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Optical Nanofibres as Probes for Cold Atoms

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Introduction

In recent years there has been much interest in the possible uses for tapered optical fibres, for example in the efficient coupling of light to optical micro-cavities and as miniature sensing devices. Due to the large evanescent field produced outside such tapered fibres they also provide a powerful tool for probing single atom and photon interactions.

Our work examines such atom/photon interactions by overlapping a tapered fibre with a cloud of cold rubidium atoms. Here, we give a brief introduction to the experimental setup and present recent results using the tapered fibre as a probe for characterising the cold atom cloud [1].

Tapered Optical Fibre Fabrication

Tapered optical fibres are produced from single mode optical fibre using a heat-and-pull technique [2]. The tapered region of the fibre must have a diameter of the same order of magnitude as the wavelength of the light to be guided (780 nm) and must have very low optical losses.

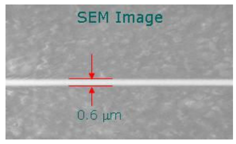

Figure 1: SEM image of a 0.6 micron fibre taper

An oxy-butane flame is used to heat the fibre and a pair of translation stages can be used to pull and taper the fibre

Experimental Setup

Cold rubidium atoms are produced using a magneto-optical trap (MOT). This consists of three counter-propagating laser beams intersecting at the zero point of an inhomogeneous magnetic field created by a pair of anti-Helmholtz coils. The lasers cool the atoms, whilst the magnetic field provides a trapping potential. The cold atoms are formed in ultrahigh vacuum to isolate them from the environment, see Fig. 2.

Typical parameters we have achieved:
Base pressure : 10^{-10} mbar
Atom temperature: ~100 µK
Number of atoms: ~ 10^7
Cloud radius: ~ 1 mm

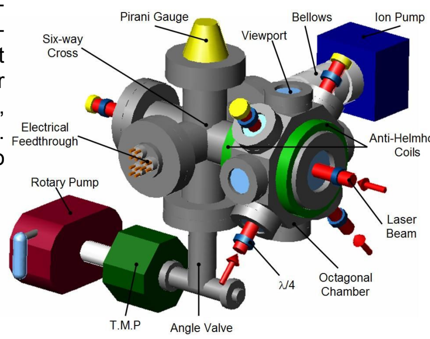

Figure 2: Schematic of the experimental setup

The tapered region of the fibre is held in a U-shaped mount, ensuring that the thinnest section of the fibre is centred in the science chamber.

The cloud of atoms is then overlapped with the tapered fibre region by moving it using a small magnet.

Fluorescence photons are constantly emitted from the cold atoms. These photons couple into the fibre and are detected by a single photon counting module (SPCM).

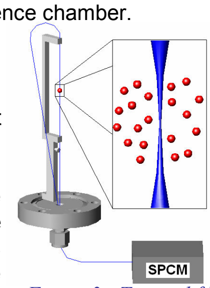

Figure 3 : Tapered fibre setup and feedthrough

Experimental Results

First indication of photons coupling from the atom cloud into the guided mode of the tapered fibre are shown in Fig. 4. There are three different photon counts achieved:

1. Repump laser ON
2. Cooling laser ON
3. Magnetic field ON

This is then reversed on the other side of the figure, with the MOT going OFF.

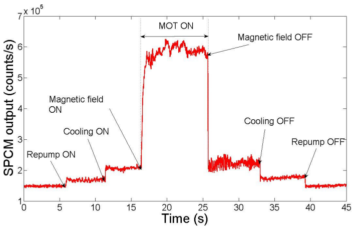

Figure 4 : Proof of coupling into the fibre

The large number of photons coupled from the atom cloud is evident by looking at the large increase once the trapping magnetic field is turned on.

Fig. 7 shows the lifetime of the MOT for both techniques, after the Rb is switched off. As can be seen the results are again in reasonable agreement – slight discrepancies between the decay times can be explained in two ways:

1. The tapered fibre is more sensitive to lower numbers of atoms still fluorescing than the photodiode.

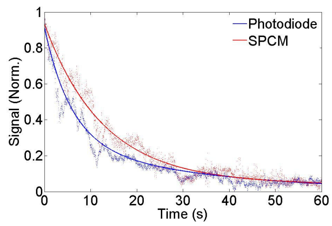

Figure 7 : MOT lifetime plots

2. Atoms closer to the centre of the cloud where the taper is placed are colder than those further from the centre of the MOT. As the MOT decays these colder atoms are the last to leave the trap.

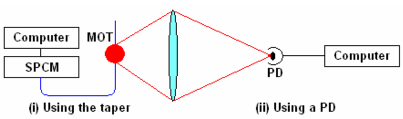

Figure 5 : Schematic of taper and PD measurement methods

Two methods were used to measure the loading time of the MOT (i) the tapered fibre and (ii) imaging the atom cloud onto a photodiode (PD), see Fig. 5.

Both results are compared in Fig. 6 and are seen to be in good agreement, thereby indicating the taper is a good probe for cold atoms.

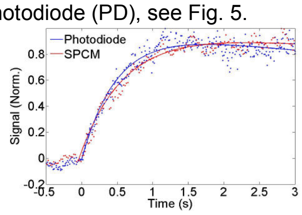

Figure 6 : MOT loading times

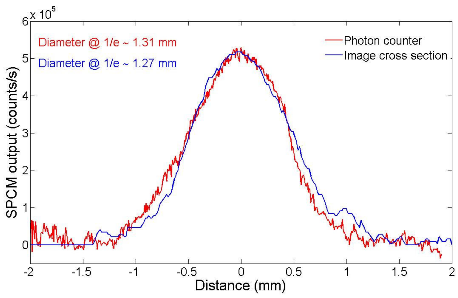

Figure 8 : Comparing MOT diameters

An image of the MOT can also be captured using a CCD camera and the MOT profile determined by taking an image cross-section. Similarly, we obtained a profile by translating the atom cloud across the fibre using magnetic fields. Fig. 8 shows the results from both techniques, which are in good agreement.

Conclusion

Here we have very briefly shown our experimental setup and results from using a tapered fibre as a probe for characterising a cloud of cold atoms.

In future experiments using this setup we plan on looking at the effects of the fibre within the atom cloud. For example, it is interesting to consider how the fibre's presence leads to a red shift in the coupled light due to the van deer Waals force.

References

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[2] J.M. Ward, D.G. O'Shea, B.J. Shortt, M.J. Morrissey, K. Deasy and S. Nic Chormaic, "Heat-and-pull rig for fiber taper fabrication", Rev. Sci. Instrum 77, 083105 (2006)

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