# Zeeman Splitting Observed and Simulated in Laser-Produced Magnetized Blast Waves

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Magnetic fields are ubiquitous in the Universe and play a critical role in laboratory experiments, fundamentally influencing plasma behavior. For example, they can smooth out discontinuities in blast waves, alter the geometry of supernova remnants from spherical to barrel-shaped, and inhibit heat transport [1, 2]. Investigating these systems requires accurate determination of the plasma's parameters (density and temperature), the magnetic fields' strength and orientation, as well as whether it has been influenced by the plasma (compression or diffusion).

The recent advent of apparatuses capable of generating strong magnetic fields coupled with high-energy laser facilities [3] necessitates the development of advanced experimental platforms and numerical codes for magnetic field diagnostics. Even though multiple diagnostics already exist, all face significant limitations; B-dot probes disturb the plasma, proton deflectometry requires an extra, high-intensity laser beam, and polarimetry is not sensitive enough for certain systems.

To address this need, we developed an optical, time-resolved, high-dispersion spectrometer (resolution of ~0.1 nm) and performed measurements on laser-produced blast waves at the LULI2000 facility. Utilizing a pulsed-power system, we generated well-characterized magnetic fields of up to 20 T, both perpendicular and parallel to the blast waves' propagation. We collected the emitted spectra of multiple intense radiative transitions of nitrogen (2s22p(2P0)3l - 2s22p(2P0)3l') and used line-shape modeling to extract the parameters of the plasma; from the distinct signatures of the Zeeman and Stark effects on spectral lines, we inferred the average magnitude of the magnetic field inside the plasma and its density while its temperature was calculated from line intensity ratios and Doppler broadening. Our experimental results were extensively compared with spectra simulated using the Stark-Zeeman line-shape code PPPB, developed at PIIM [4], to examine if the magnetic field was compressed by the plasma.

Here, we present the first clear observation of Zeeman splitting in a homogenous, low-temperature, diffuse plasma (5-20 eV, ~$10^{18}$ cm$^{-3}$) and show an excellent agreement between the experiment and the PPPB simulations for all magnetic field strengths and orientations. These results reveal that the external magnetic field diffuses into the post-shock region and demonstrate the capabilities of PPPB to accurately interpret our data, allowing for the establishment of a novel experimental platform for benchmarking atomic physics codes.

## References

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