Access Highlights - Ad A. van Well

Observation of the Goos-Hänchen Shift with Neutrons

Victor-O. de Haan, Jeroen Plomp, M. Theo Rekveldt, Wicher H. Kraan, and Ad A. van Well, Department Radiation, Radionuclides & Reactors, Faculty of Applied Sciences, Delft University of Technology, Mekelweg 15, 2629 JB Delft, The Netherlands

Robert M. Dalgliesh and Sean Langridge, STFC, ISIS, Rutherford Appleton Laboratory, Chilton, Oxfordshire, OX11 0QX, United Kingdom

The Goos-Hänchen effect is a spatial shift along an interface resulting from an interference effect that occurs for total reflection. This phenomenon was suggested for light by Sir Isaac Newton, but it was not until 1947 that the effect was experimentally observed by Goos and Hänchen. We provide the first experimental determination of the Goos-Hänchen shift for a particle experiencing a potential barrier as required by quantum mechanics: namely, wave-particle duality. Here, the particle is a spin-polarized neutron reflecting from a film of magnetized material. The shift is different for the plus and minus state. We detect the effect through a rotation of the polarization of the neutron, using the new ISIS instrument OffSpec. Here, we demonstrate, through experiment and theory, that neutrons do exhibit the Goos-Hänchen effect and postulate that the associated time shift should also be observable.

The authors were involved in the development of OffSpec, partly sponsored through a FP6 project. This unique instrument combines all specifications needed, i.e. neutron reflectometer equipped with a sensitive spin-echo option, to perform these type of experiments. The experiments were made possible via the Access Programme of NMI3, FP7.

This work resulted in the first publication from the Second Target Station of ISIS (Phys. Rev. Lett. 104 (2010) 010401).

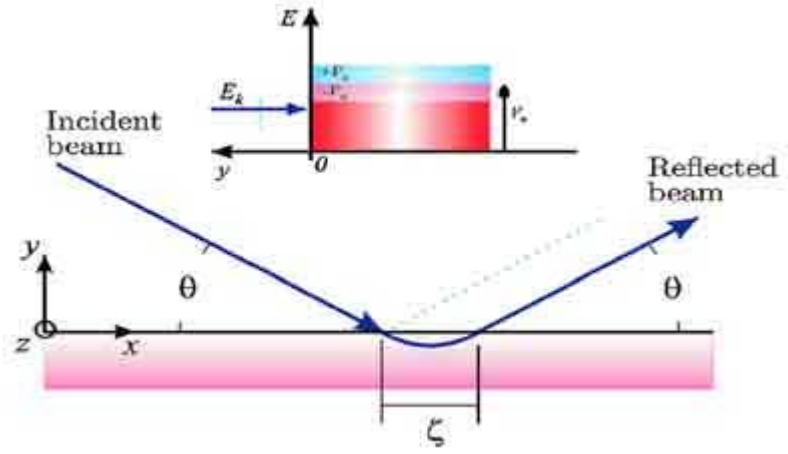

FIG. 1 Reflection of a plane wave with incident angle ϑ on a substrate boundary at y = 0 indicating the Goos-Hänchen shift. Inset: nuclear Vn and magnetic Vm, scattering potential and kinetic energy Ek associated with neutron velocity component perpendicular to the surface. Note that the shift ζ is different for the plus and minus state of the neutron.

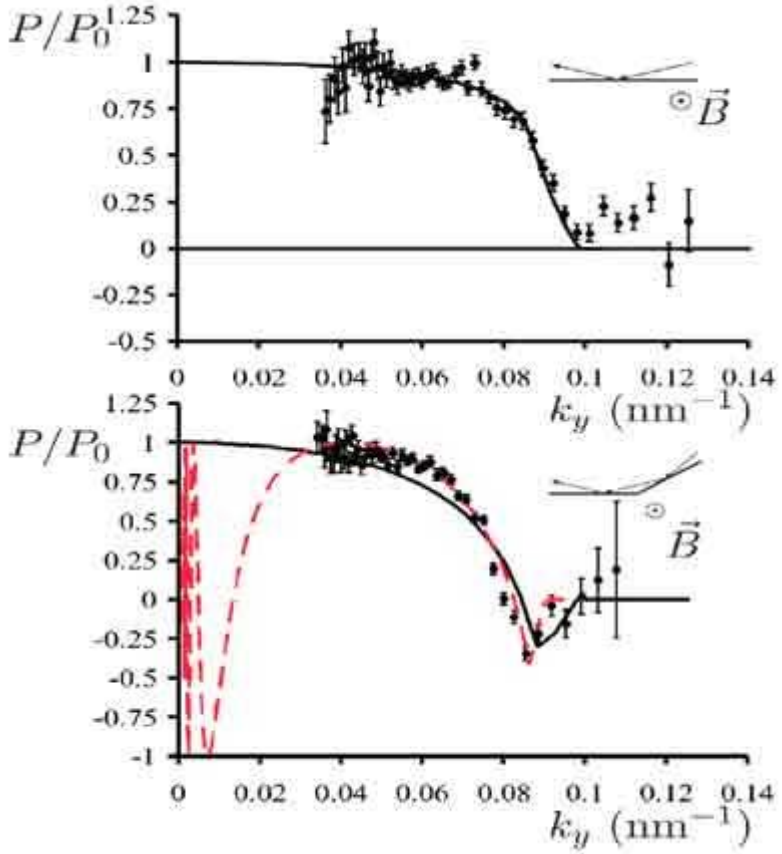

FIG. 2. Measured normalized polarization, P/P0 as function of perpendicular wave vector, ky representing the Larmor pseudo precession due to the Goos-Hänchen shift along the interface for a single (top) and double (bottom) reflection from a Permalloy thin film. The black lines represent the theoretical predictions. For the (red) dashed line in the lower graph a small correction in P0 is taken into account. These results correspond to ζ - = 2.4 and 20 μm for ky = 0.06 and 0.09 nm-1. For ζ + these values are 1.0 and 2.8 μm, respectively.