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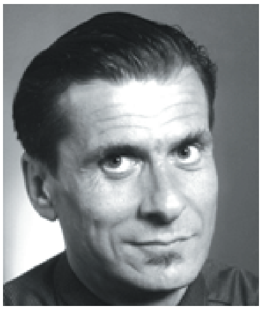
Introducing the International Committee for Display Metrology (ICDM)

guest editorial



Display Metrology: What Is It (Good for)?

Michael E. Becker

Display Metrology, the measurement of the optical properties of electronic displays, is intended to support the supply of customers with display devices that satisfy visual performance requirements resulting from specific applications.

Display metrology is practiced in order to provide physical data as an objective basis for rating of the visual performance of electronic-display devices; *e.g., luminance* is measured in order to estimate the *brightness* perceived by a human observer. Display metrology thus contributes to bridging the gap between physical measurements and the human visual perception of electronic displays and thus their ergonomic performance. It is subject to a variety of boundary conditions (canonical rules) and the way it is exercised or the results are featured may severely affect commercial competition. For example, in a court case from 2003 (NEC Mitsubishi Display of America *vs*. ViewSonic Corp., Illinois Federal Court, Case No.: 02 C 08304), NEC Mitsubishi had charged that ViewSonic could have been misleading or confusing customers with the way they had specified the contrast of ViewSonic LCD monitors. While this was a case between competitors, similar cases involving consumer advocacy groups holding manufacturers to task for issues of exaggerated technical claims have been initiated many times over the years as well. Display metrology and the resulting data is of significant commercial interest and thus often subject to manipulations. Hence, the stakes for understanding and properly exercising the practice of display metrology are very high.

In the first step, physical measurements that are significant have to be carried out, providing characteristics that are meaningful with respect to *human visual perception*, such as measuring *light* instead of infrared or ultraviolet electromagnetic radiation. The object of measurement has to be in a state that corresponds to a *realistic application situation* (*e.g.*, not in a completely dark room), and its controls have to be set accordingly (*e.g.*, luminance and contrast settings).

It is taken for granted here that display metrology is *reproducible*, *i.e.*, providing the same results when the specifications of the measurement procedures are followed, simple, and robust (*i.e.*, insensitive to small variations of the instrumentation and its geometry).

The *measuring methods*, usually specified by international standards (no qualified competent monographs are available on this complex subject; the FPDM-2 provides the required solid basis), should be clearly described to be easily understood, and all details that are important for implementation and accomplishment of the method must be disclosed (see ISO/IEC Directives, Part 3: Drafting and Presentation of International Standards). A comprehensive compilation of compulsive *terms and definitions* is a prerequisite for unambiguous communication and understanding between any two parties.

In addition, the methods should be applicable to a wide range of different display effects and technologies. They should be honest (*i.e.*, not devised to hide deficiencies), allowing for a broad range of instruments (not restricted to unusual, highly specialized, or hardly accessible instrumentation). International metrology standards should not be misused as marketing instruments for metrology instrumentation manufacturers.

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Measuring and Rating Electro-Optical Display Performance

From the moment that LCDs were introduced in the 1970s, display metrologists have worked hard to develop systems to accurately measure their performance, a constantly evolving process. This article details the history of those efforts as well as the current state of the art.

by Jürgen Laur

LIQUID-CRYSTAL DISPLAYS (LCDs) have evolved and flourished since the 1970s. After their debut in pocket calculators and wristwatches, they first created a visual interface basis for portable computers and, later, computer monitors. LCDs helped mobile telephones to offer video and TV content in truly handheld devices, and the latest wave of success brings large-area LCDs into the living room for TV and home-theater purposes.

Display-metrology instrumentation has evolved along with the features of LCDs. This article summarizes that evolution during the last 25 years. A strong example of this is the development of twisted-nematic LCDs (TN-LCDs).

Almost as soon as the electro-optical effects of liquid crystals were studied in practical structures, it became apparent that TN-LCDs offered special features, including the variation of contrast with viewing direction and its dependence on a variety of cell and material parameters. For systematic experimental optimization of TN-LCD performance, it became indispensable to accurately characterize these properties of LCDs.

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Initially, ad hoc laboratory setups with movable light sources and/or detectors performed goniometric readings at various angles of view. Later, the polarization microscope in the *conoscopic mode of observation* became the most widespread instrument used for analysis of the variation of transmittance and contrast versus viewing direction.[1,2] This approach provided direct observation of the *directions image*, but quantitative measurements were cumbersome to carry out and required special modifications of the microscope.[1,2]

In 1977, Kurt Fahrenschon, at that time working for the company Braun,[3] suggested to the Institute for Electromagnetic Theory and Metrology of the University of Karlsruhe, then headed by Professor Dieter Mlynski, to get involved in the development of an apparatus that would perform the required characterization of TN-LCDs. Since most LCDs at the time were operated in reflective mode, it thus became necessary to implement an illumination device that also provided isotropic illumination during scanning of the viewing cone of the device under test.

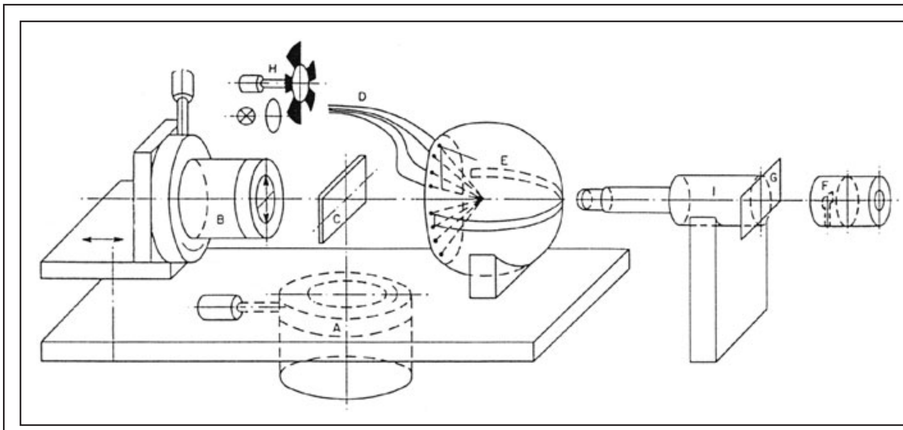

Fig. 1: *Sketch of the first DMS developed at the University of Karlsruhe in 1979. (A, B) motorized rotary stages for adjustment of inclination and azimuth, respectively. (C) Object of measurement. (D) Light fiber bundles for illumination of the diffusing hemisphere. (E) Microscope for imaging of the field of measurement with aperture stop (G) and detector (F). The light source was mechanically chopped (H) and the detection was locked to the chopping frequency.*

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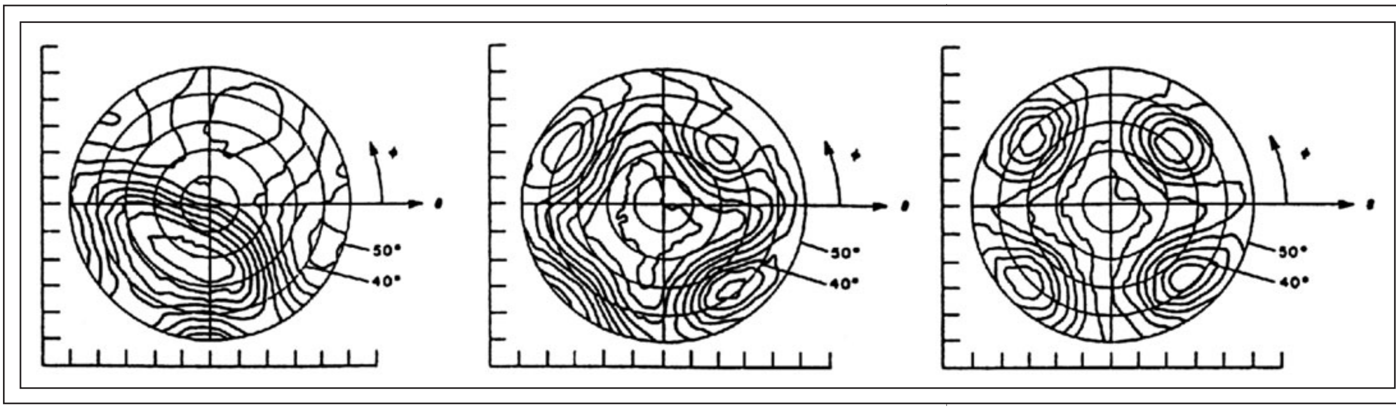

Fig. 2: The first contrast contour plots (sometimes called iso-contrast diagrams because of the lines of constant contrast, i.e., the contrast contour lines) measured with the DMS prototype and published in 1979.[4] The measurements have been carried out for driving voltages 1.5, 4, and 8 times the threshold voltage V_{th}.

The resulting apparatus was then used by Kurt Fahrenschon in his laboratory and the results of his evaluations were published as a paper in *Displays* in 1979[4] (Figs. 1 and 2). The instrument that was initially focused on measuring the directional contrast distribution, somewhat similar to that of Barna,[5] in the early 1980s was equipped with a range of extra features, making it the first computer-controlled apparatus for automated measurement of the complete set of electro-optical characteristics of LCDs. Since 1985, this instrument has been manufactured and marketed by autronic GmbH in Karlsruhe, Germany, and since 1993 by AUTRONIC–MELCHERS GmbH (Fig. 3).

The Need for Display Metrology

There are at least two good reasons for performing display metrology:

- The objective comparison of features before and after modification for device performance optimization in the laboratory.
- The objective comparison of the performance of products for purchasing

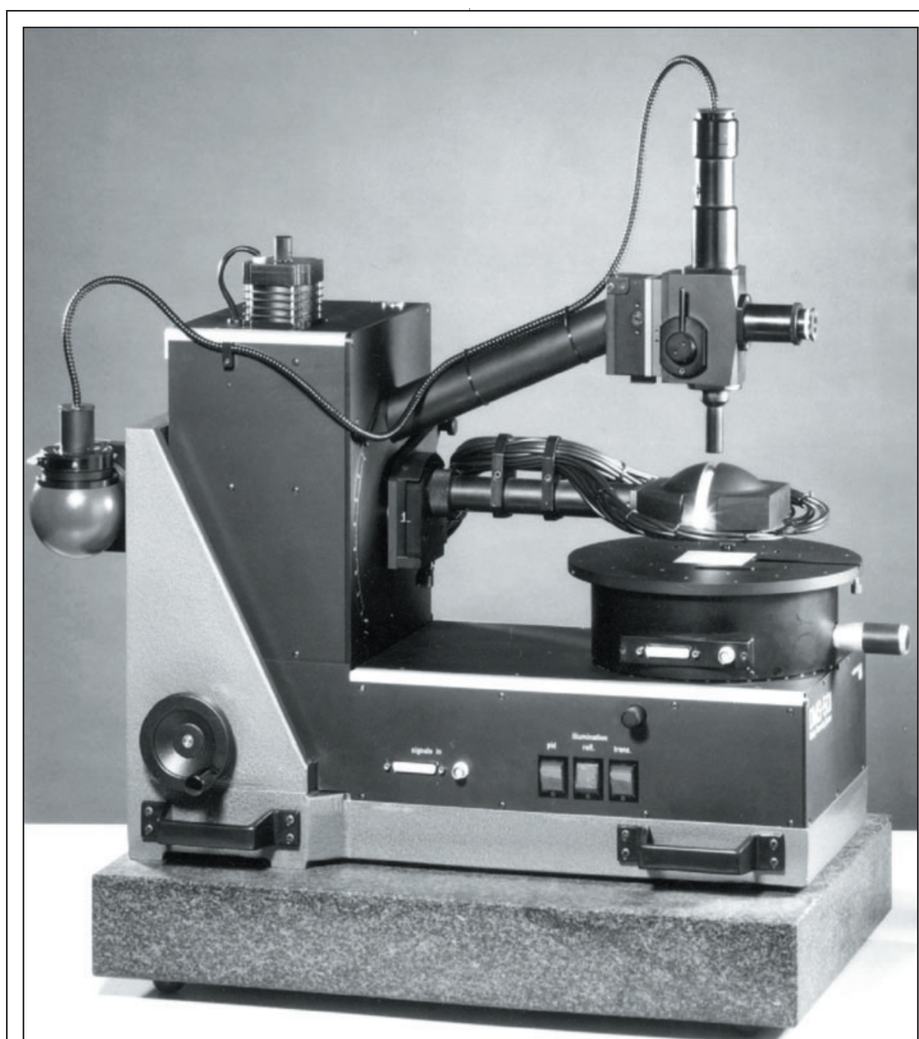

Fig. 3: DMS-500 as manufactured by autronic-Melchers GmbH in 1990 with two motorized stages for inclination of the measuring microscope and for rotation of the sample LCD. The three axes were adjusted to intersect with a maximum deviation in the range of 50 µm to enable measurement of small segments and symbols. The apparatus features two illumination sources for diffuse reflective and transmissive mode of operation.

and sourcing in the industry and in the private sector.

The second reason has gained increased attention of late because of the economical interests in securing a piece of the ever-increasing market for electronic-display devices. Even though the objective of a data sheet is "to define clear and unambiguous provisions in order to facilitate international trade and communication," (according to ISO/IEC Directives, Part 3: Drafting and Presentation of International Standards) and for that purpose should be "complete, consistent, clear, concise, and comprehensible," the customer is increasingly confronted with countless unexplained terms and skyrocketing or vanishing numbers for metrics such as contrast and response times.

This escalating hype of "dizzying performance specifications," also known as "specsmanship," has created a bazaar-like atmosphere where manufacturers' claims of contrast, response times, "brightness," "crispness of colors," *etc.*, place a higher value on attracting customers than on the accuracy of the data. This atmosphere unfortunately penalizes those companies that want to stay honest and reasonable, since they are running the risk of perishing in that cacophony of marketing blatancy.[6]

User of electronic-display devices want to have a reliable (*i.e.*, unbiased), understandable, and reasonable basis of data describing the performance of the product according to its intended application as a solid basis for a purchasing decision.

At the same time, however, the customer must realize that electronic visual displays have become so sophisticated and complex that their performance cannot be characterized simply and rated by one integral "figure of merit." Depending on the intended application (office work, display of video and movies, graphics and design, computer games, home cinema, nomadic ICT devices, *etc.*) emphasis must be placed on different individual aspects of performance, at least as long as the ideal display is not yet available at affordable prices. This simply means that the user has to continue the process of education and learning.[7]

Keeping Pace with LCD Performance

The first TN-LCDs were small and their electrodes were patterned in a seven-segmented layout for the display of numbers, sometimes with additional fixed symbols. In order to measure the contrast of such displays, the field of measurement had to be in the range of 0–1 mm and the mechanism had to ensure that the location of that spot does not change with direction of observation. The realization of a mechanism with a tolerance of the intersection of all axes in the range of 50 μm was quite a challenge for the mechanical workshop.

The optical appearance of the TN effect was usually *achromatic* (not involving colors) and thus photometric detectors (*luminance meters*) were sufficient for characterization of their visual performance. As noted above, since most of the TN-LCDs were operated in the reflective mode, a special illumination device had to assure the illumination to be isotropic for measurements as a function of viewing direction. The realization of this device with a section of an integrating sphere (*diffusing hemisphere*) also included a slit through the North Pole. This had two functions: (1) making observation of the device under measurement possible and (2) effectively suppressing specular surface reflections.[8,9]

Measurement and evaluation of the optical properties of reflective objects is not easy because the measured quantities always comprise the effect of object, illumination, and light-measuring device as well as the details of the geometry of the arrangement of all components.[8] Although it was (and still is) very difficult to make these measurements reproducible, no international standard has been created to provide assistance to those who have to carry out such measurements in their laboratories. It seems quite strange that after 30 years, there is no international standard for measurement and evaluation of reflective LCDs, but the WG2 of the IEC TC110 is currently working toward that objective. The lack of an international standard used to be compensated by the recommendation of a Japanese industry standard for reflective LCDs. This standard has been reflecting the features and limitations of a measuring apparatus developed and manufactured in Japan.[10]

In addition to contrast, the variation of the electro-optic transfer function and the dynamic response of the display under test (DUT) and its variation with viewing direction used to be of interest for optimization of the multiplexing conditions. This class of measurements also required a specific electrical driving (*e.g.*, waveforms for simulation of multiplex signals in select and non-select state, control of digital control signals for LCD modules, together with DC supply voltages, *etc.*). Coordination of electrical driving of the DUT, positioning of the detector, and data acquisition in order to keep the time required for the measurements at a minimum has required special software that also supports the definition of the series of measurements that can later be executed automatically without user interaction. This software makes a measurement system for electronic displays more than the sum of its components – its usability predominantly determines the value of a measuring system for the user and customer.

Advanced Display Metrology

With the invention of the supertwisted birefringence effect (STN) by Brown Boveri Electric in 1985, the need for *colorimetric analysis* increased because supertwisted LCDs (STN-LCDs) produce visual contrasts to a large extent by color differences between activated picture elements and the display background. As a consequence, monochromator systems and polychromators were adopted as light-measuring devices in display-measurement systems in order to support the development of better and achromatic STN-LCD screens as required for portable computers.

Although conoscopy was well known and widely used for LCD measurement and analysis since the very early days of LCDs, it was replaced by goniometric systems for three reasons: (1) quantitative analysis required focal-plane probing of very small spots that deteriorated the signal-to-noise ratio, (2) the range over which the angle of inclination could be varied used to be limited to ±30°, and (3) reflective TN-LCDs could be illuminated and measured more conveniently in goniometric arrangements.

In the early 1990s, however, when computer monitors combined a backlight unit with an LCD as a spatial light modulator, reflective displays lost market share, and LCD monitors moved into portable computers and onto the office desk. At Eurodisplay 1993, an advanced conoscopic lens with an acceptance angle of ±60° and a measuring spot diameter of 2 mm was introduced by T. Leroux from Eldim S.A.[11] This optimized lens design distinctly demonstrated the capabilities of advanced optical design and manufacturing, and triggered the development of a new generation of instruments for measurement and characterization of LCDs *vs*. viewing direction.

In the mid-1990s, some people claimed a paradigm change in LCD metrology and contended that within a short time only conoscopic instruments would remain. The commercialization of conoscopic measurement devices was severely hampered by the fact that a range of patents had been obtained on this well-known principle of measurement by a French government organization by carefully avoiding the term *conoscopy* and calling it *optical Fourier transformation* instead. After many years of legal disputes, the European patent EP 0 286 529 B1 based on the priority of the French patent FR 870 4944 was finally ruled invalid exemplarily for the Federal Republic of Germany on April 29, 2003.

More than a decade after the onset of the hype on conoscopic devices, this class of instruments has reached an amazing state of the art, but it did not succeed in eliminating and replacing gonioscopic LCD measuring equipment. Instead, it seems clear now that both approaches have advantages and limitations – choosing which one to use depends on the individual task of measurement.

Advanced conoscopic devices have been optimized for reflective measurements with collimated beam and isotropic illumination of the DUT; they can be used for measuring the LCD temporal response, and colorimetric evaluation is possible with color filters. Some features however, such as the masking of the isotropic sample illumination for suppression of specular surface reflections from the DUT, are adaptations from approaches originally developed for gonioscopic instruments.[7,8] Moreover, highly accurate colorimetry *via* spectral analysis still has not yet been adopted for conoscopic devices since its implementation is not an easy feat, except for the "brute force" solution of using 30 or more interference filters in the image path.

Looking at the current wave of TV screens that have to be measured and rated with respect to their visual performance, it becomes obvious that a *many-filter approach* is not the right way for accurate colorimetric characterization of these displays. As a solution for the conflict between measurement time and precision, we have recently implemented the concept of *multidirectional spectral analysis* (***PolyGonioscopic***), which for the first time combines fast, high-resolution spectral analysis with a minimum of time required for the full colorimetric characterization of LCD-TV screens, with extended viewing cones (Fig. 4).

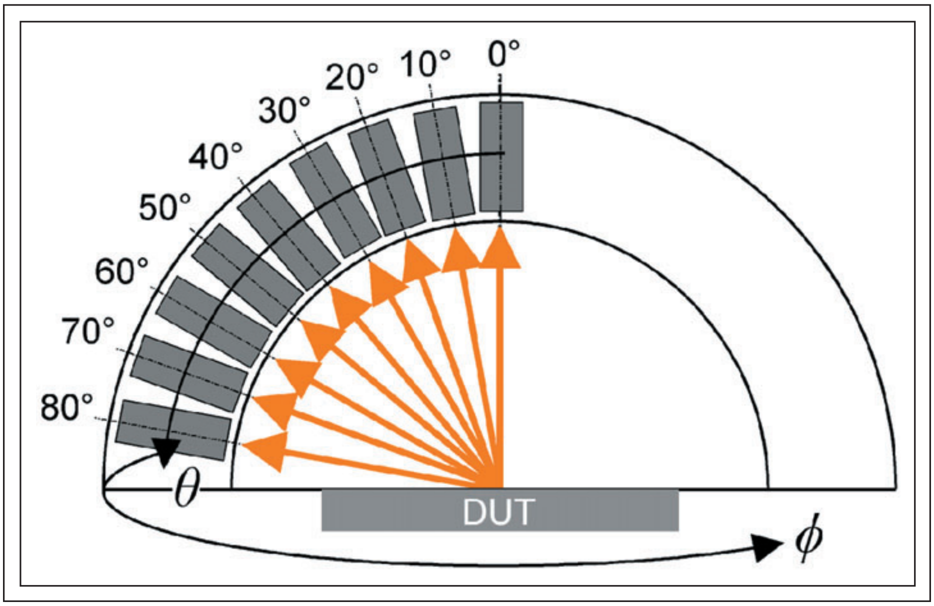

Fig. 4: *A PolyGonioscopic measuring head showing the optics of nine spectral channels. High-sensitivity spectral analysis is carried out for nine directions simultaneously. The diameter of the field of measurement is 10 mm. Motorized inclination of the assembly of the optics makes high-resolution directional scanning (inclination* θ*) possible.*

Conclusion

The continued development of increasingly complex LCD systems has posed great challenges to those charged with developing accurate display metrology systems. Because LCDs have become virtually ubiquitous in today's world, the ability to accurately measure their performance has never been more critical. New approaches, including poly-gonioscopic analysis, continue to be developed and improved.

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guest editorial

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The above requirements for measurement methods and procedures imply that there should be as many of them available as required for carrying out the daily work in the metrology laboratory, but these days, unfortunately, there are too many applicable but unsynchronized standards providing confusion of *terms and definitions* and *measurement approaches* rather than the required clarity and assistance. This confusion is often exploited by marketeers by selecting such measurements that are yielding the "best numbers" for the product data sheet. In line with that mentality of *specsmanship* (*i.e.*, abuse of technical data to establish putative superiority of one device over another) is the measurement of contrast in a dark room, yielding (very) high numbers, especially for emissive displays, but under conditions that do not represent the actual application situation (about 99% of all display-application cases are under ambient illumination). The extension of *image formation* times according to ISO 13406-2 to transitions between different levels of gray was eagerly adopted by certain LCD and monitor manufacturers because an "improvement" by a factor of 2 was granted by the fact that ISO was using the sum of both transition periods between ON and OFF while the alternative *gray-to-gray response times* (not standardized before the introduction of ISO 9241-300) only specified one of the transition periods (usually the faster one).

The international standard ISO 13406-2 proves that a standard can actually help to advance technology and the quality of products to which most of us are exposed to for many hours every day. ISO 13406-2 for the first time introduced methods for the measurement and rating of directional variations and reflections from LCDs, and with the enclosed ergonomic rating of the physical data into performance classes it has been pushing the improvement of these features, thus making better displays available on the market.

We can now simply trace back the justification for solid display metrology also from an economical starting point: Every customer (private and corporate) deserves an unbiased, honest set of data for specification of the visual performance of an electronic-display device for a specific application (office work, video and television, home-theater, medical diagnostics, *etc.*) as a basis for purchasing decisions. The visual performance of the display is being evaluated from a set of physical data that must be obtained by significant, well-defined measurements and specified by standardized technical terms and performance characteristics.

So, if you are interested in purchasing electronic-display devices that are fulfilling your performance expectations without regrets, disappointment, or hangover, you should be interested in display metrology and the international standards that define them. You then should also be interested in knowing what the specifications mean and how relevant they are for your intended application.

In response to the question posed in the title, display metrology can be helpful in acquiring electronic displays with the visual performance adequate for a specific task at an affordable price. The articles in this issue were written with this in mind.

In his contribution "Diffuse Clarification," Edward F. Kelley, the *spiritus rector* of the FPDM2, provides a clarification of display-related terms that are often confused. This appetizer is intended to illustrate that unambiguous terminology is the basis for factual understanding and thus for the communication of technical specifications.

Carsten Dolar from the Technische Universität Dortmund (Germany) describes his numerical model for simulation of the perception of moving images displayed on LCD screens. This model is based on generalized measurement results (rules and laws expressed in mathematical formalism), and it offers the advantage of accurate control of all involved parameter values. The presented model comprises the electro-optical display together with human visual perception, and it has been developed for systematic optimization of the chain of signal transmission and processing.

Joe Miseli from Sun Microsystems introduces the International Committee for Display Metrology (ICDM)), which is currently producing a Display Measurement Standard (DMS), the updated successor to the most comprehensive reference on the "art of measuring electronic displays," the FPDM2, issued by VESA in 2001. In the Spring of 2007, the FPDM working group migrated to become the ICDM, under the auspices of SID.

The field of display metrology and its evolution during the past 30 years is described by Jurgen Laur from autronic-Melchers GmbH in his article, "Measuring and Rating Electro-Optical Display Performance," from the perspective of a long-term manufacturer of display-metrology instruments.

As guest editor of this Special Issue on Display Metrology, I sincerely hope that the contributions on display metrology stimulate your interest in the subject and provide you with useful information and some helpful clues. ■

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