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Atom laser-based measurements of optical and magnetic potentials

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Atoms are employed as highly sensitive sensors in a wide range of applications, including metrology, precision gravimetry, and magnetometry. Atom lasers offer a compelling platform for mapping fields due to their large sampling area, tunable accelerations, and high atomic sensitivity.

In our work, we have conducted a series of experiments investigating the interaction of atom lasers with external potentials. For strong potentials generated by focused dipole lasers, a striking phenomenon is the formation of pronounced caustics whose shapes resemble attached or detached shocks. We have identified cusp and fold caustics in our experiments and have developed a fluid flow tracing technique to illustrate the formation of these features [1]. For very weak potentials, atomic trajectories are barely altered by the potential, but a resulting change of the quantum mechanical phase opens the possibility to perform interferometric measurements. Here, we have employed differential potentials acting on two atomic hyperfine states in rubidium and have acquired large-area interferometric images of the potential landscape through which an atom laser propagates. We have used this capability to measure differential optical dipole potentials and to map out magnetic fields in our experimental chamber [2].

Our work strongly supports the potential of atom lasers as field-mapping devices in quantum systems and we will report on the current status and future directions of these studies. This work is supported by the NSF, by the Clare Boothe Luce Professorship Program under the Henry Luce Foundation, and by the Ralph G. Yount Distinguished Professorship at WSU.

[1] Gravitational caustics in an atom laser, Nature Comm. 12, 7226 (2021).
[2] Atom interferometric imaging of differential potentials using an atom laser, Phys. Rev. Lett. 130, 263402 (2023).

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