X-Ray Optical Systems, Inc.

Innovative Optics Technology to Focus X-Rays and Neutrons

When X-Ray Optical Systems, Inc., (XOS) proposed its project to the Advanced Technology Program (ATP), the company was an early-stage venture with an unproven technology and little potential for attracting private investors. Now the company is a leader in x-ray focusing optics, and, as a niche technology business, XOS collaborates with numerous sectors of the U.S. economy. XOS continues to develop the next generation of x-ray technologies that promises to have significant social, economic, and scientific impact in medical imaging and materials research. The three-year ATP project, which ended in 1995, laid the groundwork for several follow-on contracts from other Federal agencies and enabled the company to pursue diverse applications that began to offer broad-based benefits in early 2000. As of summer 2002, XOS had developed six partnerships with businesses that sell machines specifically designed for use with XOS lenses.

COMPOSITE PERFORMANCE SCORE
(based on a four star rating)
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Research and data for Status Report 91-01-0112 were collected during July - September 2002.

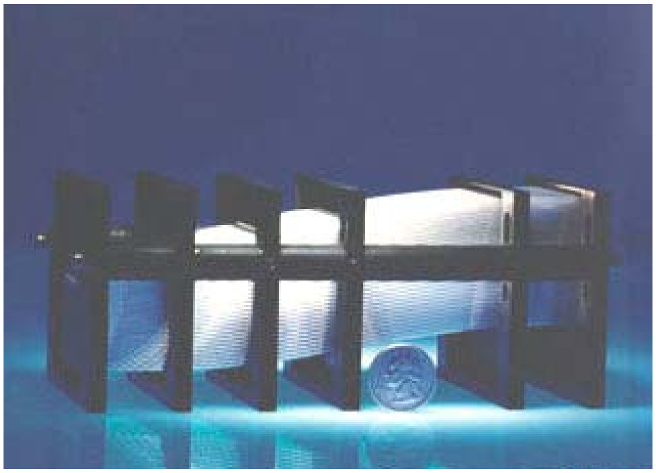
ATP Funds New Technology to Focus X-Rays and Neutrons

"At the time we started with ATP, there had never been a useful example of this technology anywhere in the world," stated David Gibson, chief executive officer of X-Ray Optical Systems (XOS). He was referring to a new method for focusing x-rays and neutrons. Mr. Gibson tried to attract investors to his start-up company; however, with no proven product, he was unable to find seed money.

Polycapillary optics may facilitate new x-ray and neutron applications for medical therapy, x-ray fluorescence, mammography, lithography, and protein crystallography.

Then, in 1990, Mr. Gibson read about ATP in an industry magazine and was immediately intrigued by ATP's unique willingness to fund high-risk technologies in need of incubation. He proposed his idea to ATP and received an award in 1992. With ATP co-funding, XOS successfully developed, tested, and perfected a new technology for focusing x-rays and neutrons by reflecting them in orchestrated arrays through thousands of tiny, curved glass optic tubes capable of controlling radiation from a divergent beam.

Multifiber polycapillary optics, which were developed through this project, are an enabling technology geared toward providing high-end x-ray and neutron components to analytical instrument original equipment manufacturers (OEMs) to increase their efficiency, mobility, and cost effectiveness. Polycapillary optics may be integrated with other components to facilitate new x-ray and neutron applications for medical therapy, x-ray fluorescence, mammography, lithography, and protein crystallography. With XOS's optics, a significant portion of the x-rays or neutrons emitted from a point source can be controlled to produce a collimated beam of radiation, enabling the acquisition of more detailed images at a lower radiation dosage. These tiny collimating optics continue to be a revolutionary factor in many types of diffraction applications. Primitive versions of polycapillary optics, which were developed in the late 1970s, were wholly unreliable and, therefore, were not widely adopted. During the time XOS was working to refine its manufacturing techniques,



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Russian, Chinese, and Japanese labs were attempting to refine polycapillary optics models, but they met with lackluster results.

XOS Focuses on Polycapillary Optics

XOS's research and development (R&D) efforts focused on two types of optics:

1) multifiber polycapillary collimating and focusing optics and

2) monolithic polycapillary optics. The second type emerged as a derivative of the first type during the ATP project.

Multifiber polycapillary optics are perfect for use with high-power x-ray sources and large-diameter beam applications. Glass fibers are threaded individually through a series of thin screens set up with hole patterns controlled at the micrometer level. A series of frames support the screens and maintain alignment. Each optic is composed of thousands of such fibers.

The major obstacle was getting thousands of string-like hollow glass tubes to bend at a precise, uniform, and reliably proper arc.

Monolithic polycapillary optics involve a different process. Individual capillaries are fused together, eliminating the need for tiny framed screens and frame supports. The monolithic optics vary in length, yet are smaller and more compact than multifiber polycapillary lenses. Moreover, they have the ability to form tighter beams for collimating purposes and smaller spot sizes for focusing purposes.

Overcoming Technical Problems of Capillary Arrays

Polycapillary optics are based on arrays of microscopic glass tubes that direct beams toward a desired focal point or to a parallel beam. Because x-rays have such high energy, however, they pass through most materials without interacting with them. XOS found that if the curvature of the capillary is kept below a certain critical limit, the x-rays reflect off the inside surfaces of the capillary, skipping like a rock across a pond. Capillary arrays can capture convergent, as well as parallel, x-ray beams and can focus or redirect their energy, thus reducing measurement times, improving spatial resolution, and increasing sensitivity.

Lab experimentation early in the development of this new technology showed that capillary arrays could focus high-energy x-rays. The lingering problem was how to make it happen consistently and without having to face recurring technical imperfections. The major obstacle was getting thousands of string-like hollow glass tubes to bend at a precise, uniform, and reliably proper arc. XOS faced another obstacle in that all existing polycapillary optics were made outside the United States. No component manufacturer was able to reliably and consistently mass-produce polycapillary collimators that were able to focus x-rays with any legitimate control.

Finding Alternative Materials that Withstand Wear and Tear

XOS conducted a thorough materials analysis to discover which materials could withstand relatively intense x-ray and neutron beam irradiation over long periods. Over time, most types of materials deteriorate from continued contact with neutrons and x-rays. Through the ATP-funded project, XOS successfully identified and developed new glass-type materials that are less susceptible to x-ray degradation.

Medical Imaging Applications

Polycapillary optics able to scan large areas have applications in soft-tissue imaging, specifically mammography and angiography. The effectiveness of this type of medical imaging depends on image contrast and resolution. Once the technology evolves and allows larger scans, polycapillary optics are expected to enhance image quality in mammographic systems by serving as a scatter-control component. Polycapillary optics can also help medical technicians and researchers detect tumors that are smaller than those currently detected, and this capability will improve as scanning areas increase. Because only relatively small areas of a sample can be imaged at one time, polycapillary optics are currently more suited for research than for use in doctors' offices. Therefore, only university hospitals and laboratories have been the early purchasers of XOS equipment.

ATP's Contribution Advances Technology by a Decade

"Without the ATP project, XOS would be at least a decade behind where it is today," Mr. Gibson stated. "And any commercial success from these new technologies most likely would not have originated in the U.S." The ATP-funded project helped to build up a small start-up company, attracted strategic partnerships with private investors and collaborators, and, most importantly, dramatically accelerated the pace of technology development. Currently, two of XOS's customers are OEMs that use the technology for high-resolution imaging of small areas.

Conclusion

After receiving the ATP award, XOS further developed the technology and attracted the interest of private investors. In addition, the ATP project laid the groundwork for several follow-on contracts with other government agencies that enabled the company to pursue different applications of the technology. This effort resulted in two new, improved lenses and imaging methods for use in high-resolution imaging machines. Moreover, the company has received several industry recognition awards as well as seven patents.

PROJECT HIGHLIGHTS
X-Ray Optical Systems, Inc.

Project Title: Innovative Optics Technology to Focus X-Rays and Neutrons (New Optics Enhance X-Ray and Neutron Focusing)

Project: To establish the capability to manufacture reliable polycapillary x-ray optics technology, which is needed for medical imaging and materials research, and to explore and experiment with design, alternative materials, and productivity models.

Duration: 6/1/1992-5/31/1996
ATP Number: 91-01-0112

Funding (in thousands):

ATP Final Cost	$1,949	84%
Participant Final Cost	371	16%
Total	$2,320	

Accomplishments: Through its collaboration with ATP, X-Ray Optical Systems (XOS) achieved a number of accomplishments, including winning the 1996 Photonics Circle of Excellence Award presented by Photonics Spectra Magazine and being listed among the R&D top 100 from R&D Magazine in 1995. XOS received the following patents for technologies resulting from this ATP-funded project:

- "Polychannel multiple-total-external reflection neutron radiography"
  (No. 5,553,105: filed October 31, 1994, granted September 3, 1996)
- "Use of a Kumakhov lens in analytic instruments"
  (No. 5,497,008: filed February 1, 1995, granted March 5, 1996)
- "High intensity, small diameter x-ray beam, capillary optic system"
  (No. 5,570,408: filed February 28, 1995, granted October 29, 1996)
- "Multiple-channel, total-reflection optic with controllable divergence"
  (No. 5,604,353: filed June 12, 1995, granted February 18, 1997)
- "Radiation focusing monocapillary with constant inner dimension region and varying inner dimension region"
  (No. 5,747,821: filed August 4, 1995, granted May 5, 1998)
- "Multiple channel optic"
  (No. 5,745,547: filed August 2, 1996, granted April 28, 1998)
- "Microcalorimeter x-ray detectors with x-ray lens"
  (No. 5,880,467: filed March 5, 1997, granted March 9, 1999)

Commercialization Status: XOS commercialized its optics technology and was working on improving the optic components' ability to scan larger areas by 2002. Furthermore, the ATP award enabled XOS to develop its technology to a level that made possible further collaboration with private and public entities for a variety of research and commercial endeavors. XOS assisted the National Aeronautics and Space Administration in determining the structure of proteins, which will have a wide impact on the study of diseases, including the possibility of preventing a rare children's disease. XOS also collaborated with the Department of Energy and with research organizations such as the Los Alamos and the Oak Ridge National Laboratories. In the private sector, XOS started numerous joint development projects with companies such as VECCO, EDAX, Roentgenanalytik, Shimadzu, Bede Scientific, Inc., and Thermo Electron. The partnerships with Shimadzu and Bede Scientific, Inc., resulted in commercialized machines that use the ATP-funded technology, while the other projects were still in the R&D stage. Although the market size for polycapillary optic lenses and collimators is small, it is growing. The lens is revolutionary because, for the first time, researchers are able to investigate materials at a level of detail once thought impossible. This technology should open new markets in the materials research and protein crystallography sectors.

Outlook: Prospective applications and benefits from this new optics technology were just beginning to be identified. Polycapillary optics were only starting to make inroads within the economy. For example, one area of future interest is in microelectronic lithography, where x-ray lenses can be used to make finer microchip features. Furthermore, polycapillary optics are useful for materials research, medical imaging, and long-wavelength x-ray applications. X-ray diffraction, for example, is useful for government, commercial, and scientific applications aimed at studying molecular structures within materials. As a component provider for customized optics, XOS is beginning to expand on this role and enter into new territory.

Composite Performance Score: * * * *

Number of Employees: One employee at project start, 22 as of September 2002.

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