Actually, the storage work is but one spin-off from our broader research into near-field scanning optical microscopy (NSOM),[2] which combines many of the advantages of traditional, far-field optical microscopy with much higher spatial resolution (currently as good as ~12 nm). Other applications include superresolution optical lithography, localized optical spectroscopy, and the non-invasive imaging of biological systems.

Of course, numerous other approaches are under investigation for the next generation of mass storage products. The most attractive feature of our near-field optical approach is that it can borrow heavily from the two most popular and commercially proven technologies—the closely flying scan head of magnetic disk drives and the recording media of conventional optical drives. This gives us a head start on the road to commercialization and permits us to take advantage of further improvements in either area. Many engineering challenges remain, including read/write speed, tracking, and fly height issues. Although these are daunting, they are perhaps not insurmountable, and the effort would appear to be justified by the observation that revenues in the mass storage industry total $40 billion annually and can be expected to grow further.

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Visible Subwavelength Point Source of Light

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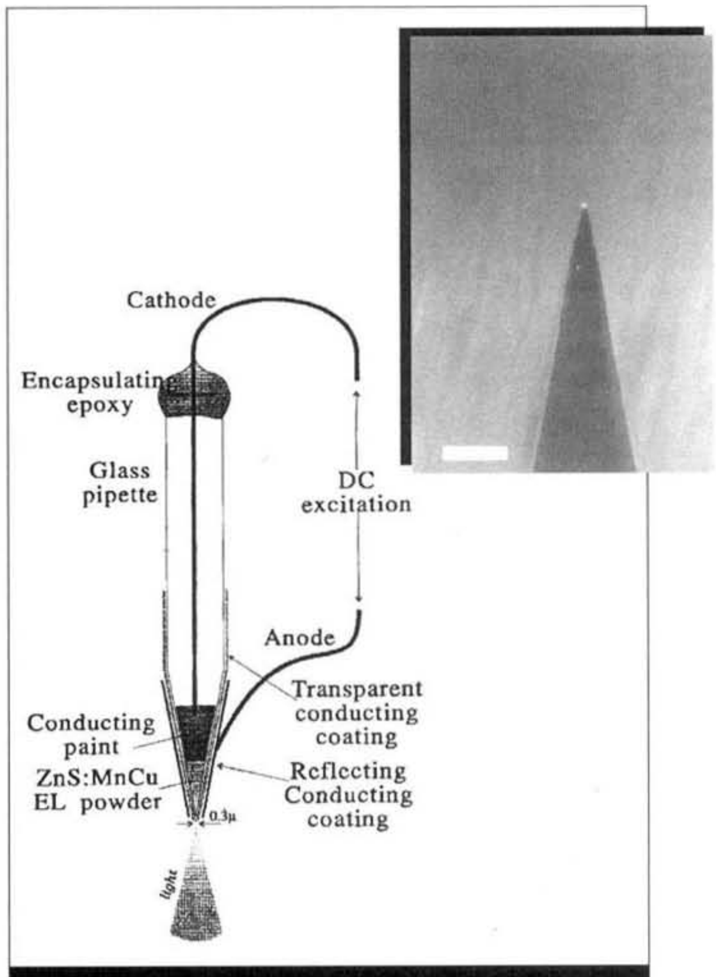
Micro-dimension light sources that can span a wide variety of wavelengths in the visible have been a major goal in optoelectronics for more than a decade. The applications for such light sources span numerous areas of advanced technology, not the least of which is the important problem of storing and retrieving the deluge of information that is engulfing mankind. For example, if a blue emitting source could be produced without any reduction in the size or the optical methodologies employed, factors of 4 improvement in data capacity could be achieved and, thus, a full length movie could be stored on one of today's compact discs. If, on the other hand, geometrical optics is bypassed and an optical device could be created that would be able to interface with the exciting developments of near-field optics,[1,2] in which a subwavelength point of light is brought within the near-field of a surface to be read or written on, then pixel sizes in the nanometer regime can be achieved and orders of magnitude improvement in storage densities could be attained.

The problem with this approach is the fact that the general methodology that has been used to create such a point of light is to pass the emission from a larger laser source through a subwavelength aperture at the tip of a glass micropipette or an optical fiber. Such an approach suffers from an exponential decrease in the intensity of the radiation as it evanescently propagates through the subwavelength hole.

We have focused on ways to circumvent this problem[2,3] and have recently attempted an approach[3] to this problem that has the potential of resolving several of the above issues by producing a submicron, subwavelength point source that can readily produce wavelengths ranging from the deep blue to the red, which can also be interfaced with near-field optics and which is not complicated by problems of evanescence. For this, we have devised a structure using a glass micropipette that allows for the insertion and the electrical excitation of a variety of electroluminescent materials at its very end. This structure (see figure) consists of a standard dc electroluminescent powder, ZnS:MnCu, that is introduced into the tip of a glass micropipette coated with a transparent coating of conducting indium oxide as the anode and an appropriate electrode placed on the inside as the cathode. The emission of our light source for this electroluminescent material is in the tip (see inset) and this light is created at the anode. The smallest size we have achieved to date is 0.3 μm. This is a result of the grain size of the electroluminescent material employed and not the achievable dimensionalities



Subwavelength electroluminescent light source assembly.

of the micropipette, which can have orifices at the tip of <10 nm. The largest intensity detected thus far from our devices was 4.2 footlamberts without any engineering optimization such as taking care to encapsulate the material so that interaction with oxygen and humidity is minimized. Future improvements in both the size and the intensity of the light source are expected, especially in view if the fact that, in the past two years, there have been significant advances in polymer electroluminescent materials[4] that can be formed in the tip of even the smallest (<10 nm) pipettes.

If the light source we presently have was used together with near-field optics for optical memory applications, nearly a gigabyte of information—or the entire *Encyclopedia Britannica*—could be stored on a dimension of 1 cm^2.

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COMMUNICATIONS & SWITCHING

Multi-Mode Interference Optical Devices Based on Self-Imaging Effects

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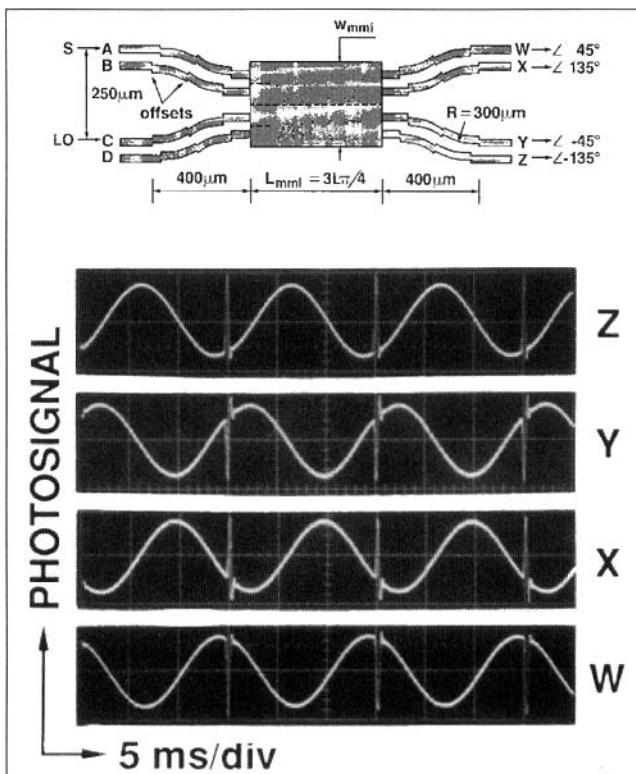
As opto-electronic integrated circuits (OEICs) become a reality, there is an increasing need for optical signal routing and signal processing devices with smaller dimensions, improved fabrication tolerances, and polarization-independent operation. Recently, several papers reported on multi-mode interference (MMI) 2×2 directional couplers that, in contrast with conventional two-mode interference (TMI) couplers, can fulfill all of the above requirements. Insertion losses as low as 0.5 dB and extinction ratios better than 30 dB have been obtained[2,3] with very compact, polarization-independent fabrication tolerant devices. The key feature of the high performance of these couplers is the self-imaging effect by multi-mode interference. Self-imaging[1] is a property of multimoded waveguides by which the exciting field at the entrance will be reproduced (either replicated or mirrored, single or n-folded) at periodic intervals along the propagation direction of the guide.

This year, the incorporation of these MMI couplers into higher level OEICs has been reported by several laboratories. Two cascaded 3-dB MMI couplers were used to realize a high-performance polarization-independent Mach-Zehnder quantum well electro-optic switch.[4] An ultra-compact monolithically integrated polarization-diversity receiver was reported[8] that featured one single polarization-independent 3-dB MMI coupler.

In addition to this, novel MMI waveguide structures have been developed. Beam splitters and recombiners based on multi-mode propagation phenomena have been demonstrated[5] in hollow waveguides at 10.6 μm wavelength. An ultra-short 1×2 optical power splitter based on MMI was reported[6] that featured low losses (≤ ldB), low unbalances (≤ 0.15dB) and polarization insensitivity for remarkably



The schematic layout of the 4×4 90° optical shows one single MMI section of width W_{MMI}=21.6 μm and length L_{MMI}=930 μm, resulting in a very compact device. Bottom: When inputs A and C are excited by light from a signal and local oscillator source, the IF beat signals in the four outputs satisfy the phase quadrature condition as evidenced by the oscilloscope traces.