Single Atom Detection Using a High-Finesse Optical Cavity

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We aim to build a single-atom detector for cold neutral atoms, that will be an important component of atom optics experiments, in analogy to single-photon detectors used in quantum optics. Detection is achieved via observations of an atom's interaction with light, and several research groups have made use of high finesse cavities to increase the interaction strength, and detect single atoms. Observations of changes in a probe beam in the detection cavity (DC) indicate the presence of a single atom. In modelling work in the earlier stages of this project we determined the optimal cavity design and operating regimes for high quantum efficiency detection [1].

Our current focus is the experimental implementation of the detection apparatus. We have built and characterised our DC. Significantly, the finesse is ~ 12000, which is moderate in comparison to the cavities used in cavity QED experiments that often have finesses in excess of 100000, making our mirror coatings easier and cheaper to manufacture. Our mirrors were custom machined and coated, and we assembled the components in a clean-room in-house [Fig 1.(a)].

The DC needs to have a stable resonant frequency with respect to the atomic transition and probe laser. In order to independently adjust the cavity and laser frequencies, we make use of a far-detuned stabilisation laser to lock the DC to an absolute frequency reference. Both probe and stabilisation lasers need to be frequency stabilised. We make use of the Pound-Drever Hall locking technique for all our locks, and employ the following novel locking scheme [Fig. 1(b)]:

The 780 nm probe is stabilised to a D2 line of ^{87}Rb. This absolute frequency is transferred to the 840 nm stabilisation laser via a transfer cavity (TC). The DC length is tuned to transmit the probe laser, and the stabilisation frequency is then tuned so that it, too, is resonant in the DC. Since both lasers need to be resonant in the DC and the TC simultaneously, we must be able to tune one of the lasers independently in *both* cavities. To achieve this, we add strong side bands to the 840 nm laser, using a fibre-coupled electro-optic modulator (EOM) and use the laser current control to shift carrier and side bands together until one of the sidebands is resonant with the DC. It is this frequency on the stabilisation laser to which the DC is locked. We then tune the relative frequency between the stabilisation side bands and carrier using the EOM controller, so that the carrier frequency is resonant in the TC, and lock the laser to that cavity using this frequency.

The next step is to use a 2D magneto-optical trap as an atomic source, and to characterise the flux of atoms from this source, using single atom detection.

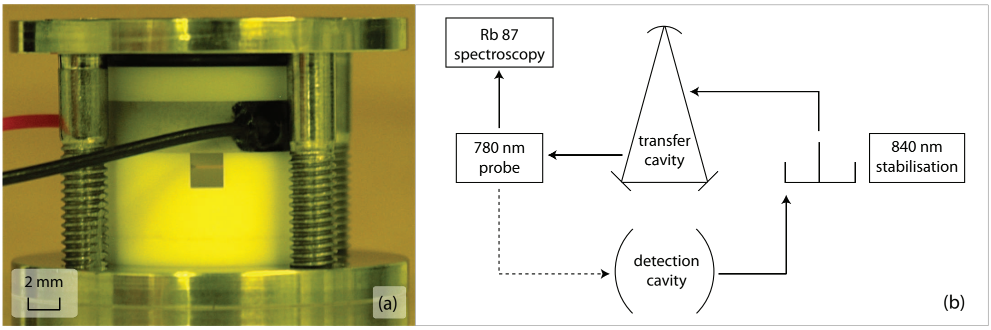

Fig. 1(a) The assembled detection cavity. (b) Frequency locking scheme.

References

[1] R. Poldy, B. C. Buchler, and J. D. Close Phys. Rev. A **78**, 013640 (2008).