dicted by theory, and many researchers have inferred it indirectly from measurements, this is the first time this type of two-state dynamics has been visualized, said the researchers.

Jean Njoroge

Nano Focus

At small scales, tug-of-war between electrons may lead to magnetism

Magnetism plays a central role in the development of many exciting new technologies including lasers, medical imaging devices, and computers. As such, there is a continued need to further understand and exploit this phenomenon. Now, R. Oszwaldowski and I. Zutic of the University at Buffalo and A. Petukhov of the South Dakota School of Mines and Technology have proposed that, at very small scales, it may be possible to create a quantum dot that is magnetic under surprising circumstances.

As reported in the April 29 issue of *Physical Review Letters* (DOI: 10.1103/PhysRevLett.106.177201), the researchers describe a theoretical scenario involving a quantum dot that contains two mobile electrons with opposite spins, along with manganese atoms fixed at precise locations within the quantum dot. The mobile electrons act as "magnetic messengers," using their own spins to align the spins of nearby manganese atoms.

Under these circumstances, conventional thinking would predict that each electron would exert an equal (but of opposite sign) influence over the spins of the manganese atoms such that neither is able to "win." However, the researchers show that the quantum dot's two mobile electrons actually influence the manganese spins to different degrees.

This occurs because while one mobile electron prefers to stay in the middle of the quantum dot, the other prefers to locate further toward its perimeter. As a result, manganese atoms in different parts of the quantum dot receive different messages about which way to align their spins.

In the "tug-of-war" that ensues, the mobile electron that interacts more intensely with the manganese atoms aligns more spins, which causes the entire quantum dot to become magnetic.

This prediction, if proven, could "completely alter the basic notions that we have about magnetic interactions," Zutic said. Studying how magnetism works on a small scale is particularly important, Zutic said, because "we would like to pack more information into less space."

Mid-infrared single-mode waveguides may allow detecting Earth-like exoplanets that show biological activity

Nulling interferometry operating in the mid-infrared (IR) range is one of the techniques being considered for the search of Earth-like exoplanets that may show biological activity. At these wavelengths many life-marker gases present absorption bands, and at the same time, the overwhelming flux of the parent star can be minimized. However, single-mode waveguides need to be used in this approach since they allow high angular resolution while reducing the star flux by ~50 dB. This may allow high spatial resolution measurements of the weak signals from biological activity to be observed against the high background of the light from the star. With this objective in mind, C. Vigreux, E. Barthélémy, and A. Pradel from the Université Montpellier II, in collaboration with L. Bastard and J.-E. Broquin from Minatec-INPG (Grenoble), M. Barillot and S. Ménard from Thales Alenia Space (Cannes), and G. Parent from Nancy-Université, France, fabricated single-mode waveguides operating in the 10–20 μm range based on Te-Ge-Ga glasses.

As reported in the August 1 issue of *Optics Letters* (DOI: 10.1364/OL.36.002922; p. 2922), the researchers selected this family of glasses because they are transparent between 6 μm and 20 μm wavelengths, films of these materials can be produced by thermal evaporation, their refractive index can be tuned according to their chemical composition, they present good stability, and they do not involve highly toxic or very volatile elements. In particular, the researchers chose $Te_{75}Ge_{15}Ga_{10}$ as the substrate due to its thermal stability and its relatively low refractive index (3.3960 ± 0.0015 at 10.6 μm), and $Te^{82}Ge^{18}$ as the waveguide core layer, since it provides a refractive index difference with the substrate of $\Delta n = 4 \times 10^{-2}$ and allows design of an efficient aperture for the coupling optics of 1.

With these components, the researchers designed single-mode rib waveguides operating in the 10–20 μm range, that they fabricated by depositing the $Te_{82}Ge_{18}$ core layer on $Te_{75}Ge_{15}Ga_{10}$ polished glass disks using thermal co-evaporation. They then used standard UV photolithography to define the rib waveguides, and transferred the pattern to the core layer by reactive ion etching under an atmosphere of a mixture of CHF_3, O_2, and Ar to achieve a depth of 9 μm. Finally, they polished the input and output facets to obtain the waveguide.

The researchers reported that the overall transmission of these waveguides varies between 15% and 35% for a 1-cm-long device, after correcting from coupling and Fresnel losses, a value they considered very promising to prove the potential of the technology developed. In the future, the research team plans to use these waveguides as a wavefront filter on a nulling interferometer.

Joan J. Carvajal

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