

Evaluating the intensity for the different modes gave a minimum of zero emission at  $\theta = 0$  for the  $TE_{01}$  and  $TM_{01}$  modes, and maxima in the range of  $30\text{--}50^\circ$ . On the other hand, the  $HE_{11}$  mode had a maximum emission at  $\theta = 0$ . The radius of the nanowire directly affected the intensity of the response of each mode, but much more for the  $TM_{01}$  and  $HE_{11}$  modes than for the  $TE_{01}$  mode. Experimentally, polarization measurements will determine the mode type and should be taken close to the top end of the nanowire to avoid interference with the radiation from the bottom end.

The researchers said that the ability to control the properties of laser emission from nanowires may open new possibilities in optoelectronics in conjunction with self-waveguiding and the possibility of nanowire array fabrication.

SIARI SOSA

### Simulation of Spin-MOSFET Predicts Strong Dependence of Spin Transport on Magnetic Configuration

Spin transistors utilizing two ferromagnetic layers as spin injector and spin analyzer, respectively, possess unique output characteristics that are controlled by the relative magnetization configuration of the ferromagnets as well as bias conditions. Together with the ability to utilize the latter as nonvolatile binary data, spin transistors could allow the fabrication of ultrahigh-density nonvolatile memory in integrated circuits (ICs) in which the memory cell consists of a single spin transistor as well as functional spin-transistor-gate-based nonvolatile reconfigurable logic. In order to attain high-performance "spintronic" integrated circuits, five requirements need to be fulfilled: (1) a large magnetocurrent ratio for nonvolatile memory and logic functions; (2) high transconductance for high-speed operation; (3) a high amplification capability (voltage, current, and/or power gains) to restore propagating signals between transistors; (4) a small power-delay product and small off current for low power dissipation; and (5) a simple device structure for a high degree of integration and high process yield.

Until now, proposed spin transistor designs have been unable to satisfy all of these requirements. The simultaneous achievement of high transconductance and amplification capability with a large magnetocurrent ratio has been difficult. S. Sugahara and M. Tanaka of the Department of Electrical Engineering at the University of Tokyo, however, have conducted a two-dimensional numerical

analysis of their spin-type metal oxide semiconductor field-effect transistor (MOSFET) design, fulfilling all five of these requirements and predicting high-amplification capability, a low power-delay product, a low off current, and extremely large magnetocurrent ratios.

As reported in the March 22 issue of *Applied Physics Letters*, the designed spin MOSFET consists of a MOS gate structure and half-metallic ferromagnet (HMF) contacts for the source and drain, similar to a Schottky source/drain MOSFET except for the HMF source/drain contacts, which are HMF/Si junctions without  $p$ - $n$  junctions. The device simulated used a channel length of 30 nm, a Si layer thickness of 10 nm, and an oxide layer thickness of 2–3 nm. The design can be applied not only to  $n$ - and  $p$ -channel devices, but also to accumulation- and inversion-type channel devices. Promising HMF materials include Heusler alloys and oxides such as  $\text{CrO}_2$  and  $\text{Fe}_2\text{O}_3$ . Of even more interest are half-metallic compounds exhibiting the zincblende crystal structure, such as CrAs, MnAs, and CrSb, since their predicted high Curie temperature and large bandgap of the insulating spin band are most useful as HMF source/drain materials, said the researchers.

Sugahara and Tanaka found that their simulations predict that the HMF source not only functions as a contact for blocking an off current, but also acts as a spin injector of up-spin electrons from the HMF source to the channel. The HMF drain selectively extracts the up-spin electrons from the channel when the magnetizations of the HMF source and drain are parallel. The scientists expect an extremely large magnetocurrent ratio due to the high spin-selectivity of the HMF source/drain when these spin-filter effects are combined. The output characteristics were calculated using the Tsu-Esaki formula with a two-dimensional transmission probability calculation and gave magnetocurrent ratios of  $>1000\%$  at  $<1.0$  V drain/source bias  $V_{\text{DS}}$  and even larger ratios at smaller  $V_{\text{DS}}$ . Other calculated device parameters such as transconductance were similar to those that have been obtained for MOSFETS with gate lengths of  $<100$  nm.

ALFRED A. ZINN

### Effects of Chirality on Goos-Hänchen Phase Shifts at Interfaces in Optical Media Explored

A light beam that is totally reflected at the interface between two different media always undergoes a phase change. Light waves with different incident wave vectors are subject to different magnitudes of this phase change. As a result of this inter-

ference among the plane-wave components with different incident wave vectors, the weight center of the reflected beam is displaced laterally with respect to the weight center of the incident beam, a phenomenon known as the Goos-Hänchen shift. This event includes both a phase shift that can either reinforce or oppose the incident wave vector and a lateral beam shift that is either in the same or opposite direction as the horizontal component of the energy flux of the incident beam. Recently, D.-K. Qing and G. Chen from the Department of Mechanical Engineering at the Massachusetts Institute of Technology investigated Goos-Hänchen shifts at the interfaces between optical media of different "handedness," or chirality.

The Goos-Hänchen shifts are well known for total reflection of light propagating in conventional dielectric materials. Such media are known as "right-handed" materials, since the wave vector, electric-field vector, and magnetic vector of light beams traveling in them form a right-handed system. However, in media that have negative permeability and negative permittivity, these vectors form a left-handed system, and thus the medium is called "left-handed." Although left-handed materials have attracted recent interest for new devices such as novel optical waveguides, superlenses, and microcavities, no previous study exists in which the light propagating through them was incident from the left-handed medium.

As reported in the April 15 issue of *Optics Letters*, Qing and Chen have determined mathematically the Goos-Hänchen phase changes and lateral beam shifts for beams propagating in both left-handed and right-handed media, reflected at interfaces between both same-handed and different-handed materials. This gives four possible situations. In a concise diagram, the researchers elucidate the differences between Goos-Hänchen shifts for each possible system. When the two materials are both of the same handedness (whether left- or right-handed), the Goos-Hänchen phase shift opposes the phase change resulting from propagation through the incident medium. This change is positive in right-handed systems and negative in left-handed ones. The Goos-Hänchen lateral shift between two same-handed systems is in the same direction as the horizontal component of the incident energy flux. Alternatively, when the two media are of opposite handedness, the Goos-Hänchen phase shift reinforces the phase variation of the incident beam, while the lateral shift is opposite the horizontal component of the incident energy flux. These observations are true for inter-