Optical Buffering Demonstrated in Quantum Well Semiconductor

To enable ultrahigh capacity laser communications in future networks, CONSRT is developing all-optical buffers, high-speed lasers, broadband optical amplifiers and memory devices to replace the speed-limiting optical-electrical-optical (OEO) switching system currently used in optic fiber communication.

To date, realization of an all-optical communication network has been stymied by the lack of a suitable optical buffer with which to delay and temporarily store optical signals while routing. An optical medium that can significantly slow down optical signals could effectively function as an optical memory. The memory storage time is adjusted by varying the group velocity reduction factor in the medium. Recently, CONSRT researchers have successfully demonstrated slow light in a semiconductor quantum well (QW) structure for the first time.

In our experiments, the optical buffering effect was achieved by slowing down the optical signals using an external control light source to vary the dispersion characteristic of the medium. The buffer medium was made of GaAs multiple quantum wells grown by molecular beam epitaxy. Population oscillations in QWs were induced by illuminating the sample with a pump beam and a tunable probe beam. The pump and probe laser beams create a coherent carrier population interference which slows down light. The phase delay and absorption of the probe beam were simultaneously measured to determine its group velocity in the irradiated QWs.

Results deduced from the dispersion experiments at low temperatures indicate that we have successfully reduced the group velocity of optical signal in a QW structure. The group velocity slow-down factor was found to increase with increasing pump intensity. A group velocity 100,000 times slower than light speed in vacuum was achieved. The transparency bandwidth window was also found to be as broad as 1~2 GHz.

Using a carbothermal reduction process at 900 degree Centigrade with a gold film as catalyst, ZnO nanowire FETs were successfully synthesized (see figure below). The intrinsic electronic properties such as carrier type, mobility and concentration were systematically studied in vacuum and a variety of ambient gases from 5- to-300 K. In air, these n-type nanowire transistors have among the highest mobility yet reported for ZnO FETs ($\mu_e = 13 \pm 5 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$), with carrier concentrations averaging $5.2 \pm 2.5 \times 10^{17}$ cm$^{-3}$ and on-off current ratios ranging from $10^3$ to $10^7$. Four probe measurements show that the resistivity of the Ti/Au-ZnO contacts is 0.002-0.02 $\Omega \cdot \text{cm}$. The performance characteristics of the nanowire transistors are intimately tied to the presence and nature of adsorbed surface species. In addition, we have also observed a dynamic gate effect that seems to involve mobile surface charges and causes hysteresis in the transconductance, among other effects.

Figure above is a simulation of 40 Gbps digital optical pulses traveling through a low-light semiconductor. As the signal group velocity is reduced, the pulses spread over a smaller space as if it were compressed. However the frequency content of the pulses remains unchanged and hence the information is undistorted. It merely travels slower. We have used a slow-down factor of 3 for ease of illustration.

This novel GHz bandwidth light-slowing technique will significantly enhance our ability to design all-optical buffer and storage in semiconductor materials, promising for ultrahigh throughput all-optical networks and other applications. We are currently working on new nanostructured semiconductor to produce broader bandwidth slow light at higher temperatures.

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ZnO Nanowire Transistor Synthesized and Characterized

CONSRT researchers at the University of California, Berkeley are developing novel nanowire synthesize and assembly techniques to produce ZnO nanowire field-effect transistors (FETs) for applications in tunable UV and IR injection lasers and light-weight solar cells, suitable for future usage in signal processing and communication in unmanned aerial vehicles (UAVs). A major step in this research is to reproducibly synthesize ZnO nanowire structures with extremely high mobility and low contact resistance for integration into complex nanoscale devices.

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Scanning electron microscopy image of a ZnO nanowire field effect transistor.

Laboratory experiments are currently focused on the fabrication of light emitting diodes (LEDs) using these ZnO and GaN nanowires as building blocks.

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