Viewpoint on "Optical measurement of damping in nanomagnet arrays using magnetoelastically driven resonances"

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The design and optimization of novel devices generally rely on the simultaneous fine tuning of materials properties and the precise realization of their purpose defined geometric layouts, extending from macroscopic sizes all the way down to the atomic scale. Related fabrication processes then generate function specific shapes and material interconnects, which enable the full utilization of physical effects that are defined either by the individual materials that are being used or their interaction and collective behaviour. In this regard, it is crucially important to identify and clearly separate effects that are generated by an actually realized device geometry from effects that are caused by materials modifications due to shaping effects, may they be intended or unintended, and may they be caused by an actual change in local materials properties or related to novel collective physical effects of specific arrangements. This distinction is becoming especially relevant in the field of nanotechnology, given that materials properties control is becoming increasingly challenging on nm length-scales, and can even be impacted by quantum mechanical interface interference effects.

Materials property control down to the nm-scale is even more relevant, if one considers that most device designs are based on a local materials property assumption, in which materials and their properties can be independently controlled from their shape and their integration into an overall component layout. While this assumption is well justified in many cases, it is most frequently very difficult to verify, because knowledge of its appropriateness requires materials characterization methodologies that are capable of measuring materials properties accurately under complex design conditions. So, it is a very important issue in the field of applied physics to identify, devise and study materials characterization techniques that are either independent from materials geometries or instead allow materials characterization in a specific geometry that is relevant for applications. In their letter, Yahagi et al. [1] demonstrate such a novel characterization methodology that succeeds in taking full advantage of a specialized sample geometry, which is very closely related to likely end application designs. With their work, the authors manage to turn a perceived methodological weakness into an asset and in doing so, they have been able to produce a new magneto-optical measurement technique for the damping constant, a crucial and often elusive material parameter.

As Yahagi et al. discuss in their letter [1], and as previously demonstrated [2], the periodic structure of their sample leads to two excitation channels upon illumination with ultra short laser pulses: one related to the direct light induced excitation of the electron system and a second one connected to surface acoustic waves (SAWs) that are generated by the same ultra short laser pulse in such structures. Due to magneto-elastic coupling, these SAWs lead to a secondary magnetic excitation channel that is far longer lasting than the direct light coupling into the electronic system. This significant difference in the excitation time scales then allows for an easy experimental separation of the two excitation mechanisms, which enabled the authors to monitor SAWs induced magnetic excitations in isolation by means of magneto-optical measurements. The most surprising and in all likelihood most relevant part of this new study [1] is now that even though the SAWs excitation leads to a more complex dynamic behaviour overall, its amplitude follows a very simple magnetic field dependence. Furthermore, this field dependence is strongly connected to the damping coefficient of the material, and thus it allows for its robust determination, even in the presence of elaborate lateral nanostructures. Thus, the here described effect and associated detection methodology open a new magneto-optical observation window for the analysis of magnetic materials.

Given the fact that the authors utilize a magneto-optical measurement technique that allows for the characterization of materials and related physical phenomena, the work also adds nicely to the many relevant works in the field of magneto-optics that have recently taken advantage of the broad availability of ultrafast lasers. While magneto-optics has traditionally been most useful due to its ability to achieve lateral resolution [3] and its high sensitivity in ultrathin films [4], recent progress in ultrafast lasers has added the investigation of fast dynamics as a key asset, and many relevant works have utilized this capability [5]. The present work [1] is another example of the repertoire of feasible studies that can be done with modern experimental tools related to the fast dynamics of ferromagnets and especially in terms of characterizing magnetic materials [6]. Given the substantial instrumentation advances that were realized during the last years, it is very likely that numerous other utilizations of ultrafast magneto-optical methodologies will be developed in the future. This is even more obvious, if one considers that some aspects of magneto-optical experiments, such as the full light polarization information, are rarely taken advantage of in ultrafast experiments [7], whereas corresponding static ellipsometry methodologies are already well established and have been breaking new ground towards an ever more precise characterization of magnetic materials [8].

References:

[1] Yahagi et al., letter paper, upon which the viewpoint is focused
[2] A. Comin et al., Phys. Rev. Lett. **97** (2006) 217201; C. Giannetti et al., Phys. Rev. B **76** (2007) 125413
[3] Jeffrey McCord, J. Phys. D: Appl. Phys. **48** (2015) 333001
[4] A. Berger et al., J. Appl. Phys. **75** (1994) 5598
[5] A Kirilyuk et al., Rev. Mod. Phys. **82** (2010) 2731
[6] Mohammed Salah El Hadri et al., J. Phys. D: Appl. Phys. **50** (2017) 133002
[7] J. Wieczorek et al., Physical Review B **92** (2015) 174410
[8] J. A. Arregi et al., J. Phys. D: Appl. Phys. **48** (2015) 305002; J. A. Arregi et al., J. Phys. D: Appl. Phys. **50** (2017) 03LT01