FY19 CELIA Report on Omega Laser Facility Experiments

Wire Point-Projection X-Ray Radiography of Rayleigh–Taylor Instabilities on OMEGA EP

Principal Investigators: A. Casner, V. Bouffetier, and L. Ceurvorst (CELIA, University of Bordeaux); G. Rigon, P. Mabey, and M. Koenig (Ecole Polytechnique); L. Antonelli, M. Khan, and N. Woolsey (University of York); R. Scott and K. Glize (Rutherford Appleton Laboratory); and W. Theobald (LLE)

The advent of MJ-class laser facilities such as the National Ignition Facility (NIF) and Laser Mégajoule's (LMJ's) PETAL makes it possible to explore states of matter in the laboratory that are relevant for astrophysics and high-energy-density (HED) plasmas under extreme conditions of pressure. For the case of high-Mach-number turbulent flows, the NIF and LMJ-PETAL are unique energy drivers because targets can be accelerated over larger areas and longer time periods than previously achieved on any other laser facilities. This enables hydrodynamic instabilities, such as the Rayleigh–Taylor instability (RTI) or Kelvin–Helmholtz instability, to be driven into their turbulent stage of development. However, even if x-ray imaging diagnostics for hydrodynamic instabilities experiments have improved over the past two decades, further developments are still needed to elevate our understanding and simulations of turbulent flows in HED plasmas.[1]

We report here on a novel planar RTI platform that takes advantage of OMEGA EP short-pulse beams to perform wire point-projection x-ray radiography.[2] The platform was first developed at the LULI2000 Laser Facility in France.[3] The experimental configuration is shown in Fig. 1. The drive laser intensity was $I \sim 2 \times 10^{14}$ W/cm^2 at 2ω with a pulse duration of 1.5 ns. The

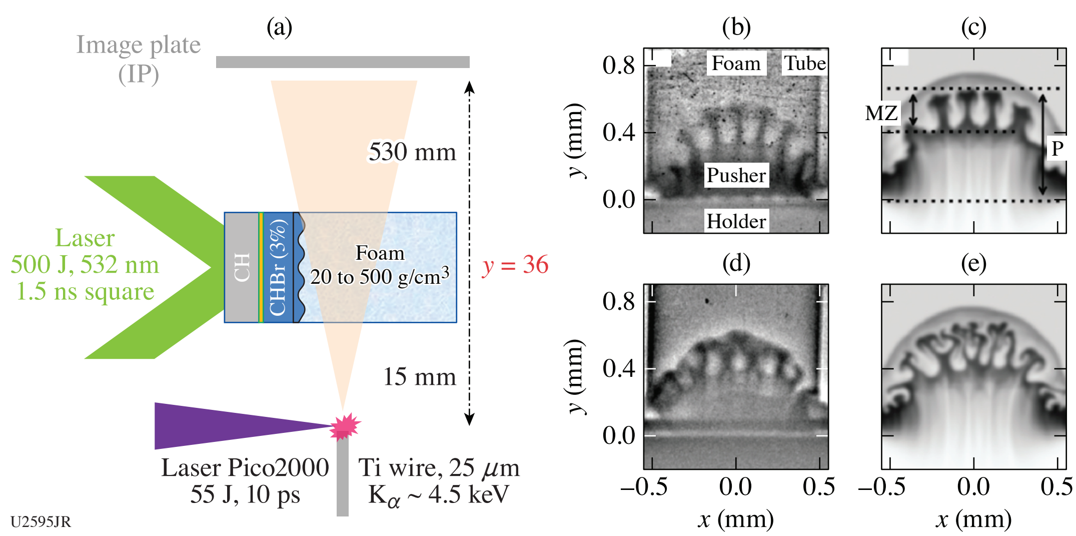

Figure 1
(a) Sketch of target composition and materials for deceleration-phase RTI experiments on LULI2000. [(b)–(e)] Comparison of [(b) and (d)] experimental and [(c) and (e)] synthetic radiographs taken at t = 30 ns for a foam with a density of 100 mg/cm^3. The mixing zone (MZ) is defined as the distance between peak and bubble.[2]

Pico2000 beam (55 J, 10 ps) was used in bottom-up geometry[2] to acquire snapshots of RTI during the linear and highly nonlinear phases. RTI is triggered during the deceleration phase with modulated targets embedded within low-density resorcinol formaldehyde foam ($C_{15}H_{12}O_4$).

The modulated package (monomode or multimode) decelerates into the lighter-foam medium, typically with densities ranging from 50 to 500 mg/cm^3. Typical radiographs acquired for foam with 100 mg/cm^3 are shown in Fig. 2. The initial perturbation wavelength and the amplitude were $\lambda = 120\ \mu$m and 20 μm peak-to-valley, respectively. The highly nonlinear regime of the RTI was reached, as can be seen by the development of mushrooms at the spike heads. *FLASH* simulations[3] agreed fairly well with the experimental radiographs [see Figs. 1(c) and 1(e)].

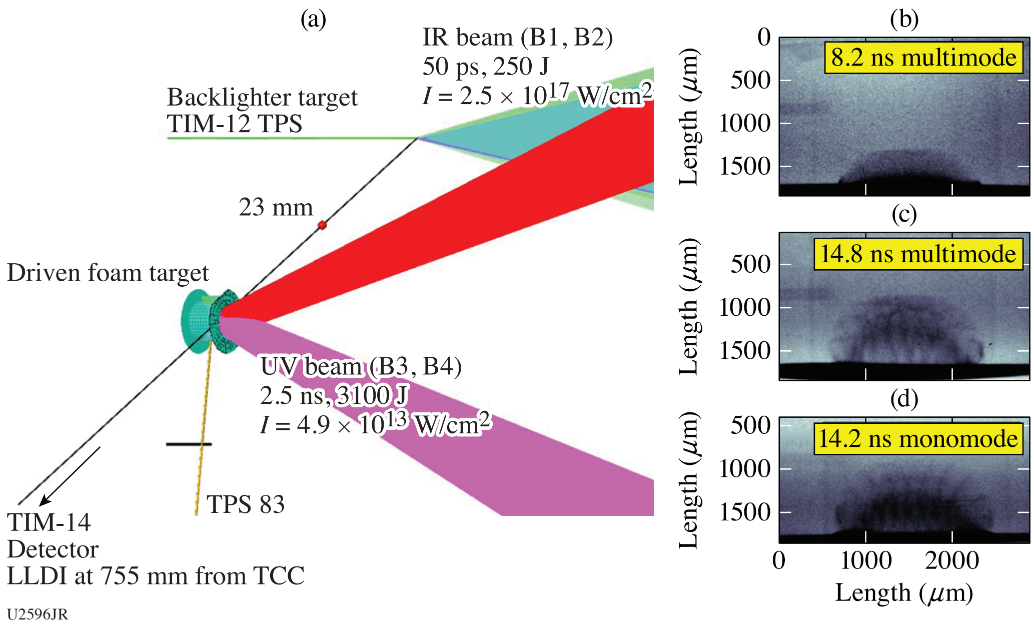

Figure 2
(a) TurboHEDP-EP-19A setup and [(b)–(d)] experimental data; [(b),(c)] multimode initial condition at $t = 8.2$ and 14.8 ns, respectively. TIM: ten-inch manipulator; TPS: Target Positioning System; TCC: target chamber center.

A scaled-up version of the LULI2000 platform was successfully commissioned on OMEGA EP in May 2019. Going to a larger facility such as OMEGA EP allowed the modulated CH/foam targets to be driven at higher laser energies with better beam quality. Figure 2(a) shows the experimental setup. The two driving UV ($\lambda = 0.35\ \mu$m) laser beams (B3, B4) provided an energy of 1550 J/beam in a 1.25-ns-sq pulse and were focused on a CH ablator (10 μm thick) with a diameter of 3.1 mm. Behind the CH ablator, a preheat shield protects a modulated CHBr (5% atomic fraction) in contact with a cylinder (1.8-mm internal diameter, 1.5 mm in length) filled with a foam at 20 mg/cm^3 to trigger RTI growth in deceleration. The UV beams were equipped with SG8-1100 distributed phase plates that produced a laser spot with a diameter of 930 μm (1/*e* value of peak fluence) and a fluence distribution envelope that is well described by a super-Gaussian function with an order of 6.0. The UV laser intensity was 2×10^{14} W/cm^2 per beam. The IR beams B1 or B2 were focused normal onto the Ti wire with the wire aligned along the axis to TIM-14, which contained a passive imaging-plate detector plate in a heavimet shielded box [LLNL Laue diffraction imager (LLDI) located at 755 mm from target chamber center]. The wire backlighter produced a strong emission between 4.5 and 5.5 keV, predominately from the He_α and Ly_α resonance lines. The distance from backlighter to CH/foam cylinder was 2.3 cm, and the distance from the CH/foam cylinder to the IP detector was 74 cm, providing a 38× magnification. Resolution Au grids were mounted on top of the cylinder and were used to infer the spatial resolution, which was found to be 33 μm.

Preliminary results of nonlinear RTI are shown in Figs. 2(b)–2(d) for the two different initial conditions (single-mode and two-mode pattern). The quality of the data is not as high as that acquired on LULI2000. A deliberate choice was also made to work with targets nearly twice as large in diameter (1.8 mm instead of 1 mm), which induces tight constraints on target alignment. Nevertheless, these preliminary data compare reasonably well with ongoing *FLASH* calculations. A follow-up campaign is envisioned for XPCI imaging of RT instabilities.

This material is based upon work supported by the Agence Nationale de la Recherche under the ANR project TurboHEDP (ANR-15-CE30-0011).

1. A. Casner *et al*., High Power Laser Sci. Eng. **6**, e44 (2018).
2. E. Brambrink *et al*., High Power Laser Sci. Eng. **4**, e30 (2016).
3. G. Rigon *et al*., Phys. Rev. E **100**, 021201 (2019).