Journal of Visualization, Vol. 9, No. 3 (2006) 241

Visualization of Capillary Flow in Sessile Drops and Detecting Spreading Stability by Laser Refracted Shadowgraphy

Zhang, N.*[1] and Chao, D. F.*[2]
*1 Ohio Aerospace Institute at NASA Glenn Research Center, Cleveland, OH 44135, USA.
E-mail: nzhang@grc.nasa.gov
*2 Microgravity Division, NASA Glenn Research Center, Cleveland, OH 44135, USA.
Received 3 January 2006

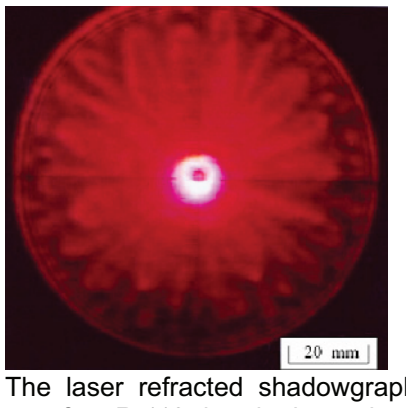

Fig. 1. The laser refracted shadowgraphic far-field image of an R-113 drop in the early stage of spreading shows multi-layer convection cells in the drop and a fold caustic with its caustic-diffraction fringes.

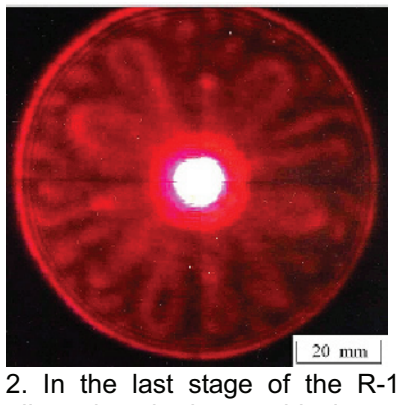

Fig. 2. In the last stage of the R-113 drop spreading, the shadowgraphic image shows single-layer convection cells in the drop and a fold caustic with its caustic-diffraction fringes.

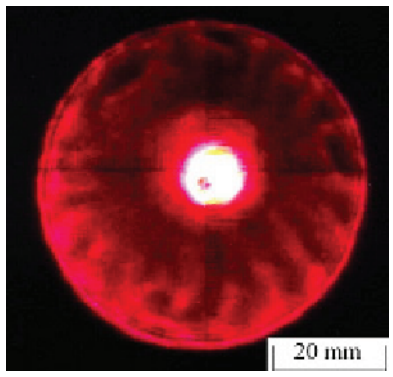

Fig. 3. Convection cells occur at the drop foot region in a spreading n-pentane drop while the fold caustic has a weak caustic diffraction.

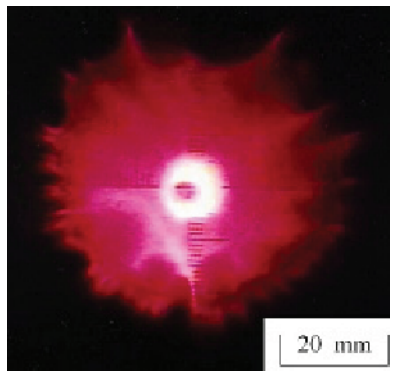

Fig. 4. No convection occurs in an ethanol drop but the drop surface creases to produce higher hierarchy of optical catastrophes.

When a parallel laser beam passes through a sessile liquid drop, the beam refracted by the drop and forms shadowgraphic image showing optical catastrophes in far field. This so-called laser refracted shadowgraphy can sensitively detect convective flow in a sessile drop, which is invisible to the naked eye, and spreading stability of the drop. These figures show the shadowgraphic images of a 5 μl sessile drop of different liquids. A perfect circle image, as shown in Figs. 1-3, indicates that this kind of drops spreads stably and has a perfect circular three-phase-line and a perfect sphere-cap profile without wrinkle on the surface. Figures 1-3 show different flow patterns and indicate that the flows have no influence on the stability of spreading. The shadowgraphy is also very sensitive to the stability of spreading through the hierarchy of optical catastrophes. Figure 4 shows no flow in the drop but the spreading is instable, manifested as an irregular circle image with saw-tooth-like ring consisting of cusps of caustic produced by a higher hierarchy of optical catastrophes. Much other important information, such as contact angle, drop profile, and height of the drop foot, can be obtained by optical calculations and catastrophic optics analysis.