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Refraction Index of Shock Compressed Water in the Megabar Pressure Range

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The behavior of water in extreme conditions has been the subject of several works [1, 2, 3], mainly because of its important planetological implications. Together with ammonia and methane, water is one of the main elements of the mantles of giant planets like Uranus and Neptune. The observation of large and asymmetric magnetic fields in those planets [4, 5] has prompted the idea that the field is originated in the mantle. Since the dynamo effect requires the presence of a conductive material, a phase transition to the metallic state has been suggested [6]. Such phase transition has been evidenced in molecular dynamics simulations.

In our work [7], we studied the behavior of the refraction index of water samples compressed by laser-driven shocks. A few measurements were done with samples mechanically precompressed to ~10 kbar. We used shock chronometry and VISAR diagnostics to measure the shock and fluid velocities. This allowed obtaining experimental points on the equation of state (EOS) of water and also determine its refraction index. For low enough shock pressure, water remains transparent. At larger pressure, water becomes opaque (corresponding to non negligible values of n_i, the imaginary part of the refraction index) Finally, water becomes reflecting when a conductive state is achieved. The changes in refraction index when water is compressed provide information on how gap closure is approached in the material.

Experimental results have been compared to quantum molecular dynamics (QMD) calculations based on density functional theory, done at CEA-DIF [7]. In agreement with experimental data, they show a rapid increase of the real part of the refraction index n_r for densities around 2.7 g/cm^3 with metallic behavior ($n_r \sim n_i$). Such transition is mainly driven by the temperature increase following shock compression along the main Hugoniot.

References

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