3142

Fibre Optics for Atom Detection

Steve Helsby, Peter Horak and Peter Kazansky
Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ
e-mail: stjh@orc.soton.ac.uk

The use of atom chips [1] for the manipulation, cooling, and investigation of neutral atoms is now well developed, with the current carrying wires used for transport, and production of magnetic traps, being integral parts of the chip. Such devices offer the possibility of scalable quantum information processing. A further step towards compact, efficient devices would be the integration of the required optical elements, both for detection and manipulation of the atoms. To this end, we are working to mount standard fibre optical components onto the chip with the goal of single atom detection. At present, two main directions are being pursued: Fluorescence detection and fibre Fabry-Perot gap cavities. Theoretical analysis has shown that both devices will have the ability to detect single atoms with the micro-cavities offering the possibility of non-destructive detection.

The fluorescence detection system comprises of a tapered lensed fibre (TLF) for atomic excitation by near resonant laser light, and a large core multimode fibre for light collection. Since the collection efficiency of our system is small (~2 %) we need to increase the interaction time between the atom and pump light in order to produce a detectable fluorescent signal. Radiation pressure will act to remove the atom from the detection region but, by red-detuning the light from the atomic transition, the induced dipole force can be used to compensate for this. It is found that detuning by 500-1000 linewidths produces a trap several microns from the lens focus and deep enough to give an interaction time ~10 ms, allowing for the collection of ~3000 photons when working at a power of about 1 mW. Figure 1 shows a prototype device using a 60 μm diameter core collection fibre and a TLF with a working distance of 22 μm. Various geometries are being investigated in combination with different focal length lenses.

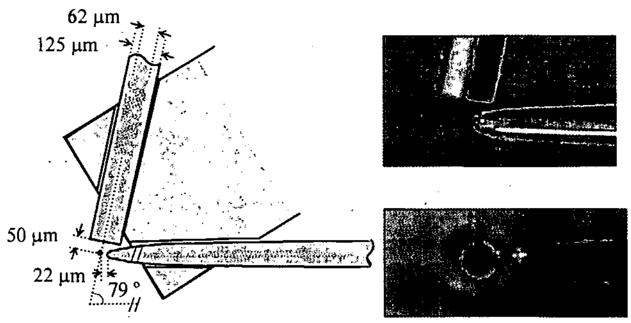

Fig. 1 Fluorescence detection prototype

As opposed to the previous method, which by design entails a high rate of spontaneous scattering, the use of a fibre standing-wave cavity (Fig.2) offers minimal disturbance to the atom and is thus a possible candidate for state selective, non-destructive detection. Using single mode fibre at 780 nm (Rubidium D2 transition), cavities have been constructed using gold mirrors and dielectric mirrors, but we are now employing Bragg grating reflectors which offer a more robust, compact and integral solution. The cavities, with ~5 μm gaps to accommodate the atoms, support stable modes with waist sizes of the order of 3 μm, resulting in strong atom-cavity coupling. It has been shown theoretically [2] that a modest cavity finesse (F~100) will enable detection with minimal atomic disturbance. Using the fibre Bragg gratings, a first all-fibre cavity with a finesse of F=150 has been constructed, with a free spectral range (FSR) of 1.3 GHz and linewidth of 9 MHz, the grating bandwidth being about 0.13 nm. Since the finesse is limited by loss in the gratings, work is in progress to investigate the use of different writing speeds and grating lengths in order to optimise the transmission properties of the cavities. With the additional freedom to alter the cavity length and therefore change the FSR, the cavity parameters can be tailored as necessary. Work is also in progress towards mounting the cavities upon a substrate and the development of the necessary tuning components for a working device.

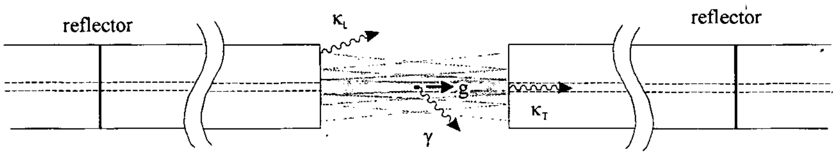

Fig.2. Fibre cavity schematic

[1] R. Folman et al., Adv. At. Mol. Opt. Phys. **48**, 263 (2002).
[2] P. Horak et al., Phys. Rev. A **67**, 043806 (2003).