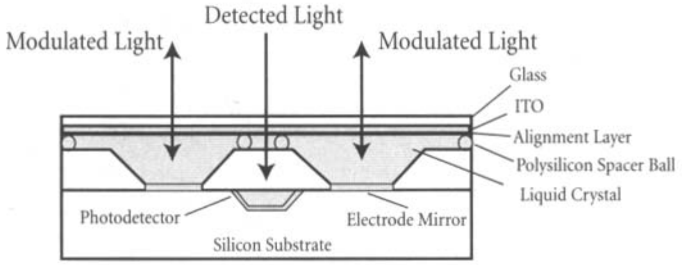

Shoop Figure 1. Cross-section view of smart pixel devices.

with a 1 × 8 linear input photodetector array. The design was implemented using a 2.0-μm silicon CMOS process on a single 6900 × 6800 μm chip. The smart pixels used a liquid crystal material known as BDH SCE-13, which has a birefringence of 0.17 and a maximum polarization axis rotation of 22°. Results from characterizing the smart pixel photodetectors, replication circuitry, multiplication circuitry, and LCOS modulators have been reported previously.[4–6] A contrast ratio of about 25 has been measured, and theoretical switching speeds of 33 ms can be realized with an applied electric field of 10 V/m.

The results of this experimental characterization clearly demonstrate the applicability of this smart pixel technology to analog signal processing applications in general, including wavelet transform applications. The accuracy of the photocurrent representations internal to the electronic circuitry indicate that process uniformity did not adversely effect this functionality and that scaling to larger-sized arrays is possible. The multiplier circuit, which operated above threshold and over a restricted operating range of ± 100 mV, provides sufficient linearity for this analog application. The LCOS modulators provide sufficient speed and linearity to accurately represent the Fourier transform of the wavelet transform at speeds up to video frame rates. Together these results indicate that a larger smart pixel architecture could provide the functionality necessary for the real-time computation of the wavelet transform in a 4-f correlator architecture.

Acknowledgments

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SOLITONS

Dark Incoherent Solitons

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Dark beams are nonuniform optical beams that contain either a 1-D dark stripe or a 2-D dark hole resulting from a phase singularity or an amplitude depression in their optical field. Thus far, self-trapped dark beams (dark solitons) have been observed using coherent light only. Recently, however, we have demonstrated self-trapping of dark incoherent light beams (or, in a broader prospective, self-trapping of dark incoherent wave-packets in nature) for the first time.[1] Both dark stripes and holes (vortices) nested in a broad partially spatially incoherent wavefront were shown to self-trap and form incoherent dark solitons in a nonlinear photorefractive crystal. These self-trapped 1-D and 2-D dark beams induce refractive-index changes akin to planar and circular dielectric waveguides, which introduces the possibility of controlling high-power laser light with low-power incoherent optical sources such as LEDs.

A spatially incoherent beam is a "speckled" multimode beam of which the instantaneous intensity pattern contains many speckles that vary randomly in time. Such an incoherent beam cannot self-trap in a material with an instantaneous nonlinearity, as each individual speckle forms a small lens, which in turn captures a fraction of the beam and eventually causes the fragmentation of the beam's envelope. However, in a noninstantaneous nonlinearity, where the nonlinear medium responds to a time-averaged intensity, self-trapping of an incoherent beam is achievable. This was first demonstrated with bright incoherent beams by use of a photorefractive self-focusing nonlinearity.[2] The theory of bright incoherent solitons was subsequently developed.[3] Later on, our numerical simulations suggested that self-trapping of dark incoherent beams is also possible in photorefractive media.[4] Incoherent solitons are altogether new entities since their phase distribution is random. This is especially true for dark solitons for which the transverse phase is supposed to play a crucial role. In fact, dark incoherent solitons represent a fundamentally new concept, and their underlying mechanism has been investigated theoretically only very recently.[4]

Our experiments of dark incoherent solitons are performed with a quasi-monochromatic spatially incoherent light source, generated by passing a laser beam through a rotating diffuser.[1, 2] The rotating diffuser introduces a new speckle pattern every ~1 μs, much faster than the response time of our photorefractive crystal (SBN:60). Thus, when the scattered beam is reflected from a $\lambda/4$ step mirror or a helicoidal phase mask, the crystal "sees" a dark stripe or a vortex hole nested in a smooth "speckle-free" spatially incoherent beam. The experimental arrangement is similar to that previously used for coherent dark screening solitons.[5] Typical results of 1-D dark incoherent solitons are shown in Figure 1a. At the crystal input face, the dark stripe is 18-μm wide, and it diffracts to 38 μm after propagating through the crystal. By applying a field of 850 V/cm, self-trapping of the dark stripe to its initial size is achieved. As expected, when the rotation of the diffuser is stopped, the crystal responds to the "instantaneous" (now stationary) speckles, which fragment the dark beam and prohibit self-trapping.[1]

When compared with coherent dark solitons, we find that incoherent dark solitons are always gray (with their grayness depending on the beam coherence). As the beam coherence decreases, the grayness increases. This observed behavior is in agreement with our numerical simulations.[1,4] Figures 1b and 1c exhibit the experimental results obtained using incoherent optical vortices. The self-trapped vortex is gray, and it becomes less visible when the beam is made less coherent. However, even when the grayness is large and the self-trapped vortex is almost invisible, we can still monitor its presence by its induced waveguide. Once an incoherent vortex soliton is formed, by translating the crystal laterally, we observe strong guidance of the carrier beam into a circular self-trapped channel induced by the vortex soliton.[1]

Although we used a "partially" spatially incoherent source, our results indicate that dark incoherent solitons can be generated using light that is both spatially and temporally incoherent, such as light from white-light sources (as demonstrated in Ref. 2 for bright incoherent solitons). This suggests that it is possible to use an incoherent light source to form a waveguide to guide other coherent or incoherent beams. In spite of recent progress in the study of dark incoherent solitons,[4] several questions still remain open. For example, how does an incoherent beam maintain a "phase memory" throughout propagation as a dark soliton? Can dark incoherent solitons be used for "coherence control" or "entropy reduction" of optical beams? We expect that incoherent solitons will bring about many new fundamental ideas in nonlinear science.

Acknowledgments

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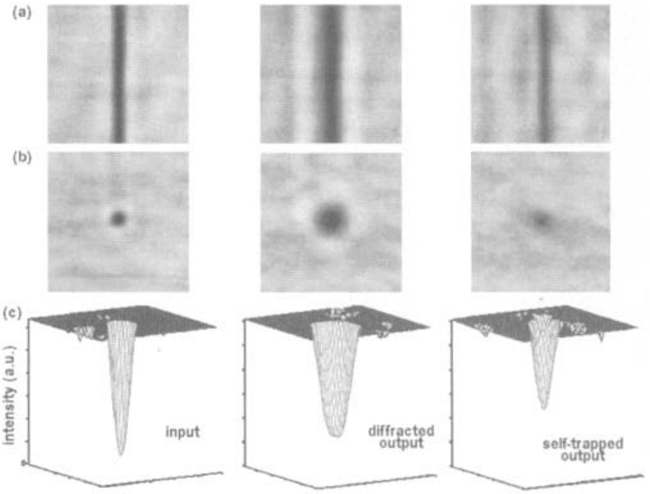

Chen Figure 1. Self-trapping of dark incoherent beams. Shown are photographs of the transverse patterns of a dark stripe beam (a) and of a dark vortex beam; (b) and the 3-D intensity plots of the vortex beam; (c) taken at crystal input face (left), output face with linear diffraction (middle), and output face with nonlinearity (right).

Splitting Light Beams with Light Itself

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Self-guided beams (or spatial solitons) are natural building blocks for a future all-optical technology where light guides and manipulates light itself in a bulk medium.[1–3] Theory shows that spatial solitons can steer each other or even be made to spiral about each other.[1,2] By colliding such solitons we can create fused beams or control the birth of new beams.[3] A number of these predictions have now been observed in the laboratory including induced optical fibers, spiraling, fusion, and soliton birth.[4,5] Recently a new phenomenon has been added to this arsenal: splitting light beams with light itself. A "bright" beam can be split into two bright beams upon illumination by a "dim" beam.[6]

To illustrate our idea we consider a self-guided "bright" beam propagating in a weakly saturating near-Kerr medium. Without a weak illumination (see Fig. 1a, page 50), the beam propagates with an almost periodic variation in width and amplitude. However, upon weak probe beam illumination, the beam splits into two beams as shown in Figure 1b.