Investigation of collective electron dynamics in relativistically transparent laser-foil interactions

R.J. Gray\textsuperscript{1}, D.A. MacLellan\textsuperscript{1}, B. Gonzalez-Izquierdo\textsuperscript{1}, H.W. Powell\textsuperscript{1}, D.C. Carroll\textsuperscript{2}, C.D. Murphy\textsuperscript{3}, L.C. Stockhausen\textsuperscript{4}, D.R. Rusby\textsuperscript{1,2}, G.G. Scott\textsuperscript{1,2}, R. Wilson\textsuperscript{1}, N. Booth\textsuperscript{2}, D.R. Symes\textsuperscript{2}, S.J. Hawkes\textsuperscript{2}, R. Torres\textsuperscript{4}, M. Borghesi\textsuperscript{5}, D. Neely\textsuperscript{2}, and P. McKenna\textsuperscript{1}

\textsuperscript{1}SUPA Department of Physics, University of Strathclyde, Glasgow G4 0NG, UK
\textsuperscript{2}STFC Rutherford Appleton Laboratory, Oxfordshire OX11 0QX, UK
\textsuperscript{3}SUPA School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3JZ, UK
\textsuperscript{4}Centro de Laseres Pulsados (CLPU), M5 Parque Científico, 37185 Salamanca, Spain
\textsuperscript{5}Centre for Plasma Physics, Queens University Belfast, Belfast BT7 1NN, UK

The interaction of an intense laser pulse with a solid target produces high energy electrons at the target-vacuum boundary. For sufficiently high laser intensities and thin foil targets, the target electrons become highly relativistic and rapidly expand into vacuum, lowering the peak electron density. The relativistic increase in the electron mass increases the critical density of the plasma. The combination of these two factors can result in the target electron density decreasing below the relativistically-corrected critical density at a given point in the laser pulse, thereby enabling the remainder of the laser pulse to propagate through the target and in the process interact with the bulk target electrons.

We report on measurements of the collective dynamics of ponderomotively-driven electrons in the relativistically-induced transparency regime. The 2D profile of the beam of accelerated electrons is shown to change from an ellipse aligned along the laser polarization direction in the case of limited transparency, to a double-lobe structure aligned perpendicular to it, when a significant fraction of the laser pulse co-propagates with the electrons. The temporally resolved dynamics of the interaction are investigated via PIC simulations.

The implications of the onset of relativistic induced transparency, and the resulting collective electron dynamics, for laser-driven ion acceleration are also explored.