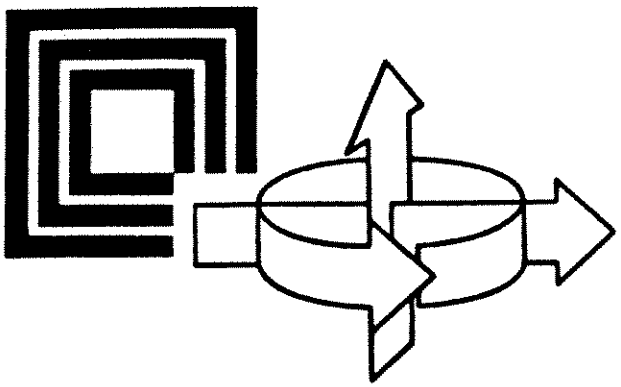


RICHARD S. HUNTER PROFESSORSHIP
AND
MUNSELL COLOR SCIENCE LABORATORY

ANNUAL REPORT 1984 - 85

Richard S. Hunter Professorship and
Munsell Color Science Laboratory
Annual Report on Activity
July, 1985

This is the second Annual Report of the Richard S. Hunter Professor on the programs and on the management of the Munsell Color Science Laboratory. The report is supplemented with a photograph of the Laboratory and a listing of the major laboratory equipment.

A new fiscal year has just begun; therefore, it seems appropriate to review the activity of the past year, and to give an account of the stewardship of the Richard S. Hunter Professorship and of the associated Munsell Color Science Laboratory.

First let me reiterate the four objectives set forth by the Richard S. Hunter Professor.

1. To provide undergraduate and graduate programs in color science, appearance, and technology.

2. To carry on research and development in the above named areas of color and appearance.

3. To establish a sound standardization program in areas where standards are either void or difficult to obtain from other sources.

4. To provide an essential ingredient for the success of the first three --- namely, liaison with industry.

Here, in summary form, is a report on what has been accomplished on each of the above listed four objectives.

I. Academic Program

Under the umbrella of the School of Photographic Arts and Sciences (College of Graphic Arts and Photography) the following technical undergraduate and graduate courses are now offered.

PPHS 313 Introduction to Colorimetry (undergraduate): An introduction to how the interaction of light, matter, and the visual system create the sensation of color. Topics include color physics; color measurement including spectrophotometry, spectroradiometry, and colorimetry; color perception including introductory color vision theory, color mixing principles, and color order systems; the CIE system; and instrumental and visual color difference evaluation. Accompanying laboratory will concentrate on instrumental measurements.

PPHS 409 Color Appearance and Technology (undergraduate): An indepth course dealing with the proper methodologies to quantify the chromatic and surface properties of objects. Topics stressed include colorimetry, glossimetry, color tolerancing, metrology problems, visual scaling techniques using color order systems, and the effects of viewing and illuminating conditions on color appearance.

PPHS 771 Colorimetry (graduate): An indepth course exploring colorimetry, the quantitative specification of color, The emphasis is on the spectral characterization of chromatic stimuli using modern instrumental methods and deriving the relationships between appearance attributes and instrumental data. Advantages and disadvantages of various imaging systems will be evaluated using many available color metrics. The course will introduce the use of computers in colorimetric applications.

PPHS 772 Advanced Colorimetry (graduate): A detailed treatment and evaluation of specialized current problems and topics of color science, appearance, and technology. Topics include turbid media theory, computer colorant formulation for subtractive imaging systems, luminescent materials, and current research in color science.

PPHS 773 Colorimetric Instrumentation and Standardization (graduate): This course will cover current methods in precisely measuring the spectral properties of object colors and of radiation sources. Proper procedures in calibration, standardization, data analyses, instrument maintenance, and standards selection will be presented. The use of standard reference materials in optical metrology will be explored. Various measurement assurance programs will be introduced for diagnostic evaluation of current colorimetric instrumentation.

The main objective of the program is to provide high level education in color science and technology. The program's aim is to educate tomorrow's leaders in color science in a broad interdisciplinary approach. In this manner, future color scientists can effectively

contribute in a wide variety of fields. Color science itself, is broadly interdisciplinary, encompassing physics, chemistry, physiology, psychology, and color reproductive sciences.

With these programs in place the students can now attain a B. S. and/or M.S. degrees in Imaging and Photographic Science with concentration in Color Science. There are four graduate students presently associated with the Laboratory: Mark Fairchild, Kelvin Peterson, Greg Snyder and Richard Riffel. Mike Beering, Eric Walowit and Chris Pearson are our first B.S. graduates, receiving their diplomas this past May.

In the development stage is a curriculum leading to a Master's Degree in Color Science for B. S. and B. A. graduates from other colleges and universities.

In addition we offer the following courses for other departments within the Institute of a less technical nature. Examples of these are:

PPHT 313 Color Measurement/Instrumentation (undergraduate): Equipment and methods used for the measurement of color will be discussed and used in the laboratory, with particular emphasis on their use in color photographic processing and printing applications. Light sources, photoelectric sensors, color filters, radiometry, spectrophotometry, printing densities, and color order systems are among the topics discussed.

PPHM 313 Introduction to Color Science and Appearance (undergraduate): A survey course exploring the basic principles of color perception, the interaction of light and objects, the effects of illumination on color appearance, the specification of illuminating sources, colorimetry, and instrumentation used for colorimetry and photographic quality control.

II. Research and Development

a. Laboratory Development

The laboratory now possesses eight spectrophotometers with various geometries and wavelength ranges. Two spectroradiometers cover the spectral range from 240nm to 1000nm. In addition to these, the laboratory is equipped with four tristimulus colorimeters and two visual colorimetric systems. The equipment for appearance study is also in place and used both as research tools and in education.

One of the most versatile instruments in the laboratory is a home built spectrogoniophotometer capable of operating at any angle from 5° to 80° in detection and illumination mode of operation and covering the usable wavelength range from 300 to 900nm.

During the past academic year, the following donations were received:

Optronics Spectroradiometer with accessories; $45,000

Pacific Scientific Spectrogard with computer color matching software; $40,000

Pacific Scientific Colorgard Colorimeter; $10,000

Bausch & Lomb (Milton Roy APD) Color Scan Spectrophotometer with DEC Rainbow; $15,000

Minolta Chroma Meter II Colorimeter; $4,500

A listing of the equipment is given in Appendix A. The estimated value is in excess of $400,000.

b. Research Activity

Research activity during the past year has included the following:

-- Safety of UV Radiation on Human Vision (on-going).
-- Spectrogoniophotometric Properties of Standard Reference Materials for Reflectance Spectroscopy*.
-- Metameric Mismatch Limits for Industrial Colorants.
-- Computer Colorant Formulation Techniques Yielding Color -- Constant Properties for Object Colors.
-- Color Appearance Sensitivity of Artist Pigments to Museum and Industrial Lighting Environments.
-- Match Criteria Dependency of Tolerancy Ellipsoid Size and Orientation Using Probit Analysis (on-going).
-- Evaluating the Concept of Correlated Color Temperature (on-going).
-- Exact Color Reproduction in CRT Film Recorders (on-going).
-- Minimization Algorithms to Improve Spectrophotometric Accuracy (on-going).
-- Color Gamut of Self Luminous Displays as a Function of Display Parameters (on-going).
-- Metrology Problems of Low Level Radiation Sources (LED's, etc.).

* A schematic of the instrument is attached as Figure 1.

III. Standards

The laboratory is now in possession of a number of standard reference materials both for transmission and reflection modes of operation. We are in continuous contact with the National Bureau of Standards, and we are conducting with them various measurement assurance programs (MAP's).

We participate in the CORM-NBS Task Force to establish the criteria for the "Intermediate Standard Laboratories" and to set up such laboratories. The Munsell Laboratory is now in position to render calibration services in spectrophotometry and provide some standard reference materials. Our interest is in basic standards, transfer standards and in diagnostic standards.

CIE Activity: The Richard S. Hunter Professor is involved in the Commission Internationale de l'Eclairage in two ways: One, as the Director of the Technical Division on Physical Measurement of Light and Radiation; and, secondly, as a board member of the Executive Council. The Laboratory is participating in the following Technical Committees of the CIE: TC2-03 LED Measurements; TC2-06 Absolute Spectral Responsivity; TC2-11 Spectrogonioreflectometry; and TC1-07 Observer Metamerism.

Calibration Work: The Laboratory is presently involved in calibration activity of SRM's for reflectance in a 0/45 geometry. In addition, preparations are underway for accurate measurement of ANSI Status T densitometry.

IV. Industrial Liaison

Industrial liaison has been established and maintained with Eastman Kodak, Bausch & Lomb, Xerox Corporation, 3M Company, PPG Industries, and duPont deNemours. We are actively furthering contacts through contract measurements, calibration services, and industrial seminars.

An Advisory Board to the Munsell Color Science Laboratory has been established consisting of academic experts and industrial research managers as follows*: Dr. James Bartleson (Eastman Kodak), Dr. Peter Kaiser (York University), Dr. D.H. Alman (duPont), Dr. F.W. Billmeyer, Dr. L.J. Thomas (Eastman Kodak), Dr. K.D. Mielenz (National Bureau of Standards), Mr. J. Kaufman (IES), Dr. Joan Mukherjee (3M), C.S. McCamy (Macbeth), Dr. V.S. Mihajlov (Xerox), Mrs. Joy Turner Luke, Mr. Richard Hunter (Hunter Associates), Ralph Stanziola (Applied Color Systems), Dr. Roy Berns and Dr. Franc Grum (RIT). The Board held its first meeting on March 29, 1985. Dr. C.J. Bartleson was elected Chairman and Dr. Roy Berns was elected Secretary. The Board has established the following charter:

* It is with the greatest regret we must state that two very important members of the Advisory Board, Dorothy Nickerson and Gunter Wyszecki, passed away this year.

"An Advisory Board shall be established in conjunction with the Munsell Color Science Laboratory of the Rochester Institute of Technology. The function of the Board shall be to provide advice and recommendations relating to technical matters of concern to the planning and conduct of research and academic programs in the Laboratory.

The Director of the Munsell Color Science Laboratory shall appoint members to the Board as he deems appropriate. Members shall be chosen to provide a broad base of technical and industrial knowledge considered helpful to the purposes of the Board. They shall serve without pay and hold no formal status on the faculty or staff of the Rochester Institute of Technology by virtue of membership on the Board. The term should be renewed annually.

The Director shall convene meetings of the Board, in whole or in part, as appropriate to consult with members of the Board on matters of technical planning and conduct of the research undertaken by the Laboratory.

The Director shall insure that members of the Board are apprised of the activities of the Laboratory periodically, but not less than once each year."

V. Donations

Besides the aforementioned donations of measurement equipment, the following companies have donated monetary gifts in support of the continued development of the Munsell Color Science Laboratory:

Eastman Kodak Company -- $5,000
I.E. duPont deNemours & Co. -- $10,000
Minnesota Mining & Manufacturing Co. -- $5,000
Pittsburg Plate Glass Corporation -- $5,000

It is through this liaison with industry that we are able to offer our students a first class, state of the art education; and we are truely greatful for this generous support.

VI. Symposia, Seminars, Talks, Papers, Awards, etc.

COMMUNICATING WITH COLOR IN ART, SCIENCE AND INDUSTRY was hosted by the William A. Kern Professor of Communications (David Wright) and the Richard S. Hunter Professor (Franc Grum) on March 28-29, 1985 at RIT. Ten noted speakers and a panel discussion highlighted this most successful event.

"COLORIMETRY, An Intensive Short Course For Industry" was offered as a 3½ day short course in May and June, 1985. This proved to be so successful that we are planning a third session in August. ADVANCED CONCEPTS OF COLOR AND COLOR MEASUREMENT will be offered through the T & E Center of the College of Graphic Arts & Sciences the last week of August, 1985.

Dr. Grum received the prestigious ISCC Godlove Award on April 16, 1985 during the ISCC Annual Meeting. In addition, the following papers have been presented by Laboratory personnel:

February 11, 1985 "Displaying Artwork: Consider the Irradiating Source" by Roy Berns and Franc Grum presented by Dr. Berns at the ISCC Williamsburg Conference.

February 12, 1985 "Development of a Color Science Center" by Franc Grum at the OSA meeting in Rochester, NY.

April 16, 1985 "Munsell Color Laboratory Activity" by Franc Grum at the ISCC Annual Meeting.

May 7, 1985 "Standards and Standardization of Optical Radiation Measurements" by Franc Grum to the TAGA Annual Meeting in St. Paul, MN.

May 30, 1985 "Munsell Color Lab Facilities" by Franc Grum to the Council for Optical Radiation Measurements (CORM) in Washington, D.C.

May 23, 1985 "Modern Methods of Color Measurement" by Franc Grum to the Canadian Society for Color at Niagara-on-the-Lake, Ontario, Canada.

June 18, 1985 "Spectrogoniophotometric Properties of Standard Reference Materials" by Franc Grum and Mitch Miller, presented by Dr. Grum at the AIC meeting in Monte Carlo.

June 21, 1985 "Metameric Mismatch Limits of Industrial Colorants" by Roy Berns at the AIC meeting in Monte Carlo.

VII. Present Staff

The leadership in R.I.T. programs in color science appearance and technology is provided by the Richard S. Hunter Professor, Dr. Franc Grum. He is assisted by Dr. R.S. Berns, Assistant Professor. Also on board are Mr. R.M. Miller, of Eastman Kodak Company, technical assistant and Mrs. Martha Pschirrer, administrative assistant. Mr. Yuan Chen a visiting scholar from Xian, China was involved in characterization of performance of laboratory instrumentation.

VIII. Future Aims

As to the future, the following activities and programs are contemplated:

Academically, we are planning a graduate course in vision and psychophysics to be taught by Dr. C.J. Bartleson; and several Liberal Arts courses in color perception. We will strengthen our curriculum dealing with computer colorant formulation.

In the research area, we will continue to work on the previously mentioned projects and begin to develop facilities for appearance studies and measurements.

Through the help of the Advisory Board, we plan to strengthen our contacts with industry in our quest for contractural work in the Laboratory and further financial support. It is our aim to use this support to aid graduate students interested in color science, technology and appearance.

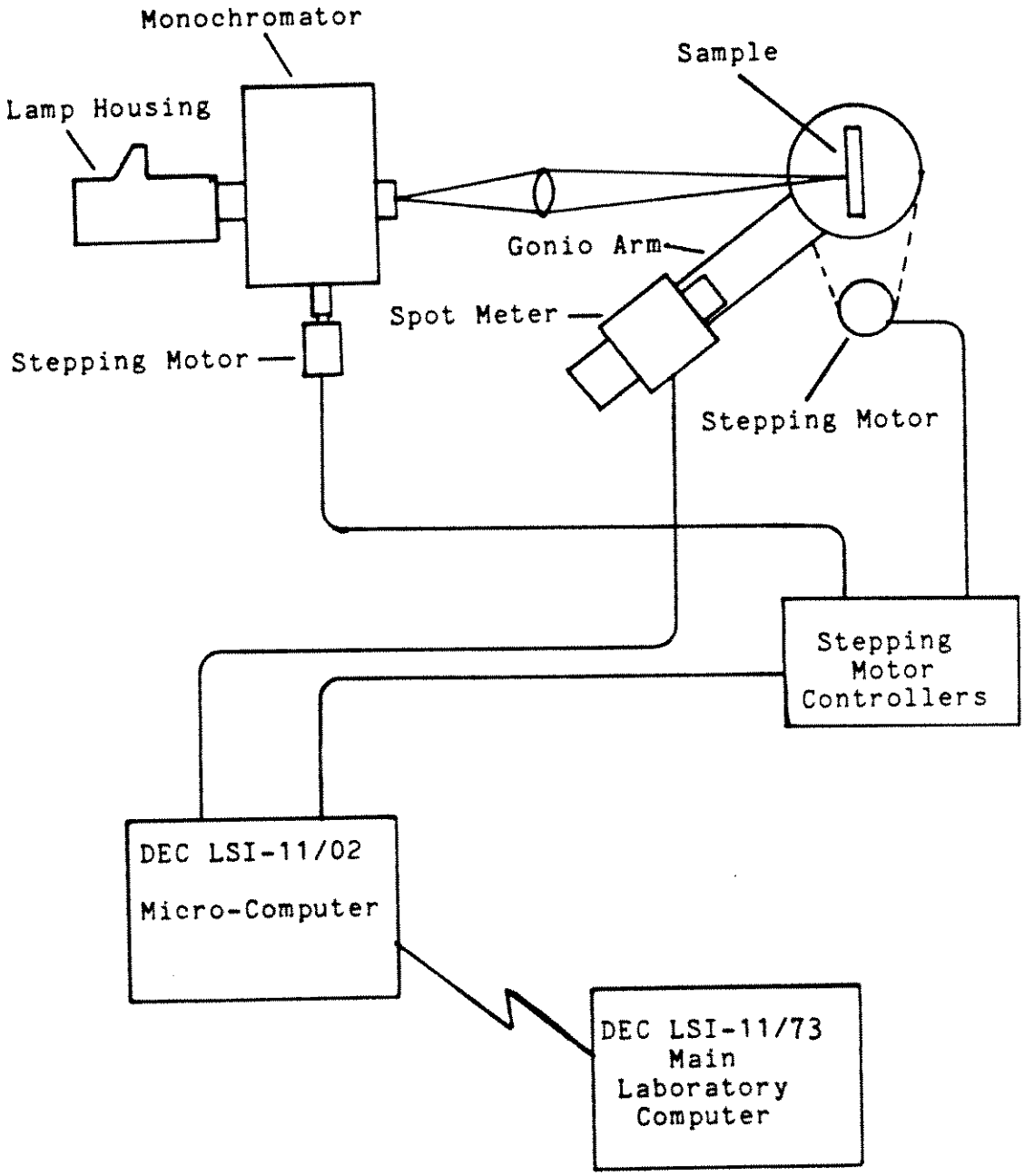
IX. Conclusion

This past year has been very challenging, and we believe very productive. Needless to say, we are most thankful for the generosity of manufacturers and industrial donors. Through their generosity the Munsell Color Science Laboratory is unusually well equipped, both for teaching and research. Also we would like to acknowledge the generous gifts previously mentioned and the aid and support of the Advisory Board. Last, but not least, our thanks go to R.I.T. management for their continuous and enthusiastic support of our programs.

Figure 1

Goniospectrophotometer

Schematic Diagram



APPENDIX A

Munsell Color Science Laboratory
Date Last Revised: June 24, 1985

Equipment and Standards in the Munsell Color Science Laboratory

SPECTROPHOTOMETERS *

Instrument Name	Features
Diano/Hardy Spectrophotometer	R, T, small area samples, computer interfaced
G.E. Spectrophotometer	R, T, Tristimulus Integrator
Beckman DK2A Spectrophotometer	R, T, UV, VIS, IR
Beckman DK2 Spectrophotometer	R, T, UV, VIS, IR
Applied Color Systems Spectro-Sensor II	R, T, large and small area samples, XYZ, CIELab, color differences, plots, computer interfaced
Beckman DU MOD 2400	R, T, 0/45 attachment
Hunterlab Labscan Spectrophotometer	R, T, XYZ, Yxy, Hunter Lab, CIELab, color differences, plots, 2 printers, computer interfaced
Diano Match Scan II	R, T, reversible optics, computer interfaced
Bausch & Lomb Color Scan	R, T, polychromatic ill.
IBM Model 9420	UV - visible, R, T
Pacific Scientific Spectrogard	R, T, polychromatic ill. computer interfaced, color matching software

* including associated standard reference materials

COLORIMETERS

Instrument Name	Features
Minolta Chroma Meter II	R, Fiber Optics Probe, Yxy, CIELab, color differences, computer interfaced, portable
IDL Color-Eye Model LSD-1	R, Large Sphere
IDL Color-Eye Model LSD-1 #2	R, Large Sphere
Hunterlab D25D2	R, XYZ and Hunter Lab
Hunterlab D25A9	R, XYZ, Yxy, Hunter Lab, CIELab, color differences, computer interfaced
Hunterlab D25A9 #2	R, XYZ, Yxy, Hunter Lab, CIELab, color differences, Tappi filter, Dominant Wavelength, computer interfaced

Minolta Chroma Meter I	R, XYZ, Yxy, L*a*b*
Minolta Chroma Meter II	0/45, R, XYZ, Yxy, L*a*b* Munsell Notation, computer interfaced
Pacific Scientific Colorgard System 1000	0/45, R, T, XYZ, Yxy, L*a*b* c*ho, computer interfaced
Colormaster Differential Colormeter	R
Hilgor Ltd. Donaldson	T, Visual colorimeter

SPECTRORADIOMETRY

Instrument Name	Features
Tracor Northern Array Radiometer	Samples spectrum an array of 1024 wavelengths between 300 and 1100 nm in 10 msec. Computer interfaced.
MCSL Spectroradiometer consisting of:	
Oriel Radiometer	for PMT or photodiode
Optronics Model 318 detector	Calibrated detector
Schoeffel GM250 Monochomator	
Superior Electric Stepper Motor	Drives monochromator
Associated stepper control logic	
2 - HP 6274A DC Power Supplies	supplies for lamp
System is computer interfaced	
Optronic Model 740	wavelength range: 280-1100 nm

Visual Apparatus

Macbeth Spectraliteviewing booth	D65, D75, CWF, Horizon narrow band fluorescent
Macbeth Prooflite D5000 viewing booth	
Macbeth Executive viewing booth	
Hunterlab Gloss Meter with 20 and 60 degree heads	
Pacific Scientific Gloss Meters 20, 60, 85 degree	
Hunterlab Dorigon	
Lovibond Tintometer	fiber optic head

COMPUTER EQUIPMENT

Digital Equipment Corp. LSI-11/23 Plus including the following:

Operating Systems:	RT11 Ver. 5.1, TSX Ver. 5.0
Languages:	Pascal - 2 Ver. 2.1D, Macro-11
Memory:	1 MB RAM
Mass Storage:	Shugart Associates Fixed Disk Drives 20 Megabytes
	Shugart Associates Floppy Disk Drives 2 Megabytes

Video Terminals:	1 - Digital Equipment Corp. VT55 Graphicscope
	1 - Digital Equipment Corp. VT100 Decscope
	3 - Digital Equipment Corp. VT50 Decscope
	1 - Lear Seagler ADM3A Terminal
	1 - Visual 50 Terminal
	1 - Heath H-19 Terminal
Printers:	Digital Equipment Corp. LA100RA (with graphics)
	Digital Equipment Corp. LA34
	Digital Equipment Corp. LA36
Plotter:	HP 7475 Digital XY Plotter

2 Heath H-11 System including two each of the following:

Operating System:	RT11
CPU:	Digital Equipment Corp. LSI-11/02
Memory:	64Kb RAM
Mass Storage:	Floppy Disk Drives 0.5 Megabyte