Comment on "Low-Power Laser Deformation of an Air-Liquid Interface"

A recent intriguing experiment claimed that a low-power laser (20 mW) could create a dimple on the air-water interface (AWI) under total internal reflection (TIR) [1]. The interface deformation was deduced from the elliptical beam profile observed after TIR, which is the key experimental result. A theoretical Comment [2] and Reply [3] debated the proposed explanation. Our objective was to experimentally reproduce the counterintuitive phenomenon of large interface deformation [1] and investigate its robustness. Using a modified setup, to eliminate competing artifacts, we clearly demonstrate undetectable interface deformations using low-power green laser up to 100 mW focused and unfocused beam.

We use a pump-probe type setup to (i) completely remove any static interface curvature near the TIR region by coupling the laser from below in a wide pot, and (ii) independently probe the deformation using another weak laser. These improvements are crucial to establish optomechanical deformation since many competing artifacts producing an elliptical beam profile (curved interface, astigmatism, etc.) are eliminated. Curvature radii up to about a meter, i.e., deformation heights of more than a few microns, can be easily measured by recording the intensity profiles of the main and probe beams. If the main laser creates a cylindrical dip, we should observe an elliptical profile as in [1] with a complimentary diverging lens effect on the probe. Our main beam is a linearly polarized diode pumped solid state laser ($\lambda = 532$ nm, half beam waist $w_0 = 1$ mm), which is slightly different from the Ar^+ laser (514 nm, $w_0 = 0.68$ mm) [1]. The probe beam, a red diode laser (630 nm, $w = 1$ mm, <1 mW), spatially overlapped the TIR region and is normal to the interface.

First, using 1–20 mW unfocused beam, no detectable deformation in the main beam profile of the AWI was observed. Careful measurements within a few degrees near the critical angle θ_c showed that the (total) reflected beam always remains circular, unlike in [1]. The overlapping probe beam also showed no measurable effect by switching the main laser on and off for all θ. We then increased the green laser power five times to about 100 mW. The profile ellipticity is extracted from y and x Gaussian fits of the intensity $I(x, y)$. The ratio of half beam waists $Wy/Wx \simeq 1$ is independent of θ within $\pm 1°$ of θ_c (see Fig. 1). The existence of TIR ($\theta > \theta_c$) is confirmed by vanishing refraction and independent measurement of the reflected power. Indeed, no significant elliptical deformation was detected for all TIR angles and TE/TM polarization. Furthermore, we loosely focused 100 mW power on AWI to ~ 100 μm spot radius (intensity, $I \sim 300$ W/cm^2, >100 times higher than [1]). In contrast to [1], no surface dip could still be detected from the recorded profiles with or without TIR. The red probe beam, overlapping on the focused TIR spot, confirmed the negative result. Our experiment supports the standard theory [2] that much higher intensity is needed to observe such large effect in [1].

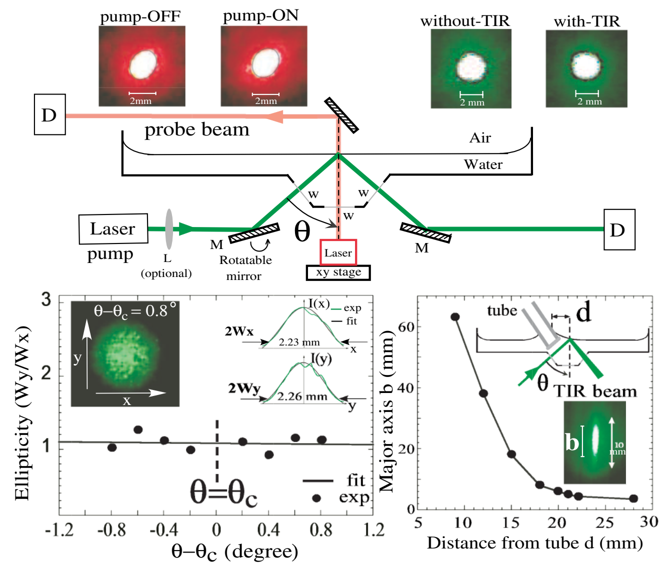

FIG. 1 (color online). Schematic setup: green pump laser 100 mW, red probe beam, D: detector, M: plane mirrors, w: flat window, and L: lens. Pot size: $15 \times 10 \times 5$ cm. Beam spots at 1.5 m from AWI for a 100 mW unfocused pump (with or without TIR) and probe (pump on or off), $\theta = 49°$. Probe spots show identical ellipticity due to the diode laser. Lower right panel: Ellipticity Wy/Wx versus $\theta - \theta_c$. Inset: intensity $I(x, y)$ at $\theta - \theta_c = 0.8°$ with its x and y Gaussian fits. Lower right panel: Major axis of elliptical profile b versus distance d as defined in the inset with a typical beam profile.

Note that the residual curvature of water near TIR due to the experimental apparatus could play an important role in making the beam profile elliptical. To prove this, we dipped a glass tube near θ_c and measured the major axis, b, of the elliptical profile versus the TIR distance from the tube edge. Surprisingly, the curvature survived for >25 mm, thus requiring a safe distance between the tubes and the TIR. Indeed, mimicking the original experiment for low water heights (4–20 mm in [1]) with tubes near θ_c also generated similar elliptical profiles. In conclusion, our experiment provides new insight into the optofluidic effect in [1] and offers a different explanation than proposed in [1].

Gopal Verma, James Nair, and Kamal P. Singh*
IISER Mohali, Sector 81, Manauli 140306, India

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*Corresponding author.
kpsingh@iisermohali.ac.in

[1] O. Emile and J. Emile, Phys. Rev. Lett. **106**, 183904 (2011).
[2] E. Brasselet, Phys. Rev. Lett. **108**, 269401 (2012).
[3] O. Emile and J. Emile, Phys. Rev. Lett. **108**, 269402 (2012).

