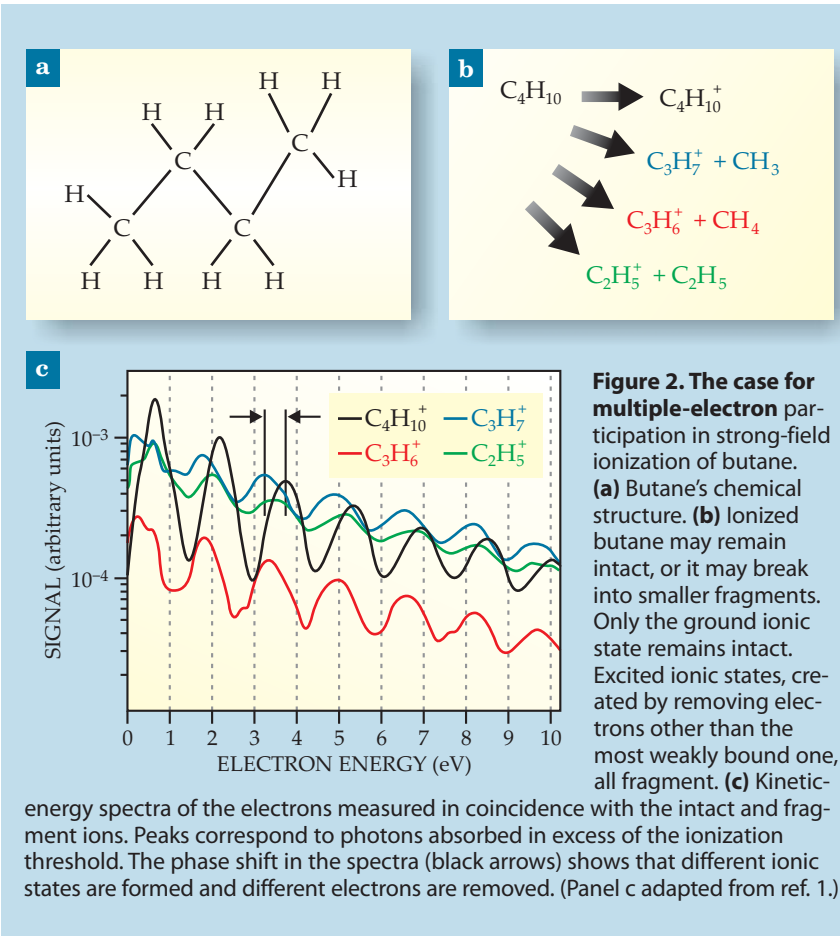

Figure 2. The case for multiple-electron participation in strong-field ionization of butane. **(a)** Butane's chemical structure. **(b)** Ionized butane may remain intact, or it may break into smaller fragments. Only the ground ionic state remains intact. Excited ionic states, created by removing electrons other than the most weakly bound one, all fragment. **(c)** Kinetic-energy spectra of the electrons measured in coincidence with the intact and fragment ions. Peaks correspond to photons absorbed in excess of the ionization threshold. The phase shift in the spectra (black arrows) shows that different ionic states are formed and different electrons are removed. (Panel c adapted from ref. 1.)

by the black arrows in figure 2c, is proof that it's not always the highest-energy electron being removed, and thus several electrons must be active in the subcycle ionization event. The $C_4H_{10}^+$ spectrum position is consistent with formation of the ground ionic state—as it must be, because that's the only state of $C_4H_{10}^+$ that doesn't fragment. The $C_3H_7^+$ and $C_3H_6^+$ spectra are in phase with each other, but they are shifted by 0.4 eV from the $C_4H_{10}^+$ spectrum, consistent with the energy of the first excited ionic state. The $C_2H_5^+$ spectrum is not in phase with any of the others, and its peaks are less pronounced, but it may result from formation of the third excited state.

Computational corroboration

To complement Stolow's experiment, Spanner and Patchkovskii studied the same ionizations computationally, without using any adjustable parameters. The method they developed bridges the gap in complexity between the single-active-electron methods traditionally used in attosecond research and the powerful tools for computing electronic stationary states in quantum chemistry. (See the article by Martin Head-Gordon and Emilio Artacho in PHYSICS TODAY, April 2008, page 58.) Because of their method's computational intensity, they were able to propagate the electron wavefunctions over just half a laser period. Still, their results—the relative yields of the ground and various excited ionized states—agree well with the experiment and confirm the involvement of multiple electrons in the subcycle SFI of polyatomic molecules.

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physics update

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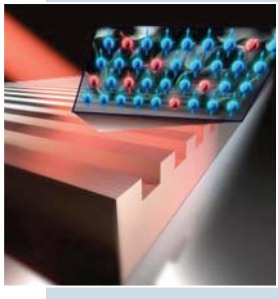

Fast times in ferromagnetic alloys. As magnetic materials for storage and other applications get pushed ever smaller and faster, a solid understanding of their behavior—including the correlated interactions among electrons, photons, and phonons—at those scales will be critical. X rays from synchrotron light sources are one way to obtain element-specific information at ultrafast time scales. Now, scientists from JILA and their colleagues from NIST and Germany have used tabletop techniques to probe magnetic dynamics on the fastest time scales; in particular, they studied the role of the exchange coupling between components in a ferromagnetic alloy. Working with magnetic diffraction gratings of permalloy ($Ni_{0.8}Fe_{0.2}$), as sketched here, the researchers first use a short, strong IR laser pulse to excite the electrons, which causes the alloy to demagnetize. Then, to trace the evolution of the magnetization, they illuminate the gratings with 10-femtosecond bursts of extreme UV light, obtained through high-harmonic generation (see PHYSICS TODAY, March 2005, page 39). At the wavelengths corresponding to the M-shell absorption edge of each element, the reflected light intensity depends on the degree of that element's magnetization, so the researchers can independently and simultaneously monitor the dynamic magnetic response of Fe and Ni, even when alloyed together. In a surprising finding, the Ni demagnetization lags that of Fe by a time on the order of 10–100 fs, depending on the spins' exchange-coupling strength (which can be varied by adding copper); after that delay, Fe and Ni demagnetize at the same rate. Such results, claim the researchers, will provide crucial information for addressing open questions in ultrafast magnetization dynamics. (S. Mathias et al., *Proc. Natl. Acad. Sci. USA* **109**, 4792, 2012.) —RJF