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All-optical magnetic imaging with a single nitrogen vacancy defect in diamond

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Résumé :

Experimental methods allowing for the detection of single spins in the solid-state, which were initially developed for quantum information science, open new avenues for the design of highly sensitive quantum sensors. In that context, it was shown that the electronic spin of a single nitrogen-vacancy (NV) defect in diamond can be used as an atomic-sized magnetometer,providing an unprecedented combination of spatial resolution and magnetic sensitivity under ambient conditions[1]. This technique has recently emerged as a versatile tool that offers valuable information on technologically relevant magnetic materials[2].Static magnetic fields are commonly measured by recording the Zeeman-shift of the NV defect electronic spin sub levels though optical detection of the magnetic resonance (ODMR)[1].Such a measurement protocol becomes however highly challenging when magnetic fields larger thanâ¼5mT are applied perpendicular to the NV spin quantization axis. In this moderate-field regime, off-axis magnetic field components induce mixing of the electron spin sub-levels, leading to a drastic reduction in ODMR contrast so that quantitative magnetic field imaging can no longer be performed[3]. This situation is inevitably reached as soon as the NV sensor is brought in close proximity to a ferromagnet,i.e.when high spatial resolution is required. However, spin state mixing is also accompanied by an overall reduction of the NV defect photoluminescence(PL) intensity. Such a magnetic-field-induced PL quenching can be exploited to map regions of magnetic samples producing large stray fields with high spatial resolution[4,5].In this work, we perform magnetic imaging with a scanning-NV magnetometer operating in the photoluminescence (PL) quenching mode under ambient conditions. We employ a single NV defect located at the apex of a nanopillar in a diamond scanning-probe unit. Once integrated into an atomic force microscope (AFM), this device enables scanning of the NV sensor in close proximity to the sample[6]. All-optical magnetic field imaging is performed by monitoring the NV defect PL intensity while scanning the magnetic sample. Using this technique, we first report on magnetic imaging of skyrmions in exchange-biased multilayer stacks such as Pt/Co/IrMn. Skyrmions diameters in the range of 50 nm are observed at room temperature and zero magnetic field. Compared to magnetic force microscopy, the main advantage of scanning-NV magnetometry is here the absence of magnetic back-action on the sample which provides unambiguous field measurements. This is particularly important for the study of spin textures in ultrathin films, which are often highly sensitive to magnetic perturbations.

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