Mapping the concentrations of gaseous ethanol in the headspace of champagne glasses through infrared laser absorption spectroscopy

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Mapping the concentrations of gaseous ethanol in the headspace of champagne glasses through infrared laser absorption spectroscopy

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Introduction

Under standard wine tasting conditions, volatile organic compounds (VOCs) responsible for the wine's bouquet progressively invade the glass headspace above the wine surface. Most of wines being complex water/ethanol mixtures (with typically 10-15 % ethanol by volume), **gaseous ethanol is therefore undoubtedly the most abundant VOC in the glass headspace** [1]. Yet, gaseous ethanol is known to have a multimodal influence on wine's perception [2]. Of particular importance to flavor perception is the effect of ethanol on the release of aroma compounds into the headspace of the beverage [1]. Moreover, triggered by the presence of ethanol in wines, the Marangoni effect increases the exhaust of flavored molecules in the glass headspace [2]. In addition, ethanol is known to modify the orthonasal detection threshold of aromas (and especially the fruity aromas [2]), and it can also trigger the trigeminal system leading to tingling and/or warm sensation [2]. **Monitoring gaseous ethanol, in space and time, in the headspace of wine glasses is therefore crucial to better understand the neuro-physicochemical mechanisms responsible for aroma release and flavour perception.**

Since the last decade at GSMA, **tunable diode laser absorption spectroscopy** has shown to be a well-adapted method to accurately monitor gas-phase CO_2 in the headspace of glasses poured with champagne [3]. Lastly, thanks to the recent **interband cascade laser (ICL) technology**, the CO_2 sensor was upgraded to monitor gaseous ethanol. This new quantum laser source, combined with previous technology developed for the monitoring of gas-phase CO_2, allowed us to **simultaneously monitor gas-phase CO_2 and ethanol** in the headspace of still wine and sparkling wine glasses, under standard tasting conditions.

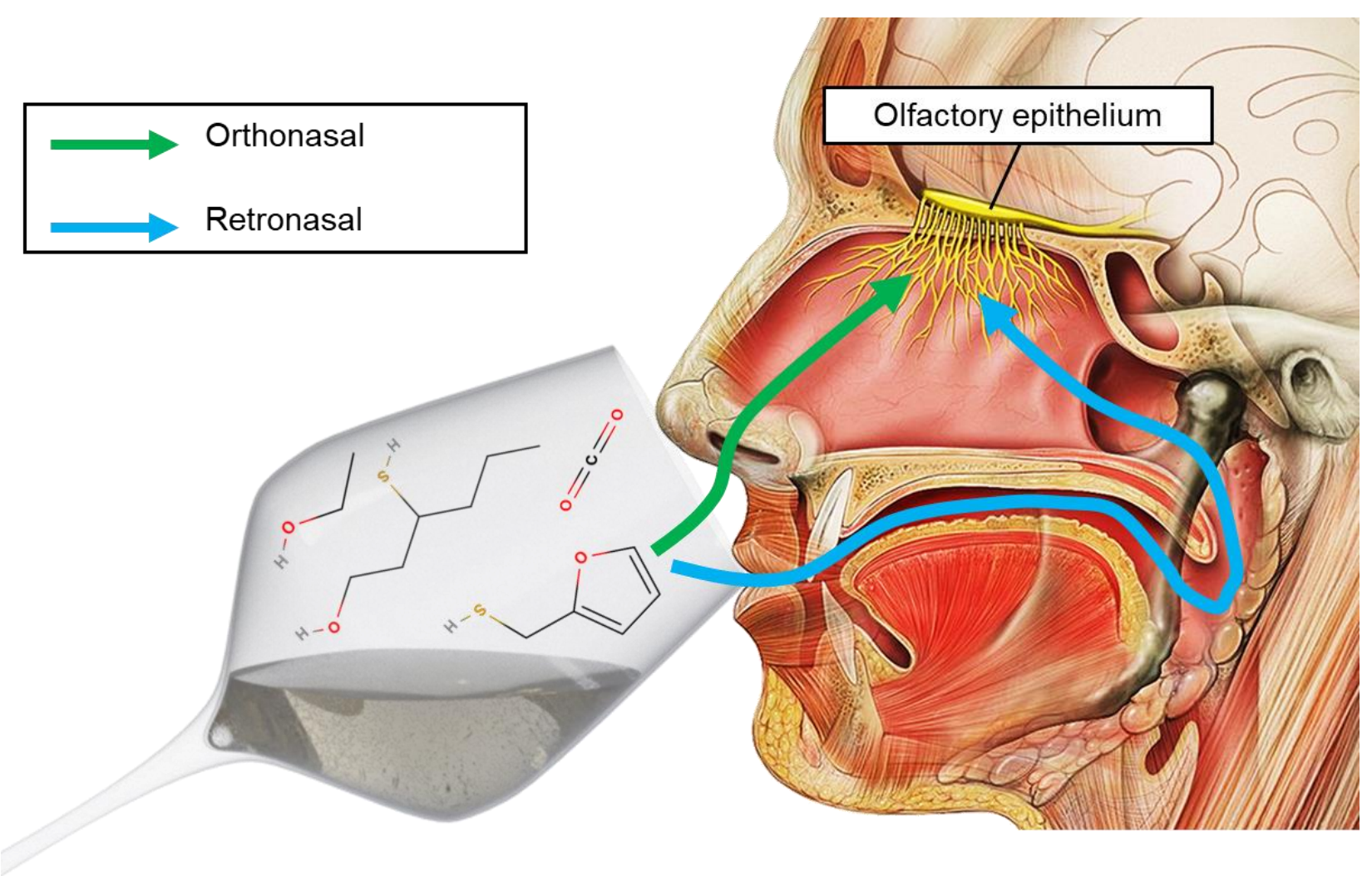


Figure 1: Schematic representation of the human olfactory system in sagittal section. Aromatic molecules smelled in through the nose follow the orthonasal pathway. In the mouth, the liquid releases aromatic molecules that trigger the olfactory epithelium via the retronasal pathway.

Experimental Setup & Data Processing

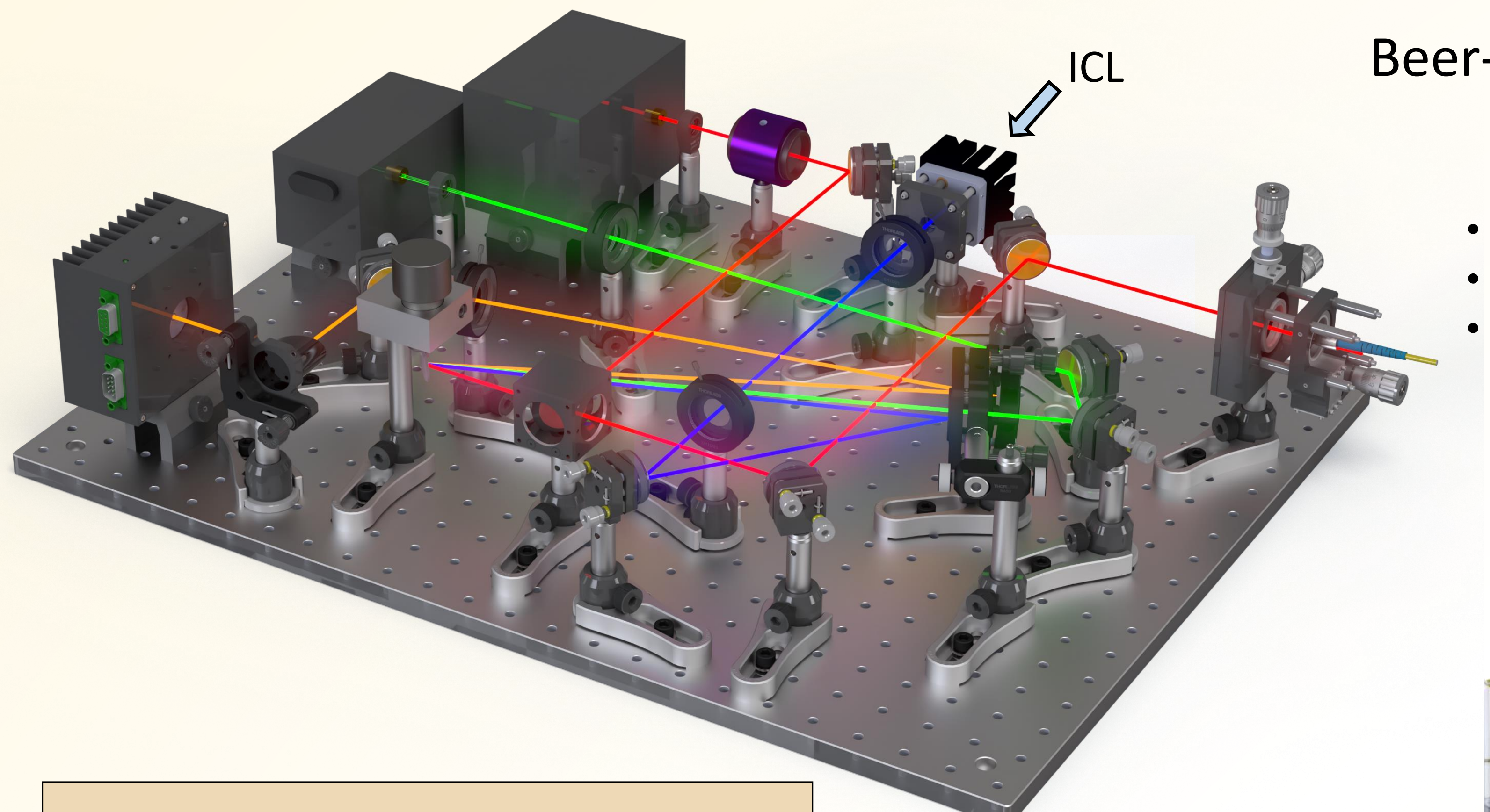


Figure 2: 3D view of the spectrometer involving three lasers, two for the monitoring of gas-phase CO_2 (shown with the orange and green beam), and one for the monitoring of gaseous ethanol (shown with the blue beam). The red beam is the common path followed by the three lasers.

Beer-Lambert law in transmission:

$$T = \exp(-\boldsymbol{\rho} N L \sigma_{eff})$$

- T: Transmission
- ρ: Molecule mixing ratio
- N: Molecule density
- L: Optical path
- σ_{eff}: Cross section (DB)

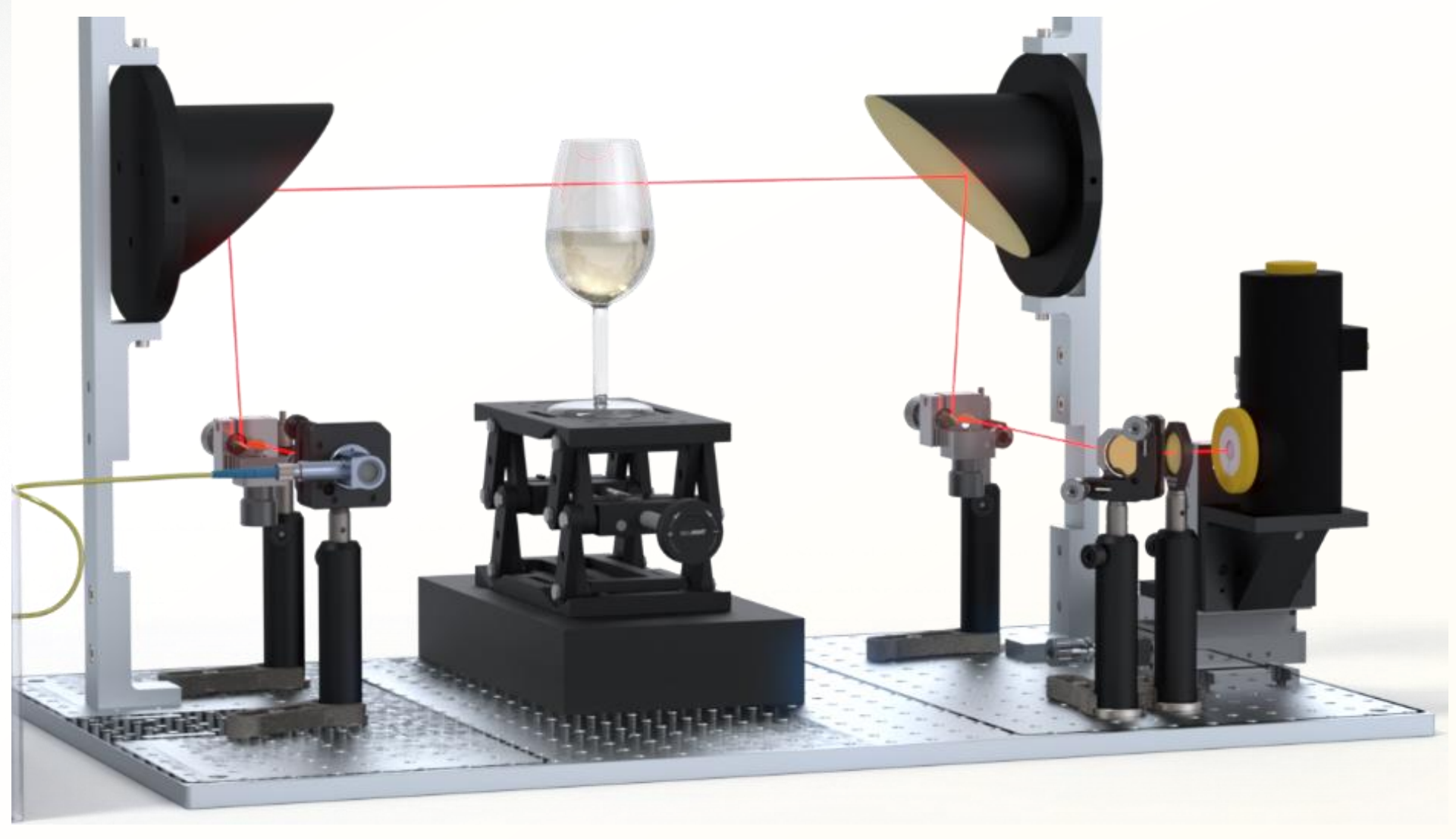


Figure 3: Global view of the optical setup dedicated to monitor the gas-phase CO_2 and gaseous ethanol at different position in the headspace of champagne glasses.

Non-linear fit :

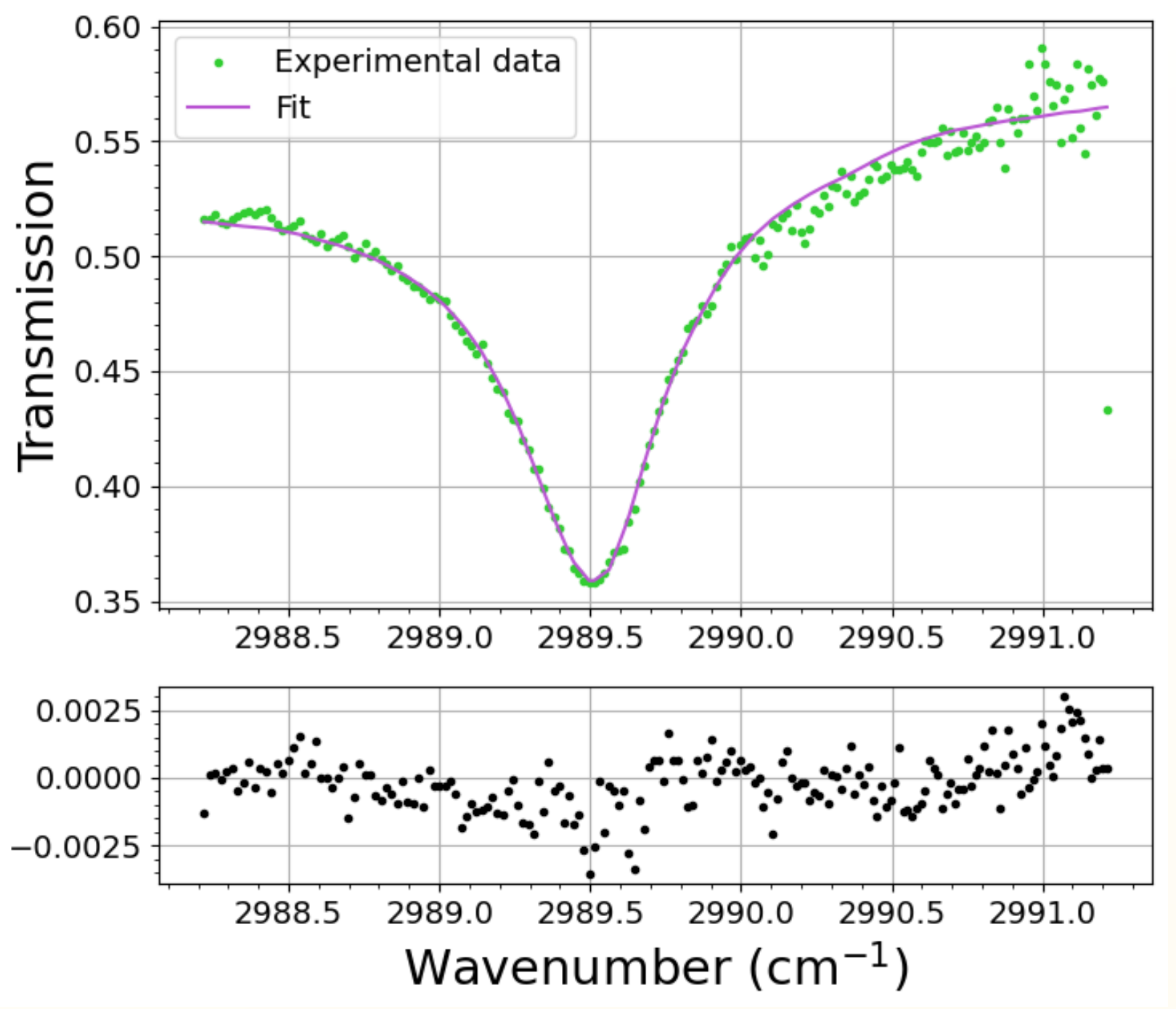


Figure 4: The fit (in purple) of an experimental transmission spectrum (in green) recorded by the ICL. The light went through a gas cell filled with 1000 ppm of ethanol broadened with nitrogen along an optical path of 150 cm under atmospheric pressure and ambient temperature. The black line is the difference between the experimental data and the fit.

Ethanol mapping in the headspace of the ŒnoXpert glass dispensed with champagne

Ethanol distribution in the glass headspace

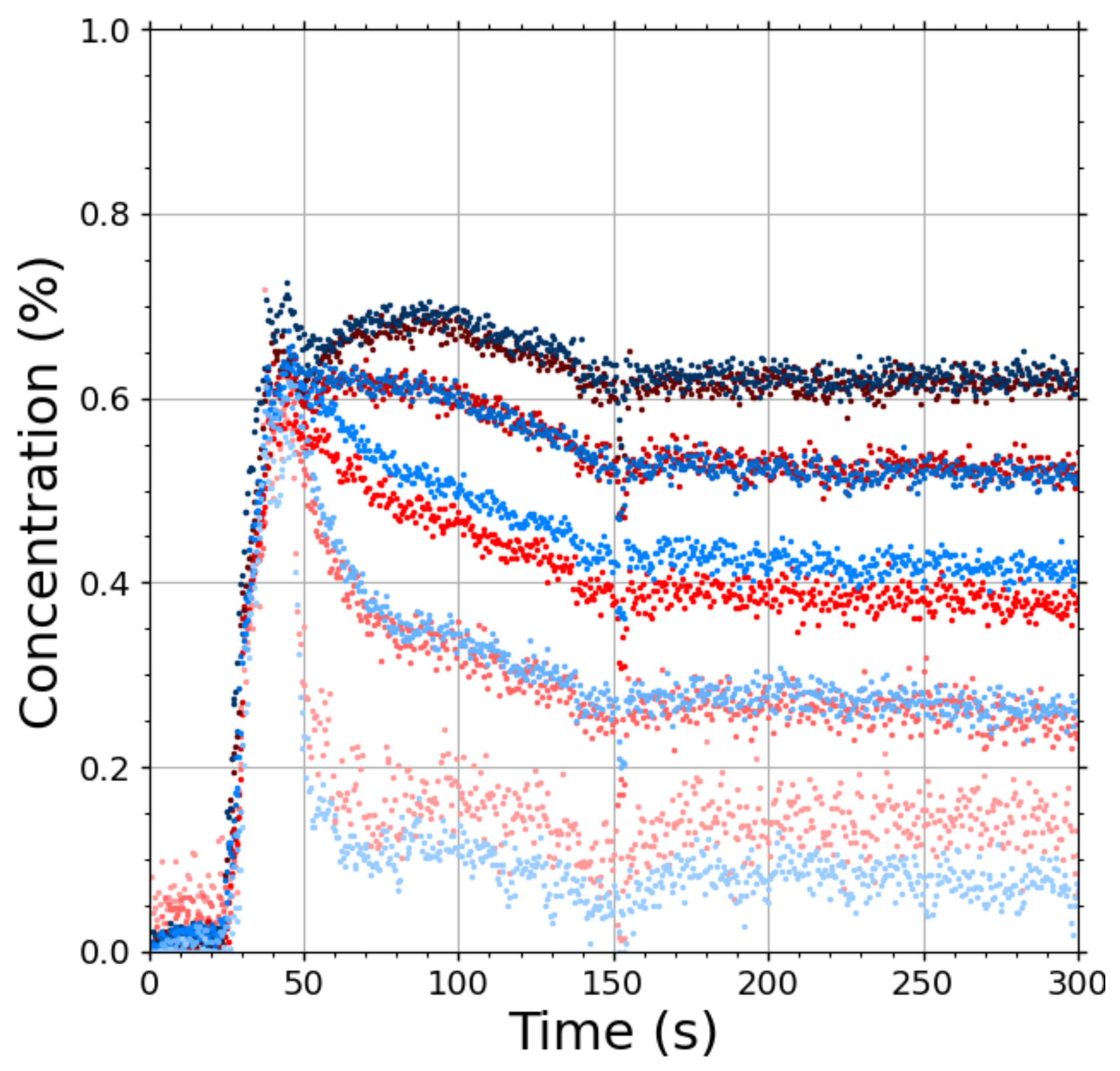
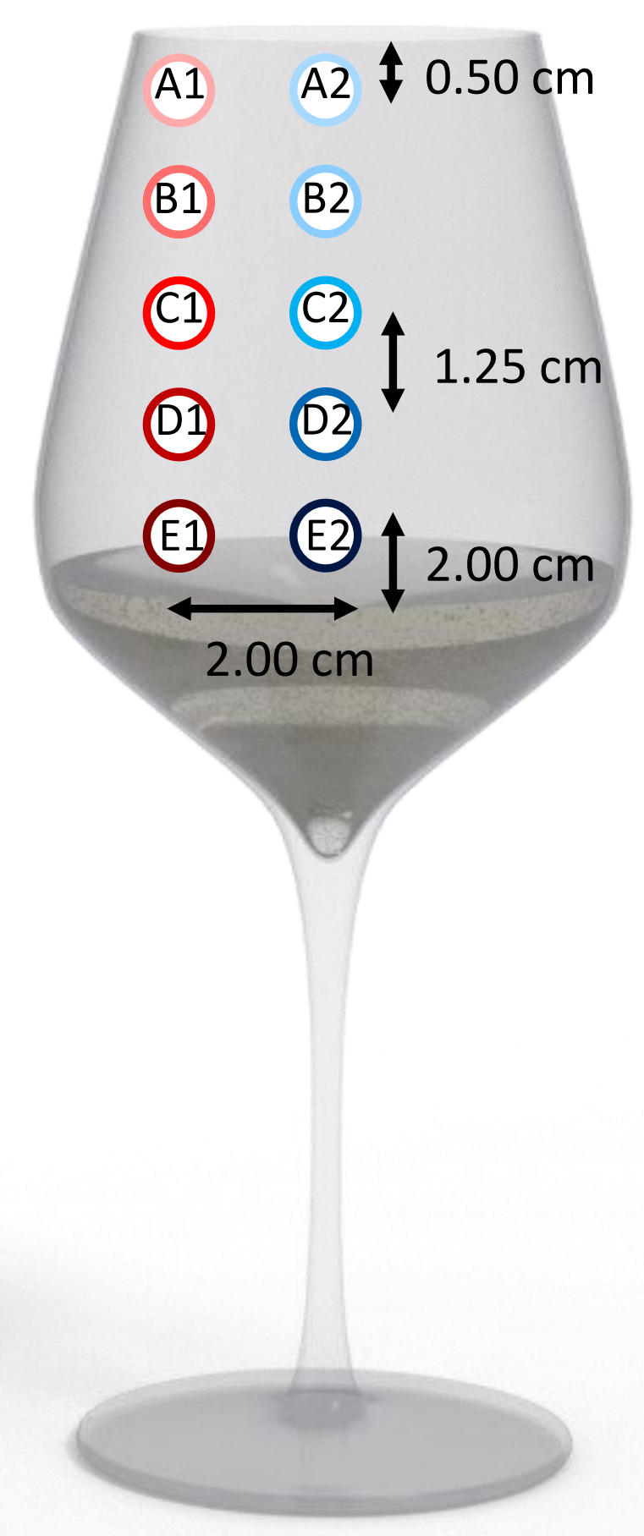
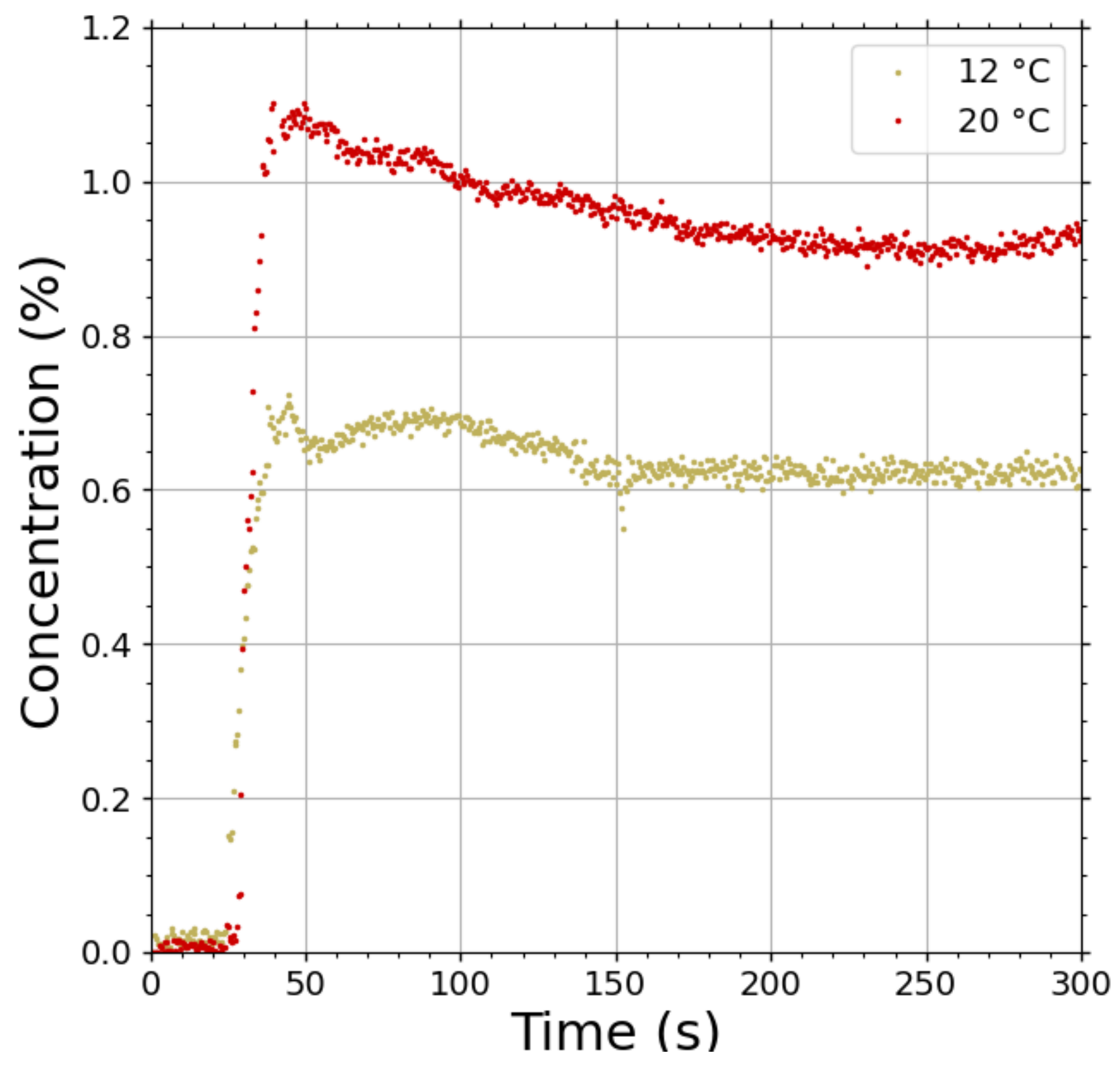


Figure 5: Monitoring of gaseous ethanol concentration (in %) in the headspace of the newly designed **ŒnoXpert glass** (along a 2D matrix of 10 points (2 × 5) displayed **below**) dispensed with 100 mL of champagne at 12 °C



As already observed for gas-phase CO_2 [3], the concentrations of gaseous ethanol show a strong vertically oriented gradient. Interestingly, As the off-center measurements come closer to the glass wall, ethanol concentrations tend to slightly differentiate from those measured along the central axis of the glass. This may be due to a Marangoni effect [4].

Impact of champagne temperature



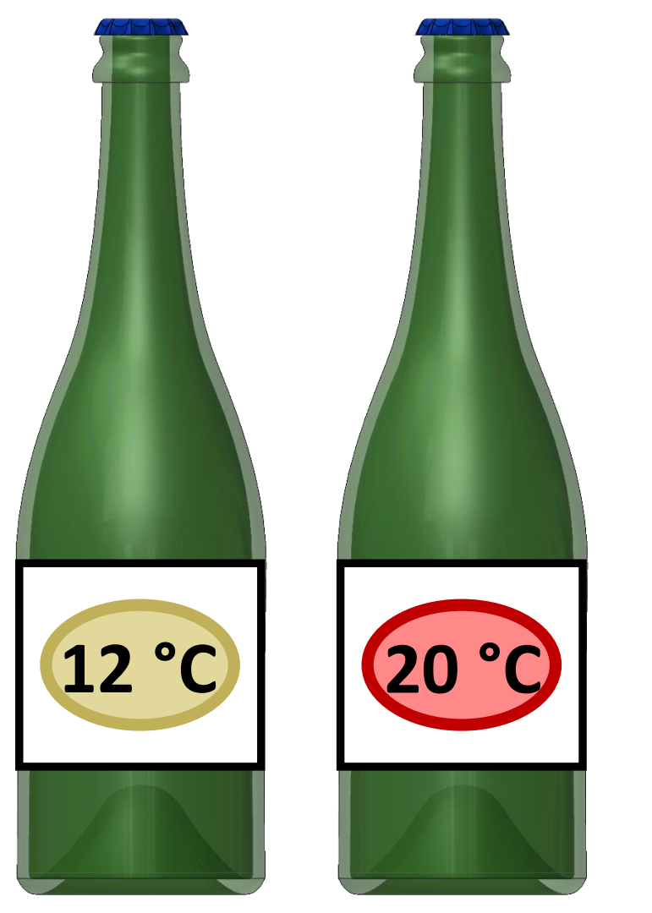


Figure 6: Monitoring of gaseous ethanol concentration (in %) in the headspace of the newly designed **ŒnoXpert glass** (5.5 cm below the glass edge in E2) dispensed with 100 mL of champagne at 12 °C (gold) and 20 °C (red), respectively.

From the beginning of the pouring step, ethanol gradually invades the glass headspace by evaporation from the liquid phase, ruled by its strongly temperature-dependent saturated vapor pressure. In the glass headspace, the level of gaseous ethanol reached at 20 °C is nearly twice that reached at 12 °C, as already shown by Cilindre et al. through gas chromatography but with a much lower data acquisition frequency [4].

References:

[1] G. Liger-Belair and C. Cilindre, Recent Progress in the Analytical Chemistry of Champagne and Sparkling Wines, *Annu. Rev. Anal. Chem.*, *14*, 21–46, **2021**
[2] C. M. Ickes and K. R. Cadwallader, Effects of Ethanol on Flavor Perception in Alcoholic Beverages, *Chemosens. Percept.*, *10*, 119–134, **2017**
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[4] C. Cilindre et al., Simultaneous monitoring of gaseous CO_2 and ethanol above champagne glasses via micro-gas chromatography (µGC), *J. Agric. Food Chem.*, *59*, 7317–7323, **2011**

Acknowledgments

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