Observation of transverse interference fringes on an atom laser beam

R. G. Dall[1], L. J. Byron[1], A. G. Truscott[1], G. R. Dennis[2], M. T. Johnsson[2] and J. J. Hope[2]
[1]*ACQAO, Research School of Physical Sciences and Engineering, Australian National University, Australia*
[2]*ACQAO, Department of Physics, Australian National University, Australia*

Like its optical counterpart, the atom laser has the potential to revolutionise future atom interferometric sensors, in which a high flux of collimated atoms is required. The ultimate performance of such sensors will rely on the signal-to-noise ratio with which atoms in the atom laser beam can be detected. In the case of a metastable helium atom laser, its constituent atoms are not in their true electronic ground state, but rather in an excited state containing 20 eV of energy. This large internal energy is enough to liberate electrons from a surface when struck by the atom, making detection of single metastable atoms possible. It is this single atom detection property that makes a metastable atom laser not only a promising candidate for future atom laser applications but also as a high resolution probe of fundamental atom laser properties.

Unlike an optical laser, the particles in an atom laser interact with each other by scattering. At ultracold temperatures this scattering can be characterised by a single parameter, the s-wave scattering length. In most cases these interactions are small since the average density in a typical continuous wave (cw) atom laser beam is low. However, as the atoms in the beam are coupled out, they probe the high density of the BEC via the same interactions, and experience a large repulsive force (so-called 'mean field' repulsion).

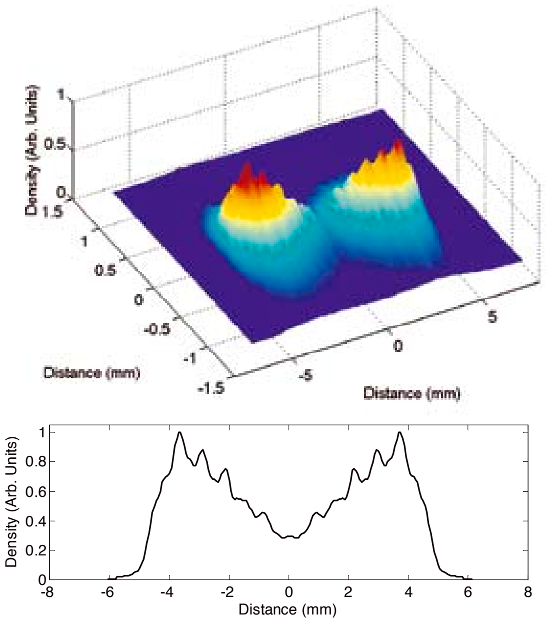

Figure 1: Experimental MCP image (upper plot) and cross-section (lower plot) showing interference fringes. Upper trace is the raw 2-D image, while the lower trace is an averaged profile.

These interactions heavily distort the atom laser beam, resulting in a profile that exhibits a double peaked structure due to classical effects, referred to as 'caustics' [1]. Besides these large-scale classical effects, it has been predicted that interference fringes should be present on an atom laser beam. Atoms starting from rest at different transverse locations within the outcoupling surface can end up at a later time with different velocities at the same transverse position, leading to quantum mechanical interference [2, 3].

Recently, we have made use of the novel detection capabilities offered by metastable atoms to image the two-dimensional transverse profile of our radio-frequency (RF) output-coupled atom laser beam. Moreover, we have observed for the first time interference fringes on an atom laser beam, demonstrating the transverse coherence of an atom laser. An image from our experiment is shown in figure 1.

References

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