GRAPHIC ART APPLICATIONS OF LASER THERMAL PRINTING

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Abstract: Kodak and other companies use Laser Thermal Printing (LTP) for digital color proofing, computer to plate preparation, and other graphic art applications with highest quality results. This paper addresses the questions a) why does LTP work so well? and b) what can we expect in the future? The LTP process consists of focusing the beam of a diode laser onto a coating containing an infra red absorber and either a dye or a thermally sensitive reagent. The infrared dye absorbs the diode laser beam and converts the energy to heat, which causes the dye to transfer, or a chemical reaction in the coating. LTP images have very high resolution because the laser spot can be focused almost to the diffraction limit. Edges are very sharp because the temperature drop at the edge of the beam is steep. An important factor in the application of LTP to graphic arts is that all the amplification is electronic and the results are therefore predictable, reliable and robust. These are essential qualities that will determine how far the printing industry can change from a skilled art and craft to an automated and standardized process.

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Introduction

Laser thermal phenomena were observed almost as soon as lasers were discovered. Early publications outlined most of the laser thermal products that are beginning to appear on the market today. Bruce and Jacobs (1977) printing dye images from coatings of crystal violet and methyl green in a nitrocellulose binder with a HeNe laser. Gibbs (1980) described laser thermal typesetting film at an SPIE meeting. The introduction of high powered laser diodes about 1988 has accelerated the pace of laser thermal printing products, and we are now in the midst of a number of new offerings.

Phototypesetting

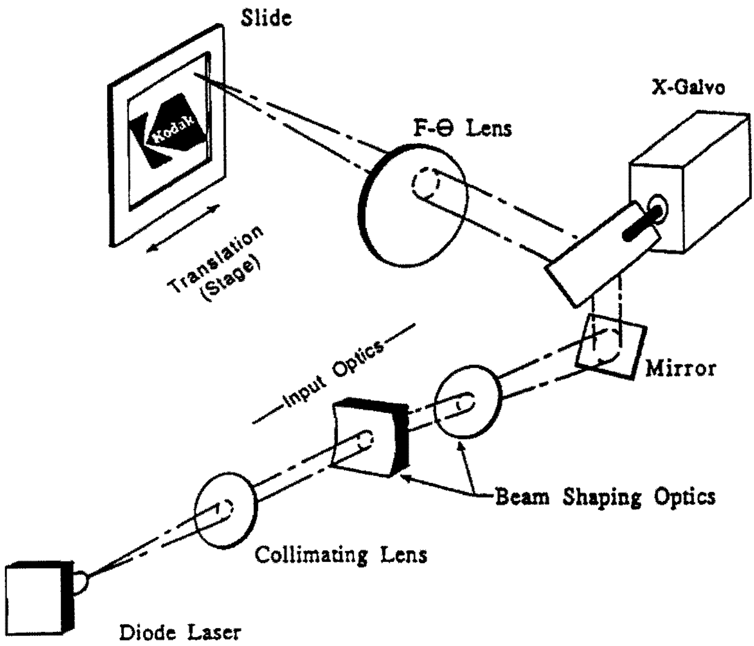
In the early 80's the first graphic arts product utilizing the laser thermal process appeared. This was Laser Mask film, coated at James River Graphics, and sold by Log-E-Tronics as a film for simultaneous dry imagesetting and proofing. The film consisted of a layer of finely divided graphite particles in a nitrocelluose binder on a polystyrene support. The film was written by scanning the film with a modulated YAG laser beam, focused through the base onto the graphite layer. The heat generated by the absorption of the laser beam caused the graphite particles to leave the support and transfer to a sheet of paper held in contact with the film. After writing, the paper provided a proof of the image, and the film was used to burn the printing plate. For many years this system has been used to print the New York Times. From the beginning the Laser Mask product was characterized by high sharpness, high accuracy and high power requirements for writing.

In digital graphic arts imaging, *accuracy* relates to the faithfulness of reproduction of the computer image by the film or plate. *Sharpness* is usually thought of as an edge phenomena, but sharpness and accuracy are related in a way, as the following micrographs illustrate:

LaserMask Original - 2.8 point type- Contact 2000 Dupe

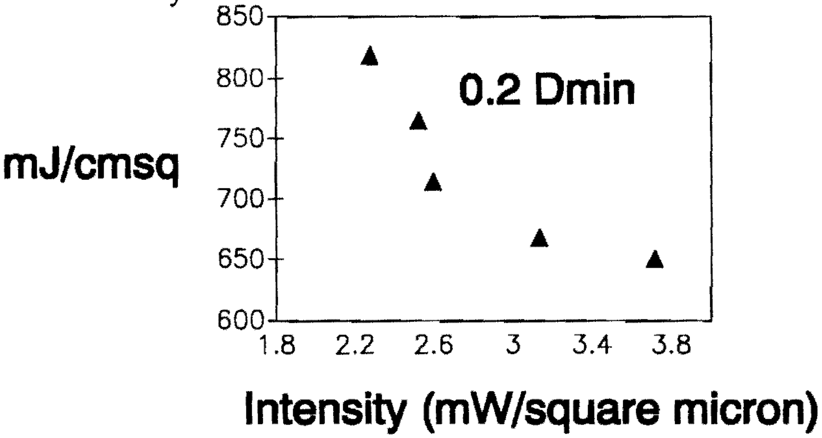
Many observers would argue that the silver halide dupe is "sharper" than the Laser Mask original because the edge is smoother. However, the "accuracy" of the Laser Mask in reproducing the pixels of the original computer image is higher, because the raster image by definition cannot have smooth edges. In that sense, the laser thermal image is sharper than the silver halide image. The edges are more square, and the thin parts of the image are not broadened.

The images shown above were written on a breadboard laser writer shown schematically below:



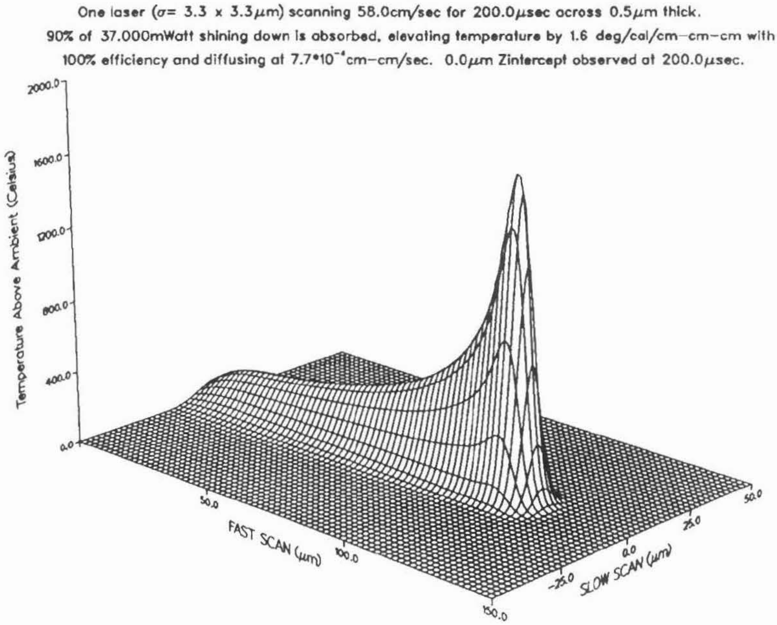
In this breadboard, a 50 mW diode laser of 830 nm wavelength is used to raster scan a film held against a vacuum platen. The laser beam is modulated simply by modulating the current supplied to the laser in accordance with an array of data from a computer record corresponding to one line of data in the image. After each line is written, the platen is incrementally moved to the position of the next line by a microstepping motor. All of the position controls of the system are open loop, i.e. there are no encoders to feed back the position of the spot. This leads to small errors in position from line to line, but the system is perfectly adequate for research measurements, although it might not be good enough for the highest quality graphic arts work. In any case the size of the image written is only 36 by 24 mm, which is too small for almost any conceivable graphic arts use.

The power required to write Laser Thermal images is high. To make an A3 separation in 5 minutes requires about 5 watts of laser power. Fortunately, high power diode laser are becoming cheaper, and cheap laser diode arrays have begun to appear on the market. In addition to the power requirement, the laser light must be capable of being focused into a small spot of high intensity in order to achieve rapid heating of the active layer without warming the supporting layer. Here is a plot of the mW required to give a Dmin of less than 0.1 with Laser Mask film as a function of the laser intensity.

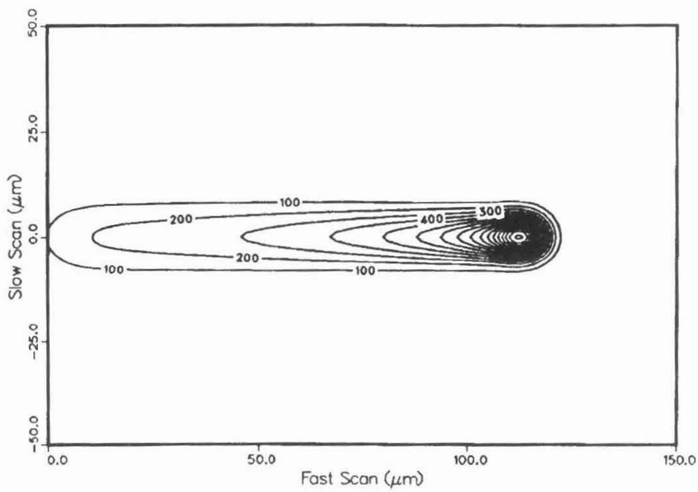


At high intensities, the plot levels off at about 600 mJ/cmsq. At that point the system can be thought of as adiabatic. All of the heat absorbed by the graphite layer is used to remove carbon from the support, and there are only insignificant losses to the heating of the support itself.

Because the system is so sensitive to intensity, the edges in laser thermal printing are sharp. Myers (1971) observed that the size of spots printed by LTP are from one third to two thirds the diameter of the laser beam. Calculation of the temperature profile based on the heat capacity and thermal diffusion rates of the materials gives the plot below. The peak temperature of 1600 degrees is almost certainly not achieved. Long before this temperature is reached, ablating material carries away enough heat to keep the temperature substantially lower.

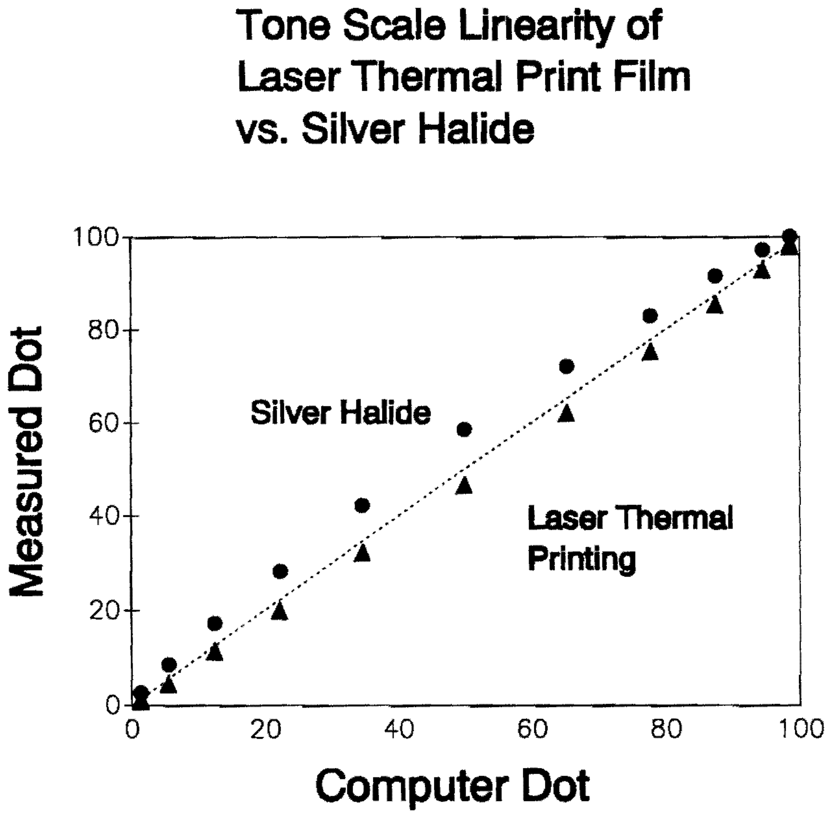


Replotting the above data as a contour plot emphasizes the steep temperature profile at the edges of the laser beam. A drop of 100 degrees is only about a micron in distance.



The steep profile of the thermal edge explains why the edge sharpness of the images is good. Confirmation of this is found in electron micrographs of the written edges, which show an edge profile of less than a micron.

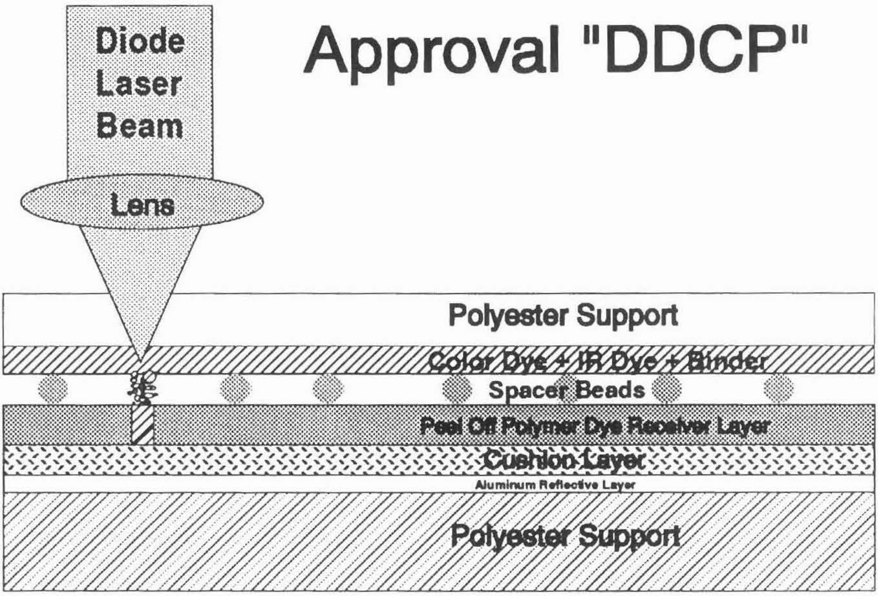
The utility of a sharp edge profile is found in a plot of the tone scale for LTP. Below is a plot of the 150 lpi tone scale for LaserMask written on the diode laser breadboard vs. the computer percent dot.



The excellent linearity of the LTP system suggests that good tone scale can be achieved with minimal look-up-table correction. Lack of calibration and correction are hallmarks of a robust system that gives immaculate results each and every time it is used.

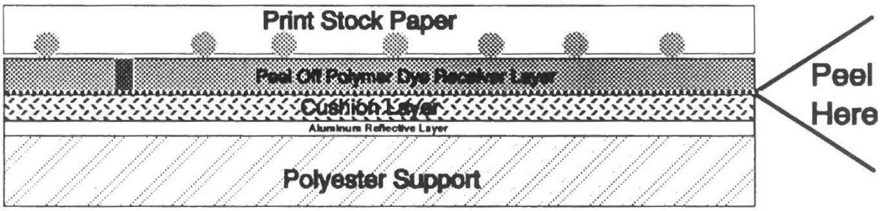
Color Proofing

Another laser thermal product is Kodak's Approval ® direct digital color proofing system.



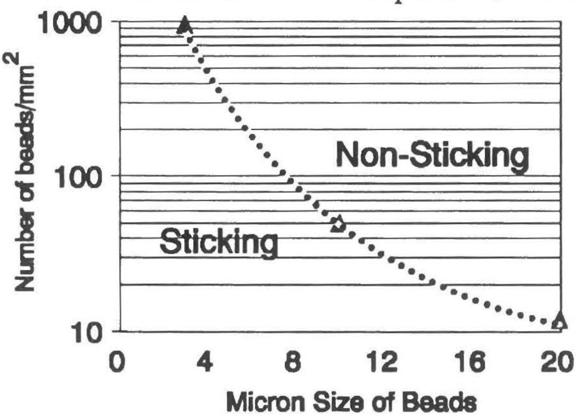
In the approval system, the diode laser beam is focused onto a dye layer where it is absorbed by an infra-red dye which converts the radiation energy into heat. The heat causes the color dye to transfer to the polymer layer of the intermediate receiver. After each color is written, the dye donor film is removed and replaced with the dye donor film of the next color. When all the colors have been printed, the intermediate receiver is laminated to the printing stock to give the final proof.

Lamination Transfer of the Approval Image to Print Stock Paper



Again, the only amplification in the process is electronic. This is why the system is robust and reliable. In practice, it has been found that two Approval systems miles apart, but fed from a common data stream, give identical proofs. In the same way, the machine delivers the same proof from day to day, week to week and month to month.

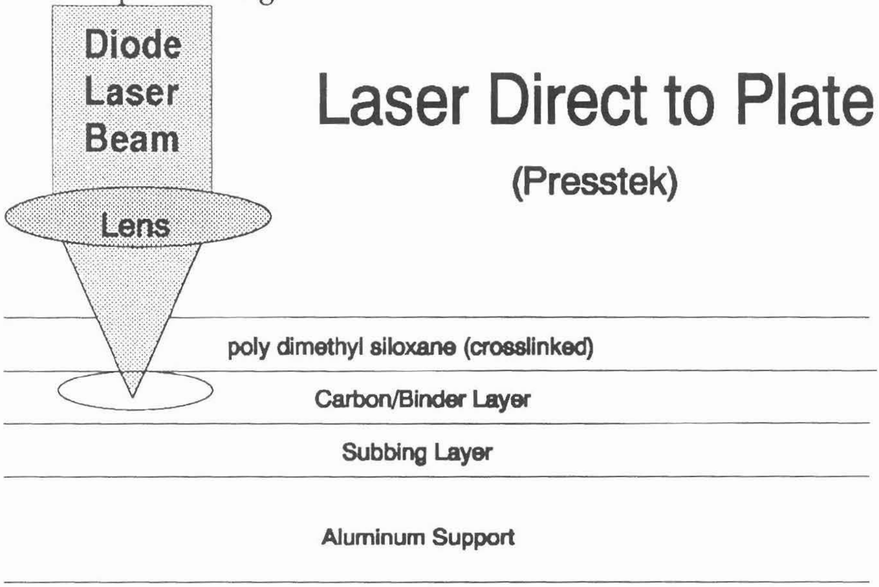
The spacer beads in the Approval intermediate receiver are interesting. When work first began on the project, there were no beads, and the images were very blotchy, with areas of low or no density and other areas of very high density. We rapidly realized that in areas of contact between the donor and receiver, two mechanisms obtained. In one, the contact provided an additional heat sink that lowered the efficiency of the process and gave low density. In the other, the contact area acted like hot melt glue, and when the donor and receiver were separated, the entire dye layer



was ripped off its support and transferred to the receiver. A systematic study of the problem showed that both the number and size of beads was important. The effect is similar to tent poles. If you have a few tall poles, the tent won't touch the ground. If the poles are short, many more are needed.

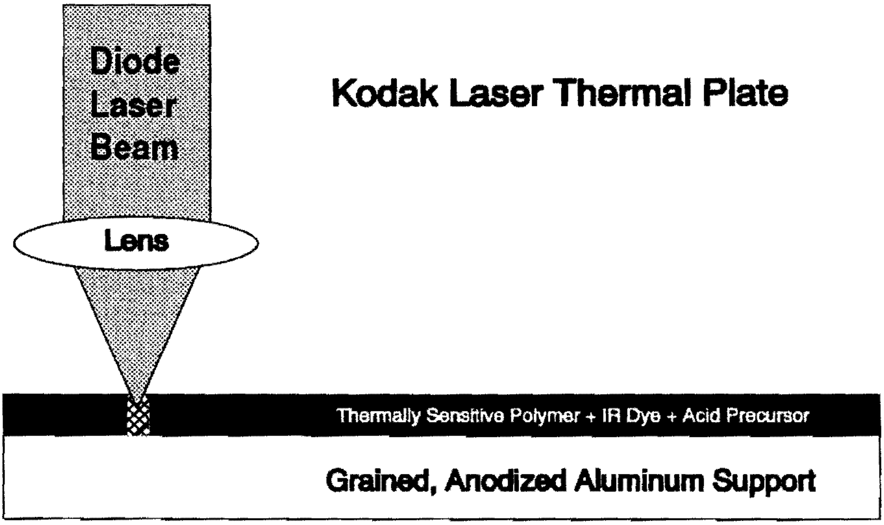
Computer to Plate Applications

There are presently two computer to plate products on the market that use the laser thermal technique. One is the Presstek plate used in the Heidelberg GTO machine, and the other is the Kodak laser thermal plate announced at Graph Expo '93. The Presstek plate is diagrammed below:



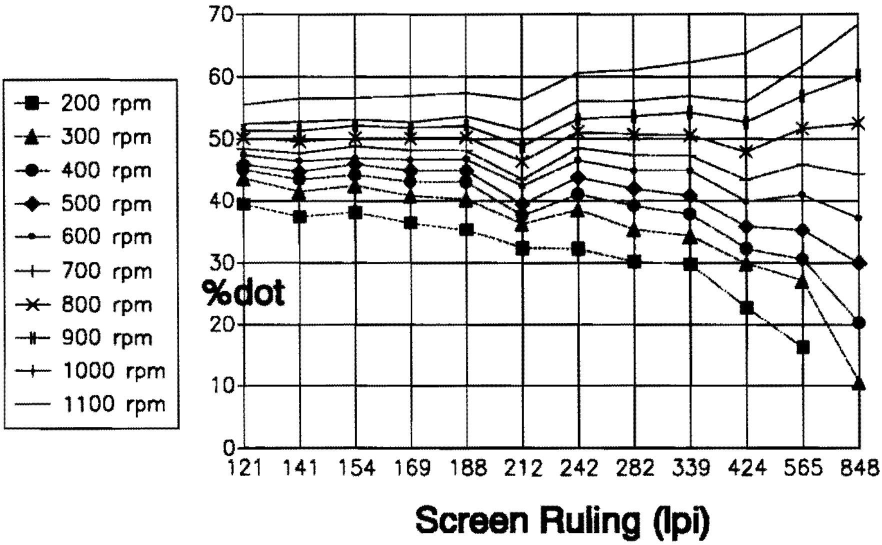
The heat from the absorbed laser beam makes a bubble that weakens the siloxane layer. After exposure, the press operator wipes away the weakened exposed areas revealing the subbing layer below. On press, the waterless ink is repelled from the siloxane and attracted to the subbing layer. The process and equipment are described by Lewis and Nowak.

The Kodak computer to plate system uses a conventionally dampened lithographic offset plate. The diode laser beam is absorbed by an infra-red dye in the active layer, and the heat thus generated decomposes an acid precursor to generate free acid in the layer. The acid is stable and can accumulate in the layer with repeated exposures. After exposure, the plate is mildly baked in an oven, which causes the acid to crosslink the binder and render it insoluble. The plate is then processed in conventional plate chemistry and is then ready for press. Plates made by this method have printed 700,000 impressions without any problems.

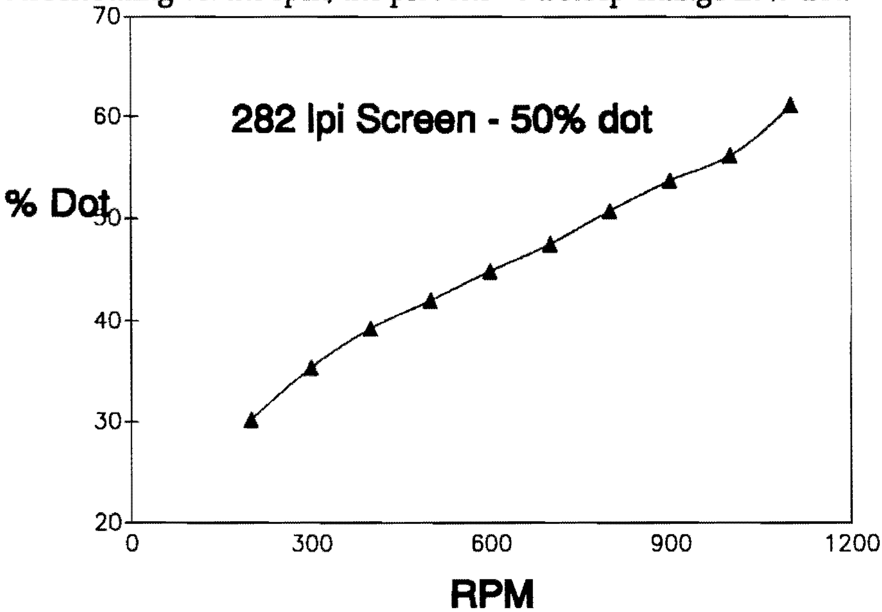


One interesting aspect of the Kodak laser thermal plate is that it is sensitive both to intense IR light, and also to conventional UV exposure. This is because the acid precursor will decompose and generate acid both by heating and by the action of UV light. This means a plate can be prepared with both digital images from the computer and also conventional separation images on film. This is a distinct marketing advantage at the present time, when printers are called on to prepare mixed digital and conventional plates.

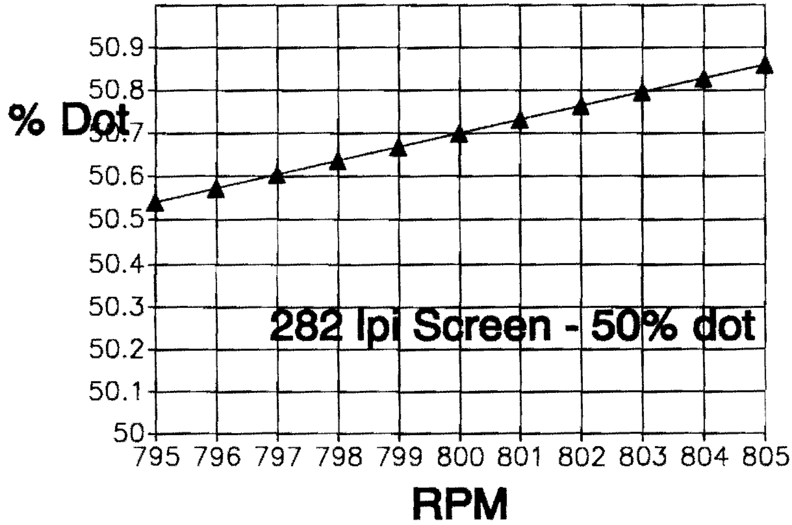
In writing the Kodak laser thermal plate, we have found that the 50% dot will change with the rpm of the printing drum. The change is greatest with very high frequency screen rulings. Here is a plot of 50% dot as a function of rpm and screen ruling.



However, this does not mean the system is non-robust, or unusually sensitive,If we plot the % dot data above for the 282 lpi screen ruling vs. the rpm, the plot shows a steep change in % dot.

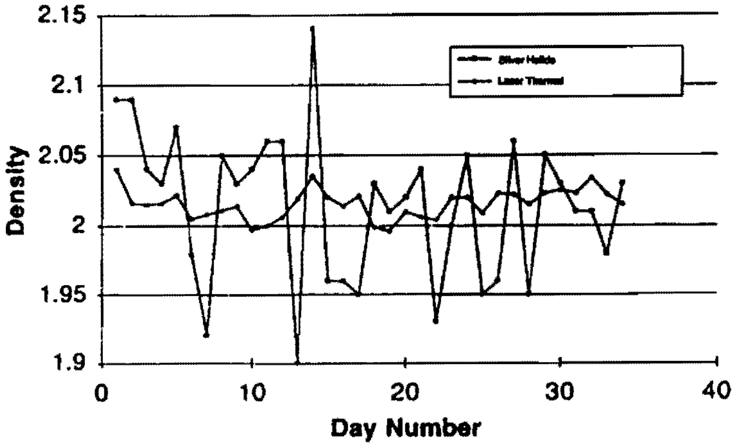


because the scale is too wide. If we expand the plot to the level of rpm's that can be easily controlled, the plot looks like this:



An 800 rpm drum will not vary more than 1 rpm, so the change in the 50% dot will be less than .03 percent. Robustness is the product of the sensitivity of the system and ease of control of the system. Laser thermal printing is a very robust system. Below is a plot of the day to day variation in density of a silver halide system compared to the day by day variation in a laser thermal printing product. The increased robustness of the laser thermal product is obvious.

Another example of the improved robustness of laser thermal printing is found in a comparison of the density variations from day to day for silver halide and laser thermal prints, as shown in the plot below. This plot includes both variations in the silver halide media itself, and also variations of the processor, and even the operator maintaining the processor. Nevertheless, this is the kind of variation seen in real work conditions. The laser thermal printing example has much less variability because the processor has been removed from the system.



Marketing acceptance of new dry process laser thermal products will be slowed by the fact that both media and hardware to write the media must be developed and sold at the same time. However, the slow penetration of the market will be inexorable, because the benefits of laser thermal printing cannot be accomplished by alternative methods. Leaving aside considerations of ecology, legislative fiat and processor inconvenience, laser thermal printing offers the opportunity to assemble a system with little or no calibration or adjustment required except for the printing press itself. Current methods for preparing a litho plate involve two exposure steps and two processing steps, all four of which can contribute dot gain or loss if they are not properly done. In a laser thermal system, all these possibilities for error are reduced or eliminated, and the concept of a zero defect plate production line begins to have meaning.

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