Magnetic fields are ubiquitously observed or inferred in a variety of astrophysical systems. These wide-spread magnetic fields are believed to have come from a dynamo process, during which a fraction of the flow kinetic energy is converted to the magnetic energy. Most dynamo theories and experiments have emphasized the important role of flow turbulence. In the so-called small-scale dynamo regime, significant magnetic fields are produced at scales comparable to or smaller than that of the flow. Theory and extensive numerical simulations have mapped out the parameter space near magnetic Prandtl number $P_m \sim 0.01 - 100$ and Mach number $M \sim 0.01 - 100$ for exciting small-scale dynamo [1]. For example, for $P_m \sim 1$ plasmas, the critical $R_m$ required for dynamo is $\sim 100$, which is likely accessible with high-energy density plasmas made by powerful lasers [2].

We describe our experiments on the OMEGA-EP wherein the turbulent small-scale dynamo was observed in the $P_m > 1$, high $R_m > 100$, and transonic turbulent regime. Extensive numerical simulations have suggested its feasibility [3]. As shown in Figure 1, a $\sim \text{mm}^3$-scale volume of turbulent, magnetized plasma is produced using the OMEGA-EP laser. Using diagnostics including a $4\omega$ laser beamline for angular filter refractometry and a sheath-accelerated proton beamline for deflectometry, we were able to reliably measure the hydrodynamics and magnetic field of the target plasma and observe the turbulent dynamo over a few nanoseconds of activity across two orders of magnitude in spatial scale, $10 < k < 1000 \text{ cm}^{-1}$.

This work was supported by LANL’s LDRD program, the DOE NNSA-ASC OASCR Flash Center at the University of Chicago, the DOE NNSA program DE-NA0003856 and the Laboratory for Laser Energetics.

References