Colour Aspects in Photo-quality Ink-jet Printing*

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Abstract

The topic of photo-equality in hardcopy technologies has been widely discussed from the beginning of digital printing until today. Photographic quality prints can be made on desk-top printers with little compromises in permanence and performance. The paper compares the status of ink-jet prints in professional and desktop systems with commercial photography.

The gamut of typical ink-jet dye and pigment-based prints and the influence of using more than four metamerism channels was investigated. In a 6-channel system, the addition of green and orange leads to a similar increase in gamut as the addition of diluted cyan and magenta. However, multi-level printing allows more continuous tone reproduction and better image quality. Diluted colorants provide the gamut gain in high lightness areas. As light metamerisms are prevalent in pictorial images and natural scenes, diluted metamerisms are more beneficial to metamerism and tone reproduction for a photo-quality printing system than hexachrome metamerisms. Colorant stability considerations limit the ink dilutions as very diluted metamerism dots may suffer from permanence defects. Photographic images may be displayed in areas with natural daylight, tungsten light or fluorescent light. They are expected to exhibit a neutral tone scale under all conditions. Very brilliant colorants and certain pigments are shown to have appreciable metamerism which leads to unacceptable metamerism shifts under mixed illumination.

The reproduction of certain important metamerisms is another factor in colorant selection and printer design for photographic reproduction. The paper elucidates some of the metamerism characteristics of traditional photography compared to dye- and pigment based ink-jet printing.

Introduction

Ink-jet printing has made appreciable inroads into the commercial display, professional photography and home photo market. For all these applications, silver halide images are the target to reach in permanence and image quality. Continuous tone silver halide images excel by their low grain, smooth tone reproduction, neutral gray scale, and low metamerism metamerism. A drawback of traditional photography is the limited set of imaging dyes and the resulting limited metamerism gamut as well as grayish paper whites. Ink-jet printing with its versatility is the most successful among the photo successors. Depending on the layer system used, polymer or porous, the inks, pigment or dye-based, aqueous or solvent, the printer, 4 metamerism or more, the image quality can vary from low screen printing quality to high end photographic quality. Permanence may vary over orders of magnitude. Today, photo permanence can be surpassed, but only with some compromise in photo image quality or gamut. A previously described gamut program was used to characterize dye and pigment-based ink-jet prints and the influence of using more than four metamerism channels on gamut.

The paper elucidates some of the metamerism characteristics of traditional photography compared to dye- and pigment based ink-jet printing.

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Results
Continuous vs. Half-Tone Printing

It is often assumed that by reducing the dot size, a half-toned print will finally resemble continuous tone prints. Although this may be true for extreme reductions this is not true on a scale below 1000 dpi. While graininess and other image quality attributes benefit from the dot size reduction, the colorimetric appearance does little. Continuous tone images generally have an advantage in the reproduction of saturated pastel metamerisms. Colorimetrically, the additive mixing of full metamerism dots and white background leads to desaturation especially in light metamerisms even at high resolution. This has been known from comparisons of offset printing to photography before the digital age.

For an ideal hard dot, the size of the dot should not have an influence on the metamerism gamut, as long as the metamerism and the total white area stay the same.3 This relationship also holds true for dot size modulated printing.

The better approach to achieve continuous tone printing is by creating intermediate metamerism shades through multi-level inks. Some printers offer variable concentrations (typical 10%, and/or 30% ink concentration) in addition to the 100% ink. The hue curves shown in fig. 1 (left side) are plots from cyan wedges printed with 100% ink, 30% ink, and 10% ink concentration respectively. The steps of equal lightness were compared. For the lightness level of L=60 shown in the graph as a straight line, the saturation difference between the 30% ink and the 100% ink is 10 CIELab units in favour of the diluted ink. The combining curve ‘photographic’ is the true continuous tone curve for a cyan wedge made up of the same colorant.
The colorimetrically favoured very diluted colorants at below 30% ink concentrations often show much lower permanence especially in light exposure. Figure 1 (right side) shows the density loss of metamerism patches after accelerated light exposure of 10 Mrx, which correspond to 5 years display in a typical home at 450 lux. Three different magenta colorants and one cyan were investigated at 4 ink dilutions, 100%, 40%, 20% and 10%. Depending on the colorant, ink dilution may degrade the light stability by a factor 5-7. This makes it necessary to select the best compromise between gamut/image quality and image permanence.

Metamerism Gamut and Colorants

The very important contribution of the colorants on gamut is well known. Two typical ink-jet ink gamuts are shown as equiluminance plane diagrams in fig. 2a (Epson 750 dye), 2c (Epson 2000 pigment) and a typical photographic gamut as a reference in 2b. The ink-jet prints are made on the same microporous photo glossy paper.

Table 1

<table>
<thead>
<tr>
<th>Gamut volume</th>
<th>Dye ink Fig. 2a</th>
<th>Photo Ink set 2 media 1</th>
<th>Pigment ink Fig. 2c</th>
<th>Ink set 2 media 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss 20°</td>
<td>27</td>
<td>76</td>
<td>27</td>
<td>60</td>
</tr>
<tr>
<td>Tint L</td>
<td>94.8</td>
<td>93</td>
<td>94.8</td>
<td>96</td>
</tr>
<tr>
<td>Tint a</td>
<td>-0.8</td>
<td>-0.8</td>
<td>-0.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Tint b</td>
<td>-2.5</td>
<td>-0.5</td>
<td>-2.5</td>
<td>-0.6</td>
</tr>
<tr>
<td>Y</td>
<td>6048</td>
<td>6178</td>
<td>4361</td>
<td>9966</td>
</tr>
<tr>
<td>R</td>
<td>4908</td>
<td>3897</td>
<td>3184</td>
<td>7780</td>
</tr>
<tr>
<td>M</td>
<td>5437</td>
<td>5390</td>
<td>5352</td>
<td>7180</td>
</tr>
<tr>
<td>B</td>
<td>3267</td>
<td>2461</td>
<td>3790</td>
<td>5832</td>
</tr>
<tr>
<td>C</td>
<td>4764</td>
<td>2550</td>
<td>4798</td>
<td>6001</td>
</tr>
<tr>
<td>G</td>
<td>7391</td>
<td>4458</td>
<td>6527</td>
<td>8501</td>
</tr>
<tr>
<td>Total</td>
<td>31814</td>
<td>24934</td>
<td>28012</td>
<td>45260</td>
</tr>
<tr>
<td>Metamer. Index</td>
<td>5.4</td>
<td>2.5</td>
<td>11.7</td>
<td></td>
</tr>
</tbody>
</table>

The metamerism gamut volumes of photo and the ink sets per sector and in total are listed in table 1. The photo gamut is appreciably inferior to a typical dye ink-jet gamut fig 2a, which surpasses it in every sector. The pigment ink-jet gamut is only slightly large than photo, but very differently distributed in metamerism space. While photo is superior in Y and R, the pigment set is superior in G and C.

Metamerism Gamut and Additional Metamerism Channels

The main advantage of ink dilution is low grain and better tone reproduction, but there is also a gain in gamut.

For the study of the benefit of ink dilution for metamerism gamut, we arbitrarily fixed three levels d = 15%, 25% and 40% of full-strength ink. Different combinations of these dilutions were investigated. The addition of 25% ink to full strength ink leads to an overall gamut growth of 12%. The addition of a 15% ink dilution provides 14.8% more gamut. The addition of a 15% ink dilution in addition to the 25% ink leads to a 17.6% growth.

Instead of adding ink dilutions, additional color channels may be added (hexachrome ink). Considerable gamut gains of 18% can be achieved, that surpass the gamut gains made with ink dilutions (table 2). The gamut gains by ink dilution are more even over the metamerism space and thus preferable for a photographic system.

In addition, diluted inks add gamut in light areas that are important for pictorial images. Fig 3 shows the gamut gain achieved by adding a 60% ink in magenta and cyan to the full strength inks Y.M.C.K for the equiluminance level of L=70 and L=80 on the same photo glossy media.

Influence of Gloss and Tint on Gamut

The receiving media used is another important factor in gamut even if we only compare the class of photo glossy products. Paper metamerism has a strong influence on the gamut of light metamerisms. An ink-jet dye set was printed on two different commercially available photo papers that vary in paper metamerism (tint) and gloss. The gamut volumes are shown in table 1, last two columns.

Table 2. Gamut gains by a) adding orange and green ink at full-strength to Y,M,C full-strength ink and b) magenta and cyan 15% ink dilution to full-strength ink

<table>
<thead>
<tr>
<th>Sector</th>
<th>a)</th>
<th>b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow</td>
<td>+35.3%</td>
<td>+6.6%</td>
</tr>
<tr>
<td>Red</td>
<td>+24.3%</td>
<td>+6.5%</td>
</tr>
<tr>
<td>Magenta</td>
<td>+0.6%</td>
<td>+26.1%</td>
</tr>
<tr>
<td>Blue</td>
<td>+0.0%</td>
<td>+20.0%</td>
</tr>
<tr>
<td>Cyan</td>
<td>+7.5%</td>
<td>+22.1%</td>
</tr>
<tr>
<td>Green</td>
<td>+28.7%</td>
<td>+19.4%</td>
</tr>
<tr>
<td>Total</td>
<td>+18.9%</td>
<td>+14.8%</td>
</tr>
</tbody>
</table>

Compared to the photo glossy media 1, the second media shows a moderate loss in gamut of 7 percent. However, most of this loss occurs in the light metamerism areas and thus becomes more objectionable. The strong influence of tint on the gamut size especially in light metamerisms is also visible when comparing fig. 2a and b. The L=90 equiluminance plane is very much smaller for the photo media than for the ink jet prints due to the inferior whites of photo.

The influence of the spectral measurement geometry (0°/45° vs. 0°/diffuse) and on the CIEL*a*b* values has been reported in the literature. Its effect on metamerism saturation and on surface finish is shown in fig. 5, for the case of a RC glossy paper a) and a fine arts print b). The prints were spectrally measured both with 0°/45° geometry and with an integrating sphere. The CIEL*a*b* yellow and magenta sector are shown for the two measurements.
 Whereas the measurement geometry has only a minor influence on the fine arts paper print (-1.5% for 45° to diffuse), it has a remarkable influence on glossy paper (-14% for 45° to diffuse). Introducing an asymptote of 1.2 in the 0°/45° data approximates the 0°/diffuse data and seems to represent the visual appearance of the prints better.

**Other Factors Important in Metamerism Reproduction in Photographic Systems**

Brilliant metamerisms are often obtained from colorants with very narrow absorption curves, but such absorption curves can lead to metamerism. Illuminant metamerism6 is created by the interaction of metamerism spectra with different light sources. A metamer index was calculated for the three ink sets of table 1 and is listed in the last row of table 1. For the metamer index a neutral grey wedge of the three ink sets is calculated from the dye spectra under illuminant A. The illuminant is changed to C while leaving the spectra unchanged. The resulting metamerisms under illuminant C are compared to the original neutral grey. The step with the highest deviation from grey is chosen and its Delta E from neutral is given as the metamer index in table 1.

**Conclusion**

Photographic metamerism reproduction cannot be characterised by the size of the gamut alone. Many digital hardcopy technologies surpass the photo gamut, but are still inferior in metamerism reproduction. Photographic prints are biased towards yellow/red reproduction and quite weak in green/cyan and white. With the freedom to add additional ink channels, there is the choice between hexachrome (addition of orange and green) and diluted metamerisms (diluted magenta and cyan). It should not be based on maximum overall gamut but on low grain of the image and smooth tone scale. The lower the density of ink used for printing the more it approaches continuous tone printing. However, very low ink concentrations do not provide the required photographic permanence.

Today’s desk-top dye-based ink-jet systems encompass the photo gamut fully, commercial desk-top pigment systems only in certain sectors. Both exhibit more metamerism metamerism than photography, which is a disadvantage for any display media that may encounter mixed or varying illumination sources.

The orientation of the metamerism gamut needs to be taken into consideration when designing photographic hardcopy systems.

**References**


**Biography**

R. Hofmann has a degree in physical chemistry from the University of Goettingen. After postdoctoral studies in atmospheric sciences at the University of Colorado, she joined Ciba for research in the field of analytical chemistry and laser applications. Since she joined ILFORD in 1985 she has been involved in research and applications for digital photography, photographic metamerism science, image evaluation of hardcopy technologies and the development of tests methods for ink-jet media. She is currently head of R&D for the ILFORD Group.
CGIV 2002 Review

IS&T’s First European Conference on Colour in Graphics, Imaging, and Vision (CGIV 2002) was held April 2-5, 2002 at the University of Poitiers in France. The goal of this conference is to give the growing European color community a venue to present their research and to encounter each other, and to concentrate the growing number of small European conferences and workshops in one larger conference. The conference will be held every two years. The next CGIV is planned for 2004, with Germany as the tentative location.

Judging by the quality of the papers presented and the feedback from the audience, this first CGIV conference was a rousing success. The conference committee under the direction of the General Chairs Christine Fernandez-Maloigne, University of Poitiers, France and Raimondo Schettini, ITIM CNR, Italy, organized a great conference in a beautiful location that attracted many high quality paper submissions and ultimately many conference attendees. A number of cooperating societies, namely the Comite Español de Color, the European Federation of the Scientific Image, The French Color Group, the German Color Group, the Hungarian National Colour Committee, the Swedish Colour Centre Foundation, The Colour Group of the South African Optical Society, the International Association of Pattern Recognition (IAPR), the Royal Photographic Society of Great Britain, and the Flemish Innovation Centre for Graphic Communication (VICG) gave their support.

The technical program co-chairs, Jean-Pierre Veal de Capelle, Xerox, USA, and Lindsay MacDonald, University of Derby, UK, compiled an excellent conference program with 61 oral and 72 poster papers. An international technical program committee that included color experts from academia and industry ably assisted them. The technical program ran three days, mostly single track, with three poster sessions.

The first day of the conference was dedicated to tutorials. Several two and four hour tutorials, in English and French, were well attended. David Alleysson from EPFL, Switzerland, discussed the relationship between retinal physiology and standard colorimetry. Ronnier Luo from the University of Derby, UK, gave insights to color appearance models. Graham Finlayson from the University of East Anglia, UK, explained how to estimate the white point in images. Patrick Emmel from Clariant SA, Switzerland, lectured about color prediction tools for printed surfaces. Theo Gevers from the University of Amsterdam, Netherlands, discussed the issues of color in image and video databases, and Thomas Madden, Eastman Kodak Company, USA, gave an introductory and advanced tutorial in digital color management. In the French tutorials, D. Pellerin from Scientek SA, France, discussed how to acquire spectral information and to calibrate imaging materials. Alain Tréméreau from the University St. Etienne talked about quality control using color image analysis in the industrial environment, and Michel Albert-Vanel, President of the French Federation of Color, explained how to extract the color palette of paintings.

The technical program opened Wednesday morning with the Color Science session, chaired by Ronnier Luo, University of Derby, UK, and Marcel Lucassen, TNO Human Factors, Netherlands. Judging from the papers presented in this session, it is clear that the role of the human visual system in color science will continue to be explored for quite a while. When not as a topic of research in itself, it will be a source of inspiration for color sensors in machine vision. There is also strong evidence that color and vision science is more and more fusing with imaging science. In the first invited presentation, Roy Berns, Rochester Institute of Technology, USA, described the need to make typical imaging practices become scientific imaging practices. He addressed various issues such as input and output sensitivities, characterization and calibration methods and targets. The following three talks covered the field of color constancy and chromatic adaptation transforms, followed by a paper on the prediction of the change of skin colors under different illuminants. The session was rounded out with talks on the recovery of the spectral device sensitivities with uncertainty, color contrast for real images, the effect of image articulation on perceptual transparency, and color rendering.

A special guest speaker, Eric Badique from the European Commission, Belgium, opened the afternoon sessions. He discussed the European Commission’s support for imaging research within the context of the 5th and 6th Framework programs. His talk was of great interest to attendees from the European academic community who participate in many European research projects.

The Vision session, chaired by Stephen Westland, University of Derby, UK, and Dominique Lafon, ENSM, France, consisted of seven presentations on topics as wide ranging as identification of traffic signals to color appearance under cinema viewing conditions. The quality of presentation of all of the talks was exceedingly high and the discussion following each talk revealed an audience that was both informed and interested. The overall message that came across from this session is that the expertise of the vision community to solve the challenging problems with which they are faced is matched only by the ability of users and developers to create new ones. In the opening talk, a description was given how the CIECAM97S color-appearance model could be applied to the segmentation of traffic signs to allow identification of the signs using a behavioral model of vision. A subsequent presentation showed how optimal quantization of images could be achieved by a three-stage model that takes into account properties of the human visual system such as frequency tuning of receptor fields. W. Thornton gave a fascinating review of a large body of work to identify the prime colors of human vision. He revealed them to be spectral lights at 450, 530 and 610 nm and outlined the consequences for modern colorimetry. The following talks described a large amount of data from psychophysical experiments used to investigate the size of color differences between pairs of stimuli, how the dark-surround condition of CIECAM97s could be used to predict color appearance in cinema viewing conditions, an investigation into the correlation between the sharpness and color of reproduced images, followed by a psychophysical experiments to investigate the conspicuity of airplanes.

The seven papers of the parallel Image Filtering session, chaired by Andreas Koschan, University of Tennessee, USA, addressed different issues of image processing specifically taking color information into account, a research area that is becoming more and more popular. The session was opened by a presentation on...
watermarking of color images. The basic idea is to put different watermarks into the image in many different locations considering the properties of the human visual system to perceive color differences. This presentation was followed by a technique for color image watermarking that is robust to JPEG compression and allows a higher compression rate. A method for adaptive impulse noise filtering using center-weighted directional information was proposed, followed by a technique for color image filtering applying adaptive varying window sizes. Another filtering talk applied the discrete ridgelet transform to color images for denoising. Van De Ville et al. studied a technique for suppressing sampling moiré by least-square resampling. This technique may be used for prefiltering in color printing. Finally, a method for transforming an image’s 3D color histogram to accurately match a predetermined target state was described.

The Poster session, chaired by Patrick Herzog, RWTH Aachen, Germany, and Olivier Colot, University of Rouen, France, was in fact the largest session of the conference. A total of 72 poster papers were divided into three groups on three different days. The posters were put up in the morning, and so they could be viewed at any time a conference attendee liked. Additionally, there were dedicated poster sessions in the morning and afternoon of each day. The poster papers covered a wide research area, including virtually all aspects of color imaging from image recording, image and color processing, color vision and vision modeling, and image reproduction. The audience was very interested in the posters, so much so that the poster displays had to be separated for the next days.

On the first day, the posters covered diverse aspects of human color vision, such as color tolerances, color size, color difference perception, the influence of gamma, chroma or noise on color perception, and what differences do observers see in color images. There were papers on opponent color spaces, chromatic adaptation transforms, color constancy, and normalization. Other papers dealt with more practical aspects such as fluorescence in color standard tiles, tone mapping, modeling of the color mixing of soil minerals, reproduction on electronic displays, propagation of tristimulus errors, and weights for tristimulus calculation.

A large section of the poster papers dealt with image processing, most of them on day two. They covered subjects like video object tracking, robot guidance, video surveillance, face recognition, vector correlation and filtering, highlight substitution, segmentation, de-noising/image restoration, texture characterization/classification, image compression and coding and quantization, watermarking, and road sign detection. Several papers dealt with image classification, image retrieval, and color equalization. Further topics were color naming and color image analysis for turkey breasts.

The third day was dedicated to color engineering, such as the color characterization of digital cameras, printers, and silver halide printers. Quality aspects of open color imaging systems were also presented, including the gamuts of input media and printers, aging, and the color characteristics of prints. Further topics were color halftoning, the restoration of faded film, and modeling the human color perception. Finally, there were several papers on spectral estimation and multispectral imaging dealing with systems, texture models, and multispectral communication systems.

At the end of the first day, a special session on the European Color Groups, organized by Joaquin Campos Acosta, Instituto de Fisica Aplicada, Spain, and Alain Trémeau, University of St. Etienne, France, gave the conference attendees the opportunity to hear about the activities of the different organizations. The following groups were represented: VFG, VICG, French Color Group, Spanish Color Committee, German Color Group, Danish Colour Group, Hungarian Colour Groups and Societies, and The Colour Group of Great Britain.

The morning session of the second day, entitled Image Classification, was chaired by Patrick Lambert, University of Savoie, France, and Ingeborg Tasl, Hewlett Packard, USA. Most of the papers discussed how color information could be used in indexing and image retrieval, a very important area in the color imaging community. Graham Finlayson, University of East Anglia, UK, explained the concept of spectral sharpening in relation to adaptation, metamericism and color matching. Spectrally sharpened sensors are linear combinations of cones that have narrower support and are more decorrelated. Reiner Lenz, Linköpings University, Sweden discussed how spaces of spectral distributions, such as color stimuli, have a natural cone-like structure. This can be exploited to compute natural coordinate systems from empirical data, such as multi-spectral measurements and images. Both invited presentations were very appreciated by the audience.

The Image Rendering session, chaired by Francis Schmitt, ENST, France, and Shoji Tominaga, Osaka Electro-University, Japan, illustrated how color science is nowadays particularly present and active in computer graphics and image processing. An invited paper by Werner Purgathofer, Vienna University of Technology, Austria, demonstrated how photorealistic image rendering requires very complex attributes of the visual system, such as time dependency, visual acuity, or color sensitivity in order to cope with the range limitations of current displays. For real-time application, such as in virtual reality, clever simplifications of these models remain a necessity. Two papers considered the problem of recovering an approximation of the bi-directional reflectance distribution function on the surface of real objects, which can open new applications in augmented reality. One estimated the Ward model parameters from a single photograph of a complex scene of which the geometry is fully known. The second estimated the Torrance-Sparrow model parameters of an object surface with arbitrary convex shape by using a CCD camera and a dedicated experimental bench. Two efficient automatic methods to improve image quality were proposed.
for still images, i.e. red eye removal, and for digital video sequences, i.e. saturation and contrast enhancement, white balance correction, preferred color reproduction with smooth time transitions and scene cut detection. For background-frame differencing applications such as moving object extraction in image sequences, many color similarity measures had been proposed. Their effectiveness was extensively compared in one paper.

The last day of the conference started with the Device Technology session, chaired by Kirk Martinez, University of Southampton, UK. The session included presentations about using general color algorithms to solve a device specific task. Reimar Lenz from the Technical University of Munich, Germany, opened the session with an in-depth overview over the state-of-the-art of professional digital cameras, specifically their sensor characteristics. The following papers discussed color calibration of a high-resolution digital camera, and the gray and color calibration of a digital photography printer.

The Ink and Media session, chaired by Paul Delabastita, Agfa, Belgium and Roger Hersch, EPFL, Switzerland, indicated that research in this field is increasingly based on mathematical modeling of the ink, media and light interactions. As reliable predictors are becoming available, the next stage will be to use them in the context of a “total image quality management” chain that includes image processing before printing, a model of the printing device, and a model for human image quality perception. One paper discussed a comprehensive prediction model for reflection on printed varnish-coated metallic surfaces, based on the Cook-Torrance model, followed by a presentation on how to use the Kubelka Munk model for the purpose of modeling light surface interactions in the context of recognizing or rendering virtual surfaces in computer graphics. The Kubelka Munk model is based on differential equations and as such is completely deterministic. An original paradigm was introduced to describe ink, media and light interactions in a way that is similar to a random walk of photons in the substrate. One paper described the complexities of quantifying image quality degradation when recycled paper is used.

The session also included an invited presentation by Rita Hofman, Ilford SA, Switzerland on the color aspects in photo-quality inkjet printing. She compared the different design options and trade-offs. The effects of extending the number of inks, the selection of the additional inks and the nature of the coloring agents were brought into relation with such qualities as color stability, color gamut, halftone graininess, metameric index and gloss appearance.

The parallel Fuzzy Logic session, chaired by Vasile Buzuloiu, Bucharest Politechnica University, Romania, and Constantin Vertan, University of Poitiers, France, brought new ideas to a field of growing interest and proved them on application examples. Using a fuzzy approach to find color edges or to segment images was the topic of three papers. One presentation discussed a new smoothing operator for noise reduction filtering whose coefficients in the computing window are calculated via a new similarity measure between two pixels of the window. A directed morphological operation by which pixels with certain properties are favored through the values of the fuzzy measure coefficients was the topic of another talk. The new color morphology and the robust filter were successfully used for pre-processing operations.

In the last session of the conference, Multispectral Imaging, chaired by Marc Mahy from Agfa, Belgium, several issues related to spectral modeling were discussed. In the invited presentation, Bernhard Hill, Aachen University of Technology, gave an excellent overview about the need of spectral information in color reproduction systems. Color management systems nowadays are mainly based on tristimulus values. However, if different illuminants are used, or if the color matching functions of observers differ, there is in general no guarantee that a color match can be obtained. These problems can be partly be solved with multispectral imaging techniques. One paper discussed how many basis functions are necessary to accurately reconstruct object reflectance functions. It was found that different data sets have different spectral properties and hence a different number of basis functions are needed to represent these data sets well. The following presentation indicated that a new reconstruction technique based on a neural network could result in much more stable spectra than using the pseudo-inverse model, especially in the presence of noise. One paper investigated the advantages and disadvantages of different metrics to evaluate the reconstruction of spectra and concluded that the best metric to be used depends on the application. In the last presentation of the conference, Rosen presented a method to optimize the number and type of filters needed to accurately reproduce a given scene.

The conference venue, Poitiers, is a beautiful medieval city in the Poitou-Charentes region southwest of Paris. Its history and regional importance was explained during a welcome drink offered by the city of Poitiers and held in the beautiful city hall. Poitiers is also home of the Futuroscope Park, which is dedicated to new imaging technologies. During the conference reception, the attorneys had time to access the different attractions, such as 3D cinemas, circular cinemas, dynamic cinemas, and laser shows, some of which are unique in the world.

A special recognition is warranted to the University of Poitiers, which hosted the conference, and the local organizing committee under the direction of Christine Fernandez-Maloigne that made sure that everything ran smoothly - from audio-visual equipment to coffee breaks to train reservations. Also, the IS&T European Chapter, under the direction of Rene DeKeyzer, Agfa, Belgium, played a significant role in the organization of the conference and the coordination with IS&T headquarter. This is the second major European IS&T conference in as many years, after DPP 2001 in Antwerp, indicating that the European Chapter of IS&T is indeed very active.

Sabine Süssstrunk
IS&T Vice President
EPFL, Switzerland
Standards Update
David Q. McDowell, Editor

This issue of Standards Update focuses on CIE Division 8, Image Technology. It is based on the recent Division Activity Report prepared by the Division Editor. The work of Division 8 was last reported on in the March/April 2000 issue of the Reporter.

CIE Division 8
The current Division 8 officers are:
Director: Todd Newman (US)
Secretary: David McDowell (US)
Editor: Mike Pointer (UK)
The Division 8 web site (www.colour.org) provides information about the division as well as contact links to the officers and committee chairs.

Terms of Reference:
The Division “Terms of Reference” are: “To study procedures and prepare guides and standards for optical, visual and metrological aspects of the communication, processing, and reproduction of images, using all types of analogue and digital imaging devices, storage media and imaging media.”

Background
The Division aims to work primarily by electronic means in order to make efficient progress. This method of working has proved worthwhile and good progress is being made in several areas.

Since its inauguration in September 1998 at a CIE Meeting held in Baltimore, US, the Division has held meetings in Warsaw, Poland (1999) as part of the CIE Quadrennial meeting and in Derby, England (2000) in association with the conference Colour Image Science 2000. Several of the Technical Committees met before or after the IS&T Color Imaging Conference in Scottsdale, Arizona in November 2001, and an informal meeting of the Division was held. It is proposed that there be a similar arrangement at the 10th IS&T Color Imaging Conference to be held in Scottsdale, Arizona in November 2002. The next formal meeting of the Division will be held in conjunction with the CIE Quadrennial Meeting, 25 June - 2 July 2003, in San Diego, USA.

As part of the initial inauguration of Division 8, Technical Committees (TC) 1 through 4 were formed. The current status of the activities of the Division 8 committees is as follows.

TC 8-01 Colour Appearance Models for Colour Management Applications
The chair of TC8-01 is Nathan Moroney of Hewlett-Packard Laboratories, Palo Alto, CA, USA.

It’s terms of reference are: “To study, develop, and recommend a colour appearance model for CIECAM97s for use in digital colour management and to develop clear usage guidelines for common applications. Consideration is to be given to colour and engineering requirements for open colour management systems.”

After two physical meetings in the summer of 2001 in Rochester, New York and in the fall of 2001 in Scottsdale, Arizona great progress has been made and the number of major revisions to be finalized is down to one. The primary unresolved issue remains the selection of the linear chromatic adaptation transform. The entire committee agrees that the revised model should include a linear chromatic adaptation transform but there is still no consensus about which one to use. A significant accomplishment was to gain consensus on the chroma scaling. Additional analysis and experiments by the technical committee have supported a reduced chroma scale for the very near neutrals, although there are two possible means to implement this revision.

The committee participated in two surveys on which linear chromatic adaptation transform should be used and the votes were about evenly split between two transforms proposed by Luo, et al. and the transform proposed by Fairchild. There would appear to be a trade-off between a higher degree of backwards compatibility, the Fairchild transform, and an optimisation based on all or most available corresponding colour data sets, the Luo et al. transforms. The performance of all of the transforms is fairly similar so secondary considerations are being investigated. Analysis by Mahy revealed that there is no significant difference between the transforms based on error propagation. Hunt and Fairchild have prepared a summary document highlighting the differences between these transforms. The second survey resulted in a small preference margin for one of the Luo et al. transforms but there is still ongoing discussion of the topic.

During the physical meeting in Rochester, New York, Alessi shared her results from TCI-27 and follow-up discussions between Alessi and Fairchild have been shared with the committee as outstanding issues that will require additional consideration by TC8-01. These include possible image dependencies in the results and possible field-of-view surround effects.

The key accomplishment for the technical committee for the year was gaining consensus on the chroma scaling. Additional analysis and experimentation by Moroney suggested that the chroma magnification for near neutrals is not present in the raw LUTCHI scaling data and may be more a result of fitting the scale without forcing an intercept at the origin. Fairchild has proposed a solution by modifying the chroma equation while Hunt et al. have proposed a new non-linear post adaptation response compression that provides a good fit to the chroma scaling data and has a small intercept. This new non-linear function also addresses a problem of saturation changes with increasing illumination of the adapting field. While a significant revision, the new non-linear function has the advantage of addressing two outstanding issues. Regardless of which revision is used, all members of the technical committee have agreed on minimizing the intercept for the fit for the chroma scale.

In December of 2001 a sub-committee, consisting of Liao, Luo, Moroney and Newman, was formed in order to prepare a draft technical report for consideration by the entire committee. This sub-committee will attempt to reach some sort of compromise on the linear chromatic adaptation transform and the non-linear response compression.

TC 8-02 Colour Difference Evaluation in Images
The chair of TC8-02 is Dr. M R Luo of the Colour and Imaging Institute, University of Derby, UK.

It’s terms of reference are: “To study and recommend methods to derive colour differences for images”

\- A draft of the proposed technical report (Version 5) was distributed to TC members for comment in December 2001. It is expected to com-
The TC will continue to generate test images, to perform psychophysical experiments in different sites and to evaluate the performance of various methods. A work plan will be distributed between members in January.

**TC 8-03 Gamut Mapping**

The chair of TC8-03 is Jan Morovic of the Colour and Imaging Institute, University of Derby, UK.

It’s terms of reference are: “To study, develop and recommend an optimal solution for cross-device and cross-media image reproduction. This solution will provide a standard procedure to calculate the colour gamut of an image, an imaging system, or procedure to calculate the colour gamut of an image, an imaging system, or its components, and either one algorithm, or a set of algorithms and rules for use in specific applications.”

- A meeting of the TC took place on 8 November 2001 in Scottsdale, AZ with the focus being on finalising the Guidelines for the Evaluation of Gamut Mapping Algorithms (GMA) that the TC has been working on throughout 2001. In addition to discussing remaining issues with the guidelines, the publication of GMA source code and the provision of test images was also discussed.
- In the course of 2001 three revisions of the Guidelines were prepared based on discussions conducted via e-mail. The focus of most of the discussions was whether a single test image or a number of test images should be made obligatory in the Guidelines and changes were also made to the obligatory GMAs that the Guidelines specify.
- A checklist that is to help participants in coordinated research was prepared to allow for easy checking of whether a study complies with the Guidelines. Fujifilm Electronic Imaging Limited (UK) have made the image that is specified as obligatory in the guidelines available to the TC for its use and distribution to participants of the coordinated research. ACANON Development Americas (USA) and Sony (Japan) have contributed test images to the TC. ACURRENT plans are to:

- Complete Guidelines and publish them as CIE technical report.
- Publish shorter version of guidelines at a conference or in a journal.
- Commence coordinated research on the basis of the Guidelines.

**TC 8-04 Adaptation under Mixed Illumination Conditions**

The chair of TC8-03 is Naoya Katoh of the Sony Corporation, Tokyo, Japan.

It’s terms of reference are: “To investigate the state of adaptation of the visual system when comparing soft-copy images on self-luminous displays and hard copy images viewed under various ambient lighting conditions.”

The TC completed a set of experimental guidelines in 2000. These were then used, during 2001, by Sueeprasan (UK) and Katoh (JP) to performed adaptation experiments. The results from these of two different laboratories showed a fair accordance in mixed adaptation ratio (ie 40-60%). This result is also in accordance with the past results of Katoh, Berns and Choh (US), and Shiraiwa et al. (JP). A TC meeting was held at 09-Nov-2001 at Sunburst Hotel, Scottsdale, AZ.

The TC also discussed the choice of CAT (chromatic adaptation transform) matrix to be incorporated into a mixed adaptation model. However, the choice of a preferred CAT is now being discussed as part of the work of TC8-01. To ensure compatibility, it was agreed that TC8-04 should follow the recommendation from TC8-01, since the differences being discussed are very subtle. With these results, it was agreed that TC should focus on preparing a technical report during 2002.

**TC 8-05 Communication of Colour Information**

TC 8-05 was established in 1999 and it’s chair is Robert Buckley, Xerox Corporation, Webster, NY, USA.

It’s terms of reference are: “To standardise a minimal set of techniques that enable unambiguous and efficient communication of the colour information in images. Two fundamental approaches will be addressed: 1. The association with the image data of additional data that describes the colour space of the image data.”

2. The representation of the image data in a standard colour space.

The standard will also define a minimal set of standard colour spaces that addresses a wide range of imaging applications. Whenever possible, existing standard colour spaces will be used in preference to creating new ones.”

The last TC meeting was held November 5, 2001 in Scottsdale, Arizona. At this meeting, results were presented evaluating the sRGB, sYCC, e-sRGB, e-sYCC, ROMM RGB and PCS LAB colour spaces against the following colour encoding criteria:

**I. Color Gamut Metrics**

A Total Color Gamut Volume
B Comparison to target color gamuts
   - real world surface colors
   - optimal colors
   - legal colors
   - CRT colours
   - photographic print colors
   - photographic transparency colours (not complete)

**II. Quantisation metrics**

A Quantisation error for single code value change
   - for colours inside all of the colour encodings
   - for colours inside real world surface colour gamut
B Quantisation efficiency (# bits needed to achieve certain error level)

**III. Complexity of transform to/from important colour spaces**

A video preview
B PCS XYZ
C PCS LAB
D SWOP CMYK

A report of this work is available through the Division 8 web page.

TC8-05 took responsibility for coordinating the CIE Expert Symposium 2000 on Extended Range Colour Spaces, held November 11, 2000 in Scottsdale, Arizona. The Proceedings of this Symposium have been published and are available as CIEEx01 2001, ISBN 3 901 906 10 X.

The next physical meeting of CIE TC8-05 is planned for November 2002, around the time of the IS&T/SID Color Imaging Conference in Scottsdale, Arizona.

**TC8-06 Image Technology Vocabulary**

TC8-06 was established in 2000 and it’s chair is J Schanda, University of Veszprém, Hungary.

It’s terms of reference are: “To liaise with other Division 8 Technical...
STANDARDS

Committees and collate definitions of terms associated with image technology.”

Up to November 2000, work was carried out by correspondence. The Chairman has submitted parts of several terminology documents to members to consider what should be included in a technical report. At the TC 8-06 meeting in Scottsdale on 11-Nov-2000 it was decided that the TC should collect terms and definitions from as many imaging related ISO TCs as possible and place them in a database. The construction of a database has been started and will be circulated to the Technical Committee members in 2002.

TC 8-07 Multispectral imaging

TC 8-07 is currently in the process of being established and receiving the approval of the CIE Board of Administration and member bodies. It’s proposed chair is Dr. Patrick Herzog, Color AIxperts GmbH, Aachen, Germany.

The proposed Terms of Reference are: “To study, develop, and recommend encoding techniques and data formats for the exchange of multispectral images, and to provide test procedures for the evaluation of multispectral imaging systems.”

It is anticipated that the subjects to be covered will include:

• Spectral test sets including data sets for simulation and testing, definition and fabrication of an experimental spectral test chart, and a test chart of pairs of metameric colors.
• Definition of sets of color matching functions of typical human observers to be used in multispectral imaging systems for the definition of observer metamerism.
• Encoding of multispectral image data including linear encoding and quantization, nonlinear encoding and quantization, mixed spectral and spatial encoding.
• Definition of data formats for the exchange of multispectral image data.

Multiple images of the interference fringes are then captured and the hyperspectral image cube calculated. The configuration and calibration of the system will be described.

“Spectrophotometric and Electrochemical Characterization of Silver Halide Conversion” by Conor D. Kelly, Department of Imaging and Photographic Technology at RIT.

The reaction of AgBr with AgCl to form the mixed halide AgClBr has beneficial effects on the optical and electronic properties of the resulting silver halide. This includes enhanced photographic speed, contrast, reciprocity and keeping (stability). Additionally, the reaction of halide species can extend the spectral sensitivity of the resulting combination, such that it extends to lower energy, longer wavelength radiation.

The rate of the halide conversion reaction affects the morphology, size, electronic properties and optical absorbance of the resulting mixed halide. The rate of reaction of the conversion process is a sensitive function of the temperature of reaction, grain size of the halide species (surface area), solubility of the halide source, and the presence of various additives, which can increase the rate of reaction (ripeners) or decrease the rate of reaction (restrainers).

In the current study, qualitative spectrophotometric data from halide reactions is compared to quantitative electrochemical measurements of the free halide ion concentration. The comparison of rate is limited to similar reactions with 0.1 and 0.35 mAgBr and 0.1 mAgCl. Previous work undertaken by this group includes qualitative in-situ spectrophotometric measurement of the rate of halide conversion reactions as influenced by temperature, solubility, grain size and presence of additives.

The following contributors to this work are gratefully acknowledged: Joaquin Calcines, Heather Dolan, Kristyn Falkenstern, Rosalyn Klinger, Erin Murphy, and Professor Bruce E. Kahn.

“Evaluation of Experimental Techniques for Characterizing the MTF of Printing Substrates” by Joshua Nauman, Senior in Imaging Science at RIT.

Substrates such as paper play a critical role in color and tone reproduction with a printing device. The substrate can be considered as an imaging component of the printing system with its own optical MTF. The phenomenon is often referred to as the Yule-Nielsen effect. This project

RIT Night

In an annual event, Rochester Institute of Technology students presented their recent work at the May meeting of the IS&T Rochester Chapter. Here are abstracts of three student papers presented at that meeting.


Hyperspectral imaging is a term used to describe the capture of images at multiple wavelengths to form what is known as an “image cube.” The cube is a three dimensional matrix of pixel values with two spatial dimensions and one dimension of wavelength. The system developed in this project produces images at wavelengths from 400 to 700 nm with 1 nm resolution. However, instead of capturing images at different wavelengths, white light was used. The white light from the object being imaged was passed through a Michelson Interferometer in order to optically generate the Fourier Transform of the hyperspectral image cube.

Summary

CIE Division 8 is involved in a very active program that has potential impact on many areas of the imaging community. If you would like to be involved in any of these activities, please contact the Chairman, Todd Newman, at todd@cra.canon.com.

If you are aware of work that should be undertaken by Division 8, and can identify a leader for such work, please also bring this to Todd’s attention. As with any CIE Division, the leaders and participants must be identified before we can start a new Technical Committee, and we are always open to volunteers.

For suggestions for future updates, or standards questions in general, please contact the author at mcdowell@npes.org or mcdowell@kodak.com.
The annual PICS Conference, an international technical meeting on digital imaging, was held in Portland Oregon, 7-10 April 2002. It was the 5th PICS Conference and the 55th IS&T spring meeting. Since it was hosted at the Portland Marriott Downtown Hotel, it was also within easy reach of various city attractions.

The PICS Conference series was established to focus on digital image capture, quality, processing and systems developments. The meeting has the full title of Image Processing, Image Quality, Image Capture, and Systems Conference. Thus, most of the 60 technical presentations and tutorials were related to digital imaging.

**Tutorials:**
This year's conference featured six tutorials in a somewhat modified format. On Sunday there was a full day of short courses offered. Two additional courses were presented on Monday, to provide greater scheduling and less conflict for those wishing to attend more than one course.

**Program:**
The technical program was limited to two simultaneous tracks. Track 1 included sessions on, applied vision models, image quality standards, modeling and psychophysics. Track 2 comprised, digital image capture, digital photography, optics for digital imaging, museum and archive imaging, and digital image processing.

"It was an ideal meeting to easily see talks in a wide range of imaging disciplines", said Scott Daly of Sharp Labs. In addition, presentation times were 30 min. allowing more questions and discussion than is usual.

Previous PICS meetings started with a plenary session of invited speakers. This year, instead of the plenary, each of the technical sessions opened with longer keynote presentations. Following the first part of each technical track, were the IS&T 2002 Honors and Awards. Wayne Jaeger, president of IS&T, made the presentations, assisted by past-president, John Meyer. Three award recipients were in attendance: Rodney Shaw (Honorary Membership), Peter Engeldrum (IS&T Fellowship) and Peter Burns (Service Award).

The conference proper was opened by Scott Daly, the chair of the Applied Vision Models session in Track 1, and Peter Burns, the General Chair of PICS 2002, in Track 2.

**Track I:** The Applied Vision Models session opened with a focal paper delivered by Jeffrey Mulligan of NASA on Vision-based Approaches to Digital Halftoning. [Published in the previous issue of The Reporter] This was followed by two talks addressing vision models in digital printing. Garrett Johnson of RIT then presented, On Contrast Sensitivity in an Image Difference Model, co-authored by Mark Fairchild.

Jian Yang of Kodak described an image degradation metric based on foveal and peripheral vision performance. This was followed by two papers on high quality image soft display. Greg Ward, of Exponent, described a wide field stereographic viewer used in a NASA virtual reality system. A high quality LCD display was then presented by Yasuhiro Yoshida of Sharp Corp. This paper demonstrated improvements when reduced quantization errors are achieved by encoding and display beyond 24-bit color. Next was a discussion of wavelet analysis of print defects (Kevin Donohue of U. of Kentucky). The session ended with and a cognitive model of color categorization, from Sergueri Endrihkovski of Kodak.

**Image Quality modeling and Psychophysics**
In this session, Hiroaki Kotera from Chiba University, presented a keynote talk, Image-dependent quality and preference control. He described progress towards adaptive, image-dependent processing, based on segmentation of scene content. Karin Töpfer, Kodak, then described a way to include preference into image quality modeling. Preference was described by a distribution for a population of observers and scenes. Peter Engeldrum of Imcotek presented, Extending Image Quality Models. He addressed cases where image quality is not monotonically related to particular visual attributes, as when an image is over-sharpened.

The encoding and display of color images was then addressed by Efthimia Bilissi of Univ. of Westminster. Various common color display methods, including ‘web-safe’ colors were compared by colorimetric measurements. This was followed by Jon Hardeberg of Gjovik University, and Color Image Quality for Multi-function Peripherals. This session ended with a presentation by Brian Keelan of Kodak, on the prediction of image quality from various perceptual attributes. A general multivariate method for combining the various attributes was described.

**Image Quality Standards and Measurement**
Edul Dalal Chaired this session, which opened with Toshihiko Inagaki of Fuji Xerox presenting, Challenges to International Standardization of Image Quality Evaluation. The measurement of printer color registration was then addressed by William Kress of Minolta-QMS. Automating rank order image quality testing was then addressed by Luke Cui of Lexmark, followed by the measurement of printer motion variation and error by Michael Mongeon of Xerox. Here, a spatial frequency-based analysis of image motion was derived from scanning of specific printed targets.

This session was continued by Peter Barten, Barten Consultancy, presenting Nonlinear effect of Modulation on Image Quality. A square-root relationship between image modulation (as limited by, e.g., a system MTF) and image quality is included in the well-known SQRI metric. An alternative to spatial frequency based image resolution evaluation was proposed by Norman Barningham of HP. This aimed at simplifying addressability and resolvable information for digital printers. Two presentations, from NexPress and RIT, were then given on aspects of image gloss evaluation for prints.

The use device MTF characteristics was the subject of three consecutive talks by Samira Bouzit (univ. of Derby), Troy Strausbaugh (HP) and Ralph Jacobson (Univ. of Westminster). This collective work was complemented by a subsequent presentation by Peter Burns, on improvements a standard method of MTF evaluation, based on slanted edges, and used by all three of the above speakers. Low-frequency, image mottle measurement and color quality was the focus of the session, with Prof. John Grojean of Kodak, presenting Phase-Plate Mottle Measurements in Color Imaging.
error propagation analysis, where then discussed by Dave Wolin ImageXper) and Peter Burns (Kodak), respectively.

Track II: A full morning was devoted to various aspects of digital image capture. The session, chaired by Paul De Keyser of Agfa, opened with a keynote talk by Albert Theuwissen, Philips Semiconductors, on the image noise characteristics of high resolution image detectors. He described how noise sources, e.g. in signal readout, and pixel non-uniformity, limit imaging performance. This lead to a discussion of the fundamental limits to imaging signal-to-noise ratio of electronic detectors. Matthew Whalen of SiliconFilm Technologies then described the technology behind the electronic film system, used in conventional SLR cameras.

Digital Photography
The signal range of scanned and encoded images was the subject of the next two presentations. Dietmar Wieller of Image Engineering described progress towards an ISO standard for dynamic range evaluation of reflection digital scanners. He included a description of testing materials, signal encoding and the influence of image noise on the results. Color signal encoding as most commonly practiced, and in extended color spaces where addressed by Kevin Spaulling of Kodak.

The image enhancement was the subject of the next talk by Koen Vande Velde of Agfa. He described how multi-resolution spatial filtering in an opponent color space was applied photographic images in a way that is practical for the batch processing in digital photo-finishing.

While the ICC has provided a framework for color information exchange, the device vendor is responsible for device profile and CMM (color management module). Huanzhao Zeng of HP, investigated the accuracy of color management commonly implemented in this way. The variation of image data with changing illumination was then addressed in terms of a Color Inconsistency Index, by Don Williams of Kodak. He introduced a performance metric and compact visual tool for digital camera evaluation.

The spatial characteristics of images were addressed by Robert Parada of Kodak. He described how the development of spatial management strategies, similar to those for color management, could simplify the exchange of images in open systems. A presentation was then added to the program in this session. Dick Lyon, presented, Color Photography with the Foveon X3 Sensor Technology, which was of keen interest to the full room.

Optics for Digital Imaging
This followed a successful session on Adaptive Optics introduced last year at PICS, also chaired by Chris Dainty of Imperial College. He presented Recent Developments in Adaptive Optics, describing applications to conformal microscopy and ophthalmology. Thomas Cathey (Univ. of Colorado) then described how adaptive optics could be used in hybrid digital image acquisition systems.

For many digital-imaging systems, it is important to know the absolute level of illumination. For detector performance modeling in particular, this information is often expressed in terms of the number of photons. Russell Palum of Kodak, reviewed how this can be done, and related this to several common parameters, such as ISO speed, exposure in lux-sec, and detector size.

The session ended with Nicholas George of Univ. of Rochester describing the use of a Logarithmic Ashree lens in a digital camera, and Larry Hubby (HP) presenting, Evolution of the Optics of the Modern Laser Printer.

Museum and Archive Imaging
This session was devoted to various aspects of the imaging of library and museum collections. Steven Puglia (NARA) compared the digitization and photographic duplication options for cultural institutions. A simplified approach to the specifica-

Image Processing
This session included a wide range of presentations on digital image processing. A novel multiprimary image display was described by Friedhelm König of Agfa, followed by a presentation of image enhancement for digital photography by Rodney Shaw. Automatic facial feature finding was described by Mark Bolin (Kodak), and Content-based Digital Watermarking was described by Nam Deuk Kim of Digimarc. Presentations on the application of wavelet formatted images to web image processing, and an approach to improved FM-based digital halftoning followed. Anne Fry of Lifetouch presided over the second Digital Image Processing session. This included three papers on various aspect of digital halftoning.

PICS2003
Next year’s PICS conference, ‘The Digital Photography Conference’, will be held 13-16 May in Rochester, New York. Prof. Mark Fairchild of RIT will be the General Chair. Plans are already in place to continue several of the successful directions of PICS 2002, with the addition of a special session on multispectral color imaging.

This book is intended to be a reference for “leading scientists, engineers, and executives in the imaging industry,” as well as a “source book and textbook” in academia. It covers silver halide photography, diazo type, electrophotography, thermal methods and ink jet technology. It is heavily weighted toward electrophotography, with over half the book devoted to toners and photoreceptors.

The first two chapters introduce conventional photographic materials. J. F. Hamilton’s chapter, Conventional Photographic Materials, is a solid state physicist’s description of the electronic structure of silver halide emulsions. Tabular emulsions are mentioned in passing, but their impact on color negative films over the last decade is not noted. These morphologies have enabled, among many other improvements, broader dynamic range color negatives. This is one of the key improvements that has enabled the Kodak single-use flash camera to deliver, on average, the best quality images to the typical consumer of any camera under $100. The chapter by L. E. Friedrich and J. A. Kapecki on Color-forming Photographic Materials discusses both image-forming couplers and couplers that inhibit development (DIRs). Henry Mustacchi’s chapter, Diazotype Papers, Films and Chemicals, is very down-to-earth. It includes a long list of formulations and a description of a coating plant. This appears to be an adequate set of information to establish a diazo paper manufacturing operation. The recent application of diazo chemistry in Fuji’s Thermo-Autochrome is not noted.

B. E. Springett has contributed a new chapter, A Brief Introduction to Electrophotography. This is a welcome addition in that it places the subsequent electrophotography chapters in context. Three chapters follow on toner materials: Paul Julien and Robert J. Gruber discuss Dry Toner Technology. Lewis O Jones discusses Carrier Materials for Imaging, the second component in two-component development. James Larsen, George Gibson and Stephen Schmidt discuss Liquid Toner Materials as used in high-quality, high-resolution color devices. Lubo Michaylov and Dene Taylor have a chapter on Di-electric Papers and Films. Electrophotography can deliver near-photographic quality images on a variety of substrates with good image permanence.

Four subsequent chapters cover photoreceptors for electrophotography: S. O. Kasap on Photoreceptors: The Chalcogenides; Paul Borsenberger and David Weiss on Photoreceptors: Organic Photoconductors; R. Joslyn on Photoreceptors: Recent Imaging Applications for Amorphous Silicon; and finally J. Mort on Applications of Amorphous Silicon and Related Materials in Electronic Imaging. The coverage of electrophotography is thorough and provides a good basis, both as an introduction to the technology and as a reference to current trends.

Thermal imaging is covered in two chapters. Each one covers more than one technology. Klaus Kasper discusses Thermal Imaging Methods. This chapter covers direct thermal print papers from the ubiquitous point-of-sale receipts to Fuji’s Thermo-Autochrome, thermal mass transfer, thermal dye transfer (dye sublimation printing) and laser thermal imaging. P. J. Cowdery-Corvan and D. R. Whitcomb discuss Photothermographic and Thermographic Imaging Materials. This chapter discusses “dry silver” imaging systems in some detail. Most of the chapter concerns the organic silver salt technology, with the structure of the silver compounds as well as the necessary additives and stabilizers. Fuji’s false-color negative-working silver halide Pictography is discussed, but their positive-working Pictrostat dye release chemistry is not described.

Walter Wnek, Michael Andreottola, Paul Doll and Sean Kelly introduce Ink Jet Ink Technology. This chapter includes discussion of both the colloidal properties of colorants and the optical properties of colorants on paper with scattering. The important issues of image stability, ink formulation and ink processing are introduced. David Bugner discusses Papers and Films for Ink Jet Printing. This chapter discusses ink-receiving layers of both the porous and swellable kinds for the various types of inks described in the previous chapter. This is the one chapter focusing on the image substrate, although the physical and optical properties of the substrate are important in every imaging technology. The chapter on cilithography in the first edition has been deleted, largely because Cycolor has not become a commercial success although there has been significant development in that technology.

I wish that the editors had edited the Handbook with more vigor. I expected a book that, as Cowdery-Corvan and Whitcomb state in Chapter 13, was “intended to be sufficiently complete to provide a basic understanding of the current state of knowledge to give a newcomer to the field a good starting point to begin to exploit its capabilities.” The different chapters cover the various imaging technologies at greatly different levels. Thermal imaging and xerography are given good high-level introductions. The two chapters on conventional photography very quickly delve into critical but specialized areas: silver halide emulsions from a solid state physicist’s viewpoint and color-forming dyes from a chemist’s viewpoint. Because there are a number of emerging technologies in thermal imaging, another chapter on that area would have been welcome.

The format of the references varies from one chapter to another. Not every author gives a good broad basic reference to the technology. It would have been helpful if Springett’s introductory chapter on electrophotography had referenced the subsequent articles in this volume. The classic photographic reference by Mees and James is called the Theory of the Electrophotographic Process in Chapter 4. In conclusion, this new handbook may make sense for someone working in electrophotography who needs a passing knowledge of competing technologies, but it serves as a poor introduction to the breadth of some of those technologies.

Julian Bullitt retired from Polaroid Corp after 27 years in various technical positions, most recently as a Research Fellow and Director of the Image Science Laboratory. He has an A. B. from Princeton University and a Ph. D. in Inorganic Chemistry from M. I. T. Julian is a member of IS&T and AAAS. Since retirement, he has been providing technical consulting services in digital imaging.
New Products
Edited by Allan Ames

DIGITAL CAMERAS

Value Priced Mega-Pixel Digital Video Camera

The Toshiba IK-SX is a Digital Monochrome Progressive-Scan video camera. It has a megapixel 2/3 inch CCD with 6.45 micron square pixels and a full scan rate of 15 frames/second at 1392 × 1040 pixel resolution. There is also an asynchronous reset electronic shutter with speeds from 1/15-1/5,000 sec. For increased speed, there is a partial scan rate that allows output of up to 60 frames/second. The SX1 has a small profile of 44 × 44 × 53 mm to accommodate tight spaces. Output is digital with a Camera Link or LVDS interface. Suggested list is $2,500. For more information call 1-949-461-4986 or website: www.cameras.Toshiba.com

High Resolution Room Temperature InGaAs Camera

Sensors-Demeter Components Group announces a room temperature camera that employs a 640 × 480 Inium Gallium Arsenide (InGaAs) focal plane array (FPA). This high-resolution short-wave infrared (SWIR) scientific imaging system operates at room temperature and is used for applications such as laser profiling, emission microscopy and imaging spectroscopy. The camera is a high resolution (640 × 480) on a 27 um pitch) short-wave infrared imaging system (0.9um to 1.7 um). The 14 bit digital output enhances the camera’s dynamic range and can easily be integrated with National Instruments’ LabVIEWÔ software. It features a snapshot mode exposure with multiple computer controlled integration times. The camera’s small size (4” × 4” × 6”) makes it easy to integrate into a wide variety of measurements.

For more information contact: Bill Woodrow, Sensors Unlimited, Inc., 609-520-0610 ext. 208; bwoodrow@sensorsinc.com

Infrared Camera - The World’s Smallest

Indigo Systems introduces the OmegaÔ thermal imaging camera. Omega is the smallest, lightest infrared camera ever built. It weighs only 3.5 ounces and is less than 4 cubic inches in size. It provides powerful features and high-performance in a package small enough to fit into applications with extreme size, weight or power limitations. Omega consumes less than 1.5 watts of power and produces uncompromising image quality in standard RS170 (or PAL) and 14-bit digital outputs - ideal for both thermal imaging and data acquisition applications. It features a modular design and a wide variety of options and accessories for easy, convenient integration into a system. Omega SmartSceneÔ video output maximizes picture quality frame by frame, by automatically adjusting the conversion algorithm. The result is a continuously maximized image, regardless of the scene. Omega can “see” at night through smoke and haze, and discern temperature differences as small as 0.06° C. It is ideal for a wide variety of commercial and military uses such as industrial process monitoring, building inspection, security and surveillance, firefighting, miniature robotics, machine vision, helmut-mounted vision systems, and unmanned vehicles. For more information, contact: Stan Laband, 805-964-9797; Fax: 805-964-7708; e-mail: sales@indigosystems.com; www.indigosystems.com

IMAGE ANALYSIS

Surface Evaluation Digital Image Analyzer

Atlas Weathering Services Group (AWSG) announced the addition of the VIEEWÔ Digital Image Analyzer to their South Florida Test Service Facility in Miami, FL. Developed by Atlas, the VIEEW Digital Image Analyzer allows laboratory personnel to analyze surface structures faster, more accurately and with enhanced reproducibility by classifying samples according to the nature and severity of the surface degradation they incur. The VIEEW system consists of a solid temperature-resistant and shock-resistant cabinet, an integrated black and white CCD camera and high-end apochromatic lenses. The classification of surface damages on the sample, such as gravel impact, cross hatch, filliform corrosion and delamination are done in accordance with current industry standards or specific customer specifications. A unique optical system allows for the use of two distinct illumination geometries created by separate light sources, direct and diffused. Direct light, which is produced by a power LED, examines top layer defects such as scratches or chipping, while diffused light, produced by several color LEDs, examines the effects that cause modifications to the surface contrast, such as color changes. For more information on VIEEW please contact an AWSG Client Service Representative by telephone at 1-800-255-3738 or via. E-mail at info@atlaswsg.com. Interested parties may also visit the AWSG website at www.atlaswsg.com

Digital Image Management Software

Celartem Technology has developed an all-inclusive security and web-based management utility management utility program to help manage digital content. Together, Protected Archives Distribution System (PADS) Controller and VFZ File Server offer users control over digital images. PADS Controller is a web-based application that gives imaging professionals the power to identify, control, track, mark, and secure each Protect file for Zooming (PFZ) file, a unique security format. The PADS system gives image owners the ability to assign client-specific usage rights to password-protected, encrypted PFZ files. PADS regulates image usage by restricting or permitting printing, saving, zooming, and quality level changes of each file. The system creates an activity log and has optional electronic watermark for tracking. The VFZ File Server is a web-based utility that allows users to manage, organize, and store their images. Users can upload TIFF, BMP, JPEG, VFZ, or PFZ files, as well as convert groups of image files to VFZ and PFZ formats. The VFZ File Server makes files widely available in large enterprise environments by storing them on a web server, where users can access images anytime or anywhere. For more information or to evaluate PADS Controller, the VFZ File Server and other Celartem products, visit www.celartemsea.com
FLUORESCENT LABELS

Fluorescent Labels for Research & Development Applications

Fluka Chemical has introduced a new range of fluorescent labels for microscopy, flow cytometry, electrophoresis, chromatography, and research and development applications. Atto labels are uniquely designed for the highest sensitivity, showing excitation and emission maxima spanning the range from 520-680 nm. This provides the opportunity to use a wide variety of excitation sources and to match wavelengths of many commonly used filter sets. All of these new labels are characterized by high molar extinction coefficients and high quantum yields, resulting in a brighter fluorescence. Atto labels are based on rigid structures and do not show any cis-trans isomerisation, thus optimising fluorescence efficiency. Most Atto labels are quite insensitive to pH fluctuations between 2 and 10. The combination of these properties makes them excellent tools for all labeling applications. All Atto labels are available as free fluorophores that might be coupled via free COOH-groups, or cuscuminyl (NHS-) esters, which can be coupled to proteins easily. Coupling procedures may be found on our product information sheets at www.sigma-aldrich.com/analytix. For Technical information contact: Mr. Don Hobbs, 314-286-6668.

PUBLICATIONS

Image-Processing Techniques for Tumor Detection, edited by Robin N. Strickland, University of Arizona, Tucson, U.S.A., ISBN: 0-8247-0637-4, $150.00. Image Processing Techniques for Tumor Detection provides a current review of computer processing algorithms for the identification of lesions, abnormal masses, cancer, and disease in medical images-presentationing useful examples from numerous imaging modalities for increased recognition of anomalies in MRI, CT, SPECT, and digital/film X-ray. This reference evaluates and compares specific image processing techniques, contains practical case studies in mammography, chest X-ray, MRI scans, and nuclear medicine. This reference discusses the enhancement of mammograms for improved sensitivity in breast cancer screening, and the design of screening systems to promote reassessment of suspicious regions in computer images. With contributions from nearly 40 international experts, Image-Processing Techniques for Tumor Detection is an indispensable guide for biomedical, optical, and electrical engineers; radiologists; computer scientists; pathologists; internists; and upper-level undergraduate and graduate students in these disciplines. For more information contact: Marcel Dekker, Inc., 270 Madison Avenue, New York, NY 10016; 212-696-9000; www.dekker.com

NEW PRODUCTS

Lyra Research’s new analytical report, Medical and Dental X-Ray Film: Demand Trends in Worldwide Markets, provides the industry with a five-year outlook of worldwide medical and dental X-ray film consumption in North America, the European Union, Asia, and the rest-of-the-world region. The report determines that use of dry-processed film will increase relative to wet and that the industry will ultimately see a gradual elimination of film usage.

Looking to the future, lower health-care costs and global access will present new marketing opportunities. The businesses and markets that are best suited to take advantage of these opportunities are those with well-developed research capabilities; specialized expertise in the development of innovative software; location in countries or regions with advanced telecommunications networks; or access to health-care distribution channels.

The report is essential reading for manufacturers and suppliers of medical and dental imaging equipment and supplies.

For more information: 617-454-2612; Web: http://www/lyra.com; Email: mgage@lyra.com.

Disclaimer

Please be advised that material presented in the New Products Update is solely for your information, and that IS&T cannot be responsible for the accuracy or the content. IS&T and its editors rely exclusively on the representation of manufacturers, representatives or vendors of the products and services described.
**IS&T President’s Message**

What a year! For all of us, individually and corporately, it has been a year of ups and downs, and that is certainly true of IS&T.

NIP, our largest meeting, began on September 30, at a time when many people were still not travelling. Attendance was about one half of what it was expected to be. Nevertheless, it was an extraordinary experience for those of us who were there. Almost all the papers were presented, thanks to many volunteers working with authors who were not able to travel. The papers were offered on-line for a three-month period so that those who could not attend, could hear the papers and see the visual presentations. All of this required yeoman effort on the part of a large group of people, and the Society is in their debt.

NIP was followed by the Color Imaging meeting six weeks later, with somewhat lower attendance than usual, but, again an excellent conference, enjoyed by all who attended.

IS&T’s financial loss in 2001 was significant (see the summary audit report on the next page). The good news here is that for the last 15 years, the Society has been able to put aside funds to shield us in the event of 9/11. In the first half of 2002, we have positive indications that people are travelling to conferences again.

**2002 Conferences**

Thus far in 2002, there have been four IS&T conferences. The Electronic Imaging Conference in San Jose, cosponsored with SPIE, had 23 conferences, 1000 papers, 23 conferences and 1200 technical registrants. For the last five years this symposium has been co-located with Photonics West, a huge SPIE event. In 2003, it will again become a stand-alone event, in Santa Clara, the week before Photonics West. Hotel rooms and overcrowding has been a problem at the San Jose facility and this move will alleviate that problem. We are looking forward to a strong conference in this new venue.

In February the bi-annual Photofinishing Symposium was held in Orlando, Florida. This smaller, focussed conference is always co-located with PMA. This year’s conference, chaired by Steve Howe and Dan English, focused on digital photofinishing.

We were delighted to introduce a new European conference this year. CGIV, the First European Conference on Color in Graphics, Imaging and Vision, was held in April in Poitiers, France. General co-chairs Christine Fernandez-Maloigne and Raimondo Schettini and program co-chairs Jean Pierre Van de Cappelle and Lindsay MacDonald and the rest of their committee did a wonderful job in assembling a fine program of 132 papers. We thank the local committee for the fine job they did hosting this conference. The report on this conference is on page 5.

The PICS conference, chaired by Peter Burns, (see report on page 11) was held in Portland, Oregon. This conference, which grew out of the spring annual conference, continues to receive high marks from participants for it’s excellent technical program focussed on digital photography and image quality issues.

Those are the conferences that we sponsor and manage, but we cooperate and participate in others as well. IS&T cooperates in the International Conference on Imaging Science, an international conference held every four years (formerly ICPS). ICIS ’02 was held in Japan in May with over 600 participants, including myself, John Meyer, IS&T past president, and Pam Forness of the IS&T staff. At that time, the ICIS committee, led by Tadaaki Tani, president, and Annabel Muenter, secretary, voted to hold the next meeting (ICIS ’06) in the U.S. IS&T will be the organizer and the meeting will be held in Rochester, NY.

Now, we are looking forward to our fall conferences. NIP18 will be in San Diego in October. The preliminary program has been released featuring over 230 papers and 34 tutorials. At this early point, there are already more than 30 exhibitors signed up. It promises to be a great conference! Then, we’ll move to Scottsdale in November to celebrate the 10th anniversary of the Color Imaging Conference. IS&T’s conferences continue to be its strength.

**Publications**

During 2001 the Journal of Imaging Science and Technology, edited by Mel Sahyun published 77 papers in 593 pages. These papers addressed various fields of interest as follows: 21 papers on non-impact and digital printing (27.3%), 20 in the area of color science (26%), 26 papers on silver halide technology (33.7%) and 10 papers (13%) in areas of general imaging science - imaging hardware, image analysis and processing, etc. The large number of silver halide papers may be attributed in part to the occurrence of the International Symposium on Silver Halide Science, which occurs only every four years, and took place in the fall of 2000. The increase in color science papers is also gratifying. During 2001 we rejected 13 papers (14.4%) of those submitted. JIST on-line became available beginning with the January/February 2002 issue.


In addition to our journal publications, IS&T publishes proceedings for each conference. This year, we have continued to focus on our website and on the creation of an “imaging digital library” that includes all journal and proceedings papers.
The focus that IS&T has maintained on strategic alliances has contributed to our success over the years. We have partners in Electronic Imaging (SPIE) and in Color Imaging (SID) TAGA (co-located annual conferences in 2004) ICIS, and other imaging groups across the globe. These relationships are shaped by the Society’s mission and purpose to advance the knowledge of imaging science and technology.

Governance

It is a privilege to serve as president of this Society and to work with a strong team on your Board of Directors and in other leadership positions within the Society. I want to acknowledge the leadership of many volunteers who help make the Society work. The Society’s officers are listed at the end of this report. Serving on the Board with the officers are representatives of the Society’s chapters. Our thanks go to John Francis from Boston and Dennis Abramsohn from Rochester, who are leaving the Board this year after several years of service. James Chung from the Tri-State Chapter, Rene De Keyzer from Europe and Takashi Kitamura from Japan will continue their roles representing their respective chapters. There are several committee chairs who have made significant contributions this year. George Marshall chaired the 2002 Nominating Committee, and the results of the election may be seen in the list of the 2002-2003 officers. John McCann chaired the 2002 Honors and Awards committee. The complete report of the committee was published in the last issue of the Reporter and may also be found on the web site. Regular Standards reports are provided to our membership by Standards Chair David McDowell (check the web site regularly for Dave’s work).

And these are only some of the people who work on our behalf to make the Society work.

Financial

A summary of the Society’s financial report appears above, and a copy of the audit report is available to any member requesting it.
Several years ago the Board of Directors set a goal for Society reserves of one year’s operating expenses. As I mentioned at the beginning of this report, this reserve fund enabled us to weather difficult economic times in 2001. This reserve fund also allows the Society to start new projects and serve the imaging community in new ways that may require extensive resources. This year and next year, for instance, we are upgrading our database, for a much improved system that will interface with our website, and allow you to make changes to your own membership record.

### Education

We continue in our efforts to support imaging education. Our website now has a page on “Where Imaging is Taught.” We expect to add more links and descriptions of imaging programs at universities around the world. We have, over the last year, published reports here in the Reporter on imaging programs at various universities.

We have continued to work with CIPE, the Center for Image Processing in Education. This year we jointly organized sessions for secondary school science teachers at the PICS meeting in Portland and also invited local high school students to participate in a poster session at PICS.

### Feedback

One of the most important jobs of the Board of Directors is to maintain contact with the membership. We aim to accomplish this in several ways, including meeting with leaders of imaging companies. Individually, we are charged with listening to our membership and potential membership to understand how we can better serve our community.

It is very important to the Society’s staff and leadership to hear from you, the member. Tell us what we are doing right, what you think we should be doing, and where we can make improvements. This is your Society!

Wayne Jaeger  
IS&T President 2001-2003

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### IS&T’S BOARD OF DIRECTORS

#### 2001-2002

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<td>President</td>
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#### Executive Director

- Boston: Calva A. Leonard
- Japan: Open
- Rochester: Open
- Tri-State: Open

#### Chapter Directors

- Boston: John Francis, Polaroid
- Japan: Open
- Rochester: Dennis Abramsohn, Xerox Corp.
- Tri-State: James Chung, Fuji Photo Film USA
**BOOKS NOW AVAILABLE FROM IS&T**

**HANDBOOK OF IMAGING MATERIALS: SECOND EDITION**  
Arthur S. Diamond and David S. Weiss, Publisher, Marcel Dekker, 676 pages, Member: $155 Non-Member: $175  
This revised and expanded reference presents the most recent developments in the materials, properties and performance characteristics of photographic, electrophotographic, electrostatic, diazo, and ink jet imaging processes—providing current techniques and modern applications for ink jet, thermal, and toner-related imaging systems.

**THE PHYSICS AND CHEMISTRY OF COLOR: THE FIFTEEN CAUSES OF COLOR: 2ND EDITION**  
Kurt Nassau, Published by John Wiley & Sons, 2001, 481 pages, Member: $95 Non-Member: $110  
This edition covers the following topics: Light and color; Color involving vibrations and simple excitations; Color involving Ligand field effects; Color involving molecular orbitals; Color involving band theory; Color involving geometrical and physical optics; and Color related topics.

**DIGITAL IMAGE PROCESSING: PIKS INSIDE: 3RD EDITION (INCLUDES CD-ROM)**  
William K. Pratt, Published by John Wiley & Sons, 2001, 735 pages, Member: $95 Non-Member: $110  
This edition provides a complete introduction to the field and includes new information that updates the state of the art. Offers coverage of new topics and includes interactive computer display imaging examples and computer programming exercises that illustrate the theoretical content of the book. This book is suitable as text for students or as a reference for practitioners.

**WYSZECKI & STILES: COLOR SCIENCE: CONCEPTS AND METHODS, QUANTITATIVE DATA AND FORMULAE: 2ND EDITION**  
Gunter Wyszecki & W. S. Stiles, Published by John Wiley & Sons, 2001, 950 pages, Member: $55 Non-Member: $63  
This 950 page publication contains chapters covering the following topics: Physical Data; The Eye; Colorimetry, Photometry; Visual Equivalence and visual matching; Uniform color scales; Visual thresholds; and Theories and models of color vision. This book is aimed towards the advanced student and research worker in color and those actively engaged in color engineering projects, Illuminating Engineers, designers and industrial consultants.

**Other Publishers Books**

- Print Unchained - Fifty Years of Digital Printing, 1950-2000 and Beyond: a Saga of Invention and Enterprise, Edward Webster, Member: $99 Non-Member: $125
- Handbook of Print Media (includes CD-Rom), Helmut Kipphan, Member: $99 Non-Member: $105
- Measuring Colour: Third Edition, Dr. R. W. G. Hunt, Member: $70 Non-Member: $80
- Psychometric Scaling: A Toolkit for Imaging Systems Development, Peter G. Engleman, Member: $85 Non-Member: $95
- Digital Image Processing: PIKS INSIDE: 3rd Edition (includes CD-Rom), William K. Pratt, Member: $95 Non-Member: $110
- Color Appearance Models, Mark D. Fairchild, Member: $85 Non-Member: $95
- Digital Color Management: Encoding Solutions, Edward J. Giorgianni and Thomas E. Madden, Member: $54 Non-Member: $64

You can get more details at The Imaging Web: http://www.imaging.org.

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**PUBLICATIONS ORDER FORM**

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7003 Kilworth Lane, Springfield, VA 22151, 703-642-9090; Fax: 703-642-9095,  
E-mail: info@imaging.org; Web: http://www.imaging.org
Upcoming IS&T Conferences

- **July 7 - 11, 2002**
  - SPIE’s 47th Annual Meeting, Seattle, WA, USA. Sponsored by: SPIE - The International Society for Optical Engineering. For more information visit: http://spie.org/conferences

- **September 22-25, 2002**

- **September 25 - 30, 2002**
  - Photokina, Cologne, Germany. Sponsored by KölnMesse GmbH. For more information email: photokina@koelnmesse.de

- **September 27, 2002**
  - 10th International Symposium on Photofinishing & Minilab Technology, Co-located with Photokina. Sponsored by IS&T European Chapter, German Photographic Society, and Prophoto GmbH. For more information visit: http://www.imaging.org

- **September 27-30, 2002**
  - OSA Annual Meeting, Orlando, FL. Sponsored by Optical Society of America. For more information: 212-416-1980; Fax: 202-416-6100; email: confserv@osa.org

- **October 27-30**
  - Xplor 2002 – Annual Electronic Document Systems Conference and Exhibit, Anaheim, CA. Sponsored by XPLOR International – Association for Electronic Document Professionals. For more information: 310-791-9521; email: info@explor.org

- **November 12 - 15, 2002**

- **January 20 - 24, 2003**
  - IS&T/SPIE Electronic Imaging: Science and Technology, Santa Clara Convention Center, Santa Clara, California. General Co-chairs: John Meyer (IS&T) and Robert Sprague (SPIE)

- **April 18-21, 2003**
  - DPP, Barcelona, Spain

- **May 13 - 16, 2003**
  - The PICS Conference, The Hyatt Regency Hotel, Rochester, New York. General Chair: Mark Fairchild

For a more complete listing of imaging conferences, visit IS&T’s web site: www.imaging.org

Short Courses

RIT (Rochester Institute of Technology) offers an ongoing series of courses on graphic arts and imaging topics. Contact: Linda Keeney; 716-475-5852; Fax: 716-475-5571; E-mail: LMKTE@rit.edu; http://www.rit.edu