Quantum kisses change the color of nothing

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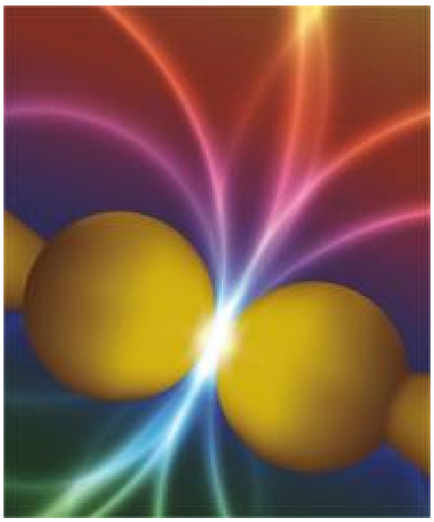

The image shows, in an artistic manner, the change in color when a quantum tunnel effect is produced in a subnanometric gap. Credit: Cambridge University

Even empty gaps have a colour. Now scientists have shown that quantum jumps of electrons can change the colour of gaps between nano-sized balls of gold. The new results, published today in the journal *Nature*, set a fundamental quantum limit on how tightly light can be trapped.

The team from the Universities of Cambridge, the Basque Country and Paris have combined tour de force experiments with advanced theories to show how light interacts with matter at nanometre sizes. The work shows how they can literally see quantum mechanics in action in air at room temperature.

Because electrons in a metal move easily, shining light onto a tiny crack pushes electric charges onto and off each crack face in turn, at optical frequencies. The oscillating charge across the gap produces a 'plasmonic' colour for the ghostly region in-between, but only when the gap is small enough.

Team leader Professor Jeremy Baumberg from the University of Cambridge Cavendish Laboratory suggests we think of this like the tension building between a flirtatious couple staring into each other's eyes. As their faces get closer the tension mounts, and only a kiss discharges this energy.

In the new experiments, the gap is shrunk below 1nm (1 billionth of a metre) which strongly reddens the gap colour as the charge builds up. However because electrons can jump across the gap by quantum tunnelling, the charge can drain away when the gap is below 0.35nm, seen as a blue-shifting of the colour. As Baumberg says, "It is as if you can kiss without quite touching lips."

Matt Hawkeye, from the experimental team at Cambridge, said: "Lining up the two nano-balls of gold is like closing your eyes and touching together two needles strapped to the end of your fingers. It has taken years of practise to get good at it."

Prof Javier Aizpurua, leader of the theoretical team from San Sebastian complains: "Trying to model so many electrons oscillating inside the gold just cannot be done with existing theories." He has had to fuse classical and quantum views of the world to even predict the colour shifts seen in experiment.

The new insights from this work suggest ways to measure the world down to the scale of single atoms and molecules, and strategies to make useful tiny devices.

More information: The paper 'Capturing the Quantum Regime in Tunneling Plasmonics' will be published in the 07 November edition of *Nature*. doi:10.1038/nature11653

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