Calculation Indicates Fractional Quantum Decay is Possible for PbSe Quantum Dots in Inverse-Opal Photonic Crystals

Erwin Schrödinger's famous *gedanken* experiment involving a cat whose fate is determined by whether or not an atom has radioactively decayed was an early illustration of the oddities of quantum mechanics. In his scenario, the probability of the atom not decaying—and thus of the cat surviving—decreases exponentially with time. However, recent advances in the field of photonic crystals have led a number of researchers to investigate the circumstances under which the time-dependence of spontaneous-emission decay in quantum systems can be modified or even eliminated.

P. Kristensen at the Technical University of Denmark, A.F. Koenderink at the FOM Institute for Atomic and Molecular Physics in Amsterdam, and their colleagues have developed a measure of so-called "fractional decay," in which a system never fully decays to its ground state and have theoretically analyzed a realistic physical system in which such an effect should be observed. They report their results in the July issue of *Optics Letters* (DOI: 10.1364/OL.33.001557; p. 1557).

Spontaneous electronic decay in quantum systems is driven by interaction with the vacuum state of the electromagnetic modes to which the system is coupled. For free space and most materials, this coupling is weak, and the structure of these modes is relatively simple, leading to an exponential time dependence of the decay probability. Recently, several groups have noted that there is a regime in which quantum systems interacting coherently with a highly structured electromagnetic mode spectrum, such as that of a photonic crystal, will not fully decay but instead remain in a superposition of ground and excited states. This "fractional decay" has not yet been observed, and previous theoretical analyses have been very general.

The Danish/Dutch group analyzed a specific physical system to determine the parameters under which fractional decay can be expected to occur. In pursuit of this goal, they developed a measure of the extent to which a system undergoes fractional, rather than exponential, decay. Their model system consists of colloidal PbSe quantum dots (QDs) emitting at $\omega_{PbSe} \approx 1.3 \times 10^{15}$ Hz, placed at the *H*–symmetry point in the Wigner–Seitz cell of a closed packed Si inverse-opal photonic crystal whose band edge is slightly detuned from ω_{PbSe}. Beginning with a calculation of the local optical density of states in the photonic crystal, the group analyzed the decay dynamics of the QDs for different amounts of optical loss (absorption) from the Si. While exponential decay dominates for moderate levels of loss, at small but physically realistic loss levels ($\alpha \leq 3 \times 10^{-4}$ cm^{-1}), an appreciable fractional decay effect emerges from the analysis. In the complete absence of loss, the fractional decay effect in the model is strong, and the QD system ultimately settles into a superposition of ground and excited states.

Given these results, it appears reasonable to hope that fractional decay may soon be experimentally observed, marking a significant step forward in ongoing efforts to engineer the behavior of quantum systems.

COLIN MCCORMICK

Modern Technology Unravels Mystery of Ancient Hessian Crucible Manufacturing Process

During the transition from the late Middle Ages to the Renaissance, advances toward higher temperature processes in alchemy, metallurgy, jewelry making, and other areas led to a rise in demand for high-quality ceramic crucibles. After the 12th century, crucible manufacturers from the Hesse region in Germany developed a technique to mass-produce these ceramic vessels with high toughness, refractoriness, and thermal shock resistance. Potters from other European regions unsuccessfully tried to reproduce these high-quality crucibles to such an extent that the quality of the crucibles was dubbed "a mystery."

Centuries later, M. Martinón-Torres of the Institute of Archeology, University College London and his colleagues, along with I.C. Freestone of the School of History and Archeology at Cardiff University decided to apply modern materials-characterization techniques to clarify this mystery. The researchers conducted testing on Hessian and non-Hessian crucibles from 10 different archeological sites.

As reported in the June issue of *The Journal of the American Ceramic Society* (DOI: 10.0000/j.1551-2916.2008.02383.x; p. 2071), the researchers analyzed cross sections of used and unused crucibles by using optical microscopy, scanning electron microscopy, energy dispersive spectroscopy, and x-ray diffraction.

Results revealed a very uniform composition among all specimens analyzed, with 0.4% as the highest standard deviation corresponding to the alumina mean value. Kaolinitic clay with 36.9% alumina composed the ceramic matrix, containing fewer than 5 vol% of impurities. This is evidence of the standardization level reached by this manufacturing process.

Another interesting finding was the presence of abundant quartz sand grains, with a size distribution between 0.25 mm and 1 mm. These grains act as crack arrestors, increasing the fracture toughness resistance of these ceramic vessels. The interfaces of the quartz grains with the ceramic matrix show a level of dissolution, evidence of exposure to a temperature higher than 1200ºC during the firing process. This is consistent with the presence of primary mullite on the ceramic matrix, resulting from the conversion of kaolinite at that temperature level.

Ingenuity and use of local natural resources allowed Hessian crucible makers to determine the correct combination of clay, quartz sand, and firing temperature for the formation of synthetic mullite to produce the earliest examples of such refractory material in Europe, several centuries before this crystal phase was identified.

Fundamental characterization of these ceramic crucibles using electron microscopy and x-ray diffraction techniques provided the researchers with evidence on the resulting phases of each component, and offered enough information to define a range of temperatures and raw material mix conditions and compositions that composed the main recipe for manufacturing these ancient crucibles.

SIARI SOSA

Silsesquioxane Nanoparticle Doping Induces Vertical Alignment in Guest-Host LCDs Without Conventional Alignment Layers

Guest-host liquid crystal displays (GH-LCDs) have desirable features, including high brightness and polarizer-free operation, which have given rise to their popularity in recent years. Typical GH-LCDs require a homeotropic cell with vertical alignment layers to initially align host liquid crystals (LCs) and guest dye molecules perpendicular to the substrate for normally white mode operation.

The industry-adopted method for producing homeotropic LCDs utilizes polyimide alignment layers, which require a high post-curing temperature, precluding the use of this technique for making flexible LCDs using plastic substrates with a low glass transition temperature (Tg). However, W. Teng and colleagues from National Tsing Hua University, Taiwan, along with S. Jeng and colleagues from Industrial Technology Research Institute, Taiwan, have developed a nanoparticle-induced vertical alignment (NIVA) technique to fabricate flexible plastic GH-LCDs without using conventional alignment layers.