QUANTUM WORLDS AND WHISPERING LIGHT

Research areas at the School of Physics, Peking University (PKU) are broad in both time and spatial dimensions, ranging from tiny atoms to the wide cosmos, and from increments of attoseconds to light years. Recent breakthroughs both at the quantum scale and in photonics illustrate its continued pursuit of research excellence.

Quantum phase transition in ultrathin crystalline films

PKU professors Wang Jian and Xie Xincheng, along with their colleagues, studied the two-dimensional (2D) superconductivity and superconductor-metal transition in ultrathin crystalline Ga films grown on GaN substrates, improving understandings of quantum phase transition in 2D superconductors.

They found that in an ultralow temperature regime, resistance versus magnetic field curves cross each other in a critical region, instead of a critical point, as reported in previous studies on amorphous or granular superconducting films. Thermal fluctuations almost disappear and disorder plays a key role in phase transition. When approaching the zero temperature quantum critical point, the dynamical critical exponent becomes divergent rather than a constant as previously believed, and the newly identified 'quantum Griffiths phase' is induced.

The finding supports the quantum version of 'Griffiths phase' proposed 40 years ago by the American physicist, Robert B. Griffiths, proving the divergence of dynamical critical exponent in experiments. Published in *Science*, the work was described in a perspective article as "offering a new perspective on the previous studies of superconductor-insulator and metal-insulator transitions" and also commended by Griffiths himself. It will inspire further investigations on 2D crystalline superconductors, as well as high-temperature and topological superconductors.

Unravelling the quantum nature of water

In a world first, a team led by professors Jiang Ying and Wang Enge from the PKU International Center for Quantum Materials quantitatively assessed the quantum component of a single hydrogen bond at a water/solid interface, unravelling questions about the structure and dynamics of water. Applying a scanning tunnelling microscope and density functional theory calculations, the team showed intermolecular hydrogen-bonding interactions, revealing to what extent the quantum motion of the hydrogen nuclei can affect the hydrogen bond.

"The main difficulty lies in probing water with single-bond precision," says Jiang, "as quantum states of hydrogen nuclei are extremely sensitive to coupling with local environments." Their solution is a novel technique called tip-enhanced inelastic electron tunnelling spectroscopy. By replacing a hydrogen atom with a heavier deuterium atom, they extracted the quantum component of the hydrogen bond, and found a much greater contribution from quantum over thermal energy even at room temperature. Anharmonic quantum fluctuations of hydrogen nuclei weaken the weak hydrogen bonds while strengthening the strong ones. This propensity is reversed when the hydrogen bond is coupled with polar atomic sites of the surface.

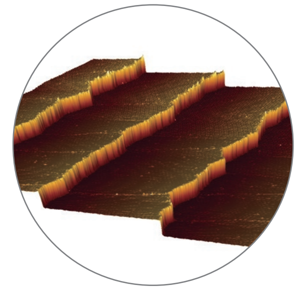
"Our work yields a cohesive picture for the nuclear quantum effects of hydrogen bonds," says Wang. "The findings may completely revamp our understanding of water and be generalized to other H-bonded materials, or even light-element materials."

Harnessing chaos to control light

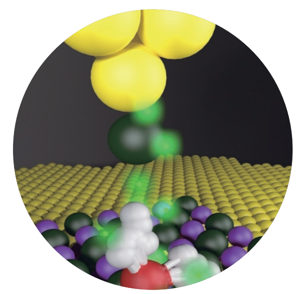
Integrated photonic circuits rely on light rather than electrons to carry and transfer information and may revolutionize communications, sensing and data processing. However, controlling and transporting light poses big challenges. Led by PKU professors Xiao Yunfeng and Gong Qihuang, a research team has demonstrated a new way to control the momentum of broadband light, using whispering gallery microcavities, a widely-used optical micro-resonator.

To couple light between different components traveling at different speeds, the PKU solution is a specifically designed asymmetric microcavity that creates chaotic channels, in which the angular momentum of light is not conserved and can change within a few picoseconds. Assisted by the chaotic motion and the dynamical tunnelling, they achieved efficient, broadband coupling between optical waveguides and microcavities, which would otherwise not couple.

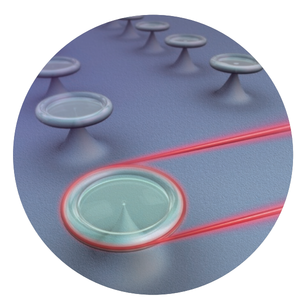
The research provides a new platform for microcavity optics and photonics, promoting applications in optical processing and storage.



A study by Wang Jian and his colleagues on ultrathin crystalline Ga films will inspire future investigations into 2D superconductors.



Through a quantitative assessment of the quantum component of a single hydrogen bond, PKU researchers have unravelled the quantum nature of water.



PKU researchers found that whispering gallery microcavities can be used to control the momentum of broadband light.