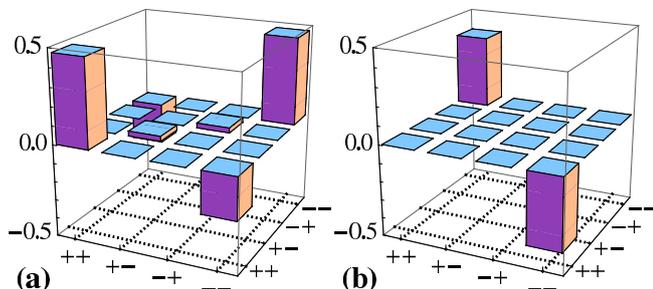


Highlights from the previous volumes

Emergence of entanglement out of a noisy environment: The case of microcavity polaritons

The concept of entanglement has played a crucial role in the development of quantum physics. It has gained renewed interest in quantum information/computation, as a precious resource enabling to perform tasks that are either impossible or very inefficient in the classical realm. Scalable solid-state devices will make use of local electronic states to store quantum correlations. Polaritons, as hybrid states of electronic excitations and light, are the most promising solution for generation and control of quantum correlations over long range. In order to address quantum coherence properties and entanglement in solid-state quantum systems, the preferred experimental situation is the few-particle regime. Then, however, noise represents a fundamental limitation, as it tends to lower the degree of non-classical correlations or even completely wash it out.

Here we show theoretically that polariton pairs with a high degree of polarization entanglement can be produced through parametric scattering. It can emerge in coincidence experiments, even at low excitation densities where the dynamics is dominated by incoherent photoluminescence. We model the polariton parametric process, producing entanglement, and the time evolution of the competing decoherence processes, using a microscopic time-dependent theory. We show how a tomographic reconstruction, based on two-times correlation functions, can provide a quantitative assessment of the level of entanglement produced under realistic experimental conditions. Our study provides a suggestive perspective towards hybrid all-optical quantum devices where quantum information can be efficiently generated and controlled within the same structure. This result puts forward the robustness of pair correlations in solid-state devices, even when noise dominates one-body correlations.



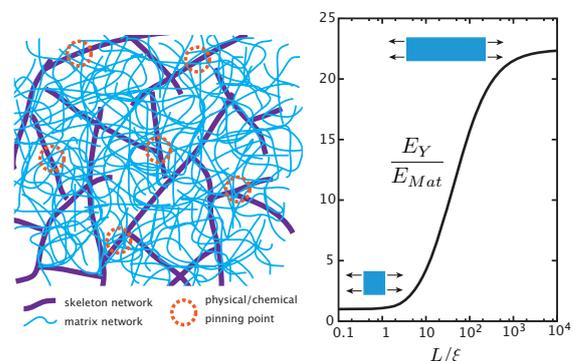
Example of tomographic reconstruction for the real (a) and imaginary (b) part of the density matrix from which we quantify the degree of entanglement of the mixed generated state for different experimental cases.

Original article by PORTOLAN S. *et al.*
[EPL, 88 \(2009\) 20003](#)

Nano-scale composite matter: Elasticity is size-dependent

Composite materials in industrial products are produced by dispersing rigid particles or fibers (reinforcement phase) into a uniform solid (matrix phase). Elastic properties of the entire system are given by the spatial average of elastic behaviors of the two phases. The existence of a sharp interface between the phases is the major promise for the averaging. There is another class of composite materials where two components are mixed on the molecular scale and the interface cannot be identified definitely. An example of this class is the cytoskeleton of eukaryotic cells, a composite meshwork of rigid and flexible biopolymers, which provides distinct mechanical properties to living cells. This observation has been exploited in the design of synthetic materials; amongst them, a double-network gel and an isotropic interpenetrating stiff and flexible polymer network achieved much improved toughness.

In the recent paper, we developed a linear elasticity theory of such composite materials. In that model, a flexible polymer network constitutes a matrix phase and stiff filaments act as a skeleton (see the left panel of the figure). Such an internal structure, generic to composites, yields an intrinsic length scale ξ by the competition between collective elastic deformations of both the components and their mutual displacements, leading to length-dependent elastic constants (see the right panel of the figure). For $L < \xi$, where L is the system size, Young's modulus is nearly identical to that of the matrix and is small, but for $L \gg \xi$, it gets much larger due to the stiff backbone as the composite behaves as a single material. This unique size-dependent elasticity is expected to be a fundamental property of those asymmetric composites, independent of their detailed architectures.

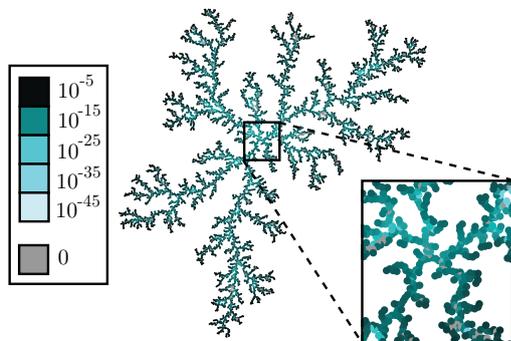


Left: microstructure of a binary network composite (cartoon). Right: size dependence of the composite's Young's modulus, E_Y , rescaled by the matrix modulus E_{Mat} , calculated from our model elastic free energy.

Original article by WADA H. and TANAKA Y.
[EPL, 87 \(2009\) 58001](#)

The harmonic measure of diffusion-limited aggregates including rare events

Geometric fractals are objects which “look the same” on many different scales and are of theoretical, experimental, and aesthetic interest. A simple stochastic surface growth model which results in a fractal pattern is diffusion-limited aggregation (DLA). The DLA growth process is performed by releasing diffusing disks far from the cluster (aggregate) until the disk touches the cluster and sticks, at which time a new particle is released. This process causes the growth of finger-like dendrites which are unstable and split into several fingers as the growth continues (see figure). The DLA structure has been found in systems as diverse as electrodeposition and aggressive tumor growth. The probability distribution of discs sticking to cluster-discs determines the growth process. This probability distribution is called the harmonic measure (see figure), and is multifractal, *i.e.*, it contains an infinite number of fractal scalings. Although it is of considerable interest, there is no theoretical prediction for the multifractal spectra of the harmonic measure for DLA. Previous numerical simulations have yielded limited success in determining the spectra because complete characterization of the spectra requires probing the fjords between fingers with probabilities frequently smaller than 10^{-20} . We have developed a biased sampling technique that has allowed us to obtain the growth probability for all accessible discs on the cluster. This technique, which we call signposting, has allowed us to measure probabilities as small as 10^{-80} . We have used this technique to verify some conjectures about the form of the multifractal $f(\alpha)$ spectra, specifically a maximum $f(\alpha)$ value for which the function is defined. In analogy to thermodynamics, this is called a phase transition. We obtained spectra for many different sizes of clusters and were able to extrapolate to determine the $f(\alpha)$ spectra for infinitely large clusters. The harmonic measure of other fractal objects has recently been determined using conformal field theory and Schramm-Loewner evolution, and the $f(\alpha)$ spectra that we determined can be compared against any future theoretical results.

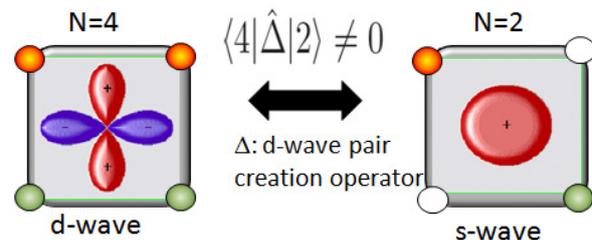


The harmonic measure of a DLA cluster with 10^4 disks, lighter colors indicate smaller measure.

Original article by ADAMS D. A. *et al.*
[EPL, 87 \(2009\) 20001](#)

Controlled preparation and detection of d-wave superfluidity in two-dimensional optical superlattices

While the exact pairing mechanism in cuprates and similar materials is still not understood, it is believed that the basic physics is contained in the simple 2D Hubbard model, in which fermionic particles move on a lattice and repel each other when they occupy the same lattice site. For the Hubbard model, d -wave pairing is expected to occur from an effective attraction caused by the exchange of spin fluctuations. Nevertheless, whether this pairing can give rise to long-range order and superconductivity is an open question. Here we propose an experimental scheme in which recently demonstrated methods for realizing optical lattices and superlattices are combined to create and to detect, in a controlled way, an ultracold-atom d -wave superfluid. Our scheme starts from arrays of isolated plaquettes which incorporate the required d -wave correlations on a short length scale. By tuning the parameters of the potentials, these plaquettes can be coupled to achieve long-range d -wave superfluid correlations, finally arriving at the generic Hubbard model.



A plaquette is the minimum system that exhibits d -wave symmetry. When loaded with four fermions the ground state is d -wave symmetric while when loaded with 2 the ground state exhibits s -wave symmetry. Consequently, the two states have a non-zero matrix element with the d -wave pair creation operator. Here we propose to load an array of plaquettes with cold fermionic atoms and use this set-up as the starting point to engineer, in a controllable way, a d -wave superfluid by coupling the plaquettes.

Original article by REY A. M. *et al.*
[EPL, 87 \(2009\) 60001](#)