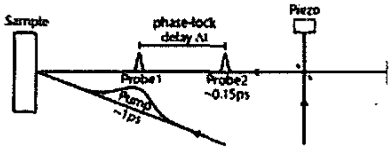
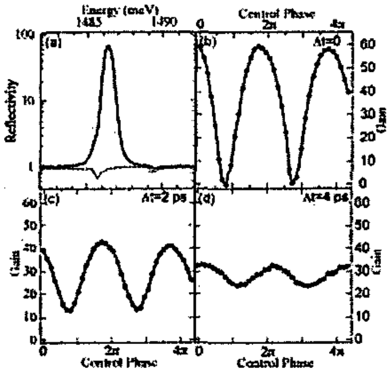
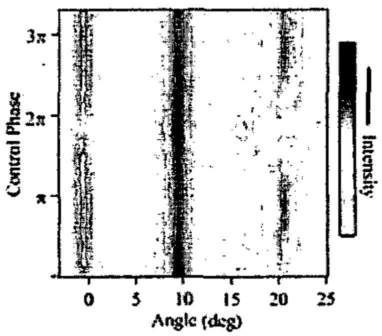


QThJ4 **Fig. 1.** Pump probe coherent control setup.



QThJ4 **Fig. 2.** Probe reflectivity for only the first probe pulse with (full line) and without (dotted) pump (a). Peak gain versus relative phase at 0 ps (b), 2 ps (c) and 4 ps (d).



QThJ4 **Fig. 3.** Angle resolved transmission versus relative phase at Δt = 0 ps (0 degree is perpendicular to the sample plane). Pump and probe transmission are attenuated by 10^4.

Our observations contribute to the understanding of quantum kinetics in high-quality microcavities, in particular the coherence of the involved excitations permits the development of ultrafast optoelectronic amplifiers and switches.

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QThJ5 Invited 3:30 pm

Solving the Puzzle of Supercontinuum Generation

Douglass Schumacher, Jennifer Tate, The Ohio State University

Supercontinuum generation (SCG) is the explosive increase in bandwidth suffered by an intense laser pulse propagating through a medium.[1] Although the details vary, it is a universal phenomenon observed in gasses, liquids, and solids using a wide range of pump pulse energies and widths. It arises due to the complex interplay of the Kerr effect, Raman scattering, ionization, and dispersion. Describing even qualitative features in the SCG spectrum generally requires treating the breakdown of the slowly varying envelope approximation and the interplay between the pulse's spatial and temporal evolution. Yet the effort to understand SCG is worthwhile, since there seems to be little limit to its application as a source of tunable short pulse radiation, in communications, in precision measurement, and even in clinical diagnostics.

There have been a number of sophisticated treatments of SCG recently that have greatly raised the standard for the quantitative treatment of this phenomenon.[2–4] We have introduced a novel measurement technique, the spectrally-resolved double pump, that allows us to settle a number of issues important to the understanding of SCG.[5] We excite SCG using a double-pulse generated by a Michelson interferometer and measure the spectrum as a function of delay and intensity. This approach allows us to explore SCG on a range of time scales and to study coherence. This is important because, for example, the relative contribution of self-phase modulation and Raman scattering depends on the time-scale. We describe a series of measurements on sapphire and fused silica, two popular media for SCG, that accurately and reproducibly measure these effects. For example, we have identified for the first time the resonances responsible for the Raman response of the media during SCG. This identification includes accurate determination of the resonance frequency, decay time, and cross-section. Although a wide number of resonances could in principle contribute, we observe that only a few actually do. We also present the results of a numerical treatment that includes all processes known to be important for our operating conditions. However, we stress that one of the main values of our experimental technique is that in many cases, it permits analysis by inspection without need for modeling and fitting.

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QThJ6 4:00 pm

Coherent Control of an Optically-Injected Ballistic Spin-polarized Current in Bulk GaAs

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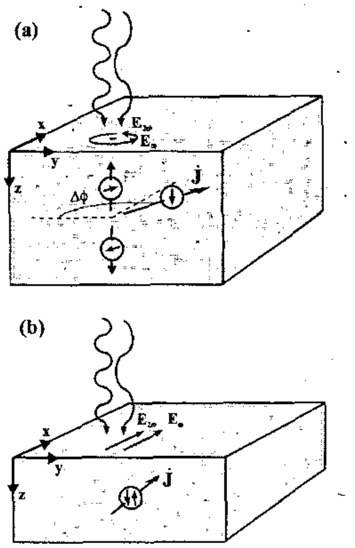
One of the major hurdles in the development of "spintronic" devices has been the problem of injecting spin-polarized currents into a semiconductor. It has been known since the 1970s that spin-polarized carrier *populations* can be optically injected into semiconductors using a single color, circularly polarized excitation beam. However, without an external bias, no current is generated. On the other hand, Haché et al.[1] have demonstrated that it is possible to optically inject a ballistic electrical current in an unbiased bulk semiconductor through the quantum interference control (QUIC) of single- and two-photon absorption. However, this electrical current was not spin-polarized. Here, we demonstrate that it is possible to optically inject a *spin-polarized* ballistic current in an unbiased semiconductor by a judicious choice of incident polarizations and to coherently control the direction of that current by adjusting the phase of the incident light, as recently predicted by Bhat and Sipe.[2]

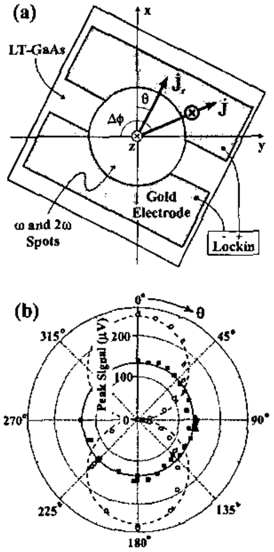
Figure 1a summarizes the predicted behavior of the QUIC ballistic currents when fundamental (ω) and second harmonic (2ω) beams have the same circular (σ^-) polarization.[2] As depicted, a net electrical current is expected in the x-y plane for light propagation along the z-axis. The direction of this transverse current is determined by the relative phase between the two incident beams, but the magnitude is independent of this phase difference. Consequently, as the phase difference is varied, the current is expected to rotate like a phasor in the x-y plane. Most importantly, this transverse current is expected to be spin polarized. By comparison, in the direction of propagation, there will be no net electrical current; however, two oppositely directed currents with equal magnitudes but opposite spins will be produced. The direction of the spin polarization will be determined and controlled by the phase between the second harmonic and fundamental beams. Since there is no accompanying electrical current, this longitudinal current is a pure spin current. Here, we confirm that the transverse current behaves as predicted in[2] and depicted in Fig. 1a, and the longitudinal currents shown in Fig. 1a are not investigated.

In our experiments, we inject the transverse spin current by focusing fundamental (1.55 μm) and second harmonic (0.775 μm) pulses (~180 fs pulse width) onto the space between the two elec-



QThJ6 Fig. 1. Schematic of electrical current generated when both ω and 2ω are (a) σ– polarized and (b) x polarized. Small arrows inside spheres show the direction of net spin-polarization.

trodes on the surface of a bulk, low-temperature-grown GaAs (LT-GaAs) sample. (A view of the sample looking along the propagation ($\hat{z}$) direction is shown schematically in Fig. 2a.) The two pulses propagate collinearly, and the phase difference between the two pulses is controlled by a scanning Michaelson interferometer. We then measure the component of the transverse current along an arbitrary direction by rotating the sample and collecting the charge produced by this current using conventional electrodes. All measurements are performed at room temperature.



QThJ6 Fig. 2. (a) Top view of the sample, LT-GaAs with evaporated gold electrodes on the top surface, showing the transverse current (jJ) predicted for ω and 2ω both σ– polarized. We monitor this current along an arbitrary direction by rotating the sample to an angle θ. (b) Measured peak voltage as a function of sample angle, θ. The solid squares (open circles) are taken with ω and 2ω both σ– (x) polarized.

According to,[2] the electrical current injection when both excitation pulses are $\hat{\sigma}$– polarized is expected to be:

$$\mathbf{j}^{I}_{\sigma-\sigma-} = j^{I}_{0}\,[\sin\Delta\phi\hat{\mathbf{x}} - \cos\Delta\phi\hat{\mathbf{y}}], \qquad (1)$$

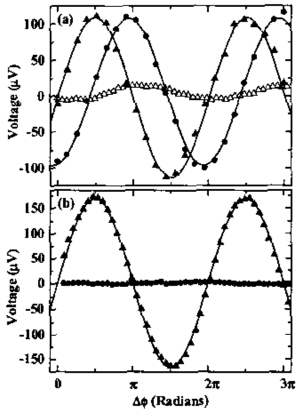
where $\Delta\phi \equiv 2\phi_\omega - \phi_{2\omega}$, and ϕ_ω ($\phi_{2\omega}$) is the phase of the ω (2ω) beam. The measured peak amplitude of this signal as a function of the sample orientation θ is shown in Fig. 2b, and is independent of θ as predicted. The dependence of this current on Δϕ at two fixed sample orientations is illustrated in Fig. 3a. As predicted, both x and y signals vary sinusoidally with Δϕ; the peak amplitudes are equal; and the two curves are out of phase by approximately 90°.

For comparison, we contrast this behavior with that observed when two pulses having the same linear polarization are used. In this case (summarized in Fig. 1b), the ballistic current is of the form:[1,2]

$$\mathbf{j}^{I}_{xx} = \sqrt{2}\,j^{I}_{0}\sin\Delta\phi\hat{\mathbf{x}}. \qquad (2)$$

This current is always in the direction of the incident polarization, and the magnitude is controlled by the phase difference, as confirmed by the data in Fig. 3b. The current measured with the sample at an angle θ should be proportional to cosθ; in agreement with the open circles in Fig. 2b. In addition, when ω and 2ω have opposite circular polarizations, the signal in Fig. 3a (open triangles) almost completely disappears, as predicted by.[2]

Together, Figs. 2 and 3 show that the magnitude of the QUIC current is independent of the phase difference between the fundamental and second harmonic beams, but the direction rotates periodically in the transverse plane with this phase difference. This data (together with additional data not shown) demonstrate that the interference between fundamental and second harmonic beams having the same circular polarization produces a net in-plane transverse current that has all of the salient features of the spin-polarized transverse current predicted in Ref. 2. This experiment is an important first step in the all-optical control of spin currents in semiconductors.



QThJ6 Fig. 3. Measurements of the electrical current along the x (triangles) and y (circles) directions showing relative amplitude and phase of these currents. (a) Solid triangles and circles: ω and 2ω both σ– polarized; Open triangles: ω beam σ–, 2ω beam σ+. (b) ω and 2ω both x polarized. Solid lines are sinusoidal fits to the data.

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QThK

4:45 pm–6:30 pm
Room: 201

Symposium on Quantum Information Science: Semi-Conductors

Atac Imamoglu, Univ. of California-Santa Barbara, USA, Presider

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QThK1 **Invited** **4:45 pm**

Exciton Rabioscillation: Coherently Manipulate Zero-dimensional Quantum States by Light

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Coherent control of a quantum mechanical system is an ultimate challenge. Rapidly growing maturity of nanofabrication technologies has made quantum two-level system in solids promising for such approaches. A variety of two-level systems as target of the coherent control has been proposed and examined. Quantum dot (QD) exciton is one such candidate. The exciton confined within mesoscopic dot serve as a series of atomic-like discrete density-of-states thereby the elastic as well as inelastic scattering events which are the primary causes of the phase decoherence are greatly suppressed leading to a long-lived coherence. The similarity between atoms and QDs together with mesoscopically enhanced oscillator strength therefore may offer a great opportunity of coherent manipulation of a well-defined single localized quantum system by optical field.

Optical Rabi oscillations are the most essential physics that coherent optical control of the quantum states relies on. Observation of the exciton population flopping thus can be a first step to the coherent control.[1,2] In this contribution, we report the Rabi oscillation of an isolated excitonic two-level system in a disk-shaped $In_XGa_{1-X}As$ quantum dot. Control of population and phase of single-dotexciton is demonstrated.

Quantum dots used in this study were disk-shaped InGaAs dots formed via unique strain-driven spontaneous reorganization of the 3.5