Controlling Atomic Line Shapes

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Science **340**, 694 (2013);
DOI: 10.1126/science.1238396

Science (print ISSN 0036-8075; online ISSN 1095-9203) is published weekly, except the last week in December, by the American Association for the Advancement of Science, 1200 New York Avenue NW, Washington, DC 20005.

ments of bubbles, followed by liquid drainage through the films and Plateau borders, and finally film rupture caused by thinning. This last event throws the system far out of equilibrium, so that we may return to the first phase, and so on.

More approximate or empirical descriptions of this motion in foams near equilibrium have been successful in analyzing many important practical scenarios such as arise in chemical engineering (*5*). For example, consider the case of local fluid flow when bubbles are rearranged by an imposed shear. In the Plateau foam, these events are considered to be instantaneous and punctuate any slow (i.e., quasistatic) evolution of a structure. In reality, these events occur on a finite time scale that is determined by dissipation associated with fluid viscosity. Time scales lie at the heart of the mysteries of foam rheology (the description of its movement): Foam belongs in the category of a complex fluid.

The new methodology should soon offer fresh insights. Still, there are many real-world cases that cannot be described by the present model. It is formulated for "dry" foams containing little liquid, as is the case of large bubbles in equilibrium under gravity. Far from equilibrium, for example, in the churning foam of a washing machine, we encounter wet foams that do not get a chance to drain.

Also, a foam out of equilibrium is subject to subtle dynamic effects associated with its surfactant-covered surfaces. Surface energy depends on surfactant surface concentration, which may vary spatially or temporally, and is coupled to bulk concentration. The term "Marangoni effect" is often applied to the phenomena that arise from this dependence, of which the most important is the very existence of the foam in a reasonably stable state (but it may be more familiar as the "tears of wine" effect for a mixed water-alcohol solvent). Surfactant-covered surfaces have a complex rheology of their own, contributing obscurely to that of the foam as a whole and also influencing the internal hydrodynamics of drainage.

Despite the eminent precedents and the help (as well as the criticism) of physical chemists, physicists have so far failed to grapple effectively with this complex of complications at the film surface. It has proved very difficult to formulate surface effects in a reliable and general way, but this impasse has somehow to be confronted if the new dynamic methodologies are to be fully realistic. However, this new class of numerical modelers has laid foundations for a fresh start. These efforts arrive just in time to help confront the mass of new data soon to be provided by x-ray tomography. It can let us look inside foams and can even be time-resolved so that the dynamics of local structural changes can be revealed.

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10.1126/science.1238247

PHYSICS

Controlling Atomic Line Shapes

Intense infrared lasers can be used to control the spectral line shapes of atoms, with implications for spectroscopy and quantum dynamical processes.

C. D. Lin and Wei-Chun Chu

The spectroscopy of light absorption is an essential tool for uncovering the microscopic structure of a material. The observed spectral line positions reveal the energy levels of the excited quantum states, whereas the line shapes are determined by how the material relaxes after light is absorbed. In the optical frequency regime, the absorption profile has a symmetric shape. By coupling the material to an intense optical laser, however, the absorption can be controlled, leading to many interesting phenomena such as electromagnetically induced transparency (EIT) (*1*), slow and stopped light (*2*), and others. Extending such manipulations to extreme ultraviolet (XUV) and soft x-ray frequencies has presented a challenge. With the advent of intense ultrafast few-femtosecond infrared lasers in recent years, as reported on page 716 of this issue, Ott *et al*. (*3*) demonstrate that such manipulations are now possible.

In the XUV region, the absorption line shape is described by the asymmetric Fano profile (*4*). The asymmetry results from the quantum interference of two ionization pathways—one by direct ionization, the other via excitation to an unstable bound state followed by autoionization. In their experiment, Ott *et al*. show that they can change the shape parameter q of a Fano resonance by adjusting the intensity of a coupling laser. This achievement owes much to their high-resolution spectrometers, which can trace accurate line profiles of Fano resonances. Because attosecond XUV pulses are used to excite the atom, the same setup will be able to control the dynamics of a many-electron wave packet, or specifically the reaction dynamics, on attosecond time scales.

Ott *et al*. co-propagated a broadband XUV attosecond pulse train and a few-cycle near-infrared (NIR) laser with a fixed time delay in a helium target. At a laser intensity of about 2 TW/cm^2, they found that the asymmetric Fano profiles of the doubly excited states turn into symmetric Lorentzian ones, and the symmetric profiles of the singly excited states, at much lower energies, turn into asymmetric ones. They attribute the change in line shapes to the additional phase acquired by the Fano resonances in the presence of the NIR laser. Thus, by tuning the laser intensity, the Fano profiles could be manipulated. Unfortunately, only the data at a fixed time delay were reported; thus, the dynamics of autoionization was left unexplored. The analysis also assumes that the laser field could only change the shape parameter q and that the line shape stays in the general form. This picture also omits the effect of ionization and coupling with other states by the intense laser field. Follow-up experiments will be designed to examine resonance profiles at different time delays and to analyze the data with possible deviations from the Fano line shape.

The same type of experiments using broadband XUV and intense IR pulses with additional control tailored to specific systems should be within reach in the coming years. Nonlinear optics developed with infrared and visible lasers can be readily extended to experiments that use both XUV and IR frequencies (*5*). In a typical EIT system involving the ground state and two Fano resonances, 2s2p and 2s^2, in the case of helium atom (see the figure, panel A), a 200-attosecond pulse is used to populate 2s2p in the presence of a

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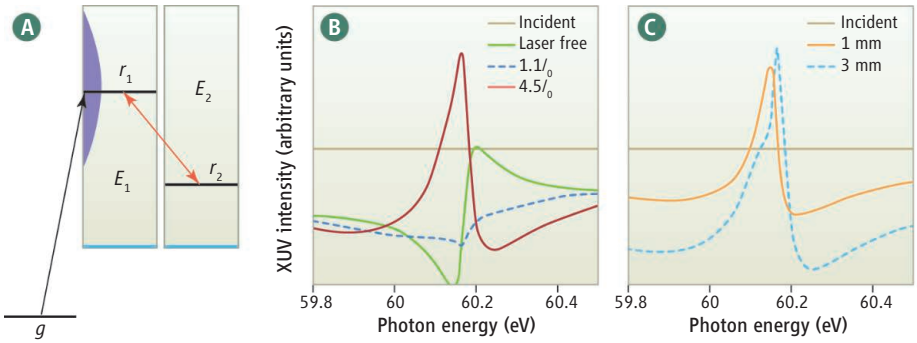

Changing shape. (**A**) Schematics of autoionizing states initiated by an attosecond pulse and coupled by an ultrashort intense laser pulse. The attosecond pulse pumps electrons from the ground state g to the resonance state r_1 and the background continuum E_1. An intense laser of a few femtoseconds couples r_1 to r_2, which is embedded in the background E_2. The decay lifetimes of both resonances are long relative to the pulse durations. The purple curve indicates that the bandwidth of the attosecond pulse covers the whole resonance line shape near r_1. (**B**) Light transmission spectra of a 200-attosecond pulse near the 2s2p resonance through a 2-mm helium gas sample at different coupling laser intensities. In the laser-free condition, the original Fano line shape is detected with a positive q. At the peak intensity of 1.1 I_0 (I_0 = 1 TW/cm^2), the resonance disappears where only the background remains. At the peak intensity of 4.5 I_0, the q parameter changes sign. The part of the spectrum higher than the incident light represents emission. (**C**) Same as (B) but for a fixed coupling laser intensity of 4.5 I_0 and for different propagation lengths. At 1 mm, the resonance part is enhanced while the background attenuates. This enhancement persists along the propagation while the background keeps dropping, as shown by the 3-mm curve. Thus, a broadband XUV pulse can be shaped when propagating through a laser-dressed helium gas medium.

few-femtosecond 540-nm laser with adjustable time delays and intensities (around 1 TW/cm^2). The laser resonantly couples the two autoionizing states in order to induce the Rabi oscillation between the two states. This coupling introduces a new pathway for the autoionization of 2s2p—via 2s2p → 2s^2 → 2s2p—in addition to the direct one. The interference between the two pathways is adjustable by the laser intensity and the time delay. The transmission of the XUV light near the 2s2p resonance is shown in the presence of the overlapping laser pulse (see the figure, panel B). At the lower laser intensity, the resulting flat transmission curve indicates that the absorption by the 2s2p state vanishes as it is transferred to 2s^2. At higher laser intensity, the originally positive q parameter becomes negative and a strong emission peak appears. This is an example of lasing without population inversion. If a helium gas medium is dressed by such a laser pulse, then the XUV would emerge from the medium with a narrow bandwidth of about 50 meV (see the figure, panel C), illustrating the shaping of XUV pulses via a laser-dressed Fano resonance.

For decades, it has been shown that the optical properties of a material medium can be dramatically modified by controlling the quantum states of an optical electron with lasers. The experiment of Ott *et al*. demonstrates that such control can now be extended to inner-shell electrons that are accessed via attosecond XUV or soft x-rays. This experiment also shows that the control is to be carried out by tuning the time delay between the XUV and the IR laser. As attosecond XUV and soft x-rays are becoming readily available (via high-order harmonic generation in a gas medium) in many ultrafast-laser laboratories, we can anticipate that coherent control of quantum states of inner-shell electrons—not only for atoms and molecules, but also for nanostructures and other materials—will become widely feasible soon. With such a high degree of control between light and matter emerging, what one can achieve in the future will be limited only by our imagination.

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10.1126/science.1238396

NEUROSCIENCE

Why Adults Need New Brain Cells

Neurogenesis and gliogenesis shape connectivity in the adult brain, influencing plasticity and repair.

Olaf Bergmann and Jonas Frisén

Few new cells are generated in the adult brain and spinal cord, and as such, nervous system plasticity was long thought to only involve modulating the contacts between preexisting "old" neurons. That view is changing. New neurons, as well as glial cells (specialized supporting cells), in the adult brain do indeed mediate certain types of plasticity, and the malfunction of such processes may cause neurological or psychiatric disease. On page 756 of this issue, Freund *et al*. (*1*) report a link between cognitive challenges, adult brain neurogenesis, and the development of individuality. This relationship supports the idea that a key function of adult neurogenesis is to shape neuronal connectivity in the brain according to individual needs.

Neurons are generated until shortly after the time of birth, with the exception of two small areas in the brain of most mammals—the olfactory bulb and hippocampus, where neurons are added by neural stem cells throughout life (*2*, *3*). Humans, however, appear unique in that there is no detectable olfactory bulb neurogenesis (*4*, *5*). Newborn neurons have special electrophysiological features for about 1 month after their generation, after which they become indistinguishable from the older neurons (*2*, *3*). The continuous production of new neurons may serve to maintain a pool of neurons with such special properties. Adult neurogenesis has a specific function in discriminating similar experiences, a process called pattern separation. Newborn hippocampal neurons help separate the perception of similar events for storage as distinct memories—for example, remembering not only that you parked your car in the parking lot, but also where in the parking lot (*2*, *6*). Pattern separation is critical for adapting to a complex environment.

How adult neurogenesis relates to brain plasticity in complex environments has been

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Published by AAAS