Emergence of Quantum Coherence in Liquid Water and Aqueous Systems

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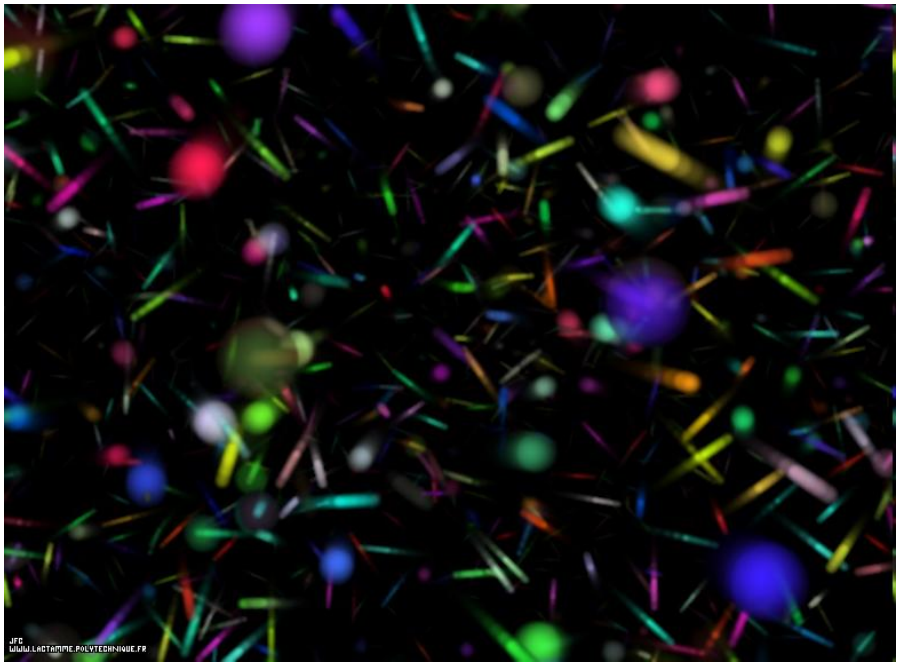
•According to general principles of

Quantum Field Theory (QFT)

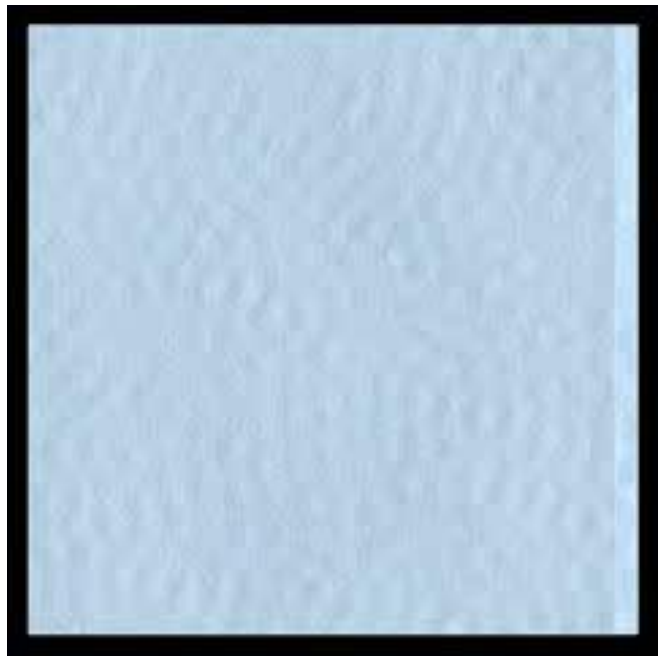
an ensemble of a large number N of atoms/molecules which are made up of particles electrically charged (nuclei, electrons), is coupled with the quantum electromagnetic fluctuations of the Vacuum.



Quantum vacuum fluctuations from www.lactamme.polytechnique.fr

Coherent Oscillations

- It is possible to prove that, when temperature is less than a critical threshold and the density N/V exceeds a critical value, the ensemble enters in a collective coherent oscillation between a pair of internal levels of its components, in tune with a non vanishing electromagnetic field.

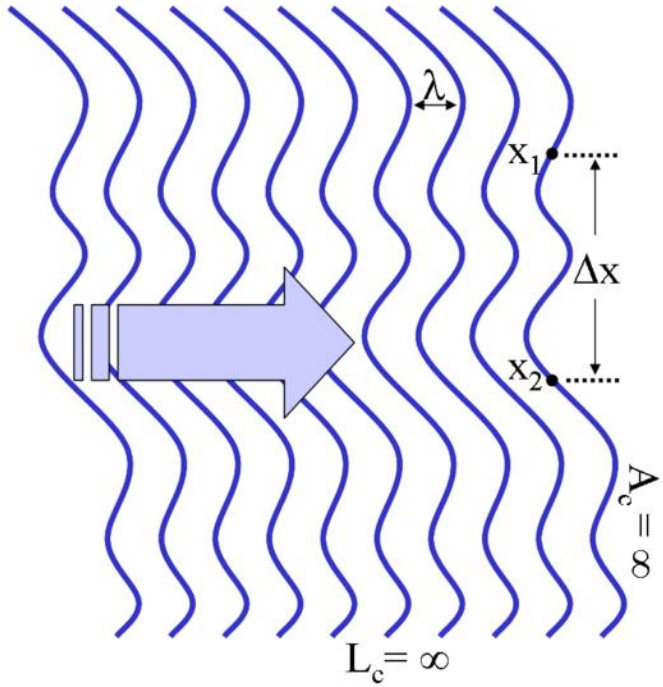


Oscillonic lattice from maltrizek (YouTube) – Formation of extended coherent structures from zero mode oscillation and thermal fluctuations

- A physical system is termed <u>coherent</u> when its *phase* (i.e. the rhythm of oscillation) is well defined (not necessarily constant).

- Take an ensemble of fluctuating atoms/molecules; since they are made up of charged particles, the fluctuations produce an electromagnetic (e.m.) field that in turn drives the fluctuating particles and so on.

- WHEN THE DENSITY OF PARTICLES EXCEEDS A THRESHOLD, there is a self-consistent physical state where particles oscillate in unison between two definite configurations in tune with a non vanishing e.m.field



A wave with a varying profile (wavefront) and infinite coherence length. (image from wikipedia)

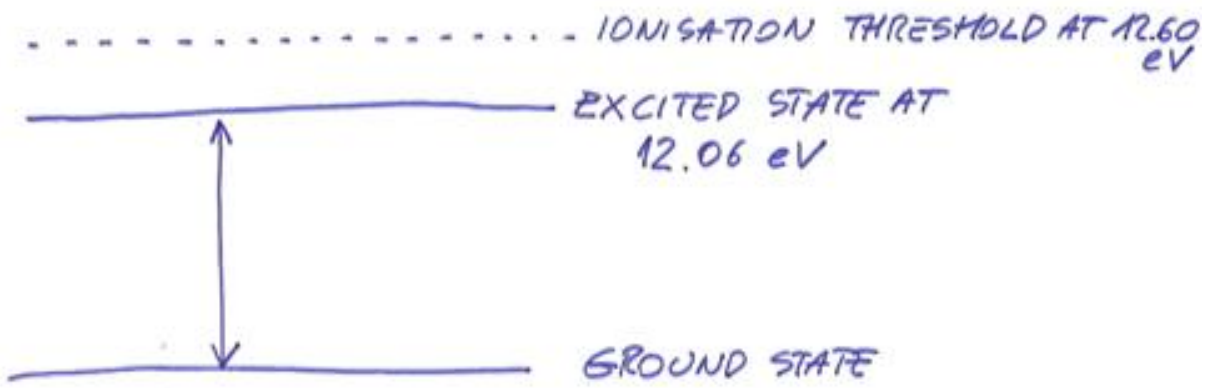
Water

- ***Gases*** are fully non coherent systems
- ***Liquids*** are systems where electron clouds are coherent
- ***Solids*** are systems where nuclei, too, are coherent

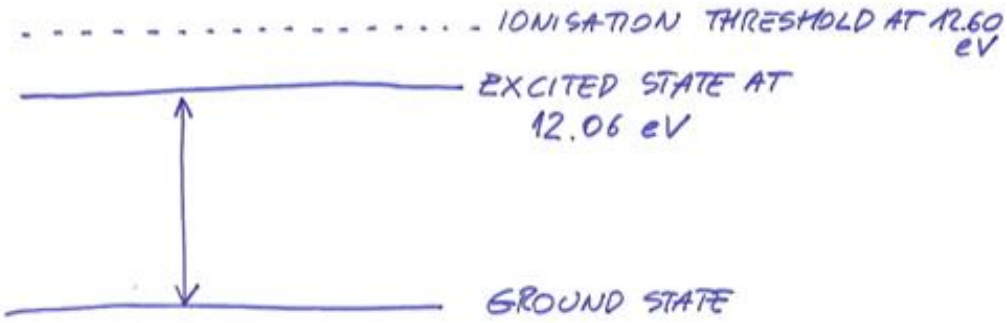
- Liquid water is peculiar, since the **coherent oscillation** connects **two electronic configurations** that have extreme features:

1) The ground configuration where **all electrons are tightly bound** (the ionization potential is 12.60 eV, corresponding to soft X-rays and to an excitation temperature of 145.000 °C !)

2) The excited configuration has an energy *E*=12.06 eV, only *0.54 eV below the ionization threshold*. So for each molecule there is an almost free electron!



Water



- The coherent state is a superposition of these states with weights 0.87 and 0.13 respectively. In a water Coherence Domain (CD) there are 0.13 almost free electrons per molecule.
- The size of a water CD is 0.1 μm
- The coherent fraction F_c is about **½** at room temperature.
- In the excited state the almost free electron settles at about 0.35 Å out of the electron core.

Water

The size of the region (**C**oherence **D**omain) where molecules are phase locked is the wavelength of the e.m. mode responsible for the coherent oscillation

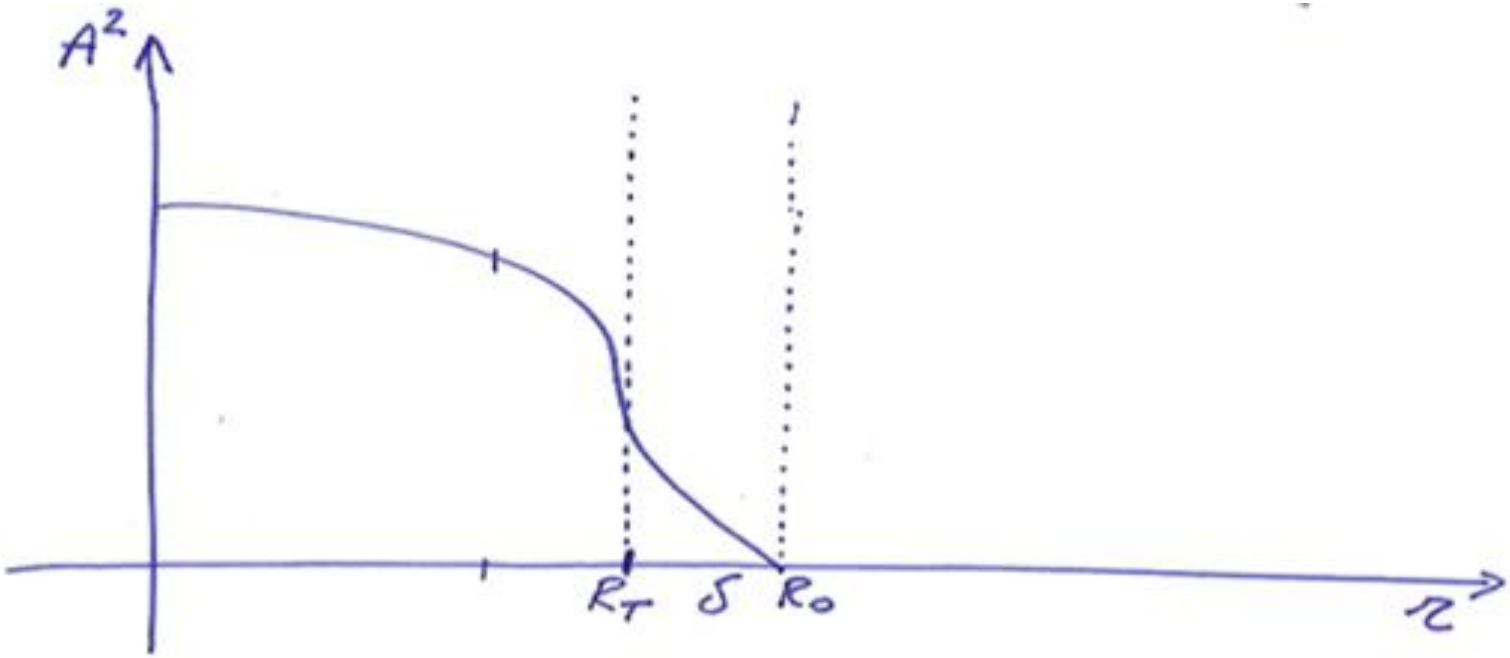
$$\lambda = hc/E_{excit}$$

in the case of water:

$$\lambda = 0.1\ \mu m$$

Water

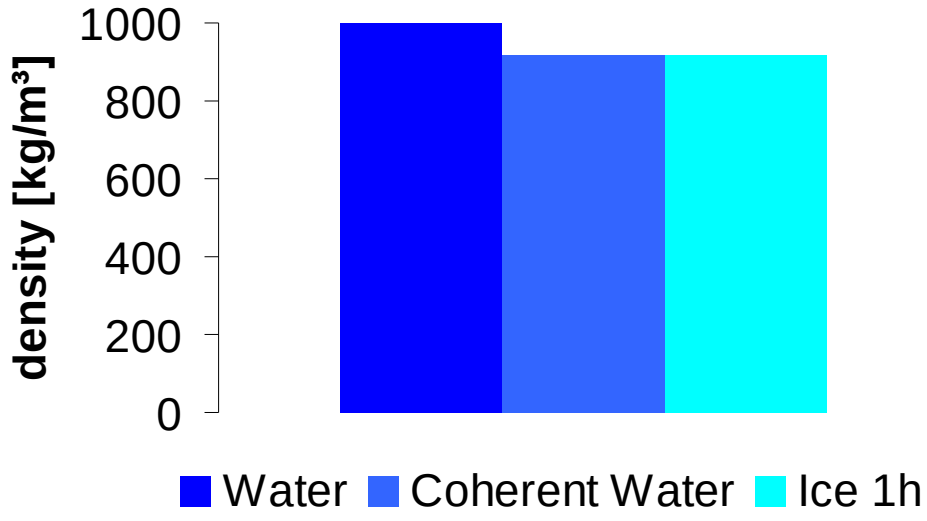
The electromagnetic field is trapped within the **C**oherence **D**omain and falls off exponentially outside.



Inside of CD Outside of CD

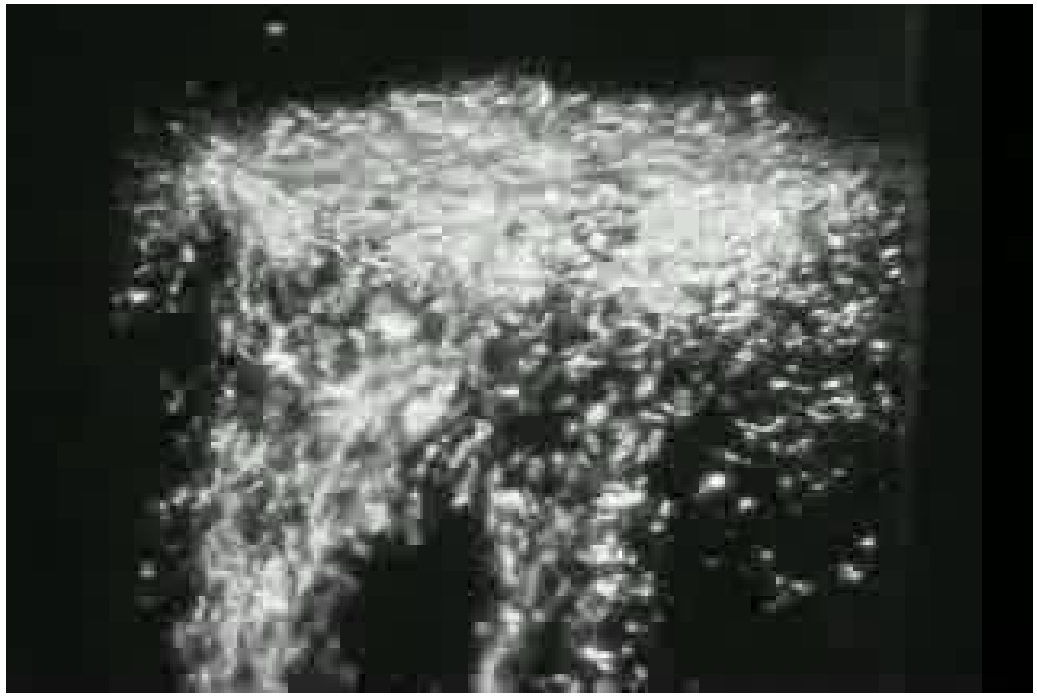
Water

The coherent electromagnetic attraction pulls the component oscillating molecules, as close as possible, producing a density of 0.92 smaller than the average density of water since coherent molecules have a larger volume than the non coherent ones.



Water

The coherent molecules usually don’t include the whole ensemble of molecules since a fraction of them is kept out of tune by thermal collisions. The picture resembles the Landau model for liquid superfluid Helium.



Beaker of liquid helium becoming a superfluid (by Alfred Leitner, 1963)

Water

- At non vanishing T, the thermal assaults decrease the size of the CD from R_0 to R_0-δ and round the CD, making it a sphere.

  So

$$F_c = \frac{\rho_c}{\rho_{TOT}} \frac{4/3\,\pi (R_0 - \delta)^3}{8 R_0^3} = \frac{\rho_c}{\rho_{TOT}} \frac{\pi}{6} \left(1 - \frac{\delta}{R_0}\right)^3$$

$$\frac{\rho_c}{\rho_{TOT}} \text{ is } 0.92, \quad R_0 = 0.05\,\mu m, \quad F_c \sim \frac{1}{2}$$

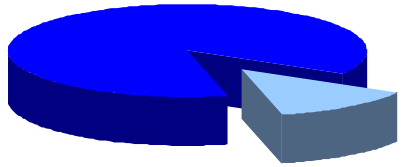
$$\delta \sim 20\,\text{Å}$$

Water

- Water **C**oherence **D**omains include an ensemble of quasi-free electrons (0.13 per molecule).
- This ensemble of electrons can be excited by external supplies of energy producing coherent excited states of Coherent Domains.
- These states have a long lifetime so that it is possible to pile up many excitations producing large electron excitations able to be transferred to nearby non-aqueous resonating molecules.
- In this way **C**oherence **D**omains as a whole can enter into oscillations.

CD electrons:

Bound electrons (87%)



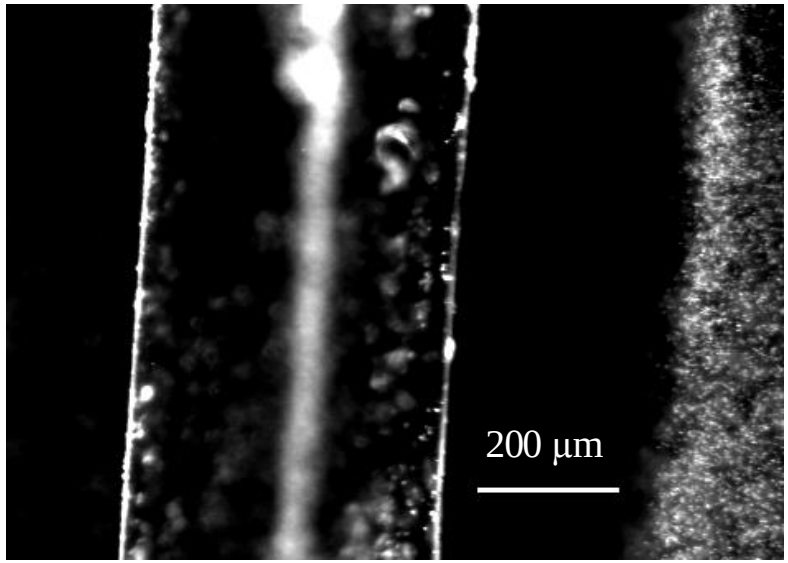
Quasi-free electrons (13%)

Water

- In bulk water the combination of e.m. and thermal fluctuations produces a flickering situation, where CDs are prevented to exhibit their peculiar features for a time long enough to allow detection.

- However, near a hydrophilic surface, the effect of thermal assaults is screened and water is almost entirely coherent on a range increasing with the electric polarisation of the surface

- Since solutes can be dissolved in the non-coherent fraction only, they cannot be present in the interfacial water (exclusion zone).



Exclusion **Z**one (EZ) water next to a PAA gel
(credits: J. Pollack,Washingten Univ.)

EZ-Water

- On the boundary of EZ water there is the difference of potential in surprising agreement with the membrane potentials.

- Is it conceivable that it is ***not the lipid membrane which produces the potential***, but, viceversa, the potential generated by EZ water may generate the variations in the solute molecule concentrations that appear as membranes?

- In standard QED, it is possible to show that a molecule able to oscillate on a frequency ***ν*** is strongly attracted in a region where there is an extended e.m. field resonating on the same frequency (laser cooling). The oscillation frequency of water CDs is 0.26 eV at T=0 and about **0.2 eV** at room temperature. Thus a non aqueous molecule is attracted in the CD if a frequency ***ν*** is present in its spectrum such that

$$| \nu - \mathbf{0.2\ eV} | \leq kT$$

- For a given temperature the above eq. tells us which molecules are candidates to be co-resonant partners of water (i.e., biomolecules) or, alternatively, for a given set of molecules what is the interval of temperature where they can resonate.

Water

- Co-resonating molecules can join the water CDs and participate in the coherent dynamics.
- In water CDs there is a reservoir of almost free electrons - **Two consequences:**

1) Almost free electrons, whose energy is

- $E = -0.54\ \text{eV} + X$

may tunnel out from CDs according to quantum tunnel effect, provided that they find out of the CD a site having the same energy. By assuming $X \approx 0.1$ eV one gets

- $E_{el} \approx -0.44$ eV

that coincides with the electronegativity of O_2 ! Thus

- $(H_2O)_{coherent} + O_2 \rightarrow H_2O^+ + O_2^-$

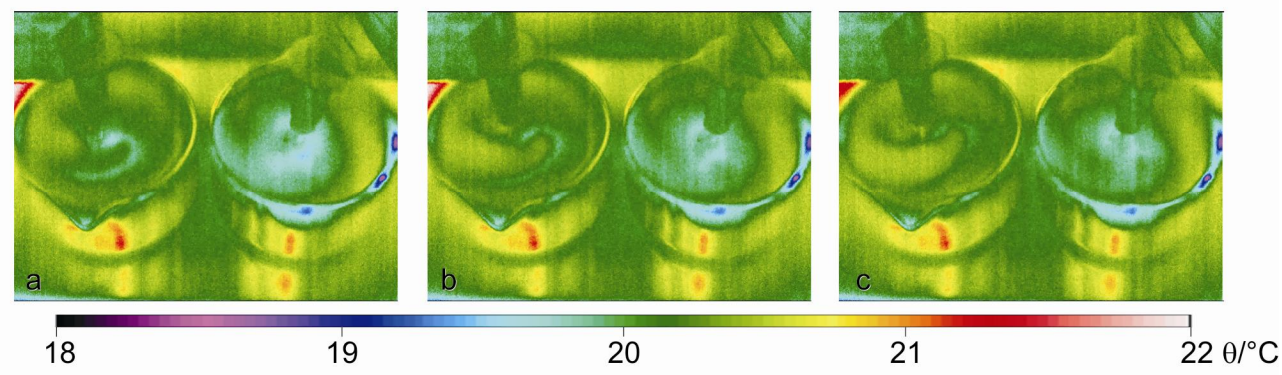
- The above reaction is the starting point of a chain of events that ends with the splitting of the water molecule

Water

- Co-resonating molecules can join the water CDs and participate in the coherent dynamics.
- In water CDs there is a reservoir of almost free electrons - **Two consequences:**

2) The almost free electrons are able to receive energy from outside producing coherent cold vortices where electrons move without colliding. Then their lifetime could be quite long!

It is possible to induce more and more vortices that sum up storing large amounts of energy.



Macroscopic vortices prior to the formation of a floating water bridge
(credits: J. Woisetschläger, TU Graz)

Water CDs

- Water CDs thus are devices able to transform
- low-grade (high entropy) energy collected in the environment into
- high grade (low entropy) energy able to induce into the"guest molecules" that have joined the CDs electronic excitations.

- Since these "guest molecules" are coherent , they are no longer independent and can receive energy only in a collective way in one stroke as in multimode lasers!

- This produces biochemical codes !

low grade
energy
high entropy

high grade
energy
low entropy

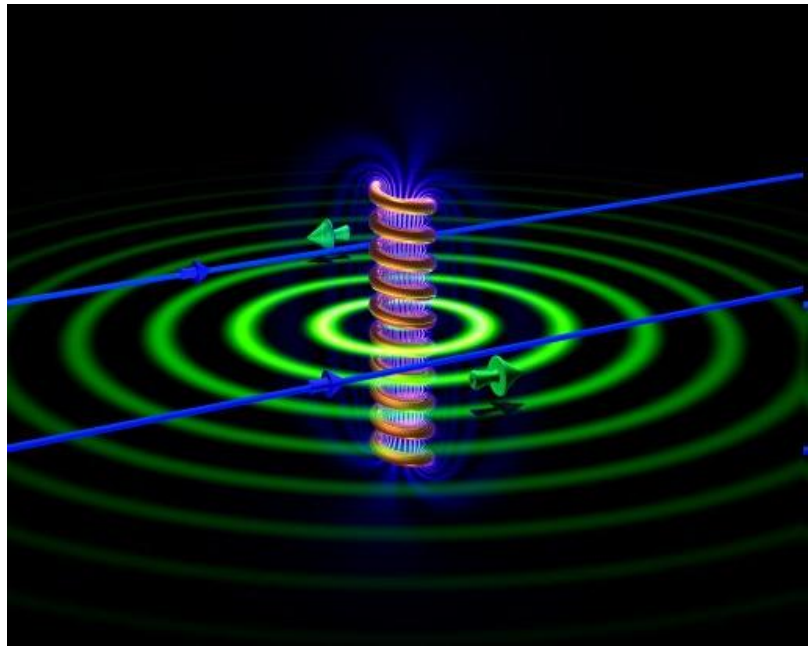
Aharanov-Bohm effect

- The phase of a coherent state is connected with the e.m. potentials by the equations:

$$\text{grad}\ \phi \propto \vec{A}$$

$$\frac{d}{dt}\phi \propto V$$

- So potentials (not the fields) produce observable effects!



Electrons (blue) passing either side of a current-carrying solenoid shows the Aharonov-Bohm effect in action (Courtesy *Physics Today*)

Water CDs

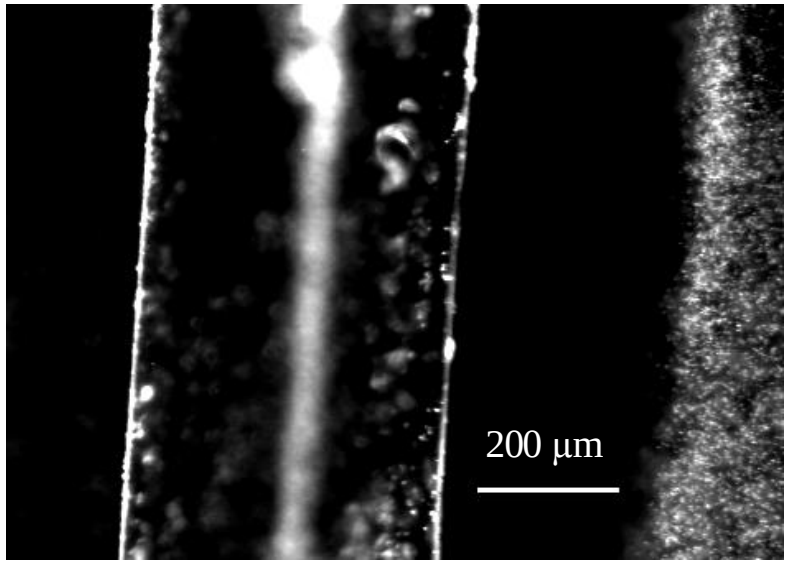
- Water CDs can thus get **excited** by collecting **ambient energy** and get de-excited by activating "guest molecules" producing so a CD oscillation.
- This oscillatory regime allows the onset of a **coherence among coherence domains** that tune together the oscillations of single CDs.
- In this way coherence extends on regions, whose size depends on the frequencies of CDs that depend in turn on the rates of chemical reactions.
- The output energy of chemical reactions load again the CDs, changing their oscillation frequency.

Water CDs

- The onset of an **extended coherence** implies the appearance of electromagnetic fields oscillating at well-defined frequencies.
- According to QuantumElectroDynamics (QED) these fields are able to attract co-resonating molecules giving rise to selective chemical attractions governed by specific chemical codes.
- The variations of the frequencies of the e.m.f. induced by the interaction with external fields is able to give rise to a variation of the chemical reactions occurring in the aqueous medium. **In this way a scheme of ordered biochemical reactions evolving in time emerges.**

Water CDs

- Should the inflow of energy occur on a large region, in a homogeneous way, the oscillations of the single Coherence Domains, could get tuned producing an extended coherence spanning large space regions.
- This could be the case of EZ water because the interaction with the wall or the water irradiated by e.m. fields of long wavelengths.



Exclusion **Z**one (EZ) water next to a PAA gel
(credits: J. Pollack,Washingten Univ.)

Water CDs

- The **variation of the frequency** of the e.m.f. in the CDs can be induced also by energy output of **chemical reactions** and other **physical processes** occurring in the aqueous medium.
- A close interplay between electrodynamics and chemistry is therefore driving the time evolution of the system.

Water CDs

The ensemble of time-dependent frequencies assumes a two-fold role:

a) It is the dynamic agent producing the selective attraction among molecules and therefore the *behavior of the soma*.

b) The ensemble of frequencies, considered in itself, becomes a sort of **MIND**, the **meaning** of the specific living organism. When perceived by other organisms this ensemble of frequencies transmits to them the **knowledge** of the transmitting organism.

The basis for the **dialogue** among living organisms and between them and the environment becomes therefore possible.

MIND MAP
(credits: ID: 1101108873 Creative Multimedia (Media Innovations))

Water CDs

The **Montagnier** experiments fit well in the this theoretical scheme.

a) When an e.m. ambient noise is present water CDs are able to collect this energy and reach excited configurations (***electron vortices***) which are able to pile up, transforming therefore an ensemble of uncorrelated bursts of energy (high entropy) into a well defined amount of coherent energy (low entropy), making happy the late Nobel Laureate Ilyia Prigogine.

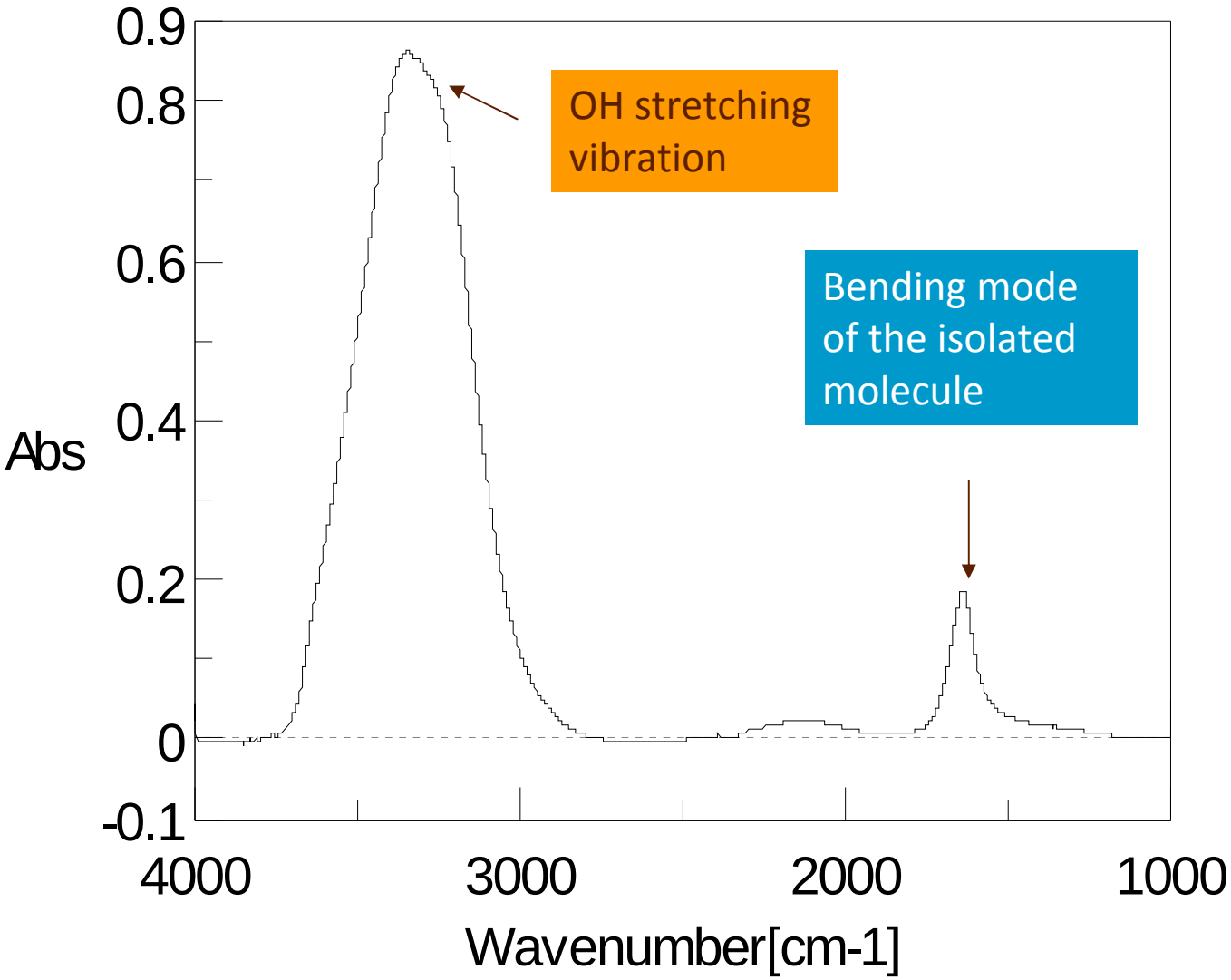
Ilya Prigogine

*1917, † 2003

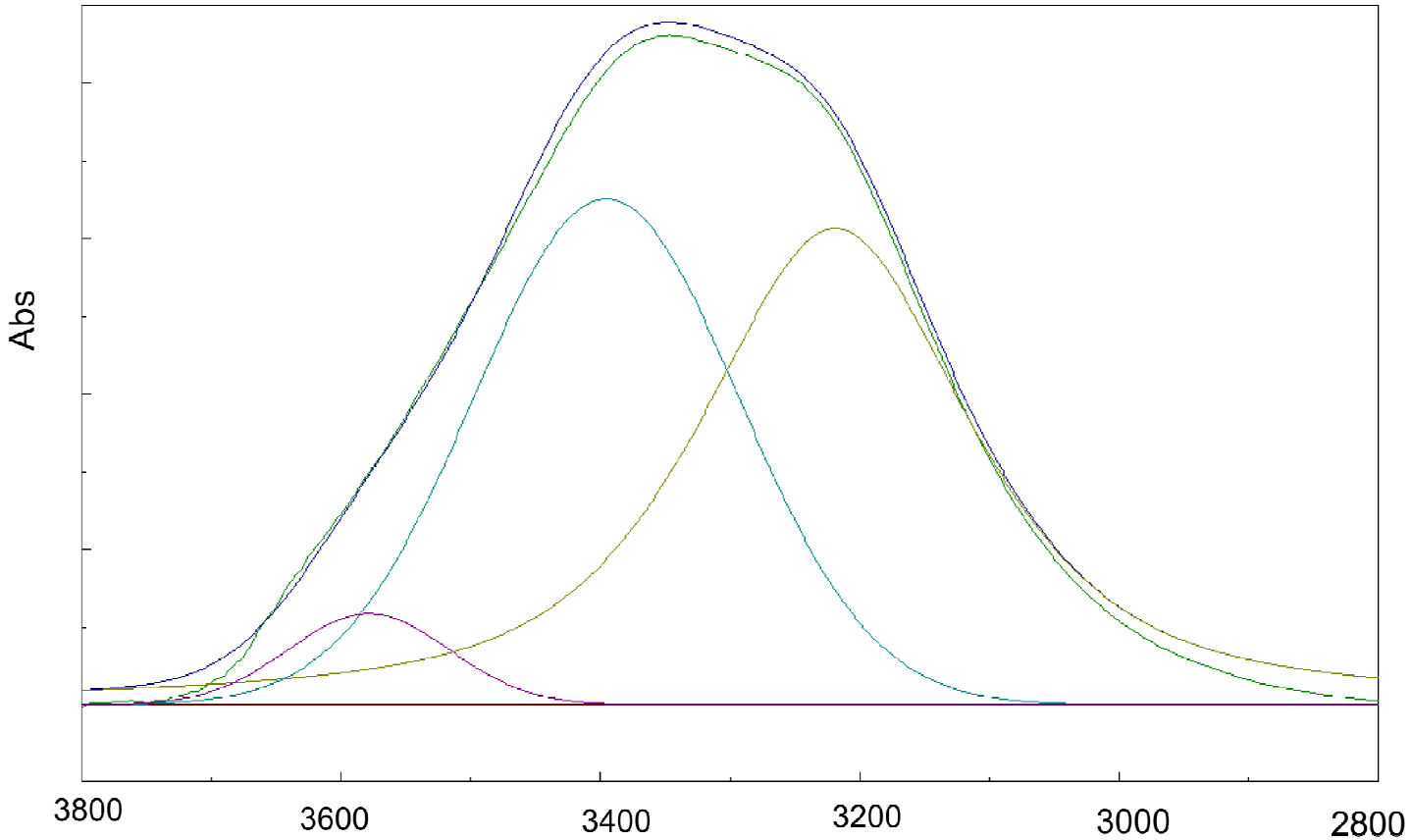
b) This collected energy could be released to the surrouding water as an e.m. signal which produces an ***inprint.***

c) When the appropiate molecules are suspended in water, the imprinted e.m. fields govern their chemical dynamics.

IR Spectra of liquid water

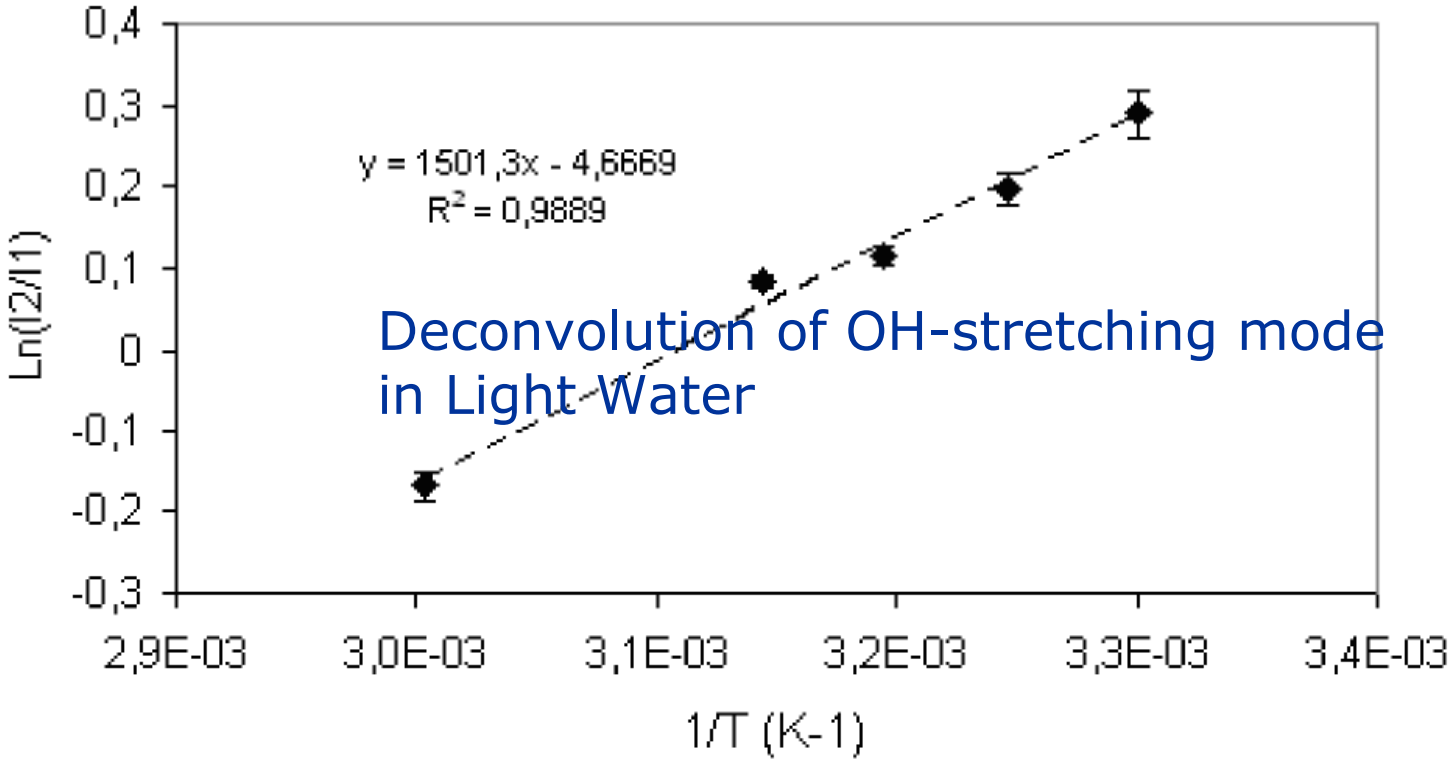


Deconvolution of OH-stretching mode in Light Water



Van't Hoff plot

$$\frac{d \ln K}{dT} = \frac{\Delta H}{RT^2}$$

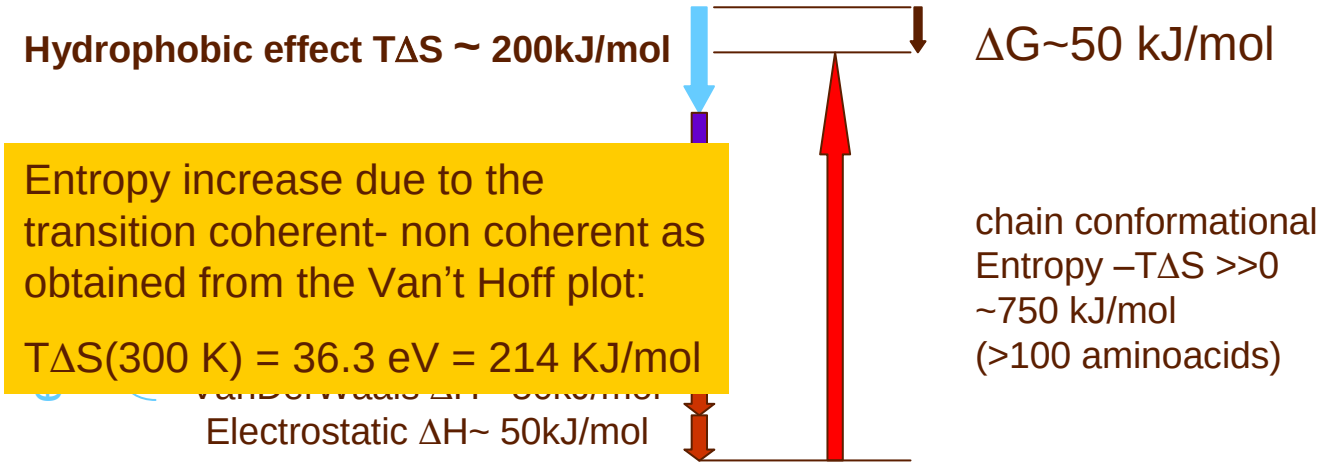


Deconvolution of OH-stretching mode in Light Water

Protein Folding Energy

Unfolded $\underset{\rightleftharpoons}{\Delta G}$ Folded

$$\Delta G = \Delta H_{system} - T \Delta S_{system} < 0$$



From James Chou Lessons 2008

THANK YOU FOR YOUR PATIENCE