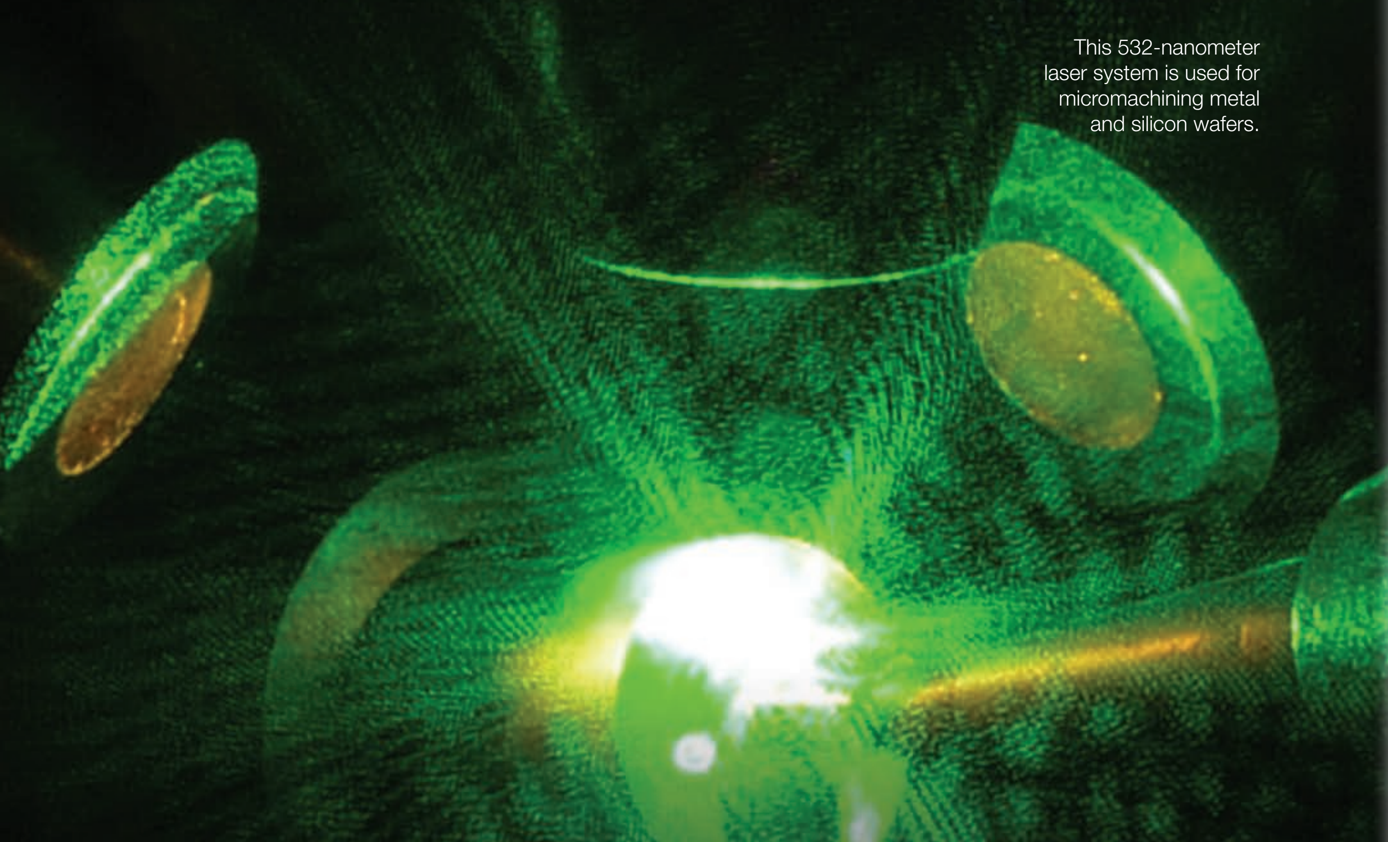
Micromachined Parts Advance Medicine, Astrophysics, and More



This 532-nanometer laser system is used for micromachining metal and silicon wafers.

NASA Technology

Anyone who remembers the Micro Machines line of toys might be surprised to learn that the tiny model vehicles are positively gargantuan compared with actual micromachine manufacturing. While specimens of the miniature toy collection may indeed have been “smaller than a silver dollar,” some industrial micromachined parts compare similarly to the breadth of a human hair, which is around 75 microns.

For example, Potomac Photonics, a Baltimore-based company, might use a high-speed laser to drill a grid of 25,000 holes, each less than two microns across, through a steel surface with an accuracy of plus or minus 0.3 microns—and do it cheaply enough that the part can be considered disposable. “That’s pushing the limits in terms of machining capability,” says Mike Adelstein, the company’s president and CEO.

The company’s website is rife with photos in which looming pennies and dimes dwarf the intricate metal gears, microfluidic channels, and 3D-printed plastic parts it has produced.

Since its founding in 1982, the company has worked on a number of Small Business Innovation Research (SBIR) contracts with the Department of Defense, the National Science Foundation, and other agencies to develop technologies such as lasers and ultrasensitive detectors. However, Adelstein says it was a set of SBIR contracts with NASA’s Marshall Space Flight Center in the mid-1990s that was especially influential in putting the company on the cutting edge of micromachining, leading to the work it does today.

There were two objectives to the Phase I and II SBIR contracts awarded to the company. One was to prove the capability of excimer lasers in crafting intricate, diffractive optical elements—lenses etched with thin, micro-structure patterns that manipulate the light passing through them. These are used in a wide variety of applications, from sensors and monitoring equipment to fiber optics, displays, and information storage. At the time, however, making these small-scale elements was time-consuming and hugely expensive.

While near-infrared lasers were commonly used to manufacture metal components, less was known about the use of excimer lasers, which operate in the deep ultraviolet range, to shape polymer and glass elements, such as lenses, Adelstein says. But the work proved the ultraviolet lasers were effective on these materials.

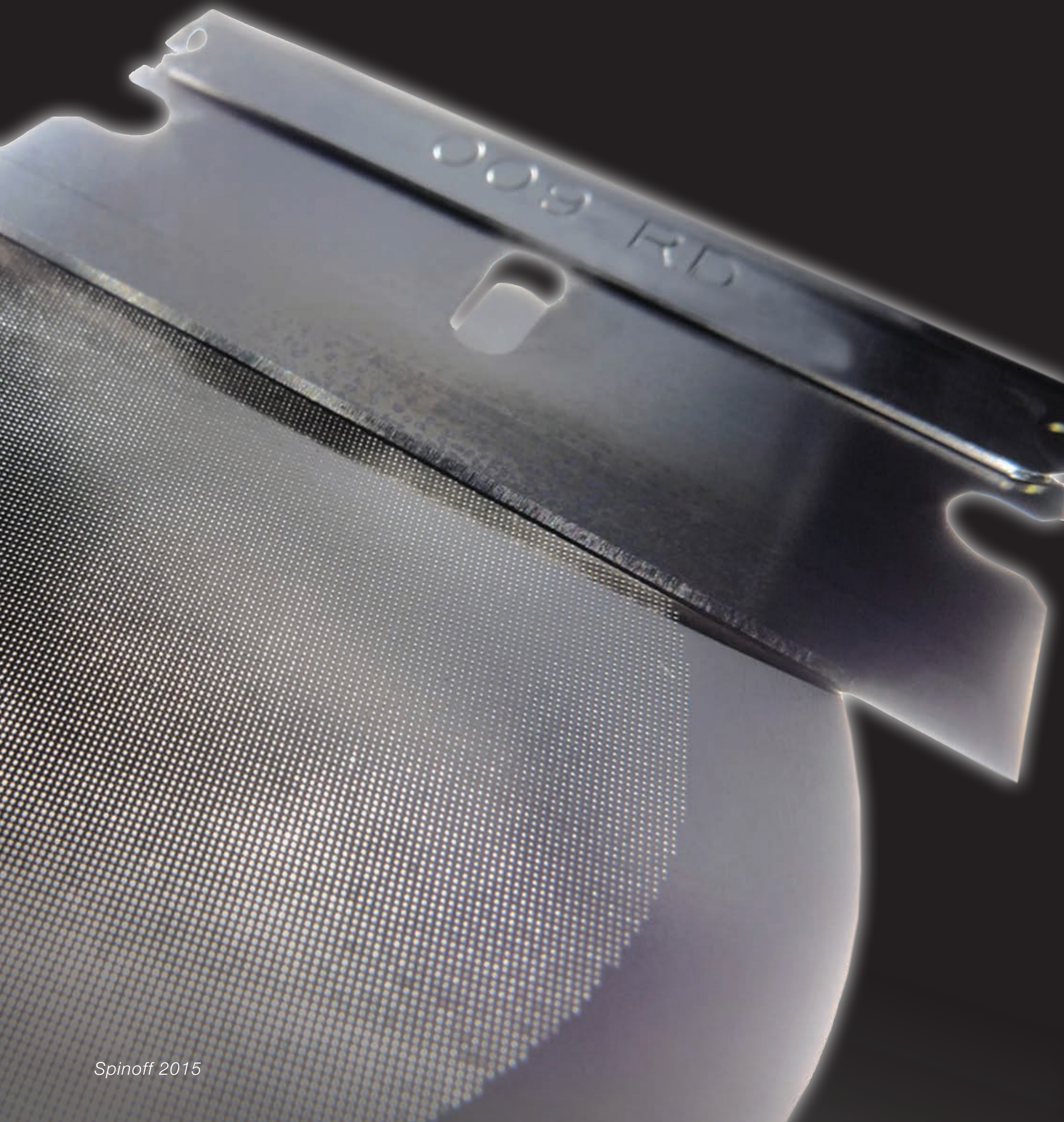
Then, the company wanted to develop an integrated, computerized workstation capable of mass-producing such optical components, using AutoCAD software to digitally control the process and make it faster, more flexible, and cheaper.

“NASA certainly was interested, because they do a lot of work with lasers and light,” Adelstein says.

The work that Potomac Photonics carried out under NASA SBIRs ended up being a major breakthrough for the company, resulting in a workstation that allowed the user to custom-design diffractive optical elements and produce them cheaply and efficiently (*Spinoff* 1998).

Technology Transfer

Although its work with NASA was geared toward manufacturing diffractive optics, the company found that the digital fabrication technology it had developed for the workstation was useful in all sorts of micromachining. And micromachining is, in fact, one common application



"The work with NASA showed a **different way** of making **these components** and **pushed the limits** of the **technology**. It really **set** the **tone** for **our direction** in leading this **field."**

— Mike Adelstein, Potomac Photonics

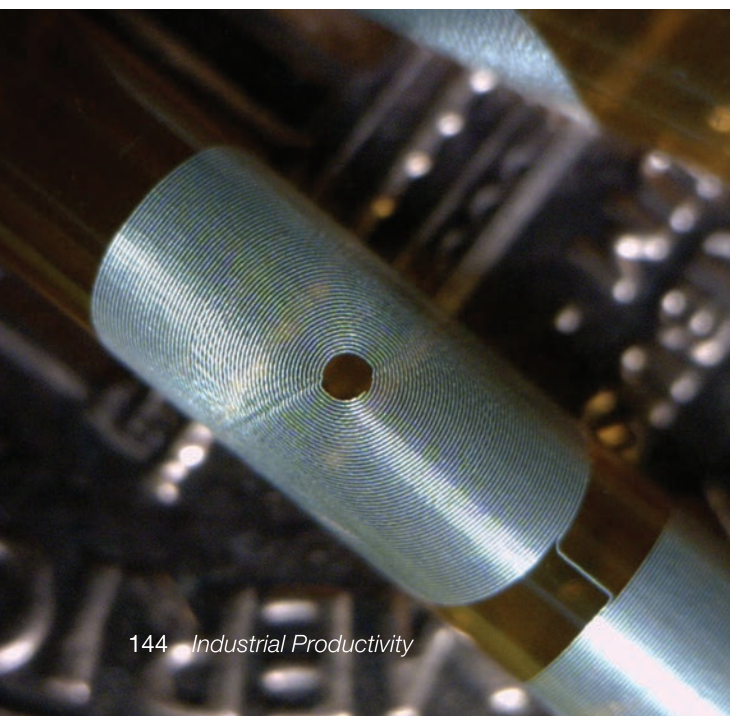
Here, a grid of tiny holes has been drilled in stainless steel. Potomac Photonics can accurately place and drill holes as small as one micron, or a thousandth of a millimeter.

of the very diffractive lenses the workstations could now cheaply produce. These lenses allow optimized, precise laser cutting, drilling, and ablation—whereby a controlled amount of material is vaporized.

"It was that breakthrough that led to everything we do now," Adelstein says of the work with NASA. "It showed a different way of making these components and pushed the limits of the technology. It really set the tone for our direction in leading this field."

Over the years, he says, the company grew a contract manufacturing business, making tiny parts to order with quick turnaround times. Around 2008, the workstations were discontinued, and the company now focuses on "rapid contract micromanufacturing," as Adelstein puts it, as well as continuing to develop new technologies to that end. The work ranges from microhole drilling and precise laser marking to hot embossing and 3D printing, working with metal, plastics, glass, ceramics, and silicon. Popular applications include medical devices, biotechnology manufacturing, and electronics, among others.

Software and laser technology have come a long way since the mid-1990s, and Adelstein says, in the company's production line and in the world of modern technology, "everything's gotten smaller, and everything's gotten more precise."



Here, silver nanoparticle conductive lines are embedded in Kapton tubing for use in a medical device.

Benefits

Potomac Photonics continues to work often with NASA as a supplier of parts and services. In the spring of 2014, the Center for Research and Exploration in Space Science and Technology (CRESST), formed by NASA, contracted the company to have laser markings inscribed on filter carriers for imaging systems on the ASTRO-H satellite being developed by the Japan Aerospace Exploration Agency, with participation from NASA and other space agencies.

"We needed some precision reference marks for which their laser system worked well," says Meng Chiao, a research scientist with the University of Maryland Baltimore County, one of the institutions that comprise CRESST.

The satellite, scheduled for launch in 2015, will look for clues to the origins of the universe using several different imaging systems to observe X-ray and gamma ray activity around black holes and supernova remnants. To get a clear picture, the various telescopes and imagers must be precisely aligned, and the detector assembly team decided to accomplish this by putting reference marks on the rings of gold-plated aluminum that hold filters in the different instruments' aperture assemblies. The marks can then be visually aligned, but they have to be placed with exact accuracy, as the slightest discrepancy would begin to take on a magnitude of light years as the imagers look deeper into space.

Chiao, who works closely with the X-ray calorimeter group in the Astrophysics Science Division at Goddard Space Flight Center, says Potomac Photonics came recommended to her by a colleague. "To my knowledge, they're the only company with this laser marking system and with precision placement capability," she says.

The company was able to turn the work around in less than 24 hours.

This example demonstrates the company's ability to laser micromachine polyethylene terephthalate, a thermoplastic polymer, at micron scale.

Since its SBIRs with NASA, Adelstein says, the company has grown by 50 to 75 percent. The staff has grown from about half a dozen to 20, and revenues for 2014 were projected at around \$3.2 million.

Another frequent client these days is Johns Hopkins Medicine, and around the time of the ASTRO-H project, Potomac Photonics returned to its roots to supply the organization with a diffractive optic lens. Also around this time, the company used its hyper-accurate 3D printer to produce a device designed to fight cervical cancer in the developing world for Jhpiego and Momo Scientific, two companies working with Johns Hopkins University.

Another recent medical project Adelstein takes pride in is the production of sutures with tiny wells in them, in which radiation can be embedded for localized cancer treatment. His wife still suffers from health issues due to radiation treatment she received for Hodgkin's disease when she was a teenager, as do many who are subjected to massive doses of radiation in attempts to fight cancer, he says. These sutures allow a much safer alternative, at least for treatment of prostate and breast cancer.

"The ability to machine parts like this that are so small—it's going to be life-changing," Adelstein says. ❖

Not limited to lasers, Potomac Photonics also fabricates tiny, plastic parts with a high-precision 3D printer. These molds the company made for Johns Hopkins University were used to make high-aspect ratio wells in a polymer material.