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# Application of absorption measurements to the temperature determination of a cloud of cold Cesium atoms

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The temperature of a cloud of about $10^8$ cold Cesium atoms in a magneto-optical trap has been determined with absorption measurements. On switching off the cooling laser, the atoms fall under gravity. The probe beam comes from a laser that is stabilized on the top of a dopplerfree saturated absorption line of a natural transition of Cesium. This laser serves to record absorption of the free falling atoms passing the probe beam positioned below the trapped cloud. By analysing the signal as a function of time and falling distance a cloud temperature of $1\,mK$ has been determined.

Testing samples of cold atoms by a probe laser beam opens a new field for spectroscopic activity. An important element for this type of experiment is the maximum absorption at a given falling distance and for a given sample. Absorption as a function of time of the free falling cloud passing a probe laser located below the trapped cloud has been recorded. The signal is known in the literature as Time-Of-Flight signal (TOF). It is usually observed by the probe induced fluorescence at falling distances of $1.1\,cm$ [1], $7\,cm$ [2] or $10\,cm$ [3]. Absorption measurements are suited for observation of the TOF signal at shorter falling distances up to $10\,mm$. The theory applied for the interpretation of the TOF signal obtained by absorption measurements is essentially the same as the one developed for the interpretation of the TOF signal obtained by the probe induced fluorescence [4].

Absorption spectra of a cold sample of Cesium atoms show three well resolved peaks corresponding to the natural transitions allowed by the selection rules $\Delta F = 0, \pm 1$. Highest absorption of 68% is measured in the trapped cloud, figure 1. The spectrum is recorded from the $F_g = 4$ groundstate with a probe intensity of $2\,mW/cm^2$.

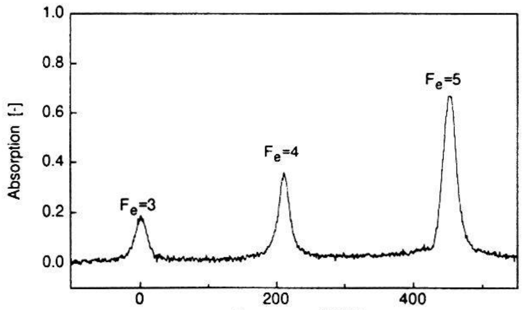


FIG. 1. Absorption spectrum of a trapped cloud of cold Cesium atoms showing only the natural transitions.

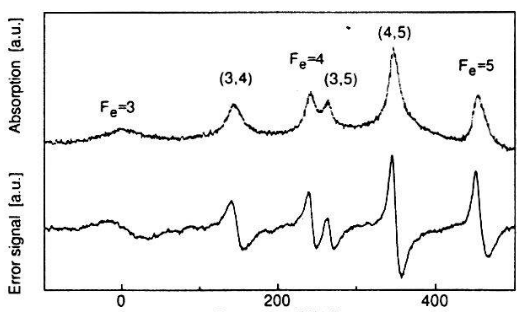


FIG. 2. Saturated absorption spectrum with error signal for stabilisation of the probe laser on the top of the $F_e = 5$ line.

To record the time-of-flight signal the probe laser is stabilized on the top of the dopplerfree saturated absorption line of the Cesium $D_2$ transition $F_g = 4 \rightarrow F_e = 5$. A recording of a typical saturated absorption spectrum with the simultaneously generated error signal used for laser stabilisation is shown in figure 2. The necessary shift in optical frequency to generate the error signal is about $300\,KHz$, resulting in an absolute stability of the optical frequency of the same order.

A typical time-of-flight signal, measured with the absorption of the probe laser, is shown in figure 3. The power of the linear polarized probe beam is $5\,\mu W$ on an area of $0.8\,mm^2$. During recording the TOF signal, the cooling laser and the magnetic field were shut off. The repumping laser coupling to the $F_g = 3$ groundstate was on. This reduces hyperfine pumping of the free falling cloud by the probe laser. Temperature, falling distance and diameter of the trapped cloud were determined as fit parameters, taking into account the finite diameter of the probe laser. The TOF signal is mainly determined by temperature and falling distance. For the calculation of the fit, absorption is assumed to be proportional to particle density and temperature is introduced by the Maxwell-Boltzman distribution. On switching off the cooling laser the cloud starts falling under gravity according to Newton's law. This leads to a displacement of the whole distribution. It's height and width in time are mainly characterised by the temperature of the cloud and determine the TOF signal.

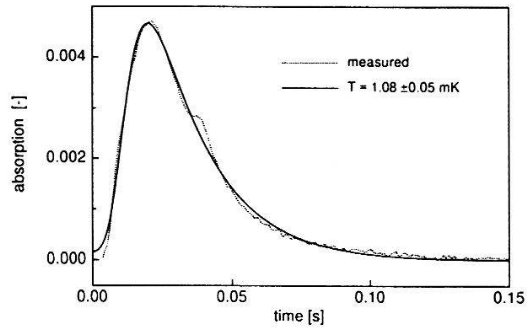


FIG. 3. Time-of-flight signal with curve fit to determine the temperature.

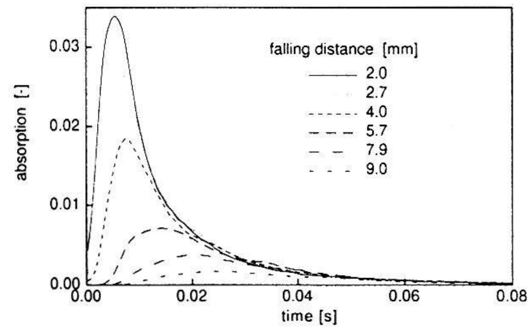


FIG. 4. Time-of-flight signals for different falling distances.

Figure 4 shows TOF signals for different falling distances. At short falling distances absorption is high. This is the range in which absorption measurements should be used for recording TOF signals. With increasing falling distance absorption decreases rapidly favouring the method of "probe induced fluorescence" [1, 2, 3, 4] for measuring TOF signals.

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# References

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