White Paper for *Frontiers of Plasma Science Panel*

Date of Submission:	***06/23/15***

Indicate the primary area this white paper addresses by placing "P" in right column.
Indicate secondary area or areas by placing "S" in right column

	"P", "S"
• Plasma Atomic physics and the interface with chemistry and biology	
• Turbulence and transport	S
• Interactions of plasmas and waves	P
• Plasma self-organization	
• Statistical mechanics of plasmas	

Indicate type of presentation desired at Town Hall Meeting.

	"X"
Oral	
Poster	
Either Oral or Poster	
Will not attend	X

Title:	Relativistic electron driven magnetic reconnection
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Co-Authors:	Karl Krushelnick (Michigan), Alexander Thomas (Michigan), William Fox (Princeton)

(Limit text to 3-pages including this form. Font Times Roman size 11.
1 page of references and 1 page of figures may also be included. *Submit in PDF format.*)

- ***Describe the research frontier* and importance of the scientific challenge.**

- ***Describe the approach to advancing the frontier and indicate if new research tools or capabilities are required.***

- ***Describe the impact of this research on plasma science and related disciplines and any potential for societal benefit.***

Relativistic electron driven magnetic reconnection

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Magnetic reconnection [1] is the fundamental phenomena where magnetic fields rearrange into a lower energy state and releases energy. This occurs during many high-energy-density processes such as solar flares [2], coronal mass ejections, during the interaction of the solar wind and the Earth's magnetosphere [3], fusion plasma instabilities [4] and during some explosive astrophysical events [5]. In previous work, we showed the first experimental evidence of laser-driven magnetic reconnection [6–8] and this work has lead to many other groups studying laser-driven magnetic reconnection [9–16]. Two high-energy, nanosecond duration laser pulses are used to heat a solid target and produce two expanding plasma plumes where azimuthal magnetic fields are self-generated due to the perpendicular temperature and density gradients. Between the two plasma plumes, opposing magnetic fields are driven together, either by the plasma flow or the Nernst effect, depending on the intensity of the laser interaction. This provides a controlled way to study magnetic reconnection in the laboratory to understand processes that can usually only be studied indirectly from astrophysical objects. Using laser pulses with nanosecond duration and moderate laser intensities ($I \sim 10^{14}$– 10^{15} Wcm^{-2}), produces plasma conditions that may be comparable with solar conditions.

For relativistic objects such as hard x-ray and higher energy spectrum bursts in solar flares [17], pulsars [18], γ-ray bursts [19–21] and active galactic nuclei [22, 23], relativistic magnetic reconnection likely plays an important role. Some of these are objects that we will only ever be able to make indirect observations of to determine the physical processes taking place. Therefore, it would be of interest to perform a laboratory study of magnetic reconnection driven by the relativistic electron currents formed during a ultra-high intensity (10^{19} Wcm^{-2}) laser plasma interaction. Developing an experimental platform to study collisionless magnetic reconnection using the relativistic electron currents produced during high-intensity laser interactions with solid targets would provide valuable data on the reconnection physics, such as timescales and plasma jet energy, to compare with existing theories. A relativistic intensity laser pulse strongly heats electrons from a solid target to MeV energies. These electrons are largely confined to the target surface by space-charge fields and therefore rapidly ($\sim$ c) expand along the target surface. Associated with this huge surface electron current is a large azimuthal magnetic field [24]. Therefore having two laser pulses focused in close proximity onto the target, will produce a magnetic reconnection geometry driven by relativistic electron currents in a collisionless regime as shown in figure 1.

This research would impact fundamental plasma science and magnetic reconnection research as well as related astrophysics and space science fields. Better understanding of magnetic reconnection processes could lead to improved understanding of solar flares, a phenomena that can debilitate the now extensive satellite network and even black-out power networks. Facilities exist for this type of experiment, such as Hercules or Tcubed (University of Michigan), Titan (LLNL), and Omega EP (LLE), but further development of ultrafast diagnostics would enable improved measurements. Numerical modeling of these interactions using state-of-the-art codes, such as OSIRIS or EPOCH, to study the physics of the processes requires access to large-scale computing facilities as it is challenging to model the dense plasma over relatively long timescales.

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Figures
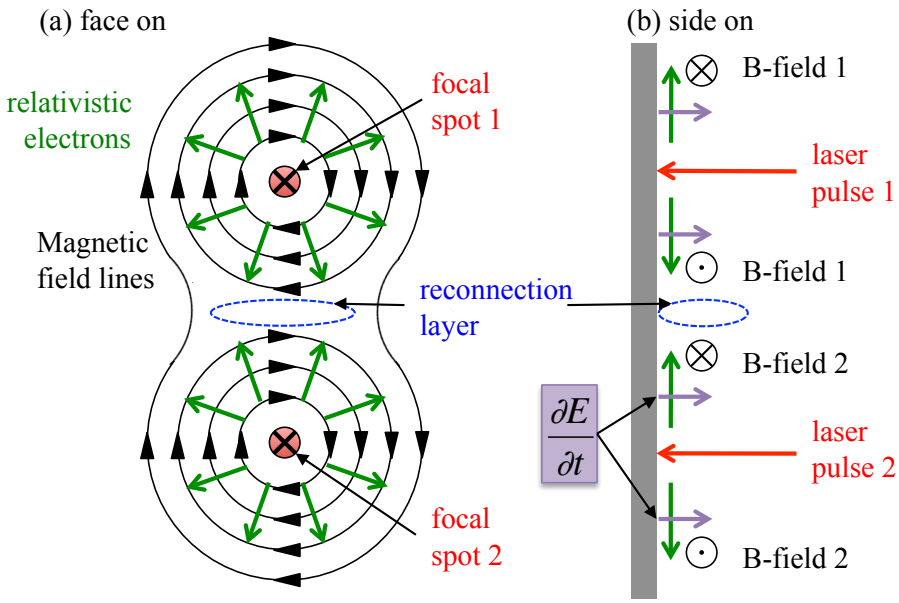
Figure 1: The basic laser driven magnetic reconnection geometry show (a) face-on and (b) side-on.