How to Make an Unforgeable Document

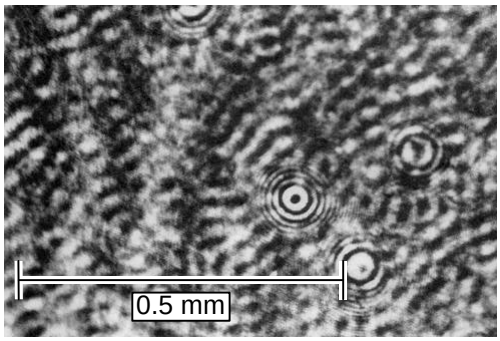
by F. Edward Boas

Modern counterfeiters now have color copiers, laser printers, and scanners at their disposal. Fortunately, there are still many things these devices just can't reproduce.

The title is, of course, an exaggeration. Any document can be forged: if you can print it, a sufficiently dedicated counterfeiter will find a way to do the same. The trick is to stay a step ahead of the game with specialized and high-tech equipment. For instance, the U.S. Treasury is currently redesigning all denominations of paper money to counter the threat of improved color copiers, printers, and scanners. This major redesign of U.S. currency, the first since 1929, will take place in stages, with a new $50 bill issued last October, and a new $20 bill to be issued later this year.

This is a visual tour of the features that make U.S. currency, as well as other secure documents such as checks, academic transcripts, and ID cards, so hard to copy.

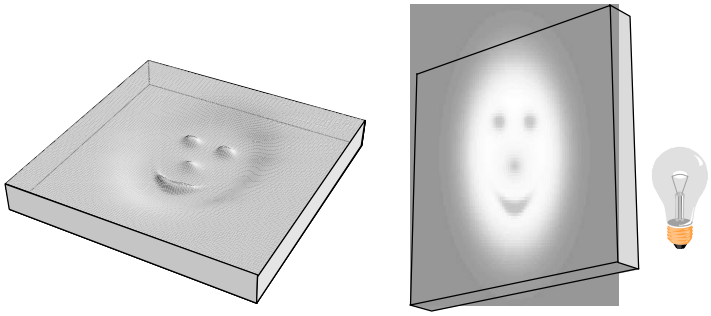
Holograms



Ronald R. Erickson and Museum of Holography

The patterns in the above hologram, shown under high magnification, reflect light in specific directions to recreate a three-dimensional waveform. Holograms, which commonly appear on credit cards and ID cards, are hard to reproduce partly because of their high resolution.

Watermarks



A watermark involves local variations in paper thickness or density (left) that produce a visible design when the paper is illuminated from behind (right). The thickness of the paper is exaggerated in the above figures for clarity. New U.S. hundred and fifty dollar bills contain watermark images of Franklin and Grant, respectively.

Did you know that:

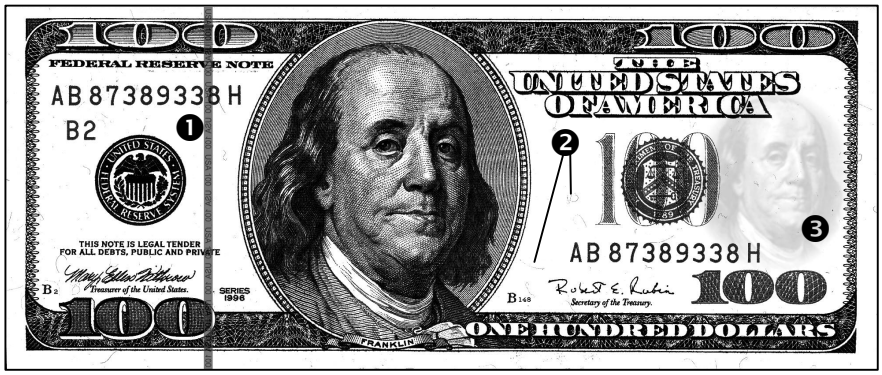
- ★ Half a percent of U.S. paper money is counterfeit.
- ★ During the Gulf War, the U.S. government airdropped counterfeit dinar notes over Iraq to destabilize their economy.
- ★ The U.S. Treasury's most effective weapon against counterfeiters is law enforcement: over 90% of counterfeit bills are intercepted before they enter the circulation.

Paper

Currency provides the best examples of security features embedded directly into paper.

❶ **Security thread**: This polyester strip glows red under UV light. It contains the words "USA 100" that can only be seen with transmitted light. Not only is the thread hard to copy, it also prevents counterfeiters from bleaching lower denomination bills to print higher ones.

❷ **Red & blue fibers**: These are randomly embedded in the paper.

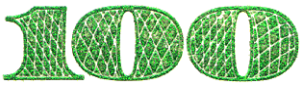


❸ **Watermark**

High quality paper: The distinctive cotton-and-linen paper used in paper money can be detected chemically, with several companies selling pens than write on counterfeit bills, but don't leave a mark on real ones.

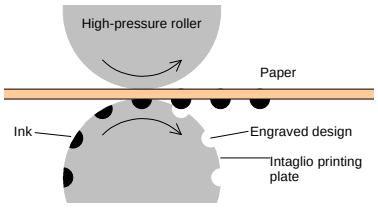
Many checks and transcripts are also printed on special paper that, for example, stains when someone tries to bleach off the ink.

Color-shifting ink



The ink used to print the denomination on U.S. 100 and 50 dollar bills looks green when viewed directly and black when viewed at an angle. This sort of color-shifting ink contains microscopic filters made of a reflective surface coated with multiple layers of thin films.

Angle- and wavelength-dependent destructive and constructive interference in these filters causes the color shift, similar to how the thin film of a soap bubble or oil slick creates colorful patterns that change with the view point.



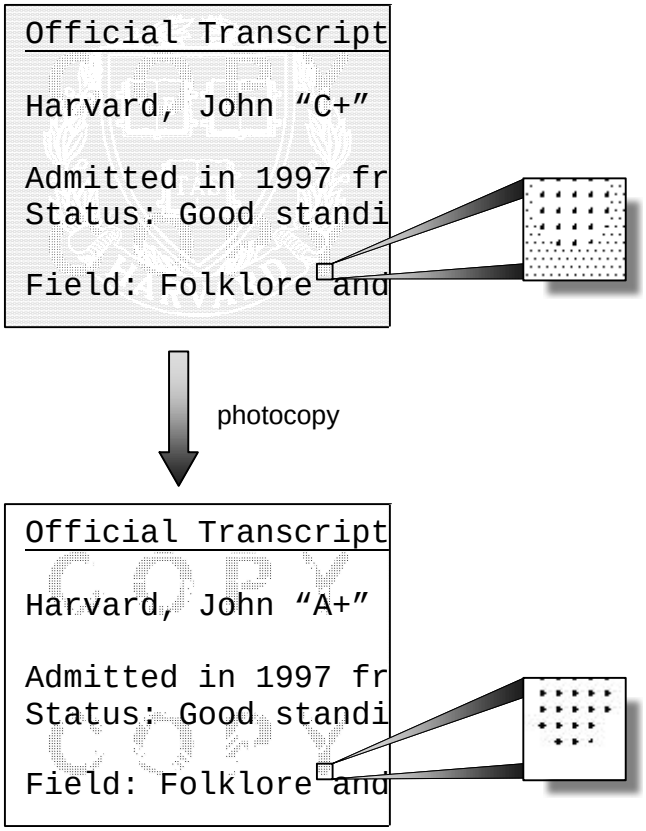
Intaglio printing

This specialized technique embosses the finely detailed drawings on paper money and some stamps. The printing process starts with an image engraved into a metal plate. The engraved grooves are then filled with ink, which is transferred onto paper under pressures as high as 15,000 psi. In contrast, most other printing methods use lower pressures and a raised printing surface.

Modern laser printers typically have a resolution of 600 dpi, and top-of-the-line printing equipment can achieve around 2400 dpi. The intaglio plates used to print paper money have an even higher resolution since they are hand-engraved drawings rather than electronically generated bitmap images. Yet, beyond a certain point, further increases in resolution produce details that are too small to see at a quick glance. For example, compare text printed at

300 dpi 600 dpi 1200 dpi

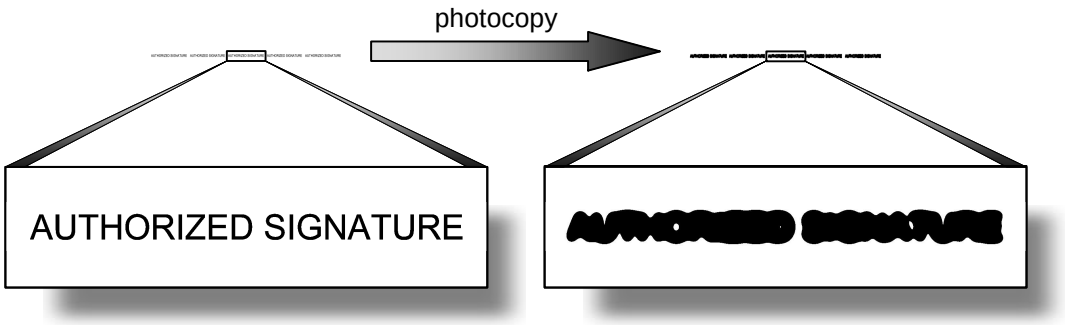
The 600 dpi and 1200 dpi text are virtually indistinguishable. However, for the specially designed images shown on this page and the next, small decreases in resolution produce a clearly visible effect, posing a problem for counterfeiters with lower quality equipment.



Dithering patterns

Photographs and dye-sublimation printers can reproduce a wide range of colors directly. Most printers, however, can only directly produce a small set of colors (black, cyan, magenta, and yellow for the typical color printer), and simulate other colors and shades of gray by combining the primary colors in a so-called dithering pattern comprised of small dots.

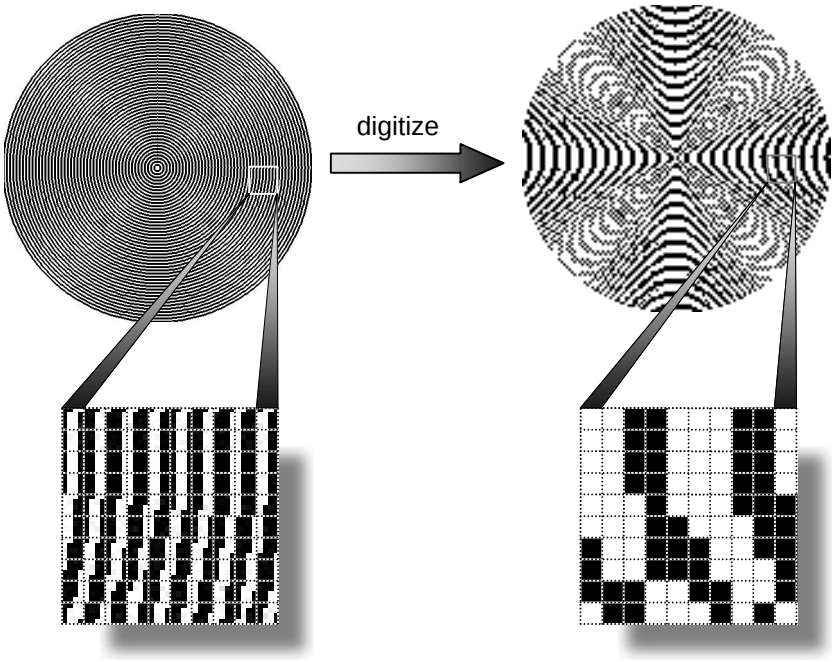
In the sample transcript shown to the right, two different dithering patterns make up the seemingly uniform 1/16 gray background. A photocopier can faithfully reproduce the dithering pattern comprised of large dots, but the dots in the other pattern are too small and thus get "washed out" in the copy.

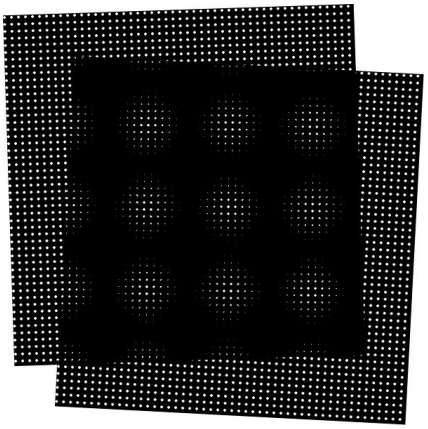


Microprint

Many checks and U.S. currency contain small lettering just barely visible to the naked eye. Such microprint challenges the resolution of many scanners and printers, and becomes blurred when photocopied.

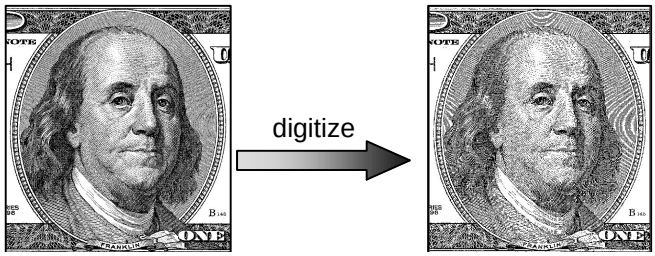
Moiré patterns





The two metal grids above are slightly misaligned, creating alternating areas of light and dark in the region of overlap. Overlapping sheets of fabric or window screens often produce a similar wavy effect, called a moiré pattern.

Digitizing (i.e. scanning into a computer) an image containing closely spaced lines or circles sometimes also produces an interference pattern. If the resolution of the scanner conflicts with the spacing of the lines, then the resulting image will look noticeably different. In the example shown above, the two magnified regions explain what's going on. Notice that each small square in the digitized image takes on the predominant color of the corresponding square in the original image.



The new U.S. 100 and 50 dollar bills exploit the difficulties in reproducing closely spaced circles: the bills have circles in the backgrounds of pictures on both sides.

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References

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Schafrik, Robert E. and Sara E. Church. "Protecting the Greenback." *Scientific American*. July 1995.