available for studying various materials in the laboratory, Kumakhov and his co-workers fabricated a lens suitable for the purpose.

"It was made by the Russians to our specifications," Hayes says.

Brought to the United States by Vladimir E. Kovantsev, who worked with the RPI group for two months, the lens consists of 919 glass fibers packed together to form a bundle with a hexagonal cross section. Made from a specially formulated borosilicate glass containing traces of sodium, potassium and aluminum, each fiber contains 547 channels, 14 microns wide, with exceedingly smooth inner walls.

"The smoothness of the glass is the critical thing, and that depends on the composition," Hayes says.

Hayes expects that improvements in the alignment and positioning of the glass fibers alone could increase the intensity of a collimated X-ray beam by an additional factor of six. The availability of such intensities would greatly expand the types of materials studies that researchers could undertake without having to go to special facilities. *— I. Peterson*

In this 6-inch-long, custom-fabricated Kumakhov collimator, diverging X-rays enter the narrow end of the hexagonal fiber bundle. Microscopic channels within each fiber guide X-rays so that they emerge from the bundle's wide end as a parallel beam about 1 inch across.

Dzaman/RPI

Etching technique lights up porous silicon three ways

With its three dimensions, a hologram packs much more information onto a flat surface than a typical photo. Holographic data storage could thus lead to denser computer memories. Chemists have now taken a step in that direction by using light-emitting silicon as the holographic surface.

Four months ago, as part of a flurry of research aimed at understanding and harnessing photoluminescence in acid-etched silicon, scientists demonstrated they could use light to control the degree of etching and, consequently, the character of the resulting porous silicon (SN: 2/15/92, p.103).

That control has enabled them to reproduce images on silicon wafers, from self-portraits to a picture of Elvis Presley.

Now those scientists, working at the University of California, San Diego, have etched porous silicon so finely that the wafers reflect light in a rainbow of colors. The precision may lead to porous silicon layers thin enough to steer light through a computer chip, Michael J. Sailor and Vincent V. Doan report in the June 26 SCIENCE. The technique also lets scientists create diffraction gratings, "so you can use this silicon surface to make a hologram," says Sailor.

Sailor likens the silicon surface to a decorated T-shirt. Nowadays, designers can reproduce a simple image, a 3-D picture or a fluorescing design on the cotton cloth. The same is true of silicon, "except it all happens simultaneously," Sailor says.

The luminescent colors arise because of the photoluminescing property of porous silicon. During etching, the San Diego chemists project a black-and-white slide — in the case of these photos, George Washington's face from a dollar bill — onto the silicon wafer through a lens that reduces the size of the image. Variations in the projected light's intensity lead to different etch rates and, as a result, to variations in the light later emitted by the silicon.

The human eye barely perceives the difference between the cherry and orange reds in the silicon's glow. But that glow's wavelengths actually reproduce the gray scale of the dollar bill image, Sailor says.

"That's a pretty novel approach," comments Terry Guilinger, a chemical engineer at Sandia National Laboratories in Albuquerque, N.M. Guilinger's group has worked to make patterns in porous silicon using ion beams.

In daylight, Doan and Sailor's etched silicon wafer becomes much more colorful. But unlike a T-shirt decorated with paint or dye, the wafer uses optical magic to create its rainbow of colors. "There is no pigment; it's just the way [the silicon layer] interferes with the light," says Sailor.

Doan and Sailor say their etching process differs from that of most other researchers. They use a smaller current and slowly make the silicon porous in a controlled fashion. The process takes about half an hour.

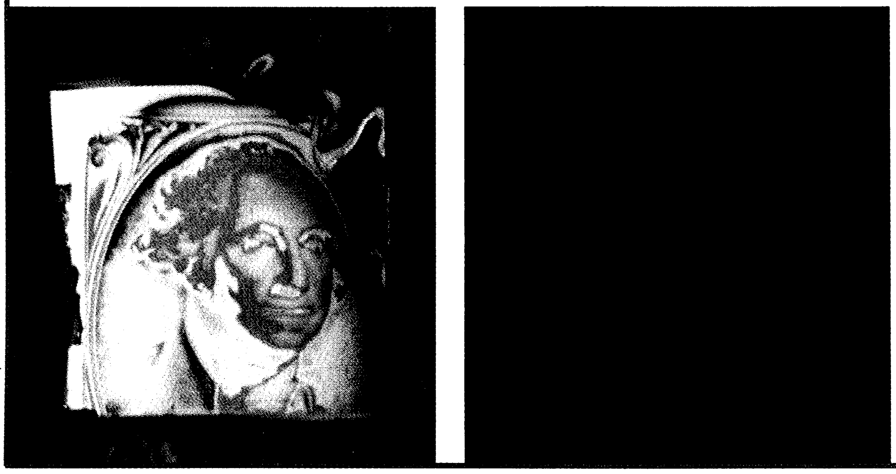
As a result, "the porous silicon is not so grainy that it causes light to scatter," Sailor explains. "You can constructively and destructively interfere with light on this film."

Thus, just as clear, colorless oil will spread to make a multicolor sheen on wet pavement, so will the porous silicon make a false-color image. Etched to one thickness, the porous silicon cancels all but green light. In other parts of the image, layers of different thicknesses impart a blue, yellow or purple hue.

Doan and Sailor also discovered that the etching recreated the fine lines used as shading in the dollar bill. When they shine a laser light on one spot on these fine lines, that one spot "splits" and reflects back as a characteristic pattern of spots, indicating that the grid of lines acts as a prism. "We see light diffracting off that grid," says Sailor. "That's the same thing as storing a holographic image."

In this way, a single technique leads to three ways of storing information on porous silicon. *— E. Pennisi*

Image of dollar reproduced on a 1-centimeter-square piece of porous silicon, seen in daylight (left) and luminescing under ultraviolet light.



Doan & Sailor/SCIENCE