

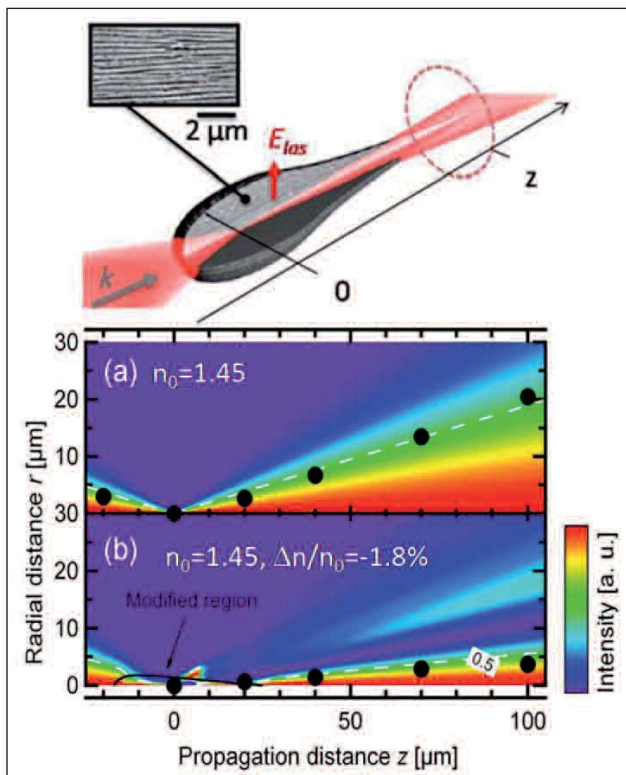
Highlights from europeans journals

OPTICS

Laser nanostructuring to create microlenses in glass

Direct femtosecond (fs) laser writing allows fabricating three-dimensional passive optical devices. However, an important fundamental question is: "what is the maximum refractive index change that can be induced without increasing the scattering or absorption of light?" The answer to this question will determine the range of applications.

In this paper, the authors have succeeded in achieving experimentally a refractive-index reduction of about 2% inside fused quartz. This is the largest refractive-index change so far created in SiO₂. Their work relies on beautifully ordered planar nanocracks that form spontaneously inside silica under repeated fs illumination.



▲ Probing the properties of the laser-written microlenses: The black circles show the measurement of the size (HWHM) of a probe beam as a function of the distance inside fresh (a) and written a-SiO₂ (b). The intensity colour scale image represents calculated intensity beam radial profiles (each normalized to I_{max}) for a refractive index change set at 1.424 (1.8% change from bulk).

By focusing 800 nm, 130 fs pulses with a peak energy of a few hundred nanojoules 75 μm beneath the surface of fused quartz slabs they form a periodic array of nanocracks which assumes spontaneously the shape of a biconvex lens. Probing

how the microlens refracts or absorbs light as a function of pulse energy, they evaluate the refractive index associated with fs laser nanostructuring.

Similar lenses are formed in a variety of glasses using high-fluence fs laser pulses. The exceptionally large refractive change is created without increasing linear absorption or scattering. It is stable and opens a route to fabricating high index contrast integrated photonic devices. ■

■ T. Barillot, D. Grojo, M. Gertsvolf, S. Lei, D.M. Rayner and P. B. Corkum,

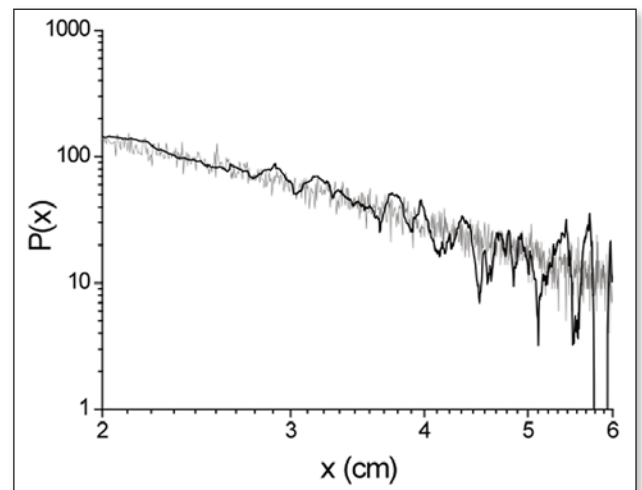
'High refractive index modification of SiO₂ created by femtosecond laser nanostructuring', *J. Phys. B: At. Mol. Opt. Phys.* **43**, 125401 (2010)

ATOMIC PHYSICS

Anomalous photon diffusion in atomic vapours

Examples of random walks abound in natural and physical systems. Their theoretical description usually involves Gaussian, or normal, statistics that essentially rely on finite first and second moments of the step distribution $P(x)$. However, examples of a less common class of random walk phenomena have recently received a lot of attention because their interpretation cannot be accomplished through normal statistics. These systems are governed by step distributions with a

▼ Distribution function of photons first-step size in a hot resonant Rb vapour. Black solid line: Experimental measurements. Grey line: Monte Carlo simulation. The best fit for both curves is a slow power-law decay $P(x) \sim x^{-\alpha}$, with $\alpha = 2.41 \pm 0.12$, characterizing a heavy-tail distribution and the consequent Levy-flight behaviour of the photons diffusion in this medium.



pronounced tail, slowly decaying as power laws, with diverging second and/or first moments. They can be described through Lévy statistics, in the frame of a General Central Limit Theorem. Their dynamics is characterized and dominated by rare, large steps, contrasting the normal diffusive behaviour, where the systematic exploration of space by the systems is characterized by a mean free path. Such a superdiffusive behaviour is called Lévy flights transport. Such behaviour has been found in a few biological, chemical, economic and physical systems.

The propagation of photons in scattering media represents a fundamental random walk process in physics. The experimental characterization of the step size distribution in these systems is, however, not straightforward, because the exiting photons have in general suffered multiple scattering processes. Having for the first time experimentally demonstrated that photons multiply scattered in a hot resonant vapour undergo Lévy superdiffusion, we use Monte Carlo simulations to further analyze the frequency redistribution that takes place at each scattering process and that is at the origin of the anomalous diffusion. ■

■ ■ ■ M. Chevrollier, N. Mercadier, W. Guerin and R. Kaiser, 'Anomalous photon diffusion in atomic vapours', *Eur. Phys. J. D* **58**, 161 (2010)

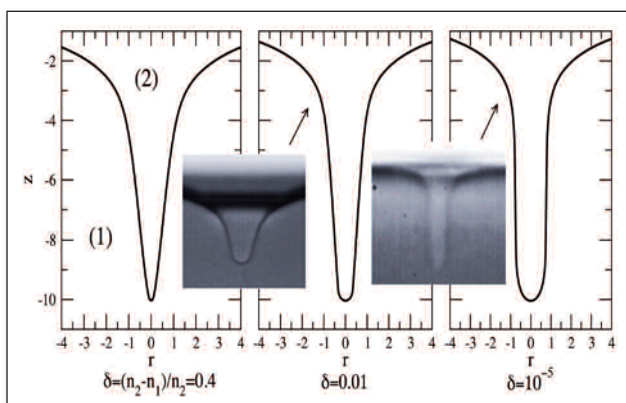
LIQUID PHYSICS

Optohydrodynamics of soft fluid interfaces

Are we able to control and actuate dynamically the shape of a fluid interface at a microscopic scale?

Among the various methods (dielectrophoresis, electrowetting, ...), the recent interest in optofluidics, *e.g.* methods based on the combination of optics and fluidics, promoted innovative approaches using the optical radiation pressure of laser beams to manipulate liquid interfaces.

▼ Equilibrium profiles of a soft liquid-liquid interface bended by a Gaussian continuous laser wave propagating from liquid (1) to liquid (2). Numerical and corresponding experimental profiles are shown for different refractive index contrasts $\delta = (n_2 - n_1)/n_2$



Since flows are optically driven, we call this emerging field optohydrodynamics. Beyond exciting academic insights, optohydrodynamics is involved in many interesting applications ranging from interface rheology to adaptive optics or surface relief micropatterning.

We present here an example of optohydrodynamic actuation based on experimental and predictive numerical results (using the Boundary Element Method), which show that the bending of a fluid-fluid interface strongly depends on the refractive index contrast between the two fluids. The characteristic time required to reach equilibrium increases when decreasing this contrast while equilibrium shapes of the deformation switch from a needle-like to a nearly-cylindrical finger. The physical feature at the origin of these behaviours lies in the nonlinear dependence of the optical radiation pressure on the local incidence angle. The viscosity ratio between the two fluids also affects the dynamics of large scale deformations. This investigation illustrates one of the simplest manifestations of optohydrodynamics and provides a frame to anticipate further developments of contactless interface micromanipulation by lasers. ■

■ ■ ■ H. Chraïbi, D. Lasseux, R. Wunenburger, E. Arquis and J-P. Delville, 'Optohydrodynamics of soft fluid interfaces: Optical and viscous nonlinear effects', *Eur. Phys. J. E* **32**, 43 (2010)

PARTICLE PHYSICS

Neutrino mean free paths in spin-polarized neutron Fermi liquids

The study of the behaviour of hadronic matter at high density and low temperature allows to have a deeper understanding of fermionic systems known as Fermi liquids using the theory first developed by Landau in the 1950's. The inclusion of an additional non-zero magnetic field, B , allows further testing properties of possibly magnetized matter. Due to the tiny value of the neutron magnetic moment $\mu_n = -1.9130427 \times 3.1524512326(45) \cdot 10^{-18} \text{ MeV G}^{-1}$ in principle huge magnetic fields, like those created on earth in heavy-ion collisions or thought to exist in magnetars, where $\log B \text{ (G)} \approx 15$, are needed to get sizable magnetization.

In order to understand how neutrinos diffuse in a magnetized neutron medium like this the neutrino mean free paths (mfp) using the Hartree-Fock approximation with effective nuclear Skyrme and Gogny forces is calculated, with the inclusion of magnetic fields. It is shown that describing nuclear interaction with Skyrme forces and for magnetic field strengths larger than $\log B \text{ (G)} = 17$, the neutrino mean free paths stay almost unchanged at intermediate densities but they largely increase at high densities when they are compared to the $B=0$ case. ■ ■ ■