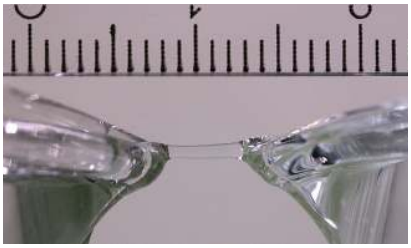
NEUTRONS AND WATER STRUCTURE: THE HEAVY WATER BRIDGE

E. C. Fuchs[1], B. Bitschnau[2], J. Woisetschläger[3], E. Maier[4], B. Beuneu[5] and J. Teixeira[5]

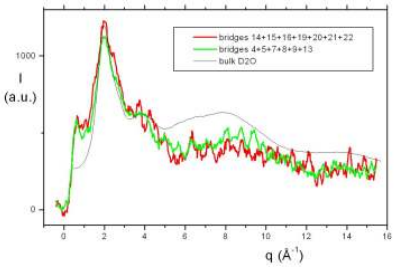
[1] *Wetsus, Center of Excellence for Sustainable Water Technology, Agora 1, 8900 CC Leeuwarden, The Netherlands*
[2] *Inst. of Physical and Theoretical Chemistry, Graz Univ. of Technology, Rechbauerstraße 12, 8010 Graz, Austria*
[3] *Inst. of Thermal Turbomachinery and Machine Dynamics, Graz Univ. of Technology, Inffeldgasse 25A, Graz, Austria*
[4] *Inst. for Chemistry and Technology of Materials, Graz Univ. of Technology, Stremayrgasse 16, 8010 Graz, Austria*
[5] *Laboratoire Léon Brillouin (CEA/CNRS), CEA/Saclay, 91191 Gif-sur-Yvette Cedex, France*

In 1893 Sir William Armstrong reported a remarkable experiment: if a high voltage is established between two wine-glasses filled to the brim with pure water and connected by a cotton thread, a rope of water is formed and remains suspended between the lips of the two glasses. This "water bridge" can subsist for a few seconds even once the thread has been removed [1].
Recently, a group of physicists from Graz University, Austria [2] succeeded on establishing a bridge (without any thread!) between the two glasses under a voltage of 20 kV. The length of the bridge may reach values larger than 1 cm, its diameter is of the order of a few mm and the lifetime currently exceeds 1 hour. Under the effect of the electrical field, the local temperature increases and reaches 60° C, a temperature sufficient to break the bridge.



Water bridge (5mm length, 1mm diameter) between two glasses filled with heavy water, under a voltage of 15 kV.
This short-lived structure due to the intense electrical field is not fully understood, although it results certainly from the unique properties of liquid water, its chemical composition, shape of the molecule and intermolecular bonds. Indeed, the role of hydrogen bonds on the general behaviour of pure water is always the object of active research because of both the fundamental aspects and importance in other domains, namely in Biology.
In order to enlighten the problem, a first measurement of the molecular structure of water inside the bridge has been performed by neutron scattering at the Laboratoire Léon Brillouin

(CEA/CNRS, reactor Orphée) at the diffractometer 7C2 for liquids and amorphous materials [3].
Generally speaking, the scattering of neutrons by nuclei gives precise information about the average local arrangements of atoms and molecules of a liquid sample. The optimisation of the experimental conditions implies the utilisation of deuterated samples, i.e., in this case, of heavy water (D_2O). This isotopic substitution has no effect on the structure of the liquid. Consequently, for the first time, a "heavy water bridge" has been successfully established between two water glasses filled with heavy water. One of the difficulties to overcome was the necessary purity of the D_2O sample.



Neutron scattered intensity of the water bridge compared to that of bulk water (black line). The important differences observed at large q (> 4 $Å^{-1}$) are not significant because they are due to the shadow of the two glasses. The first structural peak at 2 $Å^{-1}$ is not shifted, showing that both density and intermolecular distances are not different from those of the common liquid. Instead, the intensity at small q (~ 1 $Å^{-1}$) is larger what suggests complementary small angle experiments, necessary to the correct interpretation of this result [3].
The first structural peak of the scattering patterns (see figure) shows that no important differences exist between common bulk water and the water in the bridge. This first conclusion means that both density and inter-molecular distances are not different inside the "water bridge" as compared to bulk water. Although expected, this result eliminates some hypothesis suggested to explain the observed effect,

namely the eventual presence density gradients or collective molecular orientations.
Instead, the scattering at small momentum transfer (< 2 $Å^{-1}$) is different from that of bulk water. Its intensity is larger, what is explained likely by the presence of nano bubbles of gas that reinforce the effects due to the surface tension. One cannot exclude as well, the possible local arrangement of water molecules within tiny domains analogous to those existing in magnetic structures [4].
Even if a definitive explanation of the physics of the "water bridge" remains unknown, it was shown that the experiment can be achieved with heavy water and

that the structure can be measured with reasonably good accuracy, demonstrating once more the high performance of neutron scattering on the study of substances containing light atoms. Other experiments focusing on the small angle domain are under preparation and should yield complementary results.

References:

[1] W.G. Armstrong, Electrical phenomena, The Newcastle Literary and Philosophical Society, The Electrical Engineer, 10 February 1893, p.154.
[2] E.C. Fuchs, J. Woisetschläger, K. Gatterer, E. Maier, R. Pecnik, G. Holler and H.J. Eisenkölbl, J. Phys. D: Appl. Phys. **40**, 6112 (2007).
[3] E.C. Fuchs, B. Bitschnau, J. Woisetschläger, E. Maier, B. Beuneu and J. Teixeira, J. Phys. D: Appl. Phys. 42, 065502 (2009).
[4] E.C. Fuchs, K. Gatterer, G. Holler and J. Woisetschläger, J. Phys. D: Appl. Phys. **41**, 185502 (2008).

Contact : jose.teixeira@cea.fr