiment benefited from the high resolution x-ray radiography platform we developed[2], as well as our experience in dealing with RT unstable systems on medium size lasers (LULI2000)[3].

Starting from a solid target, designed to induce growth of RTI in a decelerating phase, we follow the evolution of an unstable plasma flow until it becomes turbulent. With the obtained radiographs, we reconstruct the evolution of the flow with unprecedented resolution (~ 1 μm). Thanks to this high resolution, we observed some details on the cap of the RTI spikes, which are useful to evaluate the results of simulations. This resolution also allows us to study the spatial spectrum of the flow, down to a scale not achieved in previous experiments. These spectra were compared to existing turbulence theories revealing unexpected phenomena.

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