Frontside-Illuminated GaAs/AlGaAs Quantum Well Photodetector Yields 3 THz Peak Spectral Response and µA/cm² Dark Current

There have been increasing efforts in recent years to develop practical sources and detectors for the terahertz (THz) frequency range to take advantage of this largely unused spectral range for applications including detection of molecules for food inspection, homeland security, and astrophysics. Despite recent progress, large-format array detectors required for practical imaging applications are still unavailable.

M. Patrashin and I. Hosako at the National Institute of Information and Communications Technology, Japan, have made a significant step in that direction by developing an alternative device concept based on GaAs/AlGaAs quantum well (QW) structures and achieved effective intersubband absorption in wells with a suitable barrier layer composition. Their detector achieved a peak response close to the targeted 3 THz spectral band with a low-temperature dark current in the range of 1 µA/cm² because the latter was limited to thermally assisted tunneling through the barrier.

As described in the January 15 issue of *Optics Letters* (p. 168), the researchers based their quantum well photodetector design on 18-nm GaAs QWs and 80-nm AlGaAs barriers with a 2% Al concentration. The intersubband absorption was activated by doping the center of the well with Si, which populates the QW's ground subband. Three sets of samples with 100 µm, 50 µm, and 25 µm period gratings were grown by molecular beam epitaxy (MBE) on semi-insulating GaAs substrates and consisted of a 20-period multiple QW structure sandwiched between 0.4 µm top and 0.8 µm bottom contact layers. The scientists used standard microelectronic processing to develop single element square-shaped mesas of different sizes.

The reported test results are from 1×1 mm² photodetectors with a 50 µm period grating. The detectors showed stable operation between ±60 mV down to a temperature of 3 K and did not show any hysteresis in the current–voltage (*I–V*) curve indicating good contact properties even at cryogenic temperatures. Flattening of the current density versus temperature response at 1 µA/cm² at low temperature shows that resonance inter-well and impurity-assisted tunneling are suppressed by the 80-nm barriers. By comparing the *I–V* characteristics under different photon flux conditions, a responsivity of 13 mA/W was obtained at an electric bias of 40 mV and an operating temperature of 3 K. The researchers state that by decreasing the doping concentration in the contact layer, its transmission can be improved by up to 60%, which would directly enhance the responsivity of the device. Future simulations and experiments will be conducted to clarify the mechanisms underlying the observed spectral response of the grating coupler.

ALFRED A. ZINN

Nonequilibrium Flow in Dilute Sheared Brownian Suspensions Measured

Colloidal systems are ubiquitous in modern life, found within the body as well as in a variety of industrial and geological processes. Modeling the transport of suspended material, whether for pharmaceutical drug delivery or the transport of radioactive waste in ground water, is key to designing better systems. J.R. Brown and S.L. Codd of Montana State University, M. Nydén of Chalmers University of Technology, Sweden, and their colleagues have reported the results of noninvasive nuclear magnetic resonance (NMR) experiments on colloidal suspensions that suggest dilute, colloidal Brownian suspensions exhibit particle migration and irreversibility. Particle migration has previously been thought to only occur in noncolloidal suspensions. The researchers employed pulse gradient spin echo (PGSE) NMR to monitor the flow dynamics of oil-filled polymer-shell (core–shell) particles in water using spectral resolution.

The experiments, reported in the December 14 issue of *Physical Review Letters* (240602; DOI: 10.1103/PhysRevLett.99.240602), use PGSE to independently monitor the dynamics of both the core–shell oil particles and the water in which they are suspended by differentiating between water and oil protons. Exploring flow of a dilute suspension in a capillary, radius 500 µm, with this technique, the researchers measured a probability distribution of the axial velocities of the flowing particles. While the composite axial velocity of the oil and the water maps to standard laminar Poiseuille flow consistent with a Newtonian fluid, the axial velocity distribution of the oil particles is biased toward the higher velocities. Further experiments with shear flow through the capillary reveal that the axial diffusivity of the core–shell particles increases irreversibly at a rate consistent with hydrodynamic interactions as the dynamics of the suspension enter a nonequilibrium regime.

The researchers demonstrate that the dynamics governing flow of dilute particle suspensions are "dependent on the accumulated shear strain applied to the suspension." Models of these systems would do well to incorporate chaotic dynamics and nonequilibrium mechanics, the researchers said.

ARTHUR FELDMAN

Silver Nanoparticles Substantially Enhance Fluorescence of Chlorophyll

Surface plasmons in metal films have been shown to influence the optical response of emitters in close proximity. For example, metal-enhanced fluorescence (MEF) has been observed for hybrid systems composed of metals and stable, highly fluorescing emitters. Recently, however, S. Mackowski, C. Bräuchle, and T.H.P. Brotosudarmo together with co-researchers at Ludwig-Maximilian-University, Munich, and A.O. Govorov of Ohio University applied MEF to a weakly fluorescing, light-harvesting system—the peridinin-chlorophyll protein (PCP) from dinoflagellate *Amphidinium carterae*—and found up to an 18-fold increase in the chlorophyll's fluorescence.

As reported in the December 2007 issue of *Nano Letters* (DOI: 10.1021/nl072854o), the researchers deposited PCP complexes on silver-island films (SIFs). Atomic force microscopy showed that the SIFs, which were deposited on glass cover slips using a published protocol, had silver islands with diameters ranging over 70–140 nm with heights between 30–40 nm. The PCP complexes were biochemically reconstituted, diluted in 2% aqueous poly(vinyl alcohol) (PVA), and then spin-coated onto the SIF cover slips to a thickness of about 100 nm. Organized in two clusters, PCP contains two chlorophylls and eight peridinin pigments. The dominant absorption band in the blue-green spectral region (350–550 nm) is due to the peridinins, while the chlorophylls absorb at about 688 nm (Qy band) and 440 nm (Soret band). The plasmon resonance of the SIFs, with a maximum at 450 nm and a line width of 150 nm, matches well the PCP absorption, which the researchers said makes this system ideal for examining plasmonic interactions.

Steady-state fluorescence spectra of single PCP complexes and ensembles were obtained after exciting samples at 532 nm and 632 nm, that is, at the absorption wavelengths for peridinin absorption and the chlorophyll Qy band, respectively. At 532 nm, the chlorophylls are excited through energy transfer, and the fluorescence intensities of single PCP complexes on SIF are, on average, six