Longitudinal Time-Of-Flight taking into account the slope. February 23 2006

After implementing the evaporation method using the ceramic pieces (started on January 13 2006 lab-book page 147), it was natural to come back to the problem of the longitudinal TOF that was investigated previously (June 18 2004 lab-book p128). Indeed the ceramic is a good way to stop the atomic beam, playing the role of the pushing laser beam that was used in 2004. This method suffered the fact that the pushing laser beam was not very local (because of reflections on the copper and glass tubes), and it was not clear that at release-time, the spatial distribution was an heaviside function of space (all the atoms before the pushing beam, and none after).

Here, we use a transverse magnetic field to deflect the trajectory of the atomic beam so that it hits a ceramic in $z = 0$. At $t = 0$, we stop the transverse magnetic field and leave the atoms propagate towards a probe located in $z = d$, downstream. We take into account a possible slope like the one implemented on the first $1,7m$ of the guide ($\alpha = 0.012$).

We suppose that at $t = 0$, there is no atoms between $z = 0$ (the ceramic) and $z = d$ (the probe). We suppose also that there are no collisions during the TOF, leading to a simple relation between the initial velocity distribution at $t = 0$ in $z = 0$, and the spatial distribution at a time $t > 0$ and $0 < z < d$.

At the level of the ceramic ($z = 0$), at all time, the flux is ϕ_0, and the velocity distribution is :

$$P(v) = \sqrt{\frac{m}{2\,\pi\,k\,T}}e^{\frac{m\,(v_0 - v)^2}{2\,k\,T}} \tag{1}$$

But careful : $P(v)$ is the probability for a given atom at the level of the ceramic to have a longitudinal velocity v. If we look at this probability for a given atom going through the ceramic, this is different, as for identical densities, faster atoms go through the ceramic more often than slower atoms.

For a given atom going through, the velocity distribution is proportional to $vP(v)$:

$$F(v) = \frac{v}{v_0}\sqrt{\frac{m}{2\,\pi\,k\,T}}e^{\frac{m\,(v_0 - v)^2}{2\,k\,T}} \tag{2}$$

An atom leaving $z = 0$ with a velocity v will reach the probe ($z = d$), in a time :

$$T_d = \frac{v - \sqrt{v^2 - 2\,g\,\alpha\,d}}{g\,\alpha} \tag{3}$$

and with a final velocity :

$$V_d = \sqrt{v^2 - 2\,g\,\alpha\,d} \tag{4}$$

We have to notice that T_d has a maximum value $T_{d\max} = \sqrt{\frac{2\,d}{\alpha\,g}}$, meaning that after a time $t = T_{d\max}$, the flux in $z = d$ will be stationary.

The initial velocity distribution $F(v)$ can be expressed in term of a time-of-arrival distribution :

$$(3) \Leftrightarrow v = \frac{d}{T_d} + \frac{g\,\alpha\,T_d}{2} \tag{5}$$

$$F(T_d) = \frac{\frac{d}{T_d} + \frac{g\,\alpha\,T_d}{2}}{v_0}\sqrt{\frac{m}{2\,\pi\,k\,T}}e^{\frac{m\left(v_0 - \frac{d}{T_d} + \frac{g\,\alpha\,T_d}{2}\right)^2}{2\,k\,T}} \tag{6}$$