Integrating Amplifiers and Possible Reconnection Events in WIRX

Abstract

We have developed a set of magnetic field probes to track structural changes in the magnetic field in the Wheaton Impulsive Reconnection Experiment (WIRX) and to look for candidate magnetic reconnection sites. These probes complement several existing fast imaging diagnostics. It is found that the light emitted by the plasma correlates well with the spatial position of the current as deduced from the magnetic field measurements. Both emission and magnetic profiles vary with plasma current and vacuum coil field. In some plasmas, we observe bursty, fast time scale events in both photodiode camera data and magnetic data. The propagation of these magnetic disturbances throughout the plasma has been studied using correlation techniques. Work is ongoing to assess whether these fast events may involve magnetic reconnection.

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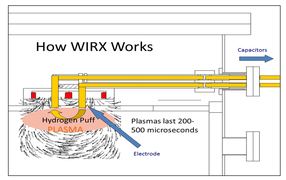
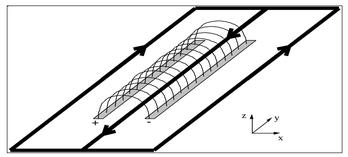
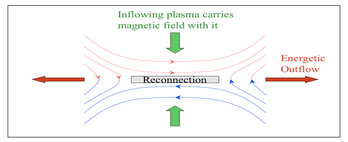






Wheaton Impulsive Reconnection Experiment

- We study Magnetic Reconnection, a process that converts magnetic energy to thermal energy in a plasma.
- Primary Goal: To learn about 3D magnetic reconnection.
- We use an inverted arcade geometry formed by long parallel electrodes and a figure-eight magnetic coil.

Magnetic Probes

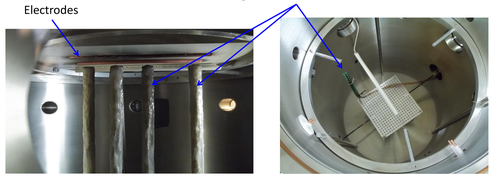
Magnetic Probe Features

- Magnetic probes are built to measure the 3 components of field at an array of locations in the plasma.
- The probes are a set of "stalk" like objects with small coils of wire arrayed on each stalk.
- Twisted pairs of wire take signal away from the sensing coils to external circuitry.
- The probes are shielded and insulated.
- Each probe can be secured at an array of locations in the vessel, allowing flexibility in measurement structure.

Probes arranged on the PCB.

Probes arranged in vacuum vessel.

Electrodes

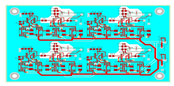


Integrating Amplifiers

Integrator Design Considerations

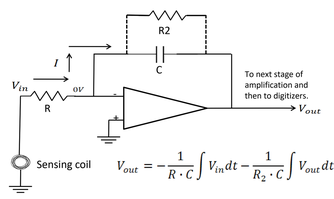
- Speed. The integrators must be fast enough to keep up with the changing plasma. We settled on a resolution of around 2μs.
- Gain. Two separate amplification (gain) settings required for necessary dynamic range.
- Drift. Op-amp bias current causes output of the integrators to drift. Fixed by adding a feedback resistor (R2 in figure) to provide finite DC gain.
- Droop. Including a drift correction resistor causes the output to droop slowly over time. Corrected by numerically adding back some of the output.

Printed circuit board (PCB) layout from CAD program.



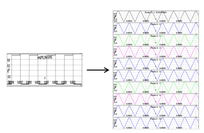
Data taken with the probes connected.

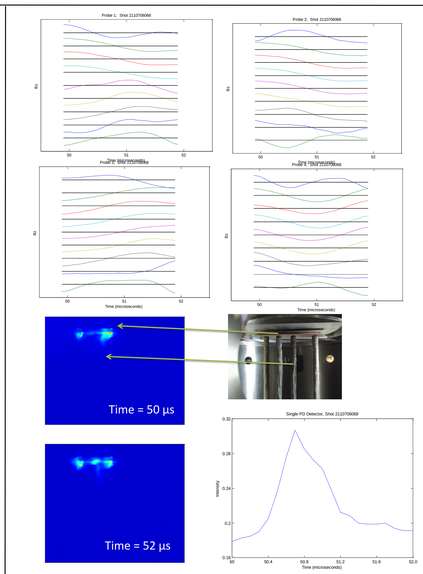
Integrator Circuit



$$V_{out} = -\frac{1}{R \cdot C}\int V_{in}dt - \frac{1}{R_2 \cdot C}\int V_{out}dt$$

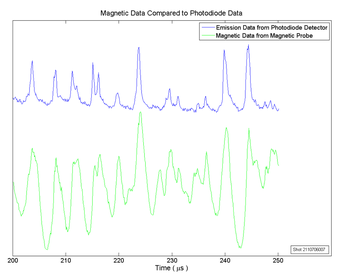
Calibrating the integrators by running a known signal though them and recording the output.



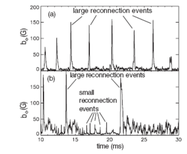


Bursts in Magnetic Data

This plot shows that the emission data is correlated with the magnetic data in time (for the bursty spikes).

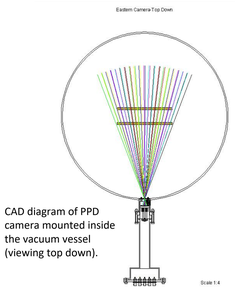


Time



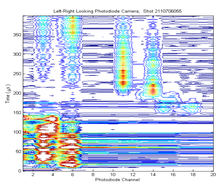
Plot of reconnection from UW Madison

Correlation of Emission Structure and Magnetic Structure



CAD diagram of PPD camera mounted inside the vacuum vessel (viewing top down).

PPD Cameras



Z Position (along electrodes)

Time

Data taken from PPD camera. Color gives intensity.

ICCD Cameras

ICCD high speed camera.

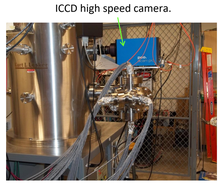
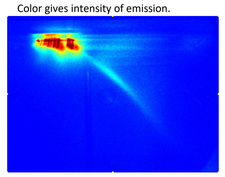


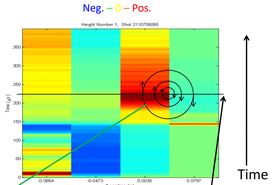
Photo (false color) taken by ICCD camera. Color gives intensity of emission.



- We have measurements of emission structure from PPD and ICCD cameras (left).
- We can find current from the magnetic data (below).
- Comparing the two (right) tells us that the current appears in regions of intense emission, allowing us to use the PPD and ICCD cameras to locate possible reconnection sites.

Red adjacent to blue indicates the field is reversing direction, so a current is flowing between those two probes.

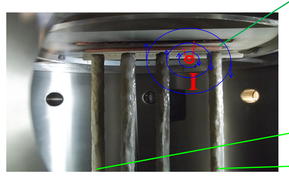
Neg. – 0 – Pos.

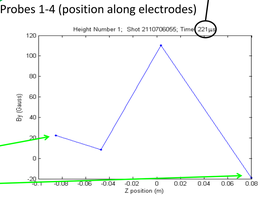


Time

Probes 1-4 (position along electrodes)

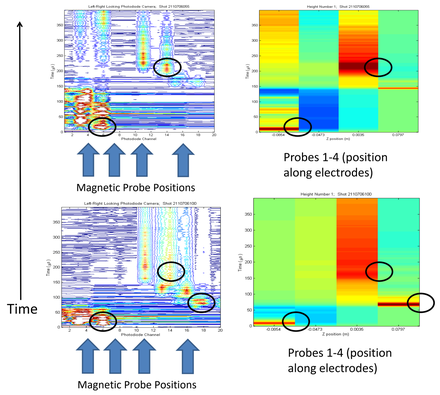
Locations where the upwards component of the field reverses sign from one probe to an adjacent probe indicate a current flowing between them.





These plots show that the emission structure is correlated with the spatial location of the current (for longer timescale changes) since the main color differences on the right (caused by current) happen at the same time and in the same location as bright spots in the emission structure on the left.

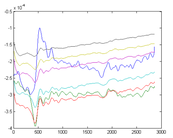
Left to Right looking.



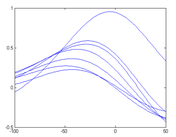
Time

Correlation and Size of Bursts

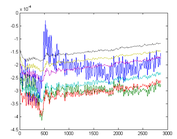
Bz data for different Y positions.



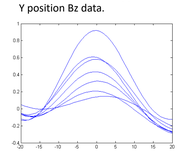
Correlation with the uppermost Y position Bz data.

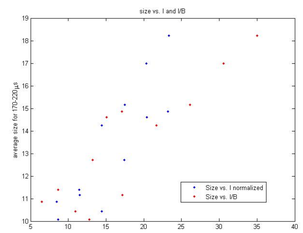


Bz data for different Y positions.



Correlation with the uppermost Y position Bz data.





2011 Matthew McMillan, Cole Adams, Mindy Cartolano, Dr. Darren Craig

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