# Silver Halide Print Media for Direct Digital Writing

*Jack Rieger*
*Eastman Kodak Company*
*Rochester, New York USA*

## Abstract

Traditionally, the word ‘digital’ is not used in combination with the words ‘silver halide’. If it is digital, prevailing wisdom assumes that it is not silver halide, and vice-versa. This assumption is now faulty, for excellent results in digital imaging can be obtained with silver halide capture and output. This talk will discuss the technology of digital silver halide output.

Eastman Kodak Company has been interested in direct digital exposure onto silver halide media for many years. In the last few years, consumer and professional photographic laboratories have begun to realize the advantages of direct digital writing onto color photographic paper. We have now introduced multiple generations of digital silver halide paper and digital silver halide display film. These formulations have been optimized for digital exposure, and have given us information about some of the unique requirements for silver halide media when exposed in digital printers. Our latest product offering gives our customers the highest level of quality and the broadest range of digital performance for a silver halide media.

Direct digital writing to silver halide print materials offers the advantages of digital while maintaining the image quality, cost, and productivity advantages of traditional photographic output. We believe that this area will allow our customers to offer new products and services that were not previously available, which will further enhance their business.

Now, the term ‘digital’ does not leave silver halide technology behind. It embraces silver halide, offering another hardcopy output choice to the digital lab.

## Introduction

### Digital vs. Silver Halide

Digital imaging is the technology in the spotlight today, for many reasons. Its strengths include instant soft display at point of capture, image quality optimization, image customization, electronic communication, and no messy photochemicals. Silver halide technology is the imaging media of choice when high quality is needed at an economical price point.

When capture and hardcopy are considered, two groupings usually emerge: digital and silver halide. ‘Digital capture’ usually assumes a camera containing a solid state image sensor, while ‘silver halide capture’ assumes a conventional camera containing film. ‘Digital hardcopy’ usually refers to inkjet, thermal, and electrophotographic technologies, while ‘silver halide hardcopy’ usually refers to analog optical printing using conventional enlargers or printers.

### Strength of Silver Halide

The term ‘digital’ should not exclude silver halide technology. ‘Silver halide’ can be a subset of the ‘Digital’ category. The strength of silver halide in image capture is its ability to record high resolution at low cost, and its archival optical storage capacity. For digital output, there is room in the industry for multiple technologies. Each of these has its own strengths and weaknesses. The strength of silver halide in digital hardcopy is its continuous tone quality, high imaging speed, and low media cost. This talk will discuss the technology of digital silver halide output.

## History

### Early Adopters

Eastman Kodak Company has been interested in direct digital exposure onto silver halide media for many years. Early adopters include the graphics industry where digital separations are generated using laser exposed silver halide media. Professional laboratories use small format digital imaging to create reversal film for direct viewing or negative film for use in the traditional optical printing process.

Commercially available silver halide print exposing engines have been available for many years. Early engines were based on CRT technology, producing low-resolution index prints or digital images $8 \times 10$ and smaller. These printers relied on using optical papers, as there were no digital papers available at the time. Since pixel exposure times are within the range of high-speed printing, no adverse problems with sensitometric response were observed.

### Explosion of Print Engines and Media

In the 90s many other exposing light sources were introduced in these digital silver halide printers. These include tungsten, laser, and LED. These sources varied dramatically in their total light output, spectral light output, and pixel exposure time. Also, the various printer designs featured customized pixel overlap, number of exposures per pixel, time between exposures per pixel, exposure uniformity across the printing surface, media transport technique and accuracy, pixel scanning technique and accuracy, etc. These unique characteristics set these printers apart from one another, but made media design problematic. Early digitally optimized silver halide products include KODAK PROFESSIONAL Digital Paper, Type 2933 and KODAK PROFESSIONAL Digital Paper, Type 2976. These products compensated for the changes made in these digital printers, and were quite successful in this emerging marketplace.

In the last few years, consumer and professional photographic laboratories have begun to realize the advantages of direct digital writing onto color photographic print media, both reflection and transmission materials. Reflection materials include not only paper, but also flex, a stiff white plastic material used for commercial displays and ID cards. An example of this is KODAK PROFESSIONAL DURAFLEX Digital Print Material. Transmission materials include Trans and Clear. These are used on a light box, and viewed with transmitted light. The Trans product has a built in white diffuser, so is used on a light box with a clear glass front. The Clear product does not incorporate any diffuser, so is used on a light box with a diffused front. Examples of these include KODAK PROFESSIONAL DURATRANS Digital Display Material and KODAK PROFESSIONAL DURACLEAR Digital Display Material.

## Digital Imaging of Silver Halide

Digital silver halide materials are exposed in a digital writer using photons of light of various intensities and colors determined from a digital file. The digital file could have a variety of origins, including scanned film and prints, computer graphics, and digital camera images.

After Raster Image Processing (RIP), the computer tells the printer how much red, green, and blue light to use to expose the media. Exposures are typically made one pixel at a time using laser, LED, CRT, or some other type of light source. With laser printers, red, green, and blue laser beams are typically combined into a single beam, then scanned across the media. In some printers, the media moves in the y direction while the scanning occurs in the x direction. In other printers, the media is held stationary while it is scanned in both directions.

The media must then be processed conventionally, converting non-visible latent image to a chromogenic print using photographic image dyes. For the media discussed here, Process RA-4 or one of the Process RA-4 derivatives is used.

Before an image can be printed, a calibration of the media on the printer must be completed. This process maps the developed density of the media to discrete power levels in the printer light source. Several iterations of expose/print/process/densitometer/calculate are often required to adjust power levels of the printer to fit a preset sensitometric aim.

## Design Considerations

The silver halide media in a digital system plays a different role than in a conventional analog imaging system. Some important design elements for these two systems are compared in the table below:

**Design Elements of Digital vs Conventional Media**

| **Attribute** | Conventional System | Digital System |
|---|---|---|
| **Tone Scale** | Determined by the media | Determined by software, within media/printer limits of minimum density and maximum density |
| **Color Repro-duction** | Determined by the media | Determined by software, within media/printer limits of color gamut |
| **Color Purity** | Determined by image dye of negative, spectral quality of printer illuminant, and media | Determined by spectral quality of printer illuminant and media design |
| **Sharpness** | Determined by the media and printer optics | Determined by software, printer, and media |
| **Text quality** | Typically added post process | Determined by software, printer resolution, and media design |

**Reciprocity**

Digital printing is characterized by a wide range of pixel exposure times. These exposures are typically high intensity and short duration, relative to optical exposures. A decade chart of exposure times for optical and digital silver halide papers is presented in Figure 1.

Optical papers at Eastman Kodak Company are optimized for optical exposure times, depending on the customer application. Digital papers for use in CRT, LED, and LASER devices are optimized for the relatively short duration exposure times. An emulsion’s response to light of varying duration is commonly referred to as the reciprocity response of the emulsion. Emulsions in Kodak’s optical papers have historically lost speed and gamma with digital exposure times. Figure 2 illustrates the sensitometric response of an optical media, KODAK EKTACOLOR Edge 7 Paper, to optical and laser exposure. This product exhibited significant density loss and irregular sensitometric response when exposed with a laser, but of course had excellent results with an optical exposure.

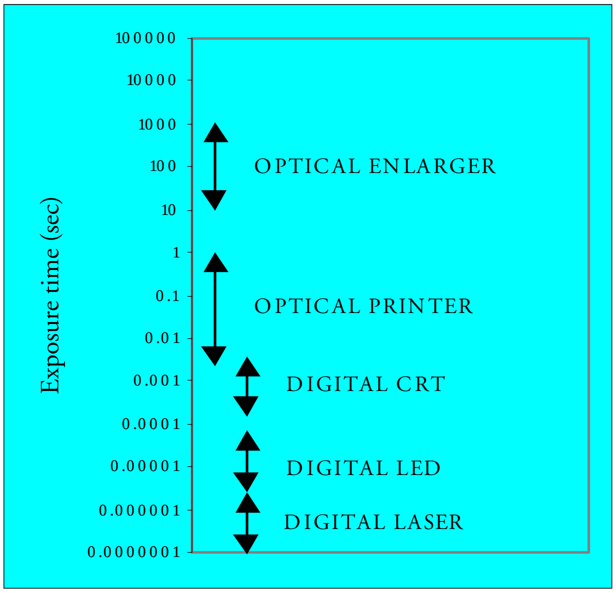


*Figure 1. Pixel exposure times for optical and digital silver halide printers*

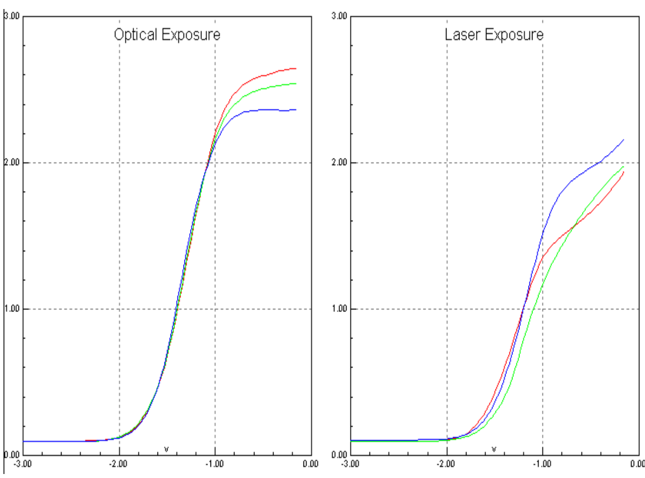


*Figure 2. Sensitometric response of KODAK EKTACOLOR Edge 7 Paper to an optical exposure (left) and a laser exposure (right)*

## Digitally Optimized Paper

The new KODAK PROFESSIONAL Digital III Color Paper is Kodak's third digitally optimized silver halide paper. It has superior density gamut in the widest range of digital devices on the market today, including but not limited to CRT, LED, and LASER light sources. Figure 3 illustrates the excellent sensitometric response of this paper. The optical exposure is a good proxy for a CRT printer, while the laser exposure is a good indication of LED and LASER printer response. This performance comes from improvements in the emulsion reciprocity. Note the absence of curve inflections and the higher densities achievable with this paper. Curve inflections can make calibration very difficult on a digital printer.

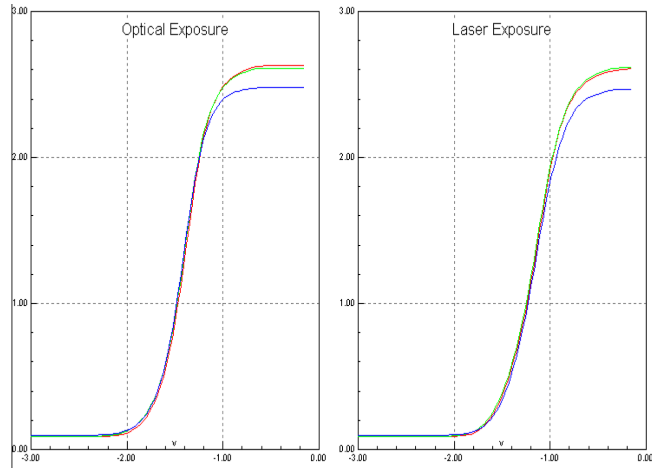


*Figure 3. Sensitometric response of KODAK PROFESSIONAL Digital III paper to an optical exposure (left) and a laser exposure (right)*

## Important Characteristics of Digital Media

There are many elements to consider when designing a silver halide media for digital exposures. Some important characteristics include:

- Density Range. The range between minimum density and maximum printing density defines the usable density gamut of the media.
- Log Exposure Range. The delta between the exposure needed to create a threshold image density and the exposure needed to create the maximum density delivered by the printer is a critical design parameter. As this exposure range is increased, higher text flare or fringing results. Fringing is an unintended exposure adjacent to areas of high exposure. This manifests itself as a blurring of the image, or fuzziness of text, particularly dark text on a light background or light test on a dark background. It is desired to match the exposure range of all three colored records, or colored fringing will result. The limiting layer at the requested maximum density will determine the color of the fringing. As exposure range is decreased, higher amplification of digital artifacts, such as banding, results. Thus, the optimum log exposure range is a balance between these two effects.
- Printing D-max. The maximum density delivered by the printer is set below the maximum density achievable by the paper. If Printing D-max is set too high on the low gamma portion of the shoulder of the sensitometric response, the log exposure range of the printer becomes too great and severe fringing may result.
- Printing D-max Speed. The log exposure needed to deliver printing D-max. Mid-scale optical speed is meaningless in a digital printer. If the printing D-max speed is beyond the power range of the printer, calibration will not be possible without a calibration aim adjustment. A media may be too fast or too slow for a printer, depending on what media the device was designed for.

- Spectral Sensitivity. The spectral overlap of the media sensitivity and the energy output of the printer is a key factor in determining system productivity and color gamut. A poor overlap will result in optical contamination of colors, where unwanted dye is created from unwanted exposure of the media. This will reduce color gamut. A poor overlap will also not take advantage of the total exposure output of the printer, resulting in productivity loss and may contribute to non-image flare. This flare is caused by extra light in the printer which is reflected out of the paper, and can cause an overall color cast on the developed print material.
- Chemical Crosstalk. This is a photoprocessing effect where unwanted image dye can be created from the unwanted diffusion of image dye forming development agent. Minimization of this diffusion is necessary to maintain maximum color gamut. This diffusion is the greatest at maximum density. A novel color contamination control layer is utilized in KODAK PROFESSIONAL Digital Paper, Type 2976 and in the new KODAK PROFESSIONAL Digital III Color Paper. This layer is effective at maintaining yellow dye purity at very high maximum density.
- Image Dye Purity. Most digital silver halide systems feature low optical color contamination. This leaves the image dye itself as a determining factor in color quality and gamut. Many printers provide a target for evaluating printer/paper performance, which contains code values representing pure cyan, magenta, and yellow colors at maximum density. Many customers now evaluate materials using these single signal colors, at the edge of the color gamut of the media. This is a severe test for the media, but is a good indication of the horsepower contained in the media/printer combination.

## Conclusion

Direct digital writing to silver halide print materials offers the advantages of digital while maintaining the image quality, cost, and productivity advantages of traditional photographic output. As a pioneer in commercializing digital silver halide media, Eastman Kodak Company has significant presence in commercial and portrait/social digital labs. The knowledge base in how to construct a digital silver halide product has grown through research, commercialization, and market experience. Digital imaging is here to stay, and the technology is rapidly changing. We believe that this area will allow our customers to offer new products and services that were not previously available, which will further enhance their business.

## References

1. John Bacilek, The Continuing Efforts of Eastman Kodak Company to Produce Direct Digital Output Silver Halide Color Media, IS&T Photofinishing Symposium, February 1998.

## Biography

Jack Rieger received his B.S. degree in Chemical Engineering from the University of Cincinnati in 1985. Since 1982 he has worked at Eastman Kodak Company in Rochester, NY. His work has primarily focused on silver halide film and paper products for consumer and professional applications. More recently, he has designed and developed several products in the field of digital silver halide hardcopy. He is a member of the IS&T.