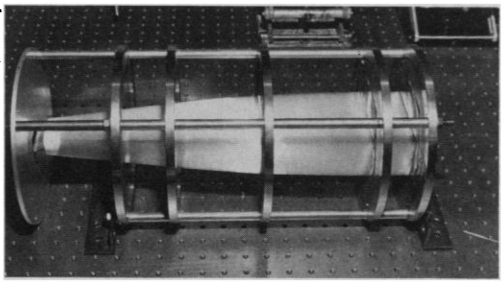
Piping X-Rays Through a Glass Brightly

Taming ordinary light takes a battery of lenses, filters, and other optical devices. For the first time, means to control x-rays with similar finesse may be in hand

WALTER GIBSON HAS AN X-RAY VISION. IN the last 2 months, this highly regarded physicist from the State University of New York at Albany, his business-minded son David, and long-time Soviet colleague Muradin Kumakhov have been going lab door to lab door talking up a new invention that may usher x-ray technology into a new, advanced generation. The device, known as the Kumakhov lens, can, they claim, focus and manipulate x-rays—a possibility that has tantalized those scientists who know of it. "Everyone in science realizes that you've never been able to focus x-rays," says physicist Timothy M. Hayes of Rensselaer Polytechnic Institute, who uses x-rays to study corrosion and metal-plating mechanisms. "If you can focus x-rays, you've got a major breakthrough."

In fact, Hayes is one of a growing number of researchers who think Kumakhov and Gibson may have done it. "I was very skeptical when I first heard about this," he continues. "But it just can't be smoke. It sounds too substantial. It looks too substantial. And Walter Gibson wouldn't do something stupid."

SUNY, Albany



X-ray bender. *The Kumakhov lens, a bundle of several thousands of glass capillaries, shapes and focuses x-rays.*

If the Kumakhov lens does live up to expectations, it could lead to safer and more effective means of treating cancerous tumors, more powerful research tools for such jobs as charting the atomic anatomy of minuscule material samples, and more reliable, simpler, and cheaper means of making the next generation of super dense electronic chips. "I think it will eventually impact every area where x-rays are used because it provides a level of control that we don't now have and will make possible some applications that we can't now pursue," Gibson says.

Donald Bilderback, a director of the Cornell High Energy Synchrotron Source who also studies ways of taming x-rays, rates the potential value of the invention this way: "The difference [it could make in x-ray technology] is equivalent to that between a pinhole camera and a well-engineered 35 millimeter camera." And all this from a device based on principles that are invariably described as "simple" by those who've heard Gibson and Kumakhov.

X-rays have proven difficult to focus because traditional lens materials absorb them instead of transmitting them, and because such lenses can barely bend the rays at all, let alone concentrate them on a small spot, even if the rays are transmitted. Scientists have achieved some control over x-rays by reflecting them off the atomic layers of crystals. But these techniques can bend the rays only at a restricted set of angles and then only x-rays carrying a limited range of energies.

Enter the Kumakhov lens. The idea behind the invention reportedly came to its namesake, a theoretician at the I.V. Kurchatov Institute of Atomic Energy in Moscow, one sleepless night in the mid-1980s in a hotel room in Minsk. As with many ideas that seem to pop into mind, the stage had already been set for this one, notes Gibson. Kumakhov is an expert on how the minuscule atomic corridors inside crystals can guide a beam of charged particles in specific directions. (It was the two physicists' uncommonly strong expertise in that topic that first brought them together in the late 1960s when Gibson visited Moscow.) The Russian physicist also knew that crystals cannot guide x-rays and uncharged particles as they do charged particles. Yet in building their x-ray telescopes, astronomers exploit a phenomenon known as total external reflection, in which x-rays barely graze a mirror surface and reflect toward a detector instead of moving past the detector's gaze.

In that Minsk hotel room, Gibson says, Kumakhov realized that the same principle would apply to x-rays traveling inside a gently curving glass capillary. They might just keep bouncing off the walls, like a flat stone skipping on the surface of a calm lake, so long as each contact angle was kept small. And by assembling many of these curved, smooth surfaces in the form of capillary bundles, the ensemble might serve as a lens for focusing, bending and shaping beams of x-rays or neutrons, much the way a camera lens focuses light onto a piece of film.

Since the mid-1980s, Kumakhov and Soviet colleagues have built several prototype lenses based on this design, showing that the devices can indeed manipulate x-rays in ways never before possible. The lenses can, for example, gather up to a 30-degree swathe of diverging x-rays and reshape them into an almost parallel narrow beam. They also can focus neutron beams, Gibson notes.

So far, the best lenses have been able to focus a wide beam of x-rays into a 100-micron spot. But based on their results so far, Gibson and Kumakhov expect improved versions to do even better—focusing an x-ray beam into a 30-micron spot while increasing the beam's intensity as much as 10,000 times. That feature could lead to exotic tools such as x-ray and neutron microscopes, the investigators suggest.

In the near term, however, a more likely application of Kumakhov lenses would be to enhance the performance of existing x-ray instruments. For example, fitting a standard laboratory x-ray source with one of the lenses should enable scientists to gather data that they might otherwise harvest only with synchrotrons, a type of accelerator that produces the most intense x-ray beams currently obtainable. That could spell the welcome end to months of long waits for synchrotron time that never seems adequate for the job at hand, Hayes notes.

The most intriguing possibility for many investigators familiar with the technology is its potential as a tool for x-ray lithography, a patterning method capable of stencilling integrated circuitry about 10 times more densely than today's more conventional lithography, which uses ultraviolet radiation.

Still, while the reported performance of the prototype lenses and the scientific and industrial potential they seem to hold have tantalized a lot of people, there has been an admixture of skepticism as well.

"There's nothing wrong with the principles," says Eberhard Spiller, an x-ray optics specialist at the IBM Thomas J. Watson Research Center. But like others intrigued by the prototype lenses, Spiller questions whether they can be assembled with precision, particularly for the stringent requirements of X-ray lithography. The lenses comprise from several thousand to several million carefully aligned glass capillaries. Adds Jerome Hastings of National Synchrotron Light Source at Brookhaven National Laboratory: "You can have a nice idea, but if you can't execute it, it remains a nice idea."

And then there are those who have become concerned not so much by the soundness of the basic science as by the selling of that science. Some researchers, such as Denis McWhan, chairman of the National Synchrotron Light Source, have been put off by the door-knocking tactics of Gibson and Kumakhov and the scarcity of published experiments using the lenses. "He [Walter Gibson] came down with his son. That put me off a little bit," he says. But that didn't prevent McWhan from saying, "It would be fun to try one of these lenses."

Gibson defends the meetings as providing a valid means for peer review and a forum for identifying potential applications for the lenses, which he says can be tailor-made for specific uses. And they are proving effective in whipping up interest. Researchers consistently express a desire to get hold of prototype Kumakhov lenses, direct some X-rays through them, and see if the technology can deliver as much as the pitch promises. For Gibson and Kumakhov that means getting lenses out to the trenches. Gibson cautions that it will take some time to do this.

The machinery to realize this goal has been set in motion, however. Last year, soon after Kumakhov contacted Gibson and suggested forming a collaboration to develop, market, and manufacture Kumakhov lenses, Gibson founded a company called X-ray Optical Systems, Inc. His son David, who is president of the company, says they expect to offer high-end lenses custom made for synchrotrons as well as "mass-produced" versions that might add on to standard X-ray sources. It's too early to put an exact cost on the lenses, but David Gibson speculates that they could run about $20,000 to $100,000.

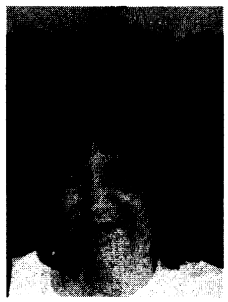
Gibson has put his hard-earned scientific reputation behind the success of the new technology and X-ray Optical Systems. And his son David, who has three degrees from MIT, including one in business management, may have gone even further, leaving a high-paying position at McKinsey & Co, a top-notch management consulting firm, to become the company president. "I put my career, and the financial security of my five children and my wife on the line for this technology," he says. ■ IVAN AMATO

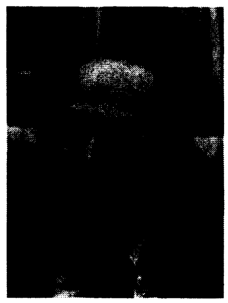
How the Nose Knows: Olfactory Receptor Cloned

The abundant variety of receptors has powerful implications for the brain's processing of smells

HERE'S A BRAIN TEASER THAT HAS PUZZLED neuroscientists for decades: How does the mammalian nervous system distinguish among 10,000 different odor molecules?

To most investigators it didn't seem possible that the nose could have a specific receptor for each odor. Indeed, many neuroscientists thought the likeliest solution was that there are a mere handful of receptor types, each detecting a wide range of odors; the specific pattern of receptors responding to any one smell would then produce a signature that the brain could decode. But what was needed to settle the question was the receptor molecule itself and, despite years of looking, no one had been able to identify the receptors. Now that seems to have changed.





Olfaction faction. *Linda Buck and Richard Axel.*

In a report in the current issue of *Cell,* Linda Buck and Richard Axel of the Howard Hughes Medical Institute of Columbia University describe a family of genes that seem to code for the long-sought odor-receptor proteins. One surprise is that the family appears to be huge—including many more receptors than most researchers would have predicted, raising the possibility that much of the discrimination between odors is done at the level of the receptor and not in the brain. And one of the beauties of Buck and Axel's work is that it provides the tools needed to find out whether that hypothesis is correct.

Most olfaction researchers agree that smells are detected when "odorants" (small, volatile, lipid-soluble molecules) bind to receptor proteins on the surface of nerve cells in the nose's olfactory epithelium, triggering electrical signals to the brain. Beyond that general agreement, however, lie some tough questions: How many types of receptors are there? And how is the job of discriminating between odors apportioned between the sensory cells and the brain? The fewer the receptors, the more complex the decoding job that would fall to the brain.

If, for example, there were a receptor type for each odorant, and each olfactory neuron had just one type of receptor "then [the brain] would simply have to ask which cells respond [to a particular smell]," says olfaction researcher Randall Reed of Johns Hopkins University. Alternatively, he says, the brain could discriminate among 10,000 odors using just 10 receptors, but "you would have this very diffuse signal, which you would have to process [in the brain] at a very sophisticated level."

What the brain actually does, however, needn't correspond to either of these extreme scenarios. An in-between view that has been held for some time by Yale neurobiologist Gordon Shepherd and others holds that the signal is not diffuse, but follows "labeled lines," corresponding to different components of a smell, making the signal easier for the brain to decode. This hypothesis proposes that sensory neurons having a particular receptor type all send their projections to the same place in the brain. In this view, the small and unique subset of receptors activated by any particular odor will produce a characteristic "fingerprint" of neuronal activity in the brain.

For many years it has been impossible to declare either the labeled-line or the diffuse-signal hypothesis a winner, because while there are data that could be taken to support each hypothesis, many questions could not be addressed directly without the receptors in hand. But efforts to identify the receptors were foiled—apparently because of the scarcity of the receptor proteins in the sensory epithelium and the difficulty of working with the lipid-soluble odorants they recognize.

In the early 1980s, neuroscientist Solomon Snyder and his co-workers at Johns Hopkins tried a strategy that had been used to purify receptors for a variety of neurotransmitters. They mixed radioactively labeled odorants with proteins from olfactory epithelium and