Red-Hot and Violet.
Photopolymer Systems at Your Service

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Abstract:
Photospeed, characteristic curves, exposure latitude, and dot reproduction of violet photopolymer (V-PP), infrared photopolymer (IR-PP) and thermal preheat plates (IR-TP) have been studied using a single beam violet plate setter and two types of infrared plate setters differing in beam geometry. It could be demonstrated that the detail reproduction capability of the system is affected by the shape of the characteristic curves of the systems and exposure beam shape as well. IR-PP and IR-TP plates show a better resolution compared to V-PP and setters with profiled beams gave better results than setters having a Gaussian beam. It could be demonstrated that the exposure latitude depends on both plate and setter parameters. V-PP plates are limited to 200 lpi screens whereas IR-PP and IR-TP allows 10 and 20 µm FM screens.

Introduction
During the last 10 years the computer to plate (CtP) market is growing rapidly and now already more than 50 % of the conventional lithographic plates in western countries have been substituted by so called "digital plates". The development of CtP is a consequence of the progress in laser technology. The first CtP systems in the market started with argon ion lasers (488 nm) , followed by fd-Nd-YAG (532 nm), and infrared laser diodes (810/830nm). Recently, plate setters based on blue emitting laser diodes (405 nm) have been introduced to the market.
To realize high exposure speed and to keep laser costs low, CtP plates with low exposure energy demand are preferred. This was the reason why the first CtP plates were based on electrophotography, silver halide and photopolymer technology requiring only 1 to 100 µJ/cm² for visible laser exposure. Presently most new CtP installations are either thermal plate setters with infrared laser diodes or blue laser diodes. Lithographic plates based on photopolymer

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technology are now dominating the 405 nm-region ("violet photopolymer", V-PP) and also find - because of their high photospeed and robustness - growing application for 810/830 nm ("infrared photopolymer", IR-PP).
Aim of the present paper is to compare the performance models of V-PP and IR-TP systems and to discuss the differences to a model of a "pure" thermal preheat system (IR-TP). Compared are photospeed, characteristic curves, exposure latitude and dot reproduction together beam characteristics of the plate setter.

Models of V-PP, IR-PP and IT-TP

The components and basic features of the chosen models V-PP, IR-PP and IR-TP are summarized in Table 1 and Table 2, respectively.
V-PP and IR-PP are photocrosslinkable radical photopolymer systems. The exposure energy is absorbed by a sensitizer that interacts with coinitiators by electron transfer reactions resulting in initiator radical formation (Timpe, 1999). The initiator radicals form a latent image that is protected against oxygen attack by an poly(vinyl alcohol) overcoat. As depicted in Fig. 1 the plate needs to be preheated before processing. In the preheat step the radicals become mobile and crosslink the monomer-binder matrix to make it insoluble in alkaline developer. It is important to note that the crosslinking does not occur to a significant degree before preheating.
The compositions of V-PP and IR-PP are very similar concerning the polymerizable matrix and differ only in the photoinitiating compounds.
The IR-TP uses an acid formed by thermal decomposition to crosslink a binder matrix by an acid-crosslinkable component. Similar to V-PP and IR-PP the crosslinking requires activation by heat.
In the IR-TP, however, the preheat step must be controlled more carefully compared to the photopolymer plates because the acid is a catalyst only which is not consumed during the crosslinking reaction, while in the PP-system the initiator radicals are consumed during polymerization.

Table 1 Components of the models of violet and infrared photopolymer and preheat negative thermal plates

Violet photopolymer (V-PP) (Baumann et al., 2004)	**IR photopolymer (IR-PP)** (Timpe et al., 2003 and 2005)	**IR thermal preheat (IR-TP)** (Haley et al., 1993 and 1995)
aromatic photo sensitizer	cyanine photo sensitizer	cyanine type light to heat converter
coinitiators	coinitiators	thermal acid generator
acrylic binder polymer with carboxylic functionalities	acrylic binder polymer with carboxylic functionalities	binder with phenolic functionalities
radical polymerizable urethane (meth)acrylate monomers	radical polymerizable urethane (meth)acrylate monomers	acid crosslinkable component
blue pigment for image contrast	blue cationic dye for image contrast	blue cationic dye for image contrast
radical inhibitor compound	radical inhibitor compound	
oxygen barrier layer (poly(vinyl alcohol))	oxygen barrier layer (poly(vinyl alcohol))	
lithographic substrate with hydrophilic surface	lithographic substrate with hydrophilic surface	lithographic substrate with hydrophilic surface

Table 2 Features of models of violet and infrared photopolymer and preheat negative thermal plates

	Violet photopolymer (V-PP)	IR photopolymer (IR-PP)	IR thermal preheat (IR-TP)
mechanisms	radical initiated crosslinking	radical initiated crosslinking	acid crosslinking
exposure energy	35 µJ/cm²	75 mJ/cm² developer A (35 mJ/cm² developer B)	70 – 100 mJ/cm²
preheat	100 – 130°C	100 – 140°C	132 – 138°C
developer consumption	80 – 90 mL/m²	30 mL/m²	200 mL/m²
safe light requirement	yellow light < 1200 lux min	white light < 1000 lux min	yellow light, like conventional negative plate
relative length of run (unbaked)	100 %	110 %	80 %
bakeability	yes	yes	yes

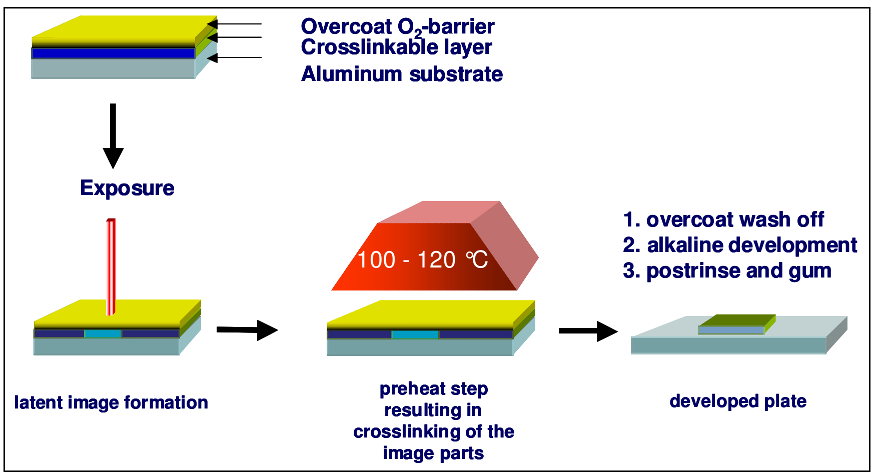


Fig. 1 Processing steps of infrared and violet photopolymer systems

Different Exposure Systems

It goes without saying that beam-quality will have an impact on dot reproduction and final image quality. For the purpose of this paper examples of setters with different beam properties were chosen.
Considering to represent “Gaussian-Violet” (GV) a Prosetter 74 (405 nm, 30 mW laser diode, internal drum), for ”Gaussian- IR” (GIR) a Topsetter 74 (808 nm, 32 laser diodes, 32 W, external drum) both from Heidelberger Druckmaschinen AG and for “Profiled-IR” (PIR) a Creo Trendsetter 800 Quantum (830 nm, 40 W laser diode, multibeam head with 220 channels, external drum) were used.
Fig. 2 shows the principle of GV and GIR machines.

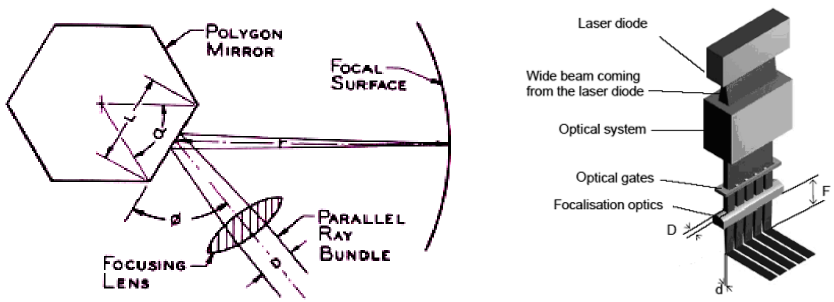


Fig. 2 Principle of single beam violet laser diode (left) and profiled beam infrared head (right) geometry

Internal drum systems may have cross-reflection of the beam and therefore also have to take measures to reduce dot gain introduced by so called flare.

Characteristic Curves and Reciprocity

Fig. 3 shows the plots of normalized optical densities vs. exposure energy in a logarithmic scale (“characteristic curve”) for V-PP, IR-PP and IR-TP. The V-PP system requires an exposure energy which is around 3 orders of magnitude lower than the energy needed for the infrared sensitive plates. The low and the high energy part of the V-PP curve is more curved and the gradient is less step compared to IR-PP and IR-TP. From the characteristic curves we can expect a more softer dot for the V-PP plate.
Fig. 4 and Fig. 5 show the dependence of the characteristic curve on the exposure power of the plate setter. IR-PP shows almost no dependency on exposure power whereas IR-TP does and becomes more efficient at higher laser power.

The different response to changes in power of IR-TP and IR-PP, i.e. the deviation from reciprocity in case of IR-TP can be explained by the different modes of reaction that take place. Fig. 6 shows the well known deactivation routes of an excited (IR)-dye molecule.

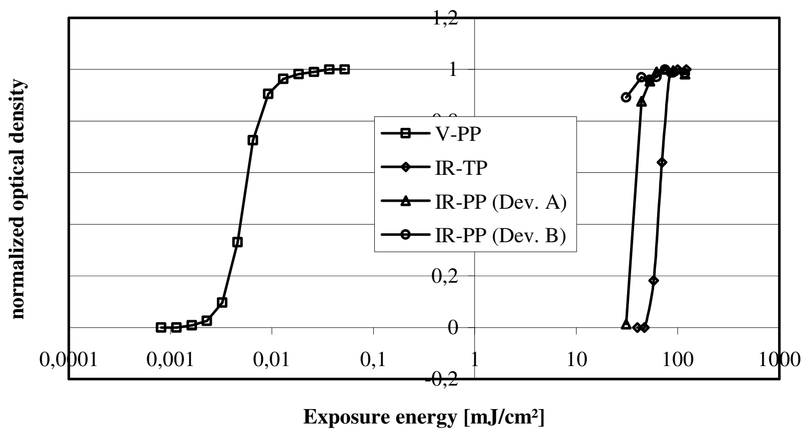


Fig. 3: Characteristic curves of V-PP, IR-PP and IR-TP

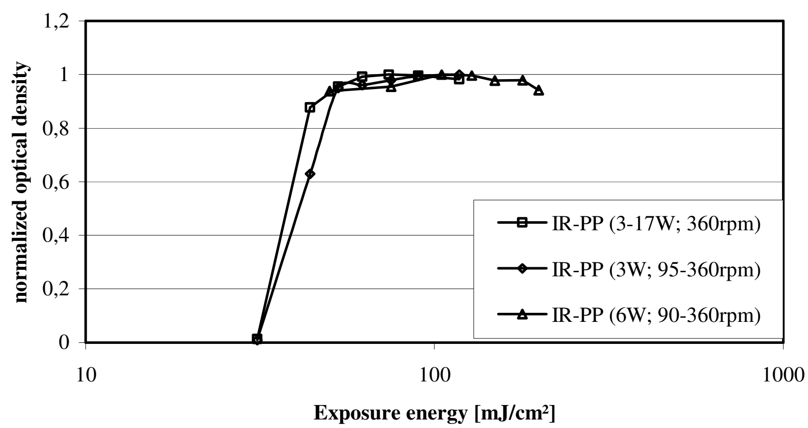


Fig. 4: Exposure series of IR-PP (values in brackets correspond to laser power and drum speed)

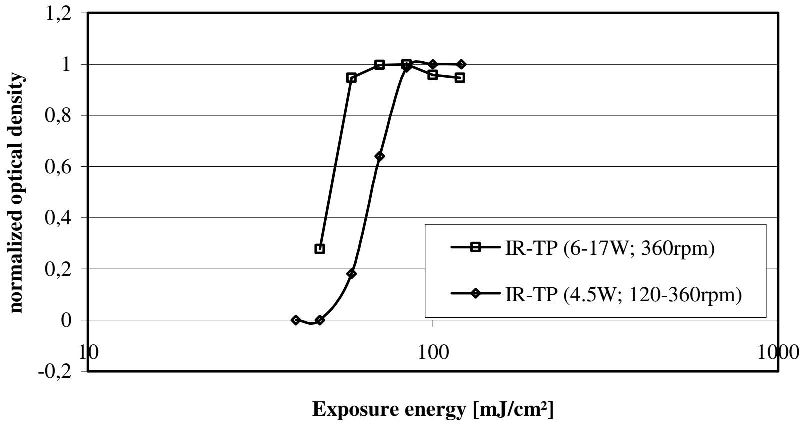


Fig. 5: Exposure series of IR-TP (values in brackets correspond to laser power of and drum speed)

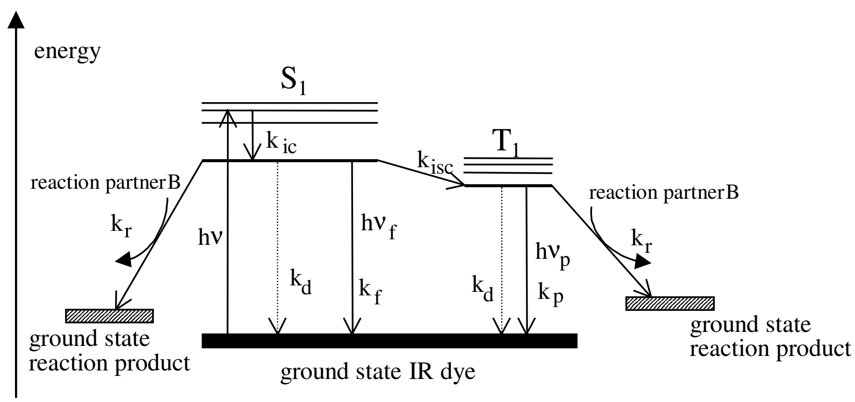


Fig. 6 Possible deactivation processes of an excited (IR)-dye-molecule

Starting from the same absorbing species - the sensitizer - different competing reaction routes are possible. If the system does not deactivate by radiation and contains an appropriate reaction-partner that can interact with the short-lived excited state S_1, then a photonic route, for instance by electron-transfer, is possible.
If there is no such partner present and if the sensitizer deactivates by internal conversion then heat is released and thermaly consecutive reactions are more likely. In such cases, many kinds of absorbing species can be used including non

reactive ones like carbon black. To create sufficient heat an absorber needs to be chosen that runs through several activation/deactivation cycles during the irradiation dwell.

The depth of absorption of the energy within the layer can be influenced by the concentration of the photosensitizer/light to heat converter. For the heat mode the absorption of the energy should be concentrated to the top of the active layer to minimize the influence of the heat sink at the aluminum substrate. The photonic mode requires sufficient concentration of excited state molecules anywhere in the bulk of the coating including the interface between coating and substrate to achieve sufficient adhesion.

Resolution, Tonal Values, Exposure Latitude

Table 3 shows the SEM pictures of 1 pixel lines (2400 dpi) exposed with Gaussian type plate setters (GV) and profiled IR (PIR) machines on the model plates. The infrared exposed plates have sharp line edges with some tendency of undercutting. The V-PP exposed by a GV setter line is obviously wedge-shaped. Furthermore it becomes obvious that lines exposed with a machine having a profiled beam are significantly smaller.

Table 4 shows the reproduction of line/gap pixel targets for the three models. At regular exposure the line resolution of V-PP is inferior compared to IR-PP and IR-TP plates. The best resolution was obtained with IR-TP on both GIR and PIR setters.

Table 3: SEM pictures of 1-pixel lines imaged at 2400 dpi

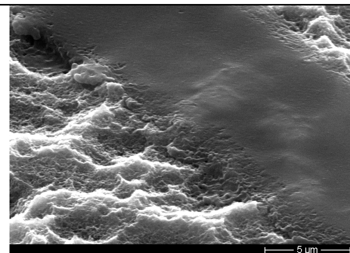
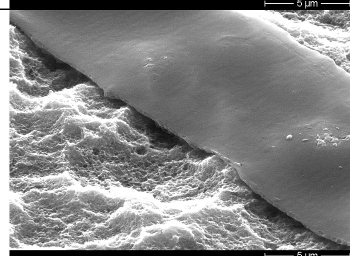
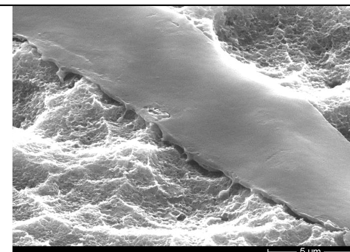
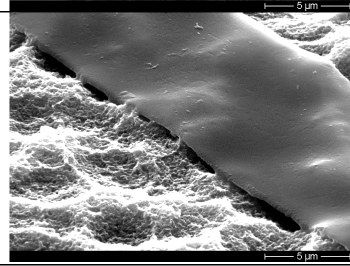
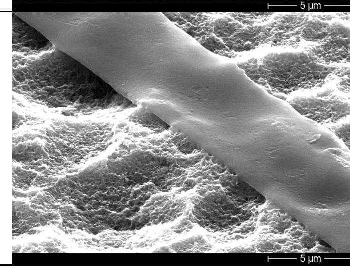
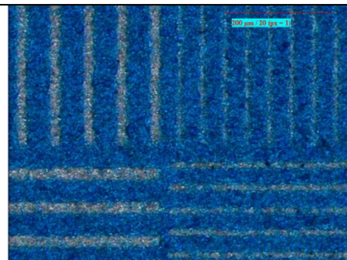
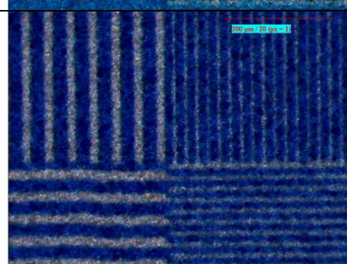
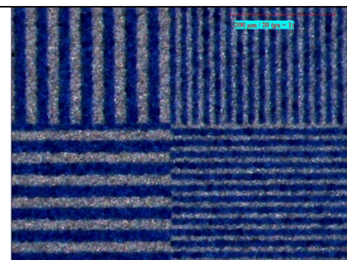
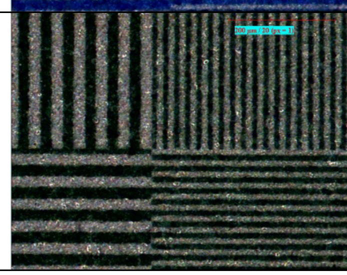
	Gaussian setter	Profiled setter
V-PP		
IR-PP		
IR-TP		

Table 4: Line resolution at 2400 dpi (1- and 2-pixel lines/gaps for IR-PP and IR-TP and 2- and 3-pixel lines for V-PP)

	Gaussian setter	Profiled setter
V-PP		
IR-PP		
IR-TP		

The dot gain curves at different exposure energies are depicted exemplarily for V-PP and IR-PP in Figs. 7 to 9. The curves for IR-TP are similar to the curves of IR-PP. Underexposed V-PP plates show a typical S-shape, because the small dots are not sufficiently stable and are attacked by the developer. To realize a sufficiently broad tonal range the dot gain in the mid tones at 200 lpi should be 8 to 16 % depending on the required length of run.

The dot gain for the IR-PP and IR-TP plates is much lower and in case of low screen rulings no linearization is necessary particularly if setters with profiled beam are used.

From the dot gain curves the exposure latitude can be quantified. Figs. 10 and 11 show the plot of the tonal values of a 50 % tint vs. exposure energy in a logarithmic scale. From the slope we calculated the exposure latitude defined as log(exposure energy) for a ± 2% shift in tonal values of a 50% tint at 200 lpi:

	Gaussian setter	profiled setter
V-PP	0.070	
IR-PP	0.153 (rpm series)	0.283 (rpm series)
IR-TP	0.089 (rpm series)	0.151 (rpm series)

The data show that a combination of shape of the characteristic curve and beam profile "make" the resolution properties of the system. It can be assumed that violet and certain thermal setters (GV and GIR) project a soft, almost Gaussian spot of pixel size onto the plate. Setters with a profiled intensity distribution provide a sharp-edged spot (Fig. 12 and Fig. 13).
The reason for better resolution of the IR-PP compared to V-PP exposed with a Gaussian spot type of plate setter is not totally understood yet. In both plates a part of exposure energy is reflected from the substrate surface because an absorption around 0.43 is chosen to realize a maximum absorption at the bottom of the photopolymer layers, as calculated by Thommes et al. (1985). The reflection of the aluminum oxide surface is similar at 405 nm and 810/830 nm (Miney et al., 2003). It can therefore be speculated that the low energy part of the V-PP plate results in less sharp dots and shadow clogging.

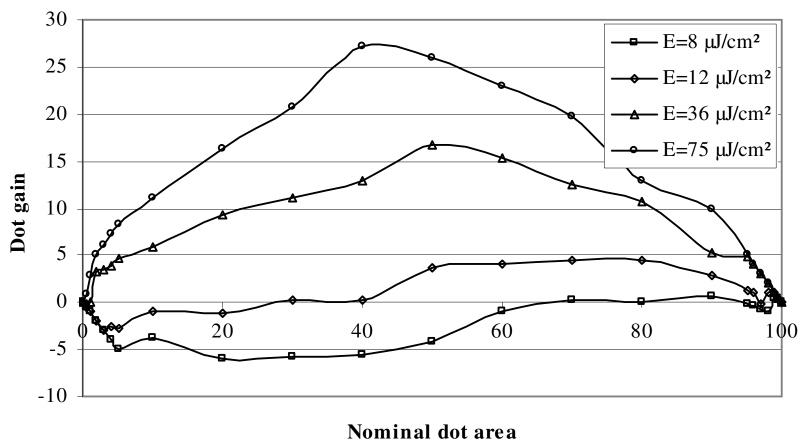


Fig. 7: Dot gain of V-PP plate at different exposure energies

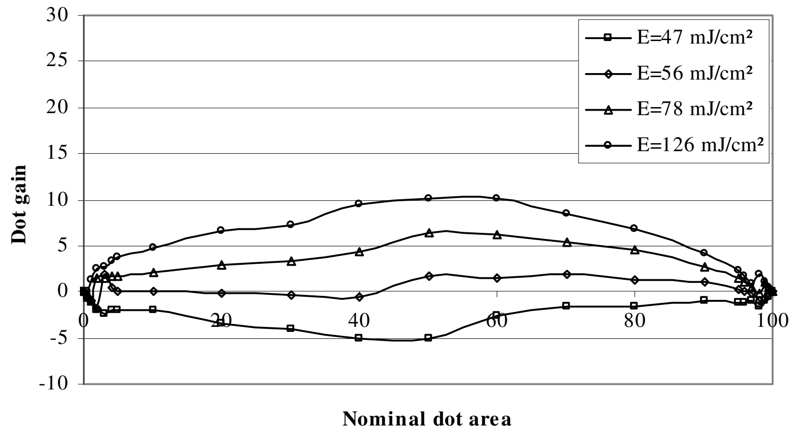


Fig. 8: Dot gain IR-PP plate at different exposure energies; Gaussian spot setter

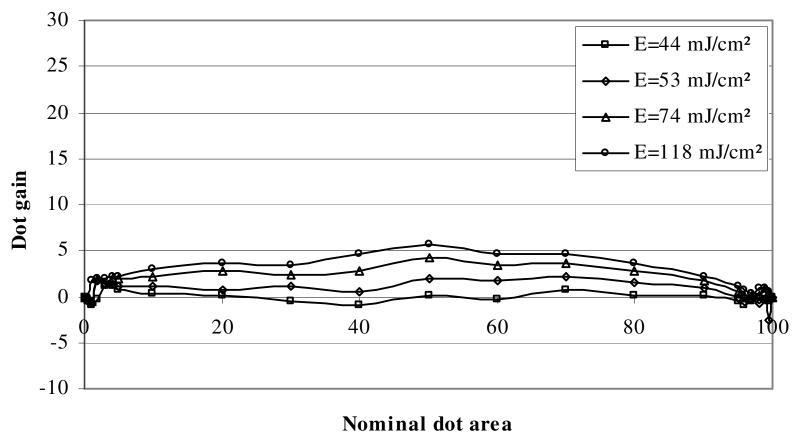


Fig. 9: Dot gain IR-PP plate at different exposure energies; profiled spot setter

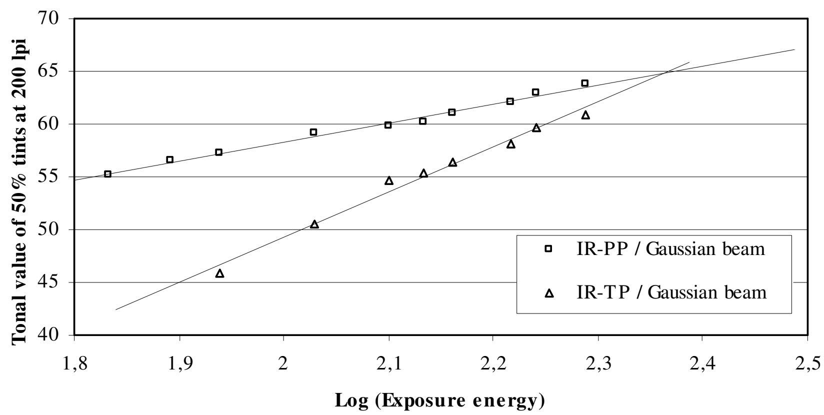


Fig. 10: Exposure latitude at 200 lpi. Gaussian spot setter, power-series at constant drum speed

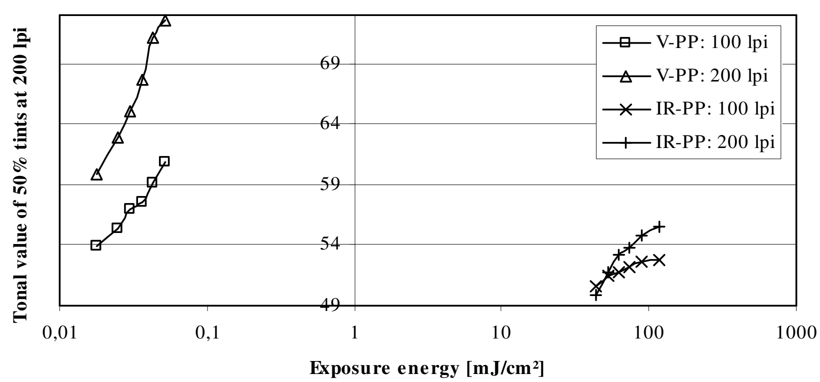


Fig. 11: Exposure latitude at 200 lpi for V-PP (Gaussian) vs. IR-PP (profiled spot)

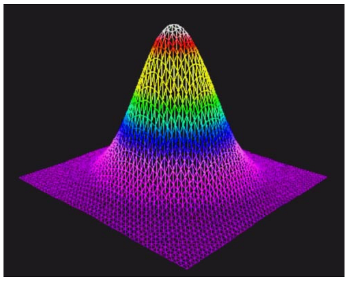


Fig. 12 Gaussian-shaped beam profile

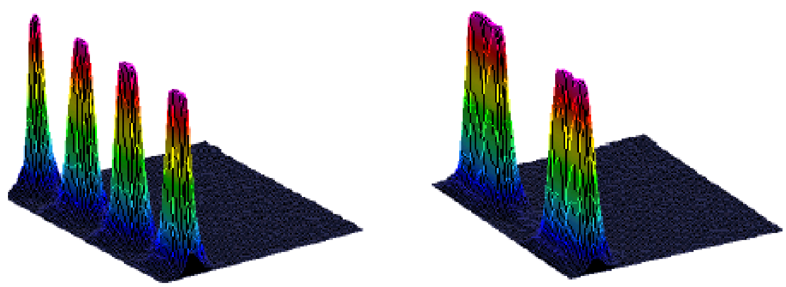


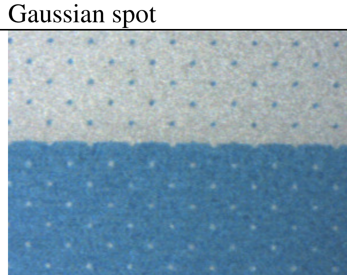
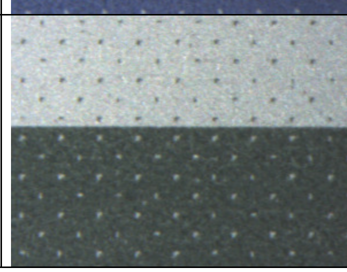
Fig. 13 Sharpened beam profile: (1 or 2 pixels on and off)

Conclusion

The comparison of the characteristic curves of the three models showed that violet photopolymer technologies allows plates having a photospeed of more than three orders of magnitudes faster than infrared photopolymers or infrared thermal preheat plates.
The advantage of the infrared sensitive plates is the significantly better detail resolution capability. The better detail reproduction can be explained by the shorter low energy part of the characteristic curve. Furthermore the beam characteristics of the infrared plate setters contribute to the better detail reproduction.
The single beam violet internal drum or flat bed machines may be less expensive than the multi-beam external drum IR-setters but have more difficulty to minimize the spot size at the necessary higher focal length.
What is the consequence of the above argumentation for practical application of the different technologies? In Table 5 the 2 and 98 % tints of a 200 lpi for V-PP, IR-PP and IR-TP are depicted. In case of V-PP the tints are linearized. It is

obvious that linearized V-PP plates show dot reproduction similar to the IR-PP and IR-TP. 2 to 98 % dots at 200 lpi can be reproduced and printed with all above discussed plates. Speed and length of run of V-PP plates make them attractive for both newspaper and commercial printing. The violet photopolymer plates, however, need more precise adjustment of the laser power because of the smaller exposure latitude and the linearization has to be made more carefully to prevent steps in continuous tones.
The better dot reproduction of IR-PP and IR-TP is a clear benefit for reproduction of 10 and 20 µm FM screens that are requested for high quality printing. V-PP plates need more careful adjustment of all exposure and processing parameters to allow FM screen reproduction. This is the reason for the currently low acceptance of violet photopolymer technology for this type of application.

Table 5: Dot reproduction of 2% and 98% tints at 200 lpi

	Gaussian spot	Profiled spot
V-PP linearized		
IR-PP		
IR-TP		

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