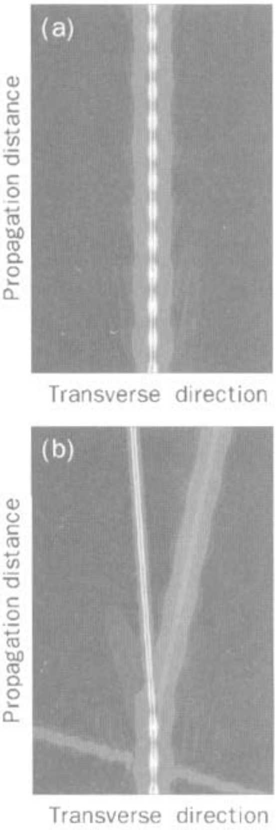

Snyder Figure 1. (a) A single soliton beam. (b) Beam splitting upon weak illumination.

Importantly, the phenomenon of beam splitting can be anticipated from simple physics. It is well known that self-guided beams of any non-Kerr medium can fuse when they collide and that the fused beam is generally periodic (see, *e.g.*, Ref. 3). We can reverse the process and thus split a periodic beam by an appropriate weak illumination. Our approach also predicts that for pure Kerr medium such a split is impossible in principle, since two Kerr solitons cannot fuse. Furthermore, because it is much easier to fuse two identical beams than nonidentical beams in non-Kerr media,[3] we would anticipate that it should be easier to split a periodic beam asymmetrically rather than in two symmetric beams. We confirm the later prediction as well, demonstrating that in many cases even a weak illumination of very simple shape (like a single probe beam) can split a soliton periodic beam asymmetrically as shown in Figure 1.

Finally, because colliding beams are predicted to fuse in any non-Kerr medium,[3] we anticipate the universal character of periodic beam splitting not only with respect to nonlinearity type, but also to the beam dimension.[6]

These findings provide the theoretical building blocks for a variety of phenomena leading to splitting and steering of beams both in slab waveguides and bulk media, allowing the construction of various all-optical devices whereby light controls light.

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Another Twist of Light: Soliton Collisions in Bulk Media

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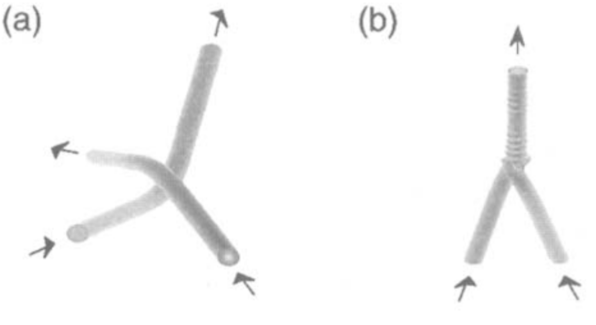
Self-guided optical beams (or spatial solitons) have attracted substantial research interest because they hold a promise of all-optical switching and controlling light by light. Typically interactions of spatial solitons have been analyzed for 2-D geometries (soliton interactions in nonlinear slab waveguides). Only recently, experimental discoveries of stable solitons in bulk nonlinear media initiated the experimental study of fully 3-D collisions between solitary beams, and some exciting results have been achieved (see, *e.g.*, Refs. 1 and 2). However, a major problem had been hampering further progress in the development of futuristic 3-D soliton switches: namely that a reliable theory of such 3-D soliton interactions had not been developed, making physical intuition and numerics the only tools for predicting experimental outcomes.

This year the situation has changed and a general theory of fully 3-D collisions of coherently interacting optical beams has been developed. It has been presented in the important example of soliton interactions in quadratic nonlinear media.[3] Quadratic nonlinearity has been chosen because it's especially attractive for potential practical realizations of all-optical switching based on two-wave spatial optical soltions (see, *e.g.*, Ref. 4). The soliton interaction theory results in a simple analytical model that provides immediate physical insight and allows us to anticipate different soliton interaction scenarios.[3] Importantly, these results strongly depend on competition between an effective "centrifugal force" (which naturally appears in the collision analysis) and a phase-dependent direct interaction force. For example, in the case of in-phase soliton collisions, an interplay between these forces leads to two qualitatively different regimes, schematically shown in Figure 1. For large impact parameter values, solitons cannot overcome the effective centrifugal potential barrier and thus they spiral about each other (see Fig. 1a, quasi-elastic collision). At smaller impact parameter values, soliton fusion may occur (see Fig. 1b, inelastic collision).

Recently, first experimental observations of 3-D collisions of quadratic solitons have been reported, showing strong dependence of the interaction result on collision angles.[5] The regimes of soliton fusion, repulsion, and crossing have been observed giving the experimental evidence of switching between inelastic collisions (soliton fusion) and quasi-elastic collisions. More advanced experiments are now in progress.

These novel results prove that interactions of spatial solitons in general and quadratic spatial solitons in particular may find their applications in all-optical processing and switching in a bulk medium, showing the world another exciting twist of light.



Steblina Figure 1. (a) Spiraling and (b) fusion of quadratic solitons.

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THz SOURCES

Measurement and Control of the Spatial Amplitude of Bloch Oscillations in Semiconductor Superlattices

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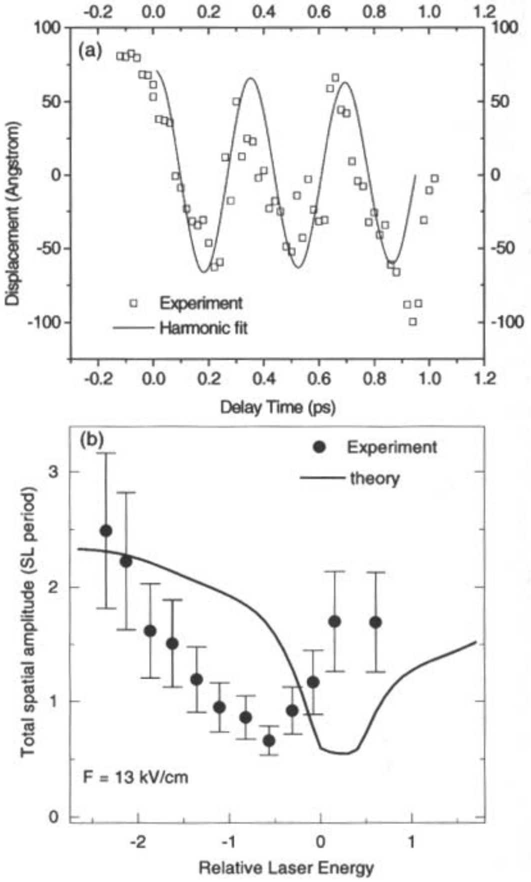
Bloch oscillations are one of the most basic effects in solids: If an electron is put into a static field, it will accelerate until it reaches the edge of the first Brillouin zone. It is then Bragg-reflected and returns to its original position, where it starts to accelerate again. The resulting spatial oscillation has never been observed in bulk solids since it is suppressed by scattering events. Bloch oscillations have recently been observed in semiconductor superlattices.[1–3] These experiments demonstrate that the frequency of the oscillations is tunable over a large range by the static electric field and that the electron oscillations lead to emission of THz radiation, which is promising for applications.

Recently, the spatial oscillation of the electrons (which was originally predicted by Zener in 1934) was observed for the first time. In these experiments, the small dipole field created by the oscillating Bloch wave packets in GaAs/AlGaAs superlattices is detected using the field shift of the optical transitions of the superlattices, which form a ladder (the so-called Wannier-Stark ladder).

Figure 1a shows the displacement of the center-of-mass of the electron wave packet as a function of time. For the given excitation conditions, the electron wave packet performs an oscillation with a total amplitude of about 150 Å. With increasing static field, the oscillation amplitude decreases as expected by theory.[3]

An exciting possibility in superlattices is to control the electron wave packet amplitude by changing the spectral laser position. For excitation below the center of the Wannier-Stark ladder, one creates a harmonic motion as shown in Figure 1a, for excitation above the motion is similar, but with an initial velocity in the opposite direction. For excitation on the center of the ladder, the electron wave packet only performs a breathing mode motion,[4] without a significant center-of-mass motion. Figure 1b shows the amplitude in units of the superlattice period in the dependence of the various excitation condition versus the excitation energy (given in units of the Stark ladder splitting). For excitation below and above the Wannier-Stark ladder center, the wave packet spatially oscillates. While exciting near the center, one finds a minimum of the oscillation amplitude, which is associated with the breathing mode motion.[5]



Sudzius Figure 1. (a) Bloch electron displacement as a function of delay time. (b) Amplitude of the Bloch-oscillatin wave packet as a function of the excitation energy.

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A New Tunable Coherent FIR-THz Source

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The electron beam in an SEM and a diffraction grating mounted in the focal region of the e-beam have been used to produce coherent radiation in the far-IR (FIR) region of the spectrum.[1] The device, termed a grating coupled oscillator (GCO), could also be described as a Smith Purcell free-electron laser.

As the beam moves over the grating, the incoherent superposition of the radiation wakes produced by indi-