Improving Schlieren methods for measuring interface topography

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Topography of an interface

Measuring the topography of a fluid-fluid interface allows to observe and quantify elusive phenomena such as waves, instabilities or the presence of particles. For transparent fluids, this can be done with synthetic Schlieren methods [1]. Among them, the so-called Moisy-Rabaud-Salsac (MRS) method [2] is an elegant method that gives accurate measurements with a simple and low cost optical setup. It has been successfully used in the case of Faraday waves, wave-droplet interactions and floating objects [3].

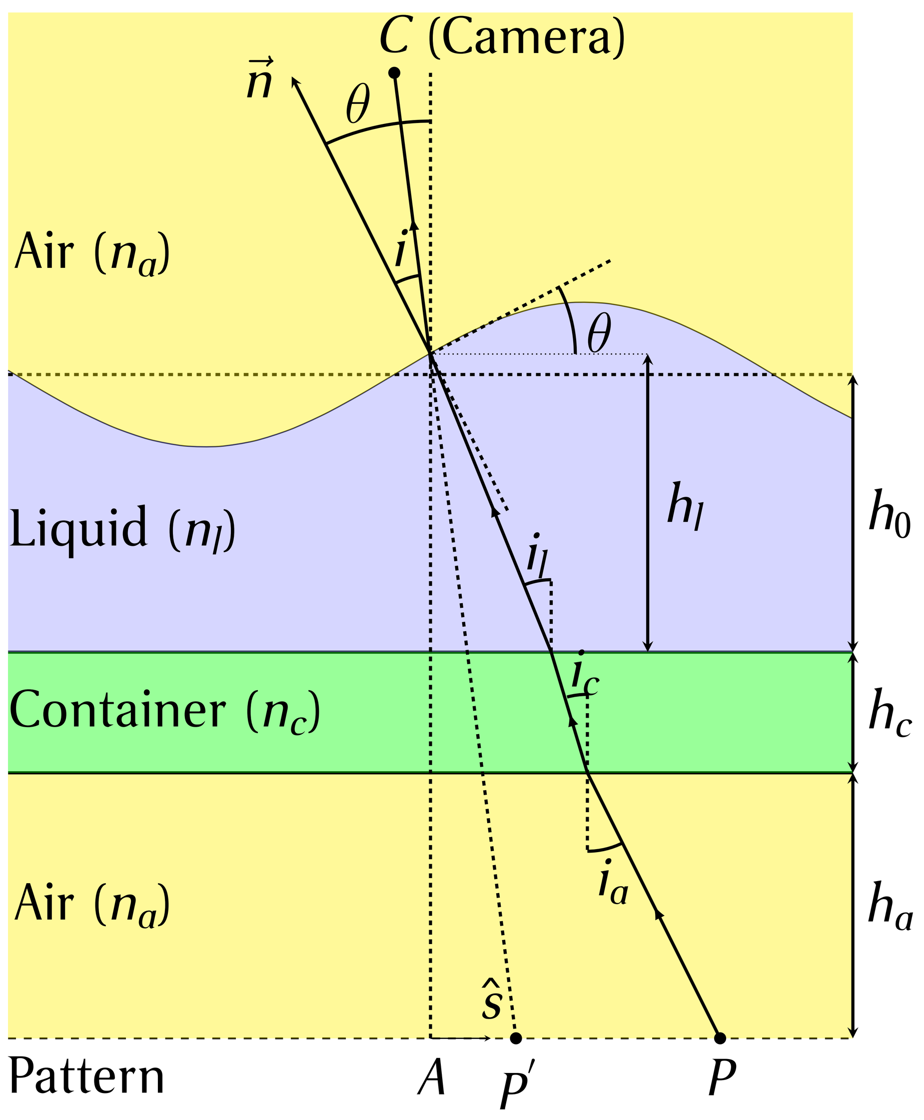
Deformation of water surface by a metallic ring

We propose an enhanced optical setup that uses a bitelecentric objective and a double pattern to measure larger slopes than the MRS method.

Moisy-Rabaud-Salsac (MRS) method

Steps:

- Pictures of the refracted pattern through the undisturbed and disturbed interfaces.
- Computing displacement field $\vec{\delta r}$ between pictures.
- Computing gradient field from displacement field.
- Integrating gradient field to get interface height.



$$\vec{\nabla} h = -\frac{\vec{\delta r}}{h^*}$$

$$h^* = \left(1 - \frac{n_a}{n_l}\right)\left(h_0 + \frac{n_l}{n_c} h_c + \frac{n_l}{n_a} h_a\right)$$

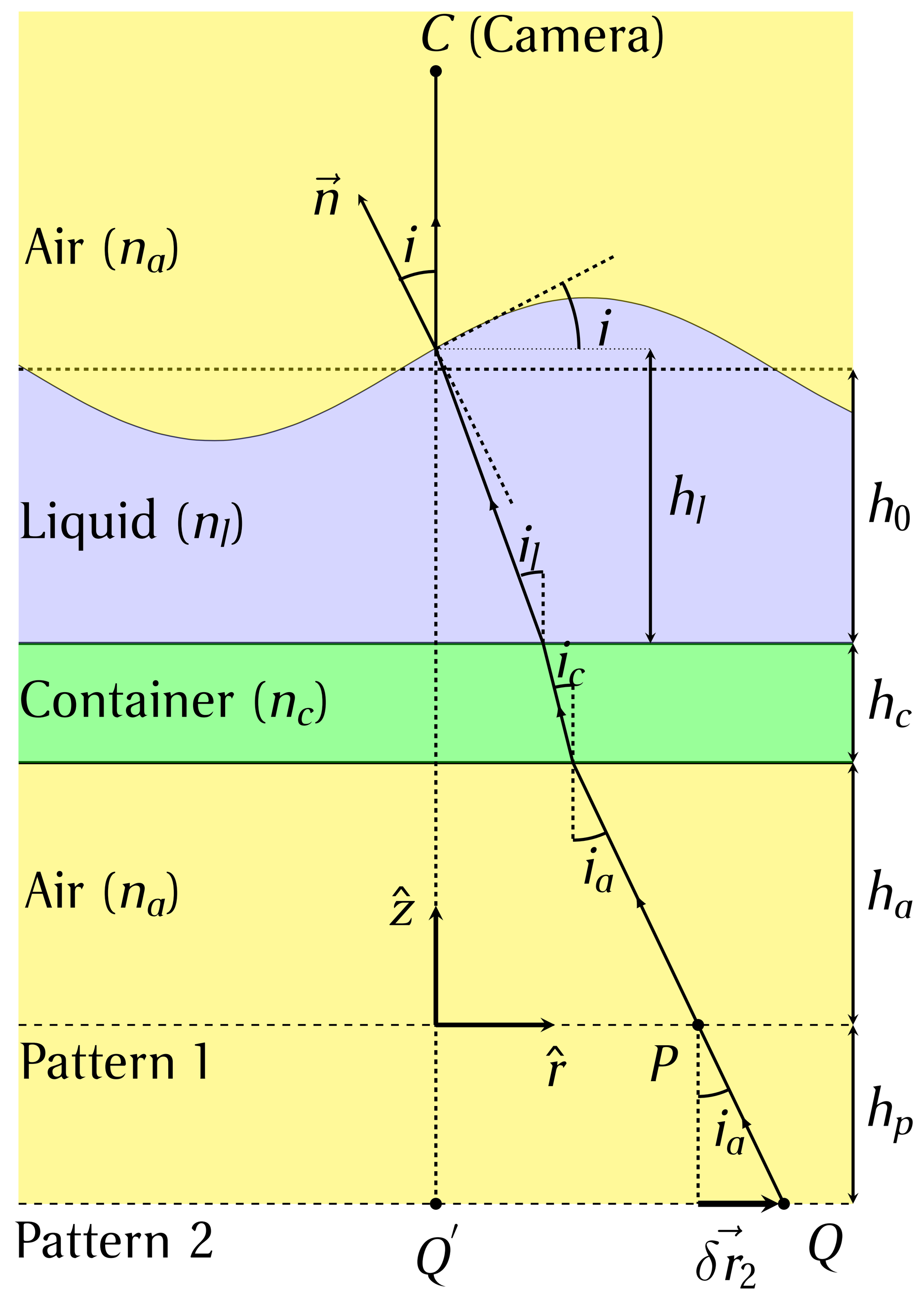
Assumptions:

- Paraxial approximation.
- Only first order terms.
- $h_l \approx h_0$

⇒ Restricted to weak deformations, weak slopes, weak paraxial angle.

Proposed method

Same procedure but new computation of gradient field.



Bitelecentric objective:

$$\vec{\nabla} h = \tan(i)\hat{r}$$

Double pattern:

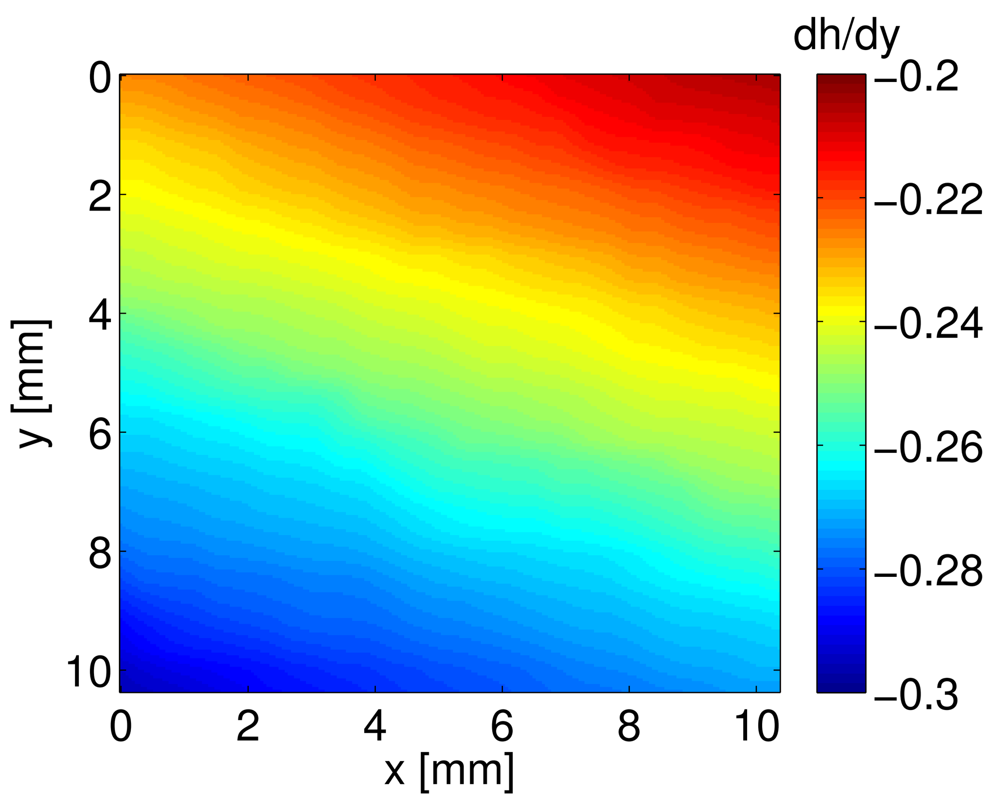
$$\begin{cases} i_a = \arctan\left(\frac{\delta r_2}{h_p}\right) \\ i_a = \arcsin\left\{\frac{n_l}{n_a}\sin\left[i - \arcsin\left(\frac{n_a}{n_l}\sin(i)\right)\right]\right\} \end{cases}$$

⇒ No parallax, no assumption, does not depend on the local height.

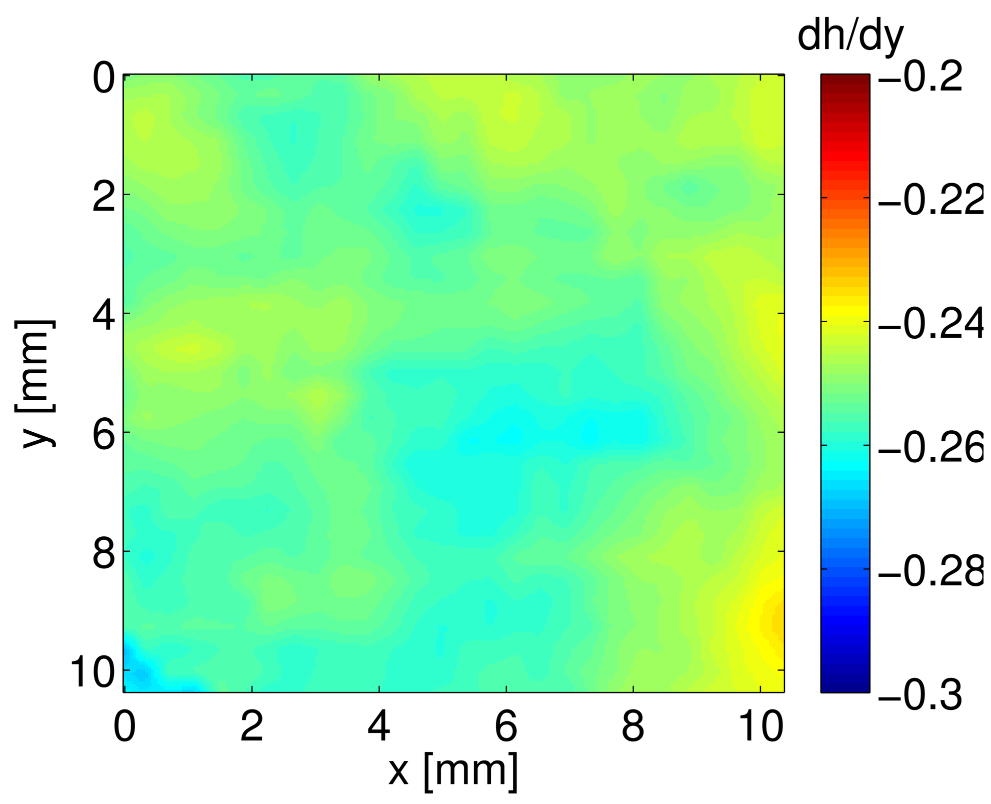
Slope of wedges

To validate our improvements, we have applied the method to glass wedges with specific angles and compared the wedge angles to the measured slopes.

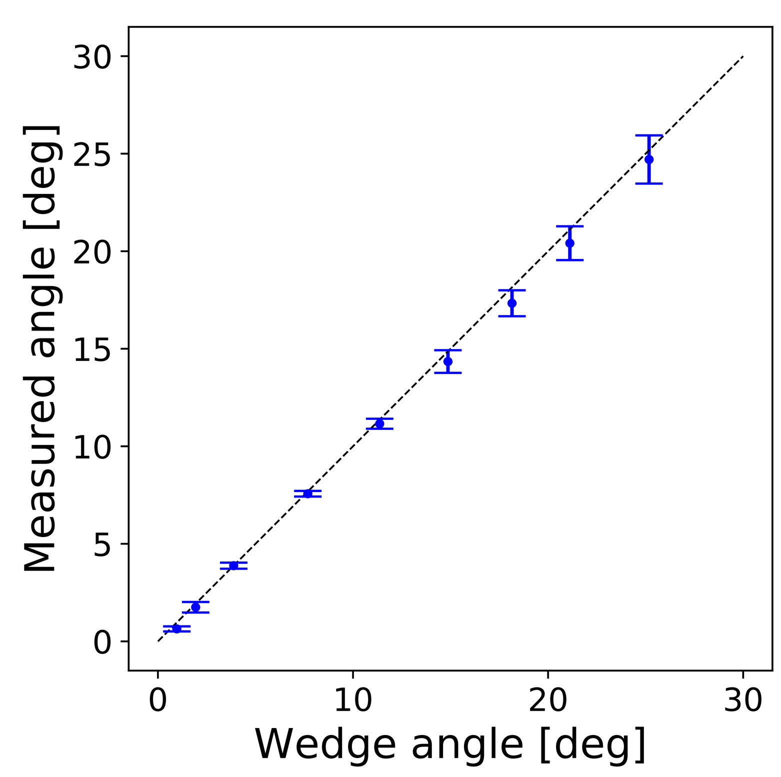
- 14,87° wedge: MRS method



- 14,87° wedge: our method



- Slopes of various wedges: our method



Conclusion

- With the proposed setup, the gradient field can be computed without approximations.
- The method does no more depend on the liquid height.
- Schlieren methods are extended to moderate slopes and deformations.

References

[1] S. B. Dalziel *et al.*, Exp. Fluids, **28**, 322 (2000)
[2] F. Moisy *et al.*, Exp. Fluids **46**, 1021 (2009)
[3] J. Metzmacher *et al.*, Eur. Phys. J. E **40**, 108 (2017)