Innovative disc camera clicks for Kodak

American challenger for international markets uses advanced optics, ICs for 'decision-free' photography

At a time when American industry is being pummelled by offshore competition, one new product that has been refreshing to the national spirit is Eastman Kodak Co.'s new disc camera.

Introduced last May, the disc camera is so portable that it fits into a man's shirt pocket. It is built around a unique rotating disc of film that holds 15 exposures and produces a higher yield of good pictures than ever before possible with a fixed focus camera.

But what is most amazing is that operation of the disc camera is essentially "decision free." By means of two integrated electronic circuits, the camera analyzes the scene, sets the proper exposure, actuates the built-in flash if necessary, takes the picture, advances the film to the next frame and recharges the flash—all in less than 1.3 seconds.

The camera doesn't use batteries, but instead is powered by a new lithium cell that is warranteed for the life of the camera. It also features a four-element, all-glass lens that approaches the "theoretical limits of perfection."

Initial sales of the cameras and film are running ahead of Kodak's estimates, and the system appears well on its way toward becoming one of the most successful products in the company's history.

How has Kodak managed to pull off this feat? Part of the answer is a research and development budget that amounts to more than $2 million per working day—an expenditure that has established a fertile breeding ground for state of the art technology.

The disc concept was conceived in the mid-1970s, when Kodak engineers were searching for ways to improve the results of 110 cameras and film and achieve even greater portability.

"Historically, our film format had been shrinking as our technology produced sharper, finer-grained film," said Jim Dierks, Kodak's corporate coordinator for the project.

"By the time we introduced the 110 format in 1972, it became clear that to go down to the next increment—an even more compact system—we would have to come up with something other than traditional roll film," he added. The standard that Kodak designers set for themselves was a camera that would fit easily into a pocket or woman's evening bag. That meant it not only had to be small, but thin and lightweight as well.

DISC ARRAY: The three new Kodak disc cameras range in list price from $67.95 to $142.95 for an outfit that includes two discs of films. The cameras are powered by new lithium cells.

THREE CHALLENGES

Arranging the tiny image frames on a flat, rotating disc of film would allow room in the camera for all of the sophisticated microelectronics required for "decision-free" photography, but several basic questions would have to be answered:

1) Could Kodak develop a film that would allow an 8 × 10 mm negative to be enlarged to today's traditional print sizes and still achieve a high degree of image sharpness? And could such a high-performance film be manufactured in volume beyond the research level?

2) Could Kodak design and manufacture a large-aperture, short-focal-length lens—"a nearly perfect lens"—that would be needed to gain both the speed and depth of field required for a fully capable fixed-focus camera?

3) Could Kodak produce a line of photofinishing equipment that would allow both low- and high-volume independent labs to process the new disc film economically?

The answer to these and other tough questions along the way was "yes," but the row was not an easy one to hoe.

Once a feasibility study was completed and Kodak determined that the disc format was viable, an implementation team was appointed. It included specialists in fields ranging from electronics to emulsions. Coordinators represented research, design, testing, manufacturing, service, distribution and domestic and international marketing divisions. As project coordinator, Dierks assumed overall system responsibility.

"In essence, management put us in a small lifeboat and shoved us off from the big corporate ship," Dierks said. "People in a lifeboat, who know they will sink or float together, soon realize their individual backgrounds don't matter. Similarly, as team members, we quickly saw that our success would depend upon cooperation and negotiation. The divisions we were tied to by dotted lines on organizational charts weren't an overriding concern."

Key decisions were based on satisfying overall system goals and consumer demands. For example, market needs dictated sandwiching as many negatives as possible on each disc film to increase system convenience for both photographers and photofinishers.

"But there were only three ways we could boost the number of negatives the disc format would hold: decrease image size, increase disc size or squeeze the negatives closer together," according to Dierks.

Each alternative quickly ran into technology constraints which, if not overcome, could have affected such important attributes as picture quality, manufacturing cost, camera size, operating reliability and photofinishing performance.

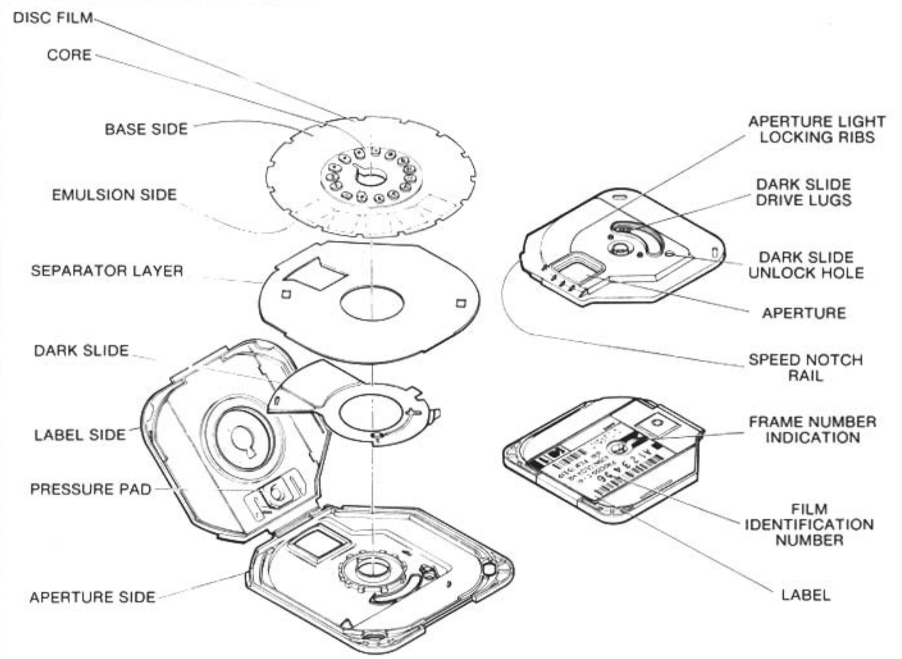
"Balancing the technology demands

among us for an optimum solution involved tough and complex negotiation supported by sophisticated math modeling and computer analysis, but we emerged with a better product. In finding the optimum system solution, though, we created some real headaches for our designers. Camera, disc and photofinishing equipment designers had to return to their drawing boards to find more precise ways to preflash film borders, meter film in the camera and position film in printers," he noted.

"This is just one example of the technological balancing act our team performed to manage this project."

One area that emerged as a special challenge was the design and manufacture of the camera's four-element, all glass f/2.8 lens. "Designing a nearly perfect lens is one thing," said William H. Price, manager of optical engineering at Kodak Apparatus Division. "Maintaining critical quality standards in a high-volume manufacturing environment is another. The lens went through about a dozen design modifications before we found the right combination to maximize manufacturability without jeopardizing quality.

"To make such a lens affordable," Price continued "we are using very sophisticated, automated manufacturing processes. This enables us to hold manufacturing tolerances for lens element curvature to plus or minus a few fractions of a wavelength of light. Considering that a wavelength of light measures about 20 millionths of an inch, that's quite an accomplishment. Our tolerances are even tighter for lens specularity, which affects light scatter." (Specularity is a measure of the amount or lack of polish on a lens. Kodak is able to maintain the microroughness of lens surfaces to within a few Angstroms.)



INSIDE THE DISC: This exploded view shows components of a disc enclosure and Kodacolor HR disc film.

FOUR-ELEMENT LENS

The focal length of the lens, 12.5 mm, describes the distance from its internal optical center to the focal plane for an infinitely distant object, but the total lens assembly measures just 15 mm from the front of the first element to the film plane. Such compactness, however, has not detracted from the lens' ability to cover a 58-degree field of view.

The four elements of the lens are made of three different types of glass chosen for both optical properties and physical or manufacturing properties. The first three are assembled in a "triplet" design, and the fourth is positioned at the rear of the lens near the focal plane to project the image across the disc negative.

The fourth element helps create a flat image surface with very little astigmatism and helps minimize the overall distance from the front vertex to focal plane.

The lead role in this ensemble, however, belongs to the second element. Unlike most lens elements, which feature special surfaces, this glass element has an aspheric face. Its primary function is to correct spherical aberration, one of several varieties of common optical errors that must be overcome in a high-quality-lens system. It occurs when sections of a spherical lens fail to bring parallel light rays to a single focus.

"We could have designed a lens of equal quality without an aspheric element," Price said. "But to obtain the required sharpness, we would have had to either use more elements and make the lens bigger or sacrifice the desired f/2.8 aperture.

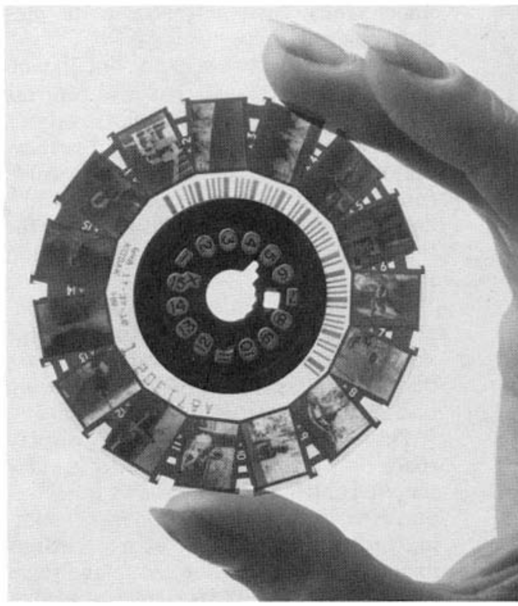
"For example, without an asphere, a lens designer could build a lens with the same number of elements that would yield a good image at an f/5.6 or an f/8 aperture. But since our system requirements dictated an f/2.8 lens, we had to do more. With the aspheric element, we obtained the desired quality at this aperture with the fewest number of elements in the least amount of space. The approach also proved to be cost-efficient."

Film chemistry, like lens design, was also a special challenge. Dr. Dave Nelander, who coordinated the Kodak Research Laboratories' efforts on disc film, said, "We never before had been asked to make such a huge improvement in one film."

"It's not unusual to be faced with a request for a faster film with the same grain and sharpness characteristics as its predecessor or even a finer grain film which provides the same speed as its forerunner. But here we were being asked to pull out all the stops to obtain simultaneous improvements in speed, grain and sharpness."

Nelander explained the problem confronting researchers in terms of a film-image-quality triangle. Speed, grain and sharpness form the triangle's sides. The overall quality of the film can be interpreted as the area within that triangle. Without technological breakthroughs, any one side of the triangle can be altered only at the expense of one or both of the other sides.

Since improving film sharpness without



HEART OF THE DISC: Small camera size was made possible by use of this 15-exposure disc negative (shown actual size).

affecting grain and/or speed appeared to be the toughest demand, the researchers first concentrated on identifying every factor that could conceivably affect sharpness. From the resulting list, the researchers zeroed in on emulsion thickness as the primary target of opportunity.

"The thinner the film emulsion layers, potentially, the sharper the film," Nelander said. "In film emulsions, silver halide crystals and other ingredients are suspended in gelatin and form a turbid medium. Like all translucent materials, emulsions scatter light. So, the farther the bottom recording layers are from the top surface, the farther the scattered light has spread before it reaches them. Thus, the resulting image is fuzzier or less sharp. Reducing the thickness of emulsion layers minimized light scatter and improved sharpness."

Another key contribution was made by Kodak's Physics Division, which invented the unique Coanda cooling device used on the new photo-finishing printers to keep the tiny negatives cool during printing. The amount of light which must be pumped through an 8 × 10 mm negative to expose a print is sufficient to possibly damage a negative this small. The device uses a cooling ribbon of air that reaches the surface of the film when needed, yet doesn't move or disturb the negative, which would affect sharpness. Without this invention, the printers would have had to use less light and work at a slower pace, which would have adversely affected photofinishing productivity.

Fifteen thousand people were involved in the project and many resources were allocated toward its success, Dierks said. "When I look back on the project and recognize the major introduction we brought to amateur photography, I can't think of too many parallel examples in industry anywhere in the world.

"It might be considered the equivalent of a major auto manufacturer coming up with a new car with a new engine that runs on some radically new fuel and then implementing it worldwide with new kinds of distribution systems and filling stations," he added.

"So often we see a company introduce a significant technological breakthrough but fail to get it into production or fail to market it properly on a large scale, like a newborn colt that can't raise its front and and hind legs up at the same time. What we've accomplished is something that we are very proud of," Dierks concluded.

—Robert C. McEwen

Disc technology eyed for advanced video display

More than 8 million Kodak disc cameras were due to be shipped to customers worldwide by the end of 1982, according to Kodak chairman Walter A. Fallon. Fallon called the disc camera, based on orders to date, "the most popular consumer camera ever introduced by Kodak."

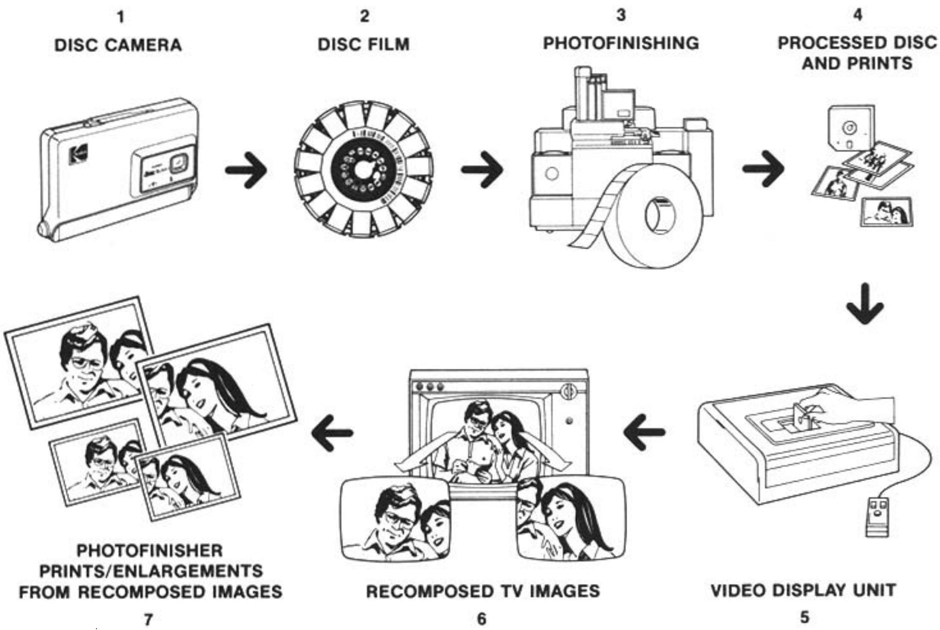
Since the concept of the Instamatic camera was announced in 1963, more than 150 million cartridge-loading cameras have been shipped by Kodak. The popular Kodak disc cameras, first shipped to dealers last May, can capture pictures in 98 percent of photographic space compared with 70 percent captured by simple cartridge-loading cameras. Photographic space is based upon Kodak studies of the typical conditions of light and distance under which customers attempt to produced photographs.

Fallon told a camera exposition in Cologne, West Germany, that disc cameras will become even more popular as related technology extends the range of display options available to users. A possible future option was demonstrated by Kodak in Cologne: a video display unit for the transfer of disc images to television screens.

In the demonstration of advanced technology, an operator scanned a 15-image disc negative and selected various images that were enlarged or cropped for viewing on a 21-inch TV screen.

This "personal control" of display space on the TV screen is possible via a remote-control unit that allows quick sequencing through 15 disc images, zooming in for a closer look at a particular image, and recomposing the image for a better view of one of its elements. Kodak scientists said such a system could enable consumers to order prints of these enlarged or cropped images from photofinishers.

KODAK VIDEO DISPLAY TECHNOLOGY



SUPER DISC: Steps in new Kodak video display technology are (1) Kodak disc camera takes lt pictures and exposed film (2) is sent to photofinisher (3) to be returned (4) with prints in protective package. The encased disc of color negatives are inserted into video display unit (5) and viewer sees color-corrected enhanced image on TV screen (6). Through encoding on core of disc, user could order more recomposed prints (7) from photofinisher.

The heart of the prototype system is an extremely high resolution solid-state imaging sensor designed and fabricated by the Kodak Research Laboratories. The sensor converts and enhances the optical image for electronic display on a TV screen. The sensor, a charge-coupled device (CCD), yields a color picture with more than 350,000 image elements, and produces and extremely detailed TV picture from each disc frame or portion thereof. The bandwidth of the luminance signal (which provides the important brightness information) is greater than 3.5 megahertz, exceeding the capabilities of most commercial TV receivers. In simpler terms, the sharpness of the image delivered to the TV is greater than can be displayed on home sets.

Fallon said the video display unit is currently in an exploratory stage, noting that Kodak has not committed itself to the manufacture or sale of such a product.