A New State of Water

Invited presentation at the
7th Annual Conference on the Physics, Chemistry and Biology of Water
Mount Snow, Vermont, USA
October 20th, 2012

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Electricity and Water
"...Amongst other experiments I hit upon a very remarkable one. Taking two wine-glasses filled to the brim with chemically pure water, I connected the two glasses by a cotton thread coiled up in one glass, and having its shorter end dipped into the other glass. On turning on the current, the coiled thread was rapidly drawn out of the glass containing it, and the whole thread deposited in the other, leaving, for a few seconds, a rope of water suspended between the lips of the two glasses. ..."
Experimental Set-up

I = 0.5 mA (const.)

Visualisation:
Panasonic Digital Camcorder,
real time.
Electric Field

- Electric displacement (calculation)

Displacement field norm (C/m^2)

Is the bridge a purely macroscopic phenomenon or is its water different on a microscopic level?
Ultrafast vibrational energy relaxation of the water bridge

- Measurement of the OH-vibration in an HDO molecule
- Duration of vibration gives information about the H-bond network
- Vibration stops faster in solid phase and last longer in liquid phase

Ultrafast vibrational energy relaxation of the water bridge

$\tau_1 (0^\circ C) = 740 \pm 40$ fs

$\tau_1 (0^\circ C) = 384 \pm 16$ fs

Woutersen et al. (1998), Phys. Rev. Lett. 81, pp. 1106-1109
Ultrafast vibrational energy relaxation of the water bridge

Vibrational lifetime against temperature

Woutersen et al. (1998), Phys. Rev. Lett. 81, pp. 1106-1109
Ultrafast vibrational energy relaxation of the water bridge

Thermalization - redistribution of energy

Population vs. Delay (ps)

- ▲ bulkwater
- ▲ waterbridge

Ultrafast vibrational energy relaxation of the water bridge

- The -OH vibrational relaxation time ($t_1$) is faster in the floating water bridge ($\sim 630\pm 50$ fs) than in bulk water ($\sim 740\pm 40$ fs), and slower than ice ($384\pm 16$ fs)

- The thermalization dynamics following the vibrational relaxation are much slower in the water bridge ($\sim 1500\pm 400$ fs) than in bulk HDO:D$_2$O ($\sim 250\pm 90$ fs)

- The observed relaxation time of $\sim 630\pm 50$ fs of the water bridge is not observed at any temperature for bulk water

- These results clearly indicate that in the bridge water exists in a new state.

Infrared emission

Visualisation:
Equus 110L (IRCAM)
338 frames / s

bright: ~40°C
High Speed Thermography

Visualisation: Equus 110L (IRCAM); bright: ~40°C
Infrared Emission

- Water bridge emission
- Water emission 47°C
- Water emission 37°C

CO₂ absorption  
H₂O vapor absorption

Infrared Emission

- 3-5μm region is as bright as 47°C, 8-12μm region as bright as 37°C water
- There is an additional, non-thermic emission at shorter wavelengths

Infrared Emission

Widths:
- Water 47°C: $1519 \pm 45$ cm$^{-1}$ ($R^2 = 0.92$)
- Waterbridge: $1172 \pm 22$ cm$^{-1}$ ($R^2 = 0.84$)

Infrared Emission

• IR emission caused by libration (hindered rotation)

Infrared Emission

IR emission caused by libration (hindered rotation)

Living Systems

- Waterbridge
  - ~10 kV/cm

- Living cells
  - 50-300 kV/cm

Tyner et al. (2007), Biophysical Journal 93, 1163–1174
Three different experimental set-ups:

- Bacteria in both beakers
- Bacteria in the anode beaker only
- Bacteria in the cathode beaker only
Escherichia coli lux

Enterobacteriaceae
- Gram negative
- Rod
- facultative anaerob

Genes from Vibrio fischeri
- luxICDABEG operon
- encodes for luminescence
**Escherichia coli lux**

Luminescence measurements with a spectrophotometer
- CPS (counts per second)

Growing cultures on agar plates and count the colonies
- CFU (colony forming units) / mL

Prokaryotic transport

Visualisation:
Panasonic Video Camera; 10 x time lapse

Bacteria in both beakers
measurements directly after exposure

Bacteria in anode beaker only
measurements over 4 days

Bacteria in cathode beaker only
measurements over 4 days

Anode            Cathode
+ 10kV

Blank                       Anode                Cathode

0    24   48   72   0    24   48   72     0    24   48   72

CPS/s

Growth experiment

different amounts of bacterial inoculate measurements over 4 days

- day 1
- day 2
- day 3
- day 4

Non-Aqueous Bridges

(a) Tetrahydrofuran  (b) Dichloromethane  (c) 2-Propanol  (d) Acetone

(e) 1-Propanol  (f) Ethanol  (g) Methanol  (h) Dimethylformamide

(i) Glycerol  (j) Dimethylsulfoxide  (k) Water

Glycerol Bridge

- Classical set-up, dynamical behaviour

Visualisation:
Panasonic Digital Camcorder, real time.

Glycerol Bridge

• Cuvette set-up with tracer particles

• Anode (+)  plastic spacer  • Cathode (-)

Glycerol, 5µm tracer particles

Visualisation:
Panasonic Digital Camcorder, real time.

1-propanol & 2-propanol

Visual

1-propanol

2-propanol

- Length ~5 mm

1-propanol & 2-propanol

Thermography

1-propanol

2-propanol

warmer bridge
colder bridge

Conclusions

- Water bridge water represents a new state of liquid water
- The IR emission of the bridge is partly non-thermal in origin and due to librations in conjunction with proton conduction
- Luminescent *E. coli* show increased activity after being in the bridge
- Floating bridges are not water intrinsic - they can be realized with a number of polar liquids with low conductivity
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Elmar C. Fuchs

With cordial gratitude to those who made this research possible and contributed to it:
J. Woisetschläger², Adam D. Wexler¹, L. Piatkowski¹¹, H. Bakker¹¹, F.T. Freund¹⁰, A.H. Paulitsch-Fuchs¹, L.J. Rothschild¹⁰, A. Nilsson⁷, B. Bitschnau⁴, J. Teixeira⁵, A. Soper⁷, E. Del Giudice⁸, G. Vitiello⁸, B. Beuneu¹, D. Cowdery⁷, K. Gatterer¹, M. Ramek⁴, H. Eisenkölbl⁸, G. Holler⁴, J. Tuinstra¹, G-J. Euverink¹, C. Buisman¹, the companies in the AWP theme, and many more.

1. Wetsus, Centre of Excellence for Sustainable Water Technology, Agora 1, 8900 CC Leeuwarden, The Netherlands
2. Graz University of Technology, Institute for Thermal Turbomachinery and Machine Dynamics, Austria
3. SLAC National Accelerator Laboratory, 2575 Sand Hill Road, MS69, Menlo Park, CA 94025
4. Graz University of Technology, Institute of Physical and Theoretical Chemistry, Austria
5. Laboratoire Léon Brillouin, Centre d’Études Nucléaires de Saclay, 91191 Gif-sur-Yvette Cedex, France
6. Graz University of Technology, Institute of Electrical Measurement and Measurement Signal Processing, Austria
7. ISIS Facility, STFC Rutherford Appleton Laboratory, Harwell Science and Innovation Campus, Didcot, Oxon, OX11 0QX, United Kingdom
8. Istituto Nazionale di Fisica Nucleare, Sezione di Milano, Milano - 20133 Italy
9. Dipartimento di Matematica e Informatica and INFN, Università di Salerno, Fisciano (SA) - 84084 Italy
10. NASA Ames Research Center, NASA Earth Science Division, Moffett Field, CA, and SETI Institute, Carl Sagan Center, Mountain View, CA, USA
11. FOM Institute for Atomic and Molecular Physics – AMOLF, Science Park 104, 1098 XG Amsterdam, The Netherlands