# Changing the rings: a key finding for magnetics design

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Researchers at the National Institute of Standards and Technology's Center for Nanoscale Science and Technology (CNST) have done the first theoretical determination of the dominant damping mechanism that settles down excited magnetic states—"ringing" in physics parlance—in some key metals.

Their results, published in the *Physical Review Letters*, point to more efficient methods to predict the dynamics of magnetic materials and to improve the design of key materials for magnetic devices.

The ability to control the dynamics of magnetic materials is critical to high-performance electronic devices such as magnetic field sensors and magnetic recording media. In a computer's magnetic storage—like a hard disk—a logical bit is represented by a group of atoms whose electron "spins" all are oriented in a particular direction, creating a minute magnetic field.

To change the bit from, say, a one to a zero, the drive's write head imposes a field in a different direction at that point, causing the electrons to become magnetically excited. Their magnetic poles begin precessing—the same motion seen in a child's spinning top when it's tilted to one side and begins rotating around a vertical axis. Damping is what siphons off this energy, allowing the electron spins to settle into a new orientation. For fast write speeds—magnetization reversals in a nanosecond or faster—a hard disk wants strong damping.

On the other hand, damping is associated with noise and loss of signal in the same drive's read heads—and other magnetic field sensors—so they need materials with very weak damping.

The design of improved magnetic devices, particularly at the nanoscale, requires a palette of materials with tailored damping rates, but unfortunately the damping mechanism is not well understood. Important damping mechanisms have not been identified, particularly for the so-called intrinsic damping seen in pure ferromagnetic materials, and no quantitative calculations of the damping rate have been done, so the search for improved materials must be largely by trial and error.

To address this, CNST researchers calculated the expected damping parameters for three commonly used ferromagnetic elements, iron, cobalt and nickel, based on proposed models that link precession damping in a complex fashion with the creation of electron-hole pairs in the metal that ultimately dissipate the magnetic excitation energy as vibration energy in the crystal structure.

The calculation is extremely complex, both because of the intrinsic difficulty of accounting for the mutual interactions of large numbers of electrons in a solid, and because the phenomenon is inherently complex, with at least two different and competing mechanisms. Damping rises with temperature in all three metals, for example, but in cobalt and nickel it also rises with decreasing temperature at low temperatures.

By comparing the calculated damping effects with experimental measurements, the team was able to identify the dominant mechanisms behind intrinsic damping in the three metals, which at room temperature and above is tied to electron energy transitions. The results, they say, point to materials design techniques that could be used to optimize damping in new magnetic alloys.

Citation: K. Gilmore, Y. U. Idzerda and M. D. Stiles. Identification of the dominant precession-damping mechanism in Fe, Co, and Ni by first-principles calculations. *Physical Review Letters* 99, 027204 (13 July 2007).

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