Magnetic field generation, dynamics, and reconnection driven by relativistic intensity laser-plasma interactions

L. Willingale[1], P. T. Campbell[1], A. E. Raymond[1], N. Alexander[2], L. Antonelli[3], A. Bhattacharjee[4], A. Bott[5], H. Chen[6], V. Chvykov[1], E. Del Rio[2], C. Dong[4], G. Fiksel[1], P. Fitzsimmons[2], W. Fox[4], G. Gregori[5], J. Halliday[7], B. Hou[1], P. Kordell[1], K. M. Krushelnick[1], Y. Ma[1], A. Maksimchuk[1], A. McKelvey[1], C. Mileham[8], E. Montgomery[9], J. Nees[1], P. M. Nilson[8], M. Notley[9], C. A. J. Palmer[5], C. P. Ridgers[3], A. A. Schekochihin[5], C. Stoeckl[8], A. G. R. Thomas[1], E. R. Tubman[7], M. S. Wei[2,8], G. J. Williams[6], N. Woolsey[3], V. Yanovsky[1], and C. Zulick[10]

[1] *Center for Ultrafast Optical Science, University of Michigan, Ann Arbor, MI, USA;* [2] *General Atomics, San Diego, CA, USA;* [3] *University of York, York, UK;* [4] *Princeton Plasma Physics Laboratory, Princeton, NJ, USA;* [5] *University of Oxford, Oxford, UK;* [6] *Lawrence Livermore National Laboratory, Livermore, CA, USA;* [7] *Imperial College London, London, UK;* [8] *Laboratory for Laser Energetics, University of Rochester, Rochester, NY, USA;* [9] *Central Laser Facility, STFC, Oxfordshire, UK;* [10] *Naval Research Laboratory, Washington DC, USA;*

The extremely energetic class of astrophysical phenomena - including high-energy pulsar winds, gamma ray bursts, and jets from galactic nuclei - have plasma conditions where the energy density of the magnetic fields exceeds the rest mass energy density ($\sigma_{cold} = B^2/(\mu_0 n_e m_e c^2)$), the cold magnetization parameter). Laboratory studies of magnetic dynamics and reconnection provide an important platform for testing theories and characterizing different regimes. Here, we present experimental measurements, along with numerical modeling, of short-pulse, high-intensity laser-plasma interactions that produce extremely strong magnetic fields (>100T). Three-dimensional particle-in-cell simulations show the plasma density and magnetic field characteristics can satisfy $\sigma_{cold} > 1$. The generation and the dynamics of these magnetic fields under different target conditions was studied using proton radiography, and relativistic intensity laser-driven, magnetic reconnection experiments were performed. Evidence of magnetic reconnection was identified by the plasma's X-ray emission patterns, changes to the electron spectrum, and by measuring the reconnection timescales. [A. E. Raymond, *et al.*, Physical Review E, **98**, 043207 (2018)]

*Supported by the Department of Energy / NNSA under Award Number DE-NA0003606 and by NSF under 1751462. The authors acknowledge the OSIRIS Consortium, consisting of UCLA and IST (Lisbon, Portugal) for the for providing access to the OSIRIS 2.0 and 4.0 framework. Work supported by NSF ACI-1339893.