Information Storage Industry Consortium
(formerly National Storage Industry Consortium)

Improved Data Storage and Access with Optical Recording Technology

In the late 1980s, optical disk storage technology promised to provide more storage and faster access times than the most advanced magnetic recording systems available. As of 1989, optical disk storage already enjoyed higher density of data on the disk surface by a factor of 10 compared to magnetic systems. Though the data were densely packed onto the disk surface, overall storage was limited by deficiencies in the lasers used to read data. Therefore, although data could be written on small areas on the disk surface, the lasers used to read the data became the limiting factor. Specifically, the lasers could not focus on areas as small as data could be written. The spot size for diode lasers could be reduced if the laser wavelength could be decreased from wavelengths in the then-available infrared or red part of the spectrum to wavelengths in the green or blue part of the spectrum. However, no commercially available diode lasers with such short wavelengths existed. An alternative approach to achieve short-wavelength light sources involved generating light from available lasers at double their normal frequency (or half the wavelength).

Because optical storage promised outstanding potential, members of the U.S. storage industry were independently conducting pre-competitive research into optical recording and, specifically, into laser-frequency doubling. This redundant research was an inefficient use of industry resources in such a highly competitive, low-margin business. Therefore, the National Storage Industry Consortium (NSIC) was founded in 1990 to encourage the storage industry to work together on pre-competitive research, including research on optical disk storage.

Through their cooperative efforts, project participants funded by NSIC (including NSIC members Eastman Kodak, Carnegie Mellon University, IBM, JDS Uniphase, University of Arizona, and SDL) hoped to gain mutually beneficial knowledge and to accelerate the development of short-wavelength light sources for optical disk storage technology. However, because of the project's risks and the participants' inability to capture all of the economic benefits from the research, private funding was not available. Therefore, in 1990, NSIC applied for and was awarded cost-shared funding from the Advanced Technology Program (ATP). By 1996, the team had demonstrated working devices that provided blue light based on frequency doubling of infrared lasers, but the efficiency and reliability of the devices were not yet adequate for commercialization. However, one participant developed spin-off products based on the thin-film electro-optical deflection technology developed during the ATP-funded project.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 90-01-0231 were collected during February 2002 - March 2003.

Magnetic Recording Technology Fails to Keep Pace with Advancements

Magnetic recording, the dominant form of storage in the computer industry in the late 1980s, could neither store as much data nor retrieve it fast enough to keep pace with advancements made in computing. Though scientists had expanded magnetic recording storage capacity by 30 percent annually for several years, they predicted that, in the near future, they would reach the limits of magnetic recording. Magnetic recording researchers estimated that by 1993, magnetic recording capacity would hinder progress in computer technology. Therefore, the industry needed to explore new storage sources to keep up with growing computer capabilities.

Optical Recording Devices Held Tremendous Promise and Substantial Risks

In the late 1980s, optical recording could already write data onto disks 10 times more densely than magnetic recording. The technology could also read data in a nonlinear fashion, allowing for data storage in clusters rather than in lines, which enabled faster data recording and reading. Before it could become the dominant form of computer storage, however, the optical recording industry first needed to develop the scientific basis and technology capabilities for improved data storage as a precursor to determining appropriate industry standards for materials. This would lead to a predictable rate of improvement so that computer manufacturers could plan their product enhancements to coincide with available storage.

This pre-competitive research plan was extremely risky, demanding a significant level of initial research before product planning could even be conceived. Working separately, industry members would have required 10 years to complete the necessary research. Therefore, to meet this need, the National Storage Industry Consortium (NSIC) was founded to encourage the storage industry to work together on pre-competitive research, including research on optical disk storage. NSIC's research plan called for a five-year program to speed innovation. NSIC proposed to conduct research in two critical areas in parallel, each of which carried substantial risk. The first area was to expand areal density by focusing an optical beam to increasingly smaller sizes. Since data bits are stored in widths that correspond to the diameter of the optical beam, halving the wavelength of the light decreases the optical beam diameter used to read data by 75 percent. The second research area involved using waveguides to double light frequencies, transforming available red or infrared lasers into the more powerful blue light lasers.

Pursuing these two different research paths in parallel required significant resources and presented substantial risk to private firms. NSIC's process, if successful, would provide a set of technical and engineering tools, along with norms for material standards and testing data, that would improve and standardize optical recording technology. Further, this improvement would significantly enhance the capabilities and competitiveness of the U.S. storage industry.

ATP Funds Collaboration Among Industry Rivals

Optical recording presented an opportunity to develop an alternative technology in order to capture some of the Japanese firms' market share. To create a viable optical recording system, however, substantial research was needed to develop standards for materials and design engineering, as well as to set protocols for how the optical recording device would interact and exchange information with devices in need of that information. That kind of industry-creating research was too expensive to conduct at the individual company level. Even after the industry coalesced around NSIC, the project did not receive private funding because of the inherent risks and the participants' inability to capture sufficient economic benefits from the required research investment. Therefore, in 1990 NSIC turned to ATP for funding assistance.

Through this NSIC project, optical recording advances could extend storage capabilities and could enable far more computing power than was previously available. To help NSIC reach these goals and to generate broad-based economic benefits, ATP awarded the NSIC-led joint venture $5.4 million in cost-shared funds over a five-year period.

Scientific Obstacles Hinder Optical Recording Device Advances

In the early 1990s, blue-light spectrum lasers with beams that were clean and precise enough for use in optical recording systems were not commercially available. After a number of vendors attempted and failed to use blue lasers, NSIC focused its efforts on generating appropriate blue wavelengths from lasers in the red and infrared spectra, a strategy intended to circumvent existing technical barriers.

NSIC targeted its research efforts on the use of waveguides, which are crystal lenses that, when fabricated from appropriate nonlinear optical materials, can increase a light beam's frequency, thereby decreasing its wavelength. NSIC sought to take an infrared laser with an 800-nanometer wavelength and decrease it to 400 nanometers with a waveguide. During the course of the waveguide research, NSIC encountered a number of problems. First, crystals pure enough to serve as waveguides were extremely difficult to find from an existing vendor. Second, when a vendor was found, the laser passing through the waveguide actually damaged the crystals, rendering them useless.

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After further research, NSIC discovered that a lack of synchronization between the peaks and valleys of the infrared and blue waves prevented the efficient generation of blue light. To correct that problem, NSIC scientists began doping the crystals to make sure the peaks and valleys of the infrared and the blue light remained synchronized. Although they demonstrated considerable progress with this approach, at the end of the project, the team still needed to increase the efficiency and reliability of the devices before commercialization could be considered.

Magnetic Recording Industry Achieves Large-Scale Storage Density Improvement

Concurrent with the ATP-funded project, the magnetic recording industry achieved a major breakthrough that enabled storage density to increase 60 percent per year instead of the 30-percent increases the industry had experienced. The 60-percent annual improvement rate would keep magnetic recording ahead of the computer industry's needs, thereby eliminating the pressing need for optical recording systems.

As a result of scientific and business difficulties, however, several NSIC members halted their research into optical disk recording. Even though much of the research in this area ended with the ATP-funded project, the focused research effort generated a substantial amount of new information and knowledge for the industry. Twelve patent applications resulted, with three granted, and nearly 80 publications contained information generated by the NSIC project.

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Of the participants that remained active in the ATP-funded project until its completion in 1996, one achieved success with spin-off products. A group of Carnegie Mellon University scientists realized during the project that it was possible to rapidly deflect a beam within an electro-optical waveguide. With that knowledge, the scientists incorporated the company Applied Electrooptics and developed a compact and efficient device that applies voltages to influence the properties of light passing through a waveguide.

Conclusion

In 1990 the National Storage Industry Consortium (NSIC) brought together a group of consortium members to address a problem affecting the optical recording industry. They hoped to develop a method of optical recording to store and retrieve data in a manner that would increase the overall storage of individual optical disks. Through the project, NSIC generated a solid body of research surrounding lasers used for optical recording. The pre-competitive research helped the storage industry decide that blue lasers were not ideal for optical recording and allowed the industry and the companies to research other, potentially more promising, recording technologies.

PROJECT HIGHLIGHTS
International Storage Industry Consortium (formerly National Storage Industry Consortium)

Project Title: Improved Data Storage and Access with Optical Recording Technology (Short-Wavelength Advanced Technology)

Project: To develop optical recording as a platform that is more efficient and effective for computer data storage than traditional magnetic recording and to develop the scientific basis and technological capabilities for improved data storage as a precursor to determining appropriate standards.

Duration: 6/1/1991-6/30/1996
ATP Number: 90-01-0231

Funding (in thousands):

ATP Final Cost	$ 5,421	38%
Participant Final Cost	8,862	62%
Total	$14,283	

Accomplishments: The National Storage Industry Consortium (NSIC) conducted a tremendous amount of research on frequency doubling during this ATP-funded project. Moreover, the recording industry gained an understanding of frequency-doubling infrared lasers to achieve light in the blue spectrum. Specifically, the industry learned that generating precise blue-light spectrum lasers efficiently and reliably was extremely difficult, and it began to define the challenges scientists must overcome to produce viable blue lasers.

One member of NSIC, Eastman Kodak, filed 12 patent applications, and its scientists wrote articles that appeared in nearly 80 publications and media outlets that reported on the project. The following three patent applications were granted:

- "Electrooptic device for scanning using domain reversed regions"
  (No. 5,317,446: filed September 29, 1992, granted May 31, 1994)
- "Waveguide nonlinear optical frequency converter with integral modulation and optimization means"
  (No. 5,317,666: filed September 29, 1992, granted May 31, 1994)
- "Quasi-phasematched frequency converters"
  (No. 5,436,758: filed June 17, 1994, granted July 25, 1995)

Commercialization Status: NSIC members did not commercialize optical recording devices based on the ATP-funded research because: (a) remaining technical obstacles would have required significant further development of the frequency-doubling technology; (b) by the end of the project, competition was looming from direct-lasing green and blue diode lasers; and (c) unexpectedly rapid advances in magnetic recording technology had reduced the urgency and the likelihood of the advanced optical storage technology's commercial success.

Outlook: Since the NSIC members did not continue their research plan beyond the duration of the ATP-funded project, the outlook for this technology is not good.

Composite Performance Score: *

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