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FY05 LDRD Final Report Spectroscopy of Shocked Deuterium

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Disclaimer

Auspices Statement

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FY05 LDRD Final Report
Spectroscopy in Shocked Deuterium
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N.C. Holmes, Principal Investigator

Abstract

We summarize the observations of unusual optical properties of shocked liquid deuterium (D_2) that led to proposing spectroscopic measurements. The apparatus built for the measurements is briefly described, along with some representative results in a test material. Unfortunately, spectroscopic measurements were not performed in shocked D_2 during the course of the project. Some reasons are noted.

Motivation

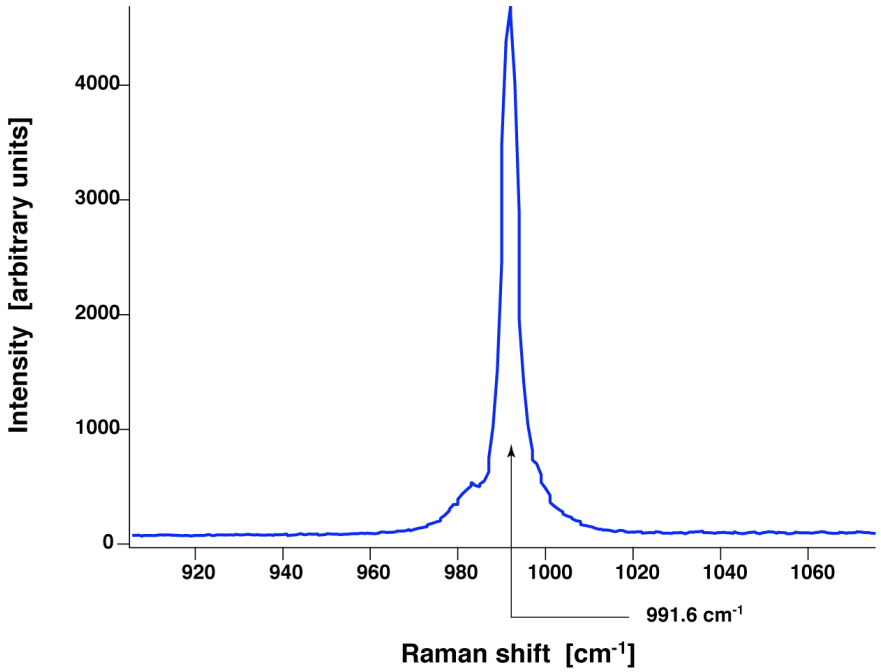
When making optical measurements of the sound velocity in liquid deuterium, we found two major surprises. At about 11 GPa on the Hugoniot, release of shock pressure caused the emitted intensity in the visible (300—800 nm) to increase, exactly the opposite of what is normally observed. Further, shocked D_2 is opaque. This is not expected in view of the very low conductivity and thus free electron density. In fact, optical depth of the D_2 starts to increase below 16 GPa, as expected, but becomes opaque below 13 GPa. These phenomena suggest a molecular basis for the optical properties. We wanted to use Raman spectroscopy to observe the D-D stretch. Here, our hope was to see modifications to the stretch spectrum indicative of strong intermolecular interactions. Optical absorption would be measured by double-pass absorption spectroscopy.

Research Activities

Both of the spectroscopic methods had been used before, but had to be developed anew because of the methods used previously for water[1] and benzene[2] were incompatible with the target geometry used for liquid D_2, and the optical absorption we expected meant that we must use a visible wavelength for the Raman spectroscopy. This was important since the scattering cross section would thus be lower, as it varies with the inverse fourth power of the laser wavelength.
Since neither method had been employed within a decade, we had to rebuild our capability. For the Raman system, we purchased a laser to operate at 532 nm, with pulses of about 300 mJ, 8 ns FWHM. We used this to irradiate a test fluid (benzene) using the cross-beam method described in Ref. 1. We then developed and tested the optical diagnostic system we needed to use for two-stage gun experiments.
Prototype targets were designed for cryogenic Raman experiments. For absorption spectroscopy, no commercial light sources were available, so we had a new source designed and built. It's aim was to produce "white Light" (effective color temperature of roughly 1.5 eV) pulses with constant intensity over at least a 10 microsecond interval, with a energy storage of about 300 J.
Theoretical calculations indicate that triangular complexes of D_2 molecules cannot account for the measured optical properties.

Results/Technical Outcome

We were successful in building a Raman system that was able to achieve data with acceptable signal/noise using benzene as a test fluid. The ring-breathing mode as used to simulate the D-D stretch. A single-shot spectrum is shown in the figure. This quality may have been able to perform adequately with liquid deuterium.



Unfortunately, we were unable to rebuild our capability to trigger this system at the gun; the project did not have enough time or funding to repair the gun barrel we planned to use.
The light source started for the project was not completed during the life of the LDRD. After another year, it was completed and is in use for other spectroscopic projects, notably LDRD

Exit Plan

The result of the LDRD has been to allow us to rebuild our capability for spectroscopy in shocked materials. We have retained the capability, and plan to use it to study deuterium as funding permits. Two other LDRD projects were made possible by the investment in this LDRD, work on optical properties of metals (LDRD 05-ER-030), and extreme chemistry (LDRD 05-ERD-014).

Summary

This project was a partial success in that it rebuilt an important cabability and led to the other LDRD projects' capability. It failed to achieve its main goal to study the molecular properties of shocked deuterium. It is important to comment on the role the funding timetable had on this work. It was started as a mid-year, then was put in hiatus until halfway into the following fiscal year. This meant we had only 1 full year of funding, and much momentum was lost. We recommend that funding be steady for full effectiveness of complex experimental projects. On the other hand, the LDRD office was very sensitive to our equipment needs during the project.

References

1. N. C. Holmes, W. J. Nellis, W. B. Graham, and G. E. Walrafen, *Phys. Rev. Lett,* **55**, 2433 (1984)
2. N. C. Holmes, *Rev. Sci. Instrum* **64**, 357 (1993)