L.5: UHV pressure measurement by MOT loading

The measurement of ultra high vacuum (UHV) pressure from the magneto-optical trap (MOT) loading data is reported here. The loading time (τ_L) and saturated number (N_s) for a MOT loaded from the background vapor depend on the pressure in the chamber. The partial pressure due to Rb-vapor can be varied by varying the dispenser source current. By measuring N_s and τ_L from MOT loading data at different values of dispenser current, the partial pressure due to Rb-vapor (P_{Rb}) and background pressure (P) due to non-Rb gases have been estimated. It is found that estimated pressure at MOT position (near to dispenser) is much different from the pressure read by the sputter ion pump (SIP) attached away from the MOT position. This precise knowledge of pressure at MOT position is important for further work on magnetic trapping. This method of pressure measurement reported here has a potential in developing the UHV as well as extreme-high vacuum (XHV) pressure standards.

The loading of atoms in a MOT is governed by the rate equation,

$$\frac{dN}{dt} = R - \frac{N}{\tau_L}, \qquad (1)$$

where N is the number of atoms at any time (t) in the MOT, R is the MOT loading rate and τ_L is the MOT loading time. The loading time (τ_L) depends upon the partial pressure (P_{Rb}) due to Rb atoms as well as pressure (P) due to non-Rb atoms/molecules in the chamber. It is given as

$$\tau_L = \frac{1}{\beta P_{Rb} + \gamma_b}, \qquad (2)$$

where the term βP_{Rb} represents the collisional loss rate due to untrapped Rb atoms and γ_b represents the collisional loss rate due to non-Rb atoms/molecules.

The solution of Eq. (1) can be written as

$$N(t) = N_s[1 - \exp(-t/\tau_L)], \qquad (3)$$

$$\text{with} \quad N_s = R\tau_L = \alpha P_{Rb}\tau_L, \qquad (4)$$

Here, N_s denotes the saturated number in the MOT and α is MOT trapping cross-section. From Eq.'s (2) and (4), the relation between N_s and τ_L is given as

$$N_s = \frac{\alpha}{\beta}(1 - \gamma_b \tau_L), \qquad (5)$$

By measuring the variation in N_s with τ_L, the parameters α/β and γ_b can be obtained by fitting the measured data with Eq. (5). N_s and τ_L have been measured by fitting Eq. (3) to the measured MOT loading data at a given dispenser current (Figure L.5.1). Then variation in N_s with τ_L was obtained by changing the Rb-dispenser current and measuring N_s and τ_L. This plot is shown in Figure L.5.2, which gives α/β=(6.65 ± 0.30) x10^7 and γ_b = (2.90 ± 0.06)x10^{-2} s^{-1} after a fit to Eq. (5). Using these values obtained from the fit, and β=4.4x10^7 $Torr^{-1}$ s^{-1} and γ_b/P = 4.9x10^7 $Torr^{-1}$ s^{-1} from the literature, the partial pressure due to Rb-vapor P_{Rb} (P_{Rb} = $N_s/\alpha\tau_L$) and the background non-Rb gas pressure (P = γ_b/4.9x10^7) in the chamber can be estimated. Using this method, the estimated non-Rb gas pressure in our UHV chamber (for atom-chip MOT) is ~5.9x10^{-10} Torr. The estimated partial pressure values due to Rb vapor are ~1.4x10^{-10} Torr and ~4x10^{-9} Torr at dispenser current values of 2.8 A and 3.4 A, respectively.

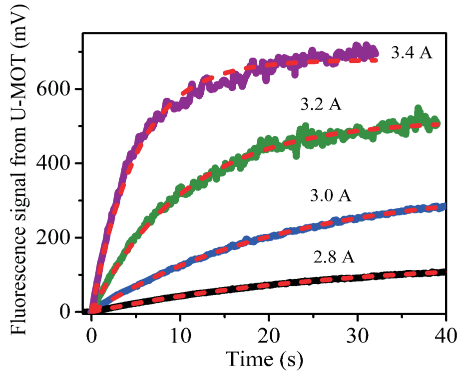

Fig. L.5.1: Increase in MOT fluorescence signal (i.e., number of atoms in MOT cloud) with time during loading of MOT at different values of dispenser current. Dashed curves show a fit to Eq. (3).*

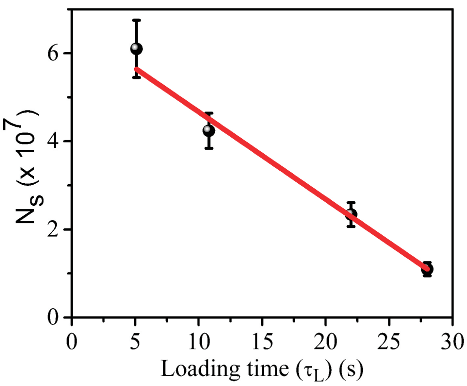

Fig. L.5.2: The measured variation in N_s with τ_L and a fit to Eq. (5).*

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