Laser Beam Expanders for Cold Atom Technologies

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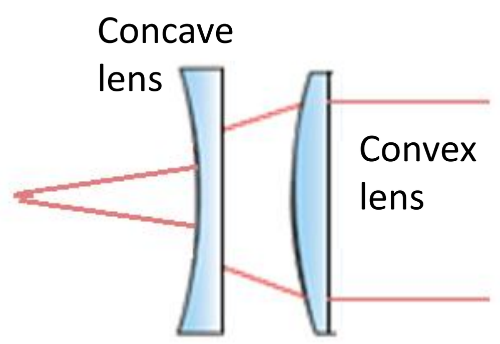
Introduction

Laser cooling is a pathway to many quantum technologies with significant real life applications.

Diffraction gratings used in these systems require a laser beam, for which the size directly effects the performance.

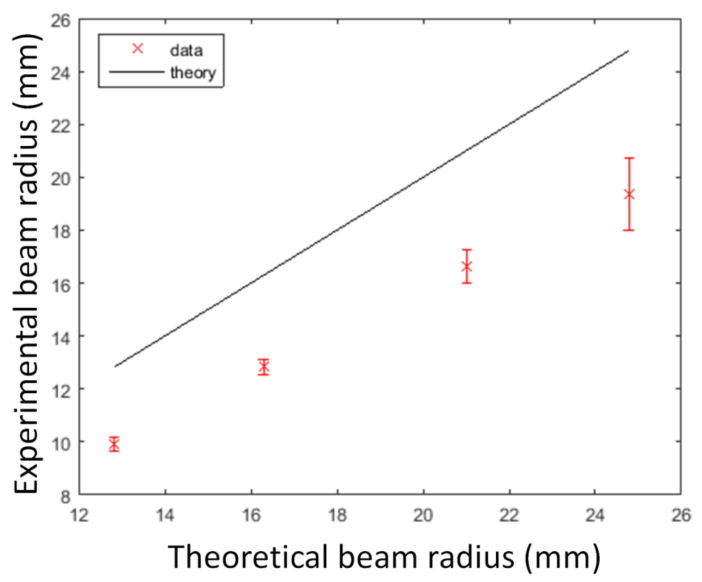
Using a beam expander reduces the size of the system. Accurate measurements of the effect the beam size and divergence has on performance is important for optimising such a system.

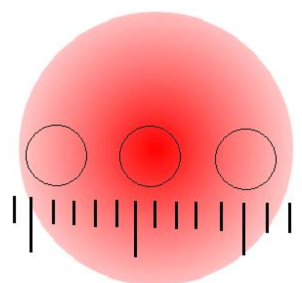


A laser beam can be expanded in size by using two lenses, a concave lens and then a convex. This lets you set the size and divergence of the beam.

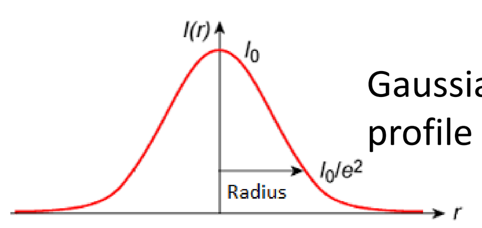
Beam Profiling

By translating an iris over the width of a Gaussian beam, you can measure the intensity of the beam at different points across its width and subsequently produce an intensity profile. [1]





Beam profiling by translating a fixed circular iris across the beam

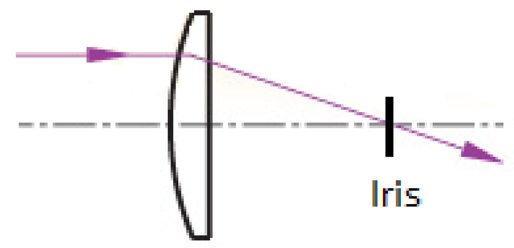


Gaussian Intensity profile

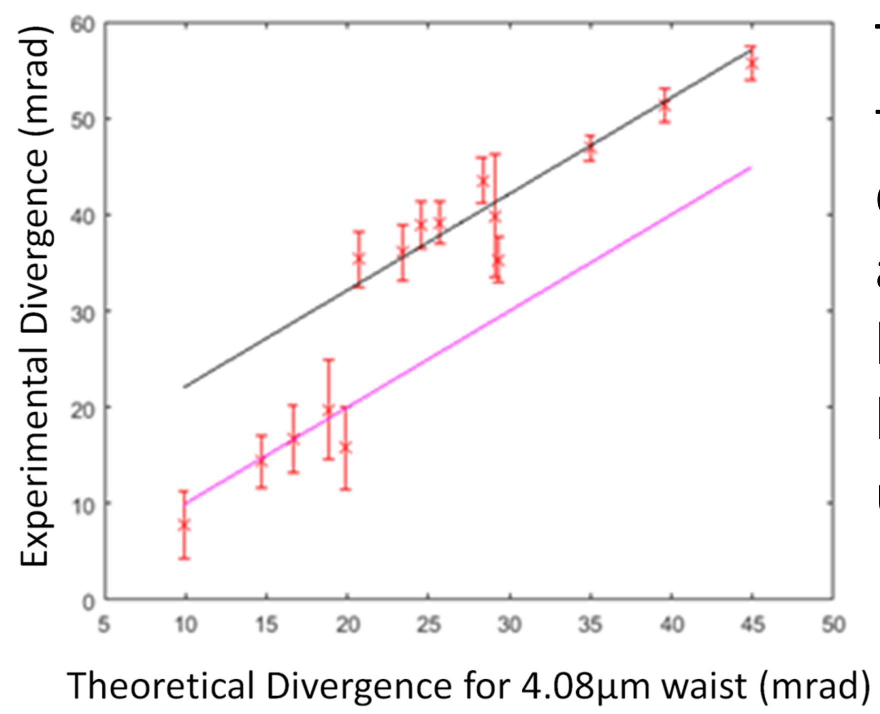
The beam radius measured for low diverging beams were shown to closely follow the theory for an initial beam width (waist) of 4.08μm rather than the 3.35μm which was the expected result.

Divergence

To measure the divergence, a third lens is added to the system. [2]



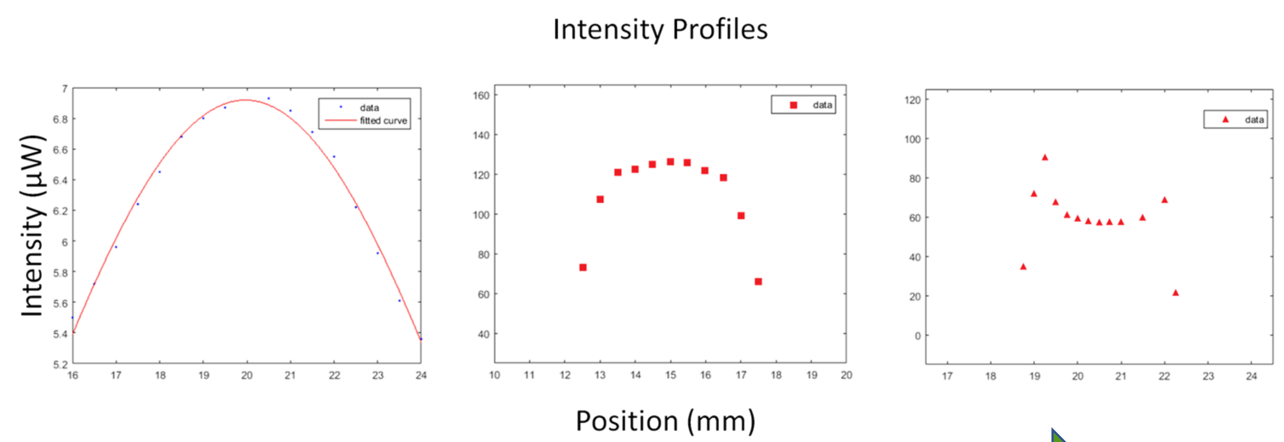
The convergence cannot be measured accurately using this method as the whole width of the beam does not pass through the same focal point.



There is a 'jump' in the readings for the divergence. This is at the moment the beam goes from being clipped to unclipped.

Interference

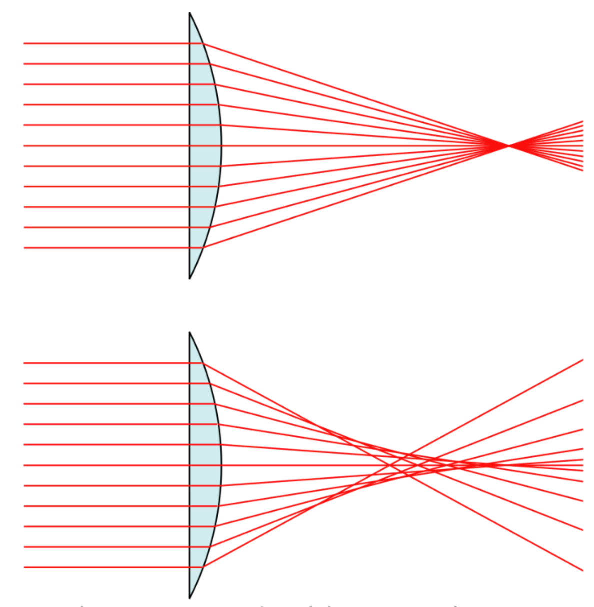
When a beam size is greater than that of the lenses, the beam becomes clipped, meaning that only a portion of the laser beam goes through the lens. This can lead to interference effects for highly diverging beams as seen below.



Increasing interference

The intensity profiles start off as Gaussian distributions but lose their shape with increasing interference.

Improvements



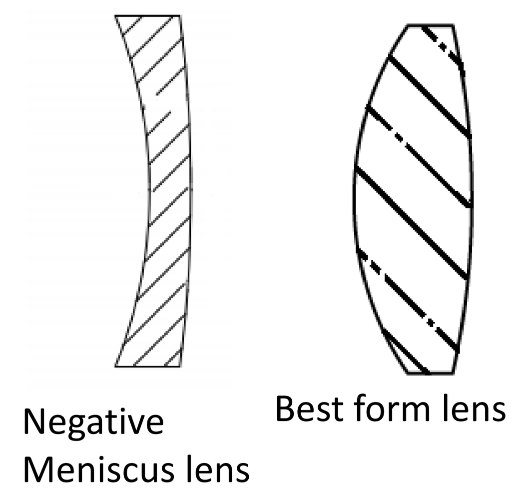
The spherical design of lenses leads to laser beams not correctly converging over the width of the beam.

A best form lens is designed to minimise spherical aberrations by having a slightly curved side instead of a straight edge.

Top lens is an ideal lens without spherical aberrations.

Bottom lens is a real lens showcasing spherical aberrations

Meniscus lenses are also possible options to help reduce aberrations. [3]

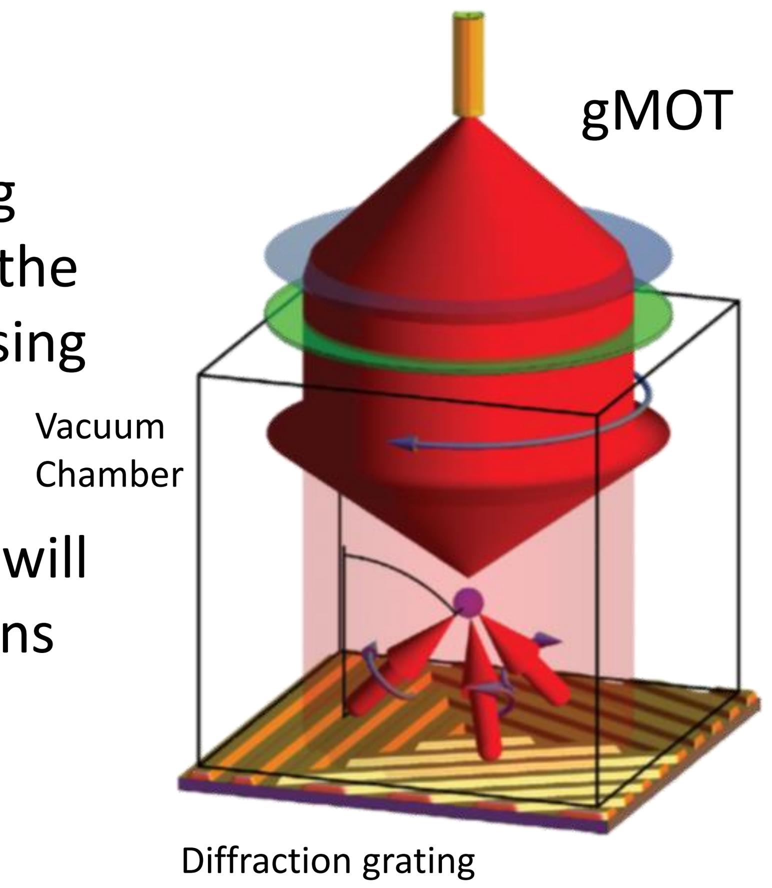


Future

The beam expander combined with grating magneto-optical traps (gMOT) and miniaturised vacuum systems will form a cold atom source sub-system, portable enough to be taken out of the laboratory.

The finished system will be a critical component of upcoming quantum technologies such as the atomic clock and quantum sensing devices.

Making these portable devices will have a wide range of applications such as in construction and increased precision of GPS.



References: [1] T. S. Khwaja and S. A. Reza Vol. 58, No.4/1 February 2019/Applied Optics
[2] Standard for the Measurement of Beam Widths, Beam Divergence, and Propagation Factors, Proposal for a Working Draft, ISO/TC 172/SC 9/WG 1, April 29, 1992.
[3] Thorlabs, 'Negative Meniscus Lenses' Thorlabs.de 08/2019