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First experimental measurement of the speed distribution of ballistically-evaporated atoms

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Experimental measurements of the speed distribution of atoms in an equilibrium gas agree with the predicted Maxwell-Boltzmann (MB) distribution from kinetic theory. It has been almost universally presumed that the MB distribution also applies to vapour atoms that are ballistically ejected into vacuum from liquid or solid surfaces, calculated assuming that the vapour is an equilibrium gas with a temperature equal to the temperature of the condensed phase. We identify, however, that ballistic evaporation of a vapour is entirely different from the effusion of a gas from an oven due to the lack of gas-phase collisions and surface adsorption-desorption events on the isothermal walls of the oven that establish thermal equilibrium. Remarkably, and to the best of our knowledge, there currently exist no experimental studies that have rigorously measured the speed distribution of ballistically-evaporated atomic vapour. These measurements are necessary experimental validation for theoretical models of thin film coatings and their technological use. Our main research objective is to develop an experimental apparatus and procedure to accurately and precisely measure this distribution using modern experimentation techniques.

Our current experimental setup evaporates silver into vacuum using a commercially available rod-fed electron-beam evaporator. The speeds of evaporated atoms are then mechanically filtered using a high-transmission slotted cylinder velocity selector (or, spindle) that is capable of rotation up to 170 hertz (10,000 rotations per minute). It was constructed from stainless steel using direct metal laser sintering and has 83 helical channels; each channel has an angular aperture of 3.33 degrees tilted at a 4.00-degree pitch angle. Evaporated atoms that travel parallel to the cylinder axis are aligned with only one of its channels, and, when rotating, it selectively transmits atoms within a restricted range of speeds. Two detectors that operate on different physical principles, namely a hot-filament ionization gauge and a quartz crystal microbalance, are positioned directly above the spindle and detect transmitted atoms. The speed distribution is determined from transmission measurements as a function of the spindle's rotation speed. Currently, the apparatus and control system is substantially complete: this talk will focus on its development and testing.

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