First Ten Ångstroms

IFT Measurements in Cuvettes

20 February 2007

Cuvettes are used as convenient liquid chambers for Laplace-Young drop shape measurements. The purpose of this note is to describe the conditions under which you can obtain identical results from

- a hanging pendant drop with no cuvette present
- a hanging pendant drop inside the cuvette (but no other liquid present)
- a vapor bubble up from J needle in cuvette filled with liquid

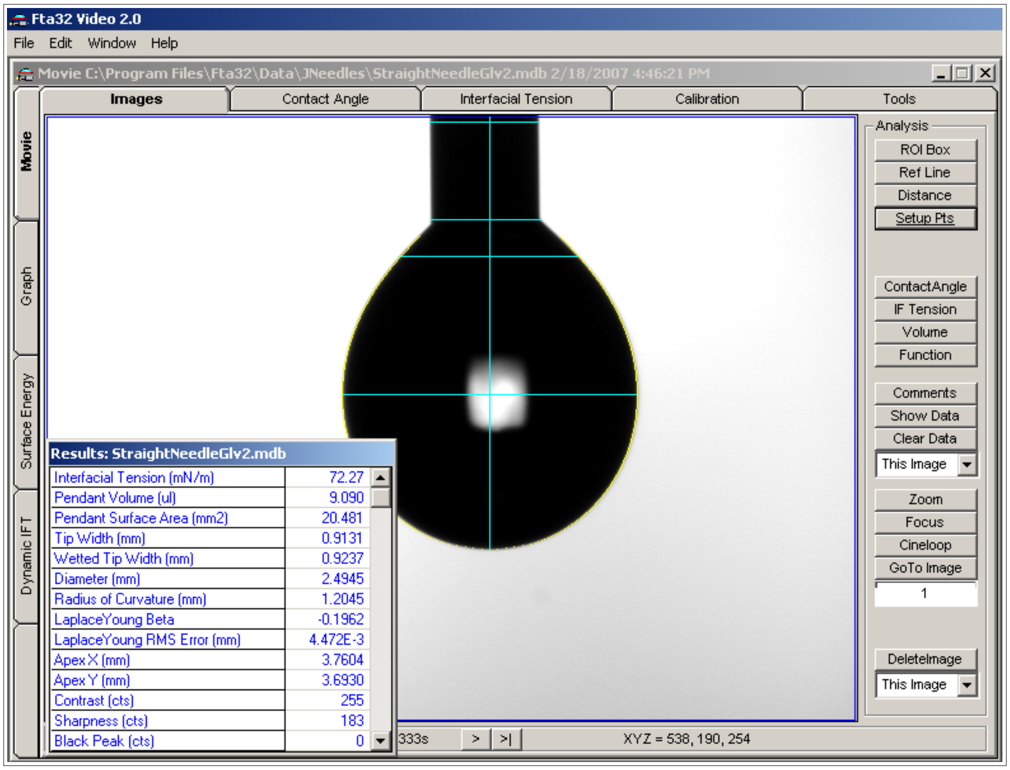
As long as the liquid involved and the vapor phase are the same, we expect all three configurations to give the same result. We now investigate what must be done to achieve this. We used DI water as a test liquid and a FTA200 for measurements.

Baseline Measurement

A baseline was established by a hanging down pendant drop of water from a #20 stainless steel needle. The cuvette and J needle used are shown below.

The usual issues of cleanliness, focus and magnification calibration must be honored. For a discussion of these, see http://www.firsttenangstroms.com/faq/SoYouWant728.html. The image on the following page shows a typical SnapShot. If you wanted the very finest results, you would take a Movie and then average over many frames. In round numbers, we expect a standard deviation of about ±0.5mN/m for SnapShots under these conditions. We specifically measured the diameter of the needle with a micrometer because we used it as a magnification standard. The measured diameter was 913 microns. The liquid-vapor interfacial tension is 72.27mN/m. This is not unreasonable as the room temperature was above the 20C at which the well-known 72.8 value is obtained. Water IFT decreases about 0.15mN/m for each degree rise.

465 Dinwiddie Street • Portsmouth, Virginia 23704 • 1.757.393.1584 Fax: 1.757.393.3708
http://www.firsttenangstroms.com



Dry Cuvette

Next the cuvette was inserted in the optical path. The drop was still the hanging pendant drop. This test shows the effect of the cuvette walls on the optical path as the light must travel through the rear and front walls of the cuvette. The cuvette walls are not optically perfect. They can act as lens. The cuvette we used here is of intermediate quality: polished glass. The very highest quality cuvettes are fused quartz but they are fragile, expensive, and come in limited sizes. We will see that good results can be obtained with polished glass, but that certain precautions must be observed. You still have to observe precautions with quartz, so quartz alone does not solve all problems.

The cuvette walls can do the following:

- magnify the image (something we can correct)
- distort the aspect ratio (correctable but something we want to avoid)
- offset the apparent position of the needle if not exactly perpendicular (unimportant)
- change the focal length

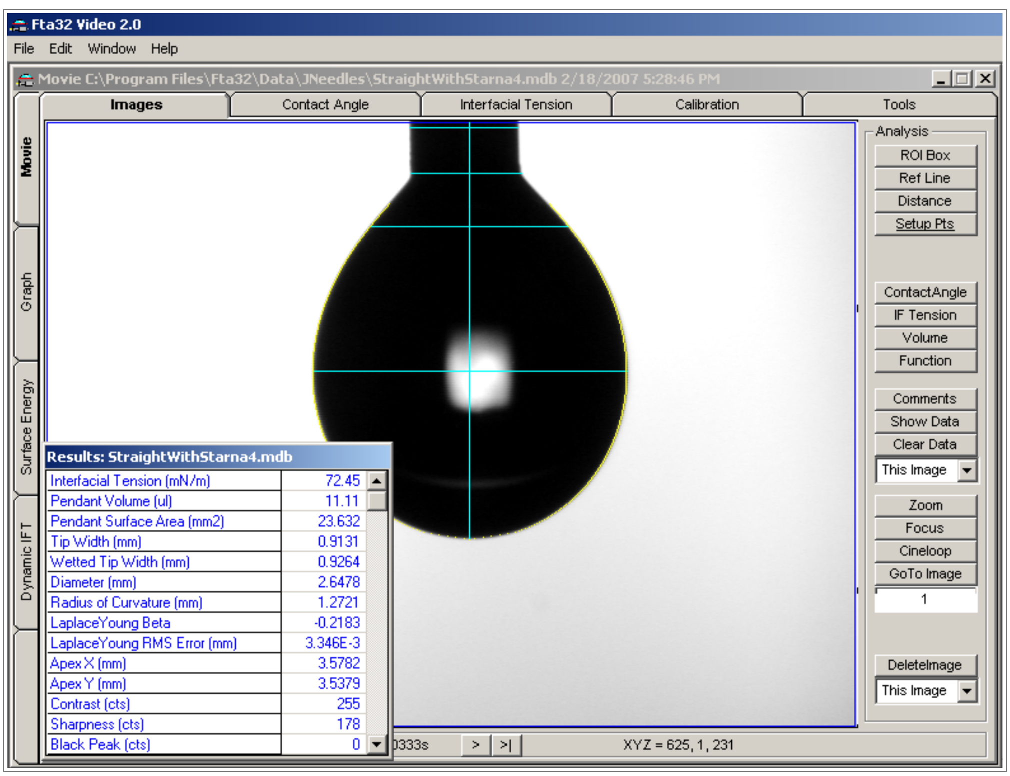
Magnification change is slight, but important to Laplace-Young measurements. We correct the magnification so the apparent needle size is the same in every case. A summary table at the end shows the actual magnification observed in each of the three cases discussed.

Aspect ratio is the relative magnification between horizontal and vertical. Laplace-Young measurements are very sensitive to aspect ratio errors. The consequence of an aspect ratio error is that the magnification (a horizontal measurement of the tip diameter) is correct but the calculated IFT (depends on both horizontal and vertical dimensions) is wrong. We will find that the IFT's for each case fall within the expected statistical spread, so the aspect ratio error in this glass cuvette is small.

If the cuvette is not sitting with its walls perpendicular to the optical path, the needle will appear offset to one side or another. This is easily observed by twisting the cuvette. This error is, however, unimportant. Nevertheless you want the walls perpendicular to minimize the “lens effects” of curvature in the walls.

The glass will definitely change the apparent working distance of the microscope. You will have to refocus. In fact, you must refocus between a dry cuvette (looking at the dry needle) and a wet cuvette. The water in the cuvette has the same effect.

The following image shows the same hanging pendant drop but with the dry cuvette in place. We had to recalibrate magnification and refocus. The measured IFT is 72.45, slightly higher than before but within statistical expectations.

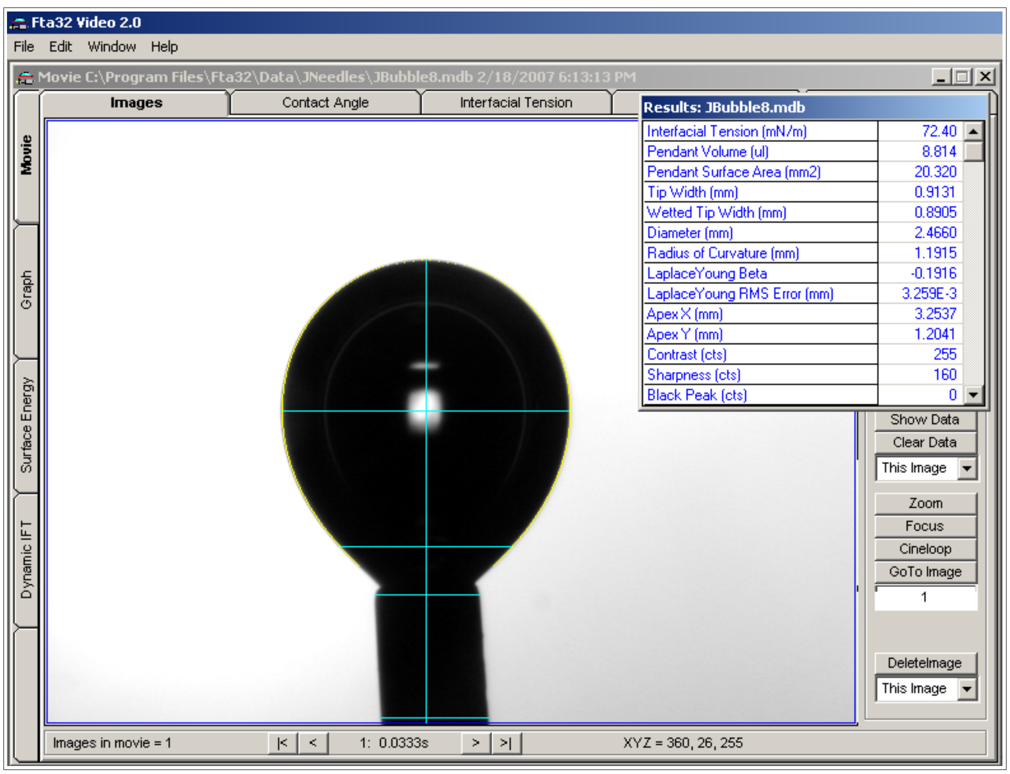


Wet Cuvette

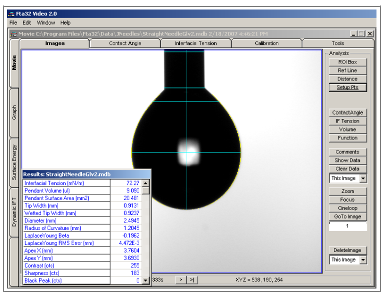
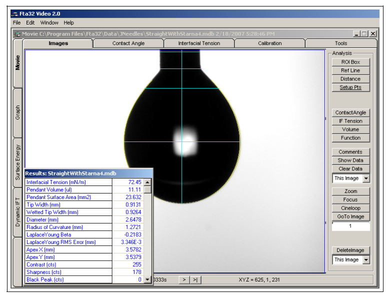
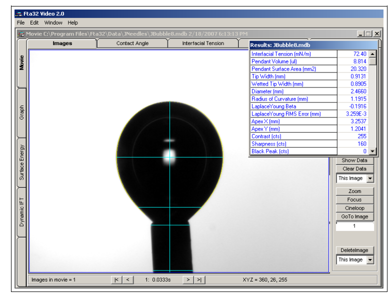
Finally, the cuvette was filled with water and a J needle was used to make bubbles rising up from its tip. The positions of the heavy phase (water) and the light phase (vapor) have now been reversed. A typical bubble is shown in the following image. When you start this work, you often have trouble forming stable bubbles. The same rules (surface tension, gravity, etc.) apply as before, but now everything is, shall we say, upside down:

- if you are pumping air with your syringe, the compliance of the air inside (its willingness to compress) fights against the surface tension of the air-water interface on the bubble. You will get situations where a small bubble emerges and then pops off – you can't seem to get a stable pendant-like shape like the figure below. The problem is your syringe has too much air inside: either use it with the plunger almost at the bottom or use a smaller syringe.

- the bubble will adhere to the inside diameter rather than the outside diameter of the needle. The liquid wets to the internal bore of the J needle. Actually, *it wets as far as it can*. In the normal hanging pendant drop, the liquid wets to the outside, wetting as far as it can. Because of this, you will intrinsically make smaller bubbles than hanging drops with the same size needle. To get back to the same drop size, use a larger needle.



A final difference with a wet cuvette is that the long optical path in water causes some dispersion in the image. You can get *almost* the sharpness, *almost* the focus quality, and *almost* the contrast of the dry cuvette case. You will have to make adjustments relative to the dry cuvette case. These may include adjusting the backlight intensity, microscope aperture, or camera brightness and contrast. You do not not need to adjust all of these to achieve good results. You can choose from between them. Trust your eye. Does the image of the J needle bubble *look* like the image of the straight needle pendant drop? To illustrate this, we line up all three cases:

Summary of Magnification and IFT

Case	Magnification (nm per pixel)	Measured Tip Width (microns)	Measured IFT (mN/m)
hanging pendant drop	10789	913.1	72.27
dry cuvette	10732	913.1	72.45
wet cuvette & J needle	10899	913.1	72.40

Magnification adjusted in each case to show same needle width. The similarities in IFT indicate that any aspect ratio problems are small for this cuvette.

File: IFTCuvettesAndJNeedles.odt