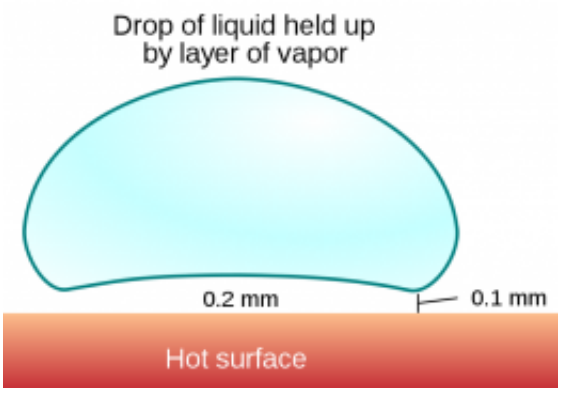
High speed camera study shows why boiling drops take off

July 26 2012, by Bob Yirka



Leidenfrost droplet. Image: Wikipedia.

(Phys.org) -- Everyone knows what happens if you drop water onto a hot pan, it separates into flat bottomed bubbles that appear to float above the bottom of the pan then move around of their own accord until disappearing. This whole process is known in science circles as the Leidenfrost effect, after Johann Gottlob Leidenfrost, who studied it closely and wrote about it way back in 1756. Now new research by a French team made up of Franck Celestini, Thomas Frisch, and Yves Pomeau has found other things are going on as well, which they describe in their paper published on the subject in *Physical Review Letters*.

Leidenfrost noted that when water or other liquids encounter a hot surface a vapor coat forms all around the drop. The vapor underneath is

what causes the drop to hover and to lose its friction grip with the metal pan below. But what happens when more of the water drop evaporates, before it disappears?

To find out, the French team first developed a theoretically model of what they believed would occur, then filmed both water and ethanol droplets landing on a heated copper surface with a high speed camera to see if their ideas matched.

The team believed that as time passed the amount of vapor would increase causing the droplet to be lifted higher off the surface as its cushion grew thicker, its weight matching the upward pressure of the gas, until a certain point was reached where the upward pressure would overtake the weight of the drop causing it to shoot skyward. In watching the recordings they made, they found that this is exactly what happens. First the water droplets bounce, then they hover moving ever slightly higher off the surface, all the time growing smaller; then at a certain size, they rocket into the air above the heated surface. Prior theories had suggested that the vapor cushion beneath the drops grew thinner as the drops became smaller because of less water being available for conversion to a gas.

When they watched ethanol droplets hitting the heated metal, because it has a lower boiling temperature, the whole process occurred so much more quickly that the bouncing that occurs with water didn't have time to happen; the bubble simply shot skyward almost on contact.

These new findings could help other researchers develop more efficient diesel engines or with processes that rely on cooling sprays.

More information: Take Off of Small Leidenfrost Droplets, *Phys. Rev. Lett.* 109, 034501 (2012) DOI:10.1103/PhysRevLett.109.034501

Abstract
We put in evidence the unexpected behavior of Leidenfrost droplets at the later stage of their evaporation. We predict and observe that, below a critical size Rl, the droplets spontaneously take off due to the breakdown of the lubrication regime. We establish the theoretical relation between the droplet radius and its elevation. We predict that the vapor layer thickness increases when the droplets become smaller. A satisfactory agreement is found between the model and the experimental results performed on droplets of water and of ethanol.

Physics Synopsis