TOPICAL MEETING ON QUANTUM-LIMITED IMAGING & IMAGE PROCESSING TECHNICAL DIGEST

Summaries of papers presented at the Quantum-Limited Imaging & Image Processing Topical Meeting

March 31–April 2, 1986

Honolulu, Hawaii

Conference Edition

Sponsored by the

Optical Society of America

Optical Society of America
1816 Jefferson Place, N.W.
Washington, DC 20036
(202) 223-8130

SUNDAY, MARCH 30, 1986

PREFUNCTION AREA

6:00–8:00 PM **REFRESHMENTS**

MONDAY, MARCH 31, 1986

HONOLULU III

8:30–8:40 AM
OPENING REMARKS
G. Michael Morris, *Chair*

8:40–10:00 AM
QUANTUM-LIMITED DETECTORS: 1
Edward H. Eberhardt, *Presider*
ITT Electro-Optical Products Division

8:40 AM Page 4
MA1 **Imaging Microchannel Plate Detector Systems,** J. Gethyn Timothy, *Stanford U.* Imaging detector systems based on the microchannel plate electron multiplier are in use at all wavelengths from the x-ray region to the near infrared. This paper reviews the performance characteristics of the different systems and discusses the prospects for future developments. **(Invited paper)**

9:10 AM Page 5
MA2 **Imaging Photon Counting Detectors,** Costas Papaliolios, *Harvard U.* A comparison of four available detectors, the Boksenberg, the MAMA, the PAPA, and the resistive anode, points out their individual strengths and weaknesses. **(Invited paper)**

9:40 AM Page 6
MA3 **Wedge and Strip Image Readout Systems for Photon Counting Detectors in Space Astronomy,** O. H. W. Siegmund, M. Lampton, J. Bixler, S. Chakrabarti, J. Vallerga, S. Bowyer, R. F. Malina, *UC-Berkeley.* Results of development of wedge and strip anode schemes, in microchannel plate dtectors for ultraviolet and optical wavelengths, are described and future developments are discussed.

10:00–10:30 AM **BREAK**

MONDAY, MARCH 31, 1986—Continued

HONOLULU III

10:30 AM–12:10 PM
QUANTUM-LIMITED DETECTORS: 2
Costas Papaliolios, *Presider*
Harvard University

10:30 AM Page 12
MB1 **Low Light Level CCD Imaging in Astronomy,** J. Anthony Tyson, *AT&T Bell Laboratories.* Faint galaxies and stars of 27 V magnitude are detected in 2-h integration on a 4-m telescope. This corresponds to 2 photons/s. **(Invited paper)**

11:00 AM Page 16
MB2 **Photon Counting Imaging on the Space Telescope,** A. Boksenberg, *Royal Greenwich Observatory, U.K.* The technique of image photon counting as now conventionally used in optical astronomy is described. Typical scientific results are given to illustrate the properties of such systems. **(Invited paper)**

11:30 AM Page 17
MB3 **Photon Counting Array Detectors for the FUSE/ Lyman Satellite Telescope,** E. Roberts, T. Stapinski, A. Rodgers, *Mount Stromlo & Siding Spring Observatories, Australia.* The development and application of advanced multichannel photon-counting detectors to the FUSE/Lyman ultraviolet satellite telescope is described.

11:50 AM Page 21
MB4 **Miniature Solid-State Photodetectors for Photon Correlation Spectroscopy and Laser Anemometry,** R. G. W. Brown, K. D. Ridley, *Royal Signals & Radar Establishment, U.K.* The purpose of our investigations was to characterize cooled silicon avalanche photodiodes and assess their suitability as photon counting detectors for photon correlation laser anemometry and spectroscopy.

12:10–2:00 PM **BREAK**

HONOLULU III

2:00–3:10 PM
ASTRONOMICAL IMAGING: 1
J. Christopher Dainty, *Presider*
Imperial College

2:00 PM Page 24
MC1 **Astronomical Speckle Interferometry and Speckle Masking at Low Light Levels,** G. Weigelt, *Erlangen Physikalisches Institut, F. R. Germany.* Speckle interferometry, speckle masking, speckle spectroscopy, and multiple-mirror interferometry are discussed. Speckle masking yields diffraction-limited images in spite of the atmosphere. **(Invited paper)**

2:30 PM Page 28
MC2 **Pupil Plane versus Image Plane in Michelson Stellar Interferometry,** Francois Roddier, *National Optical Astronomy Observatories.* Photon noise statistics are used to estimate the effect of image motion or guiding errors in the SNR for fringe visibility either in pupil-plane or in image-plane measurements.

2:50 PM Page 32
MC3 **Signal-to-Noise Ratio in Photon Counting Speckle Interferometry with Real Detectors,** Steven Ebstein, *Harvard U.* The SNR for speckle interferograms taken with the PAPA is compared with theory. Modifications for nonideal detectors are discussed.

3:10–3:30 PM **BREAK**

HONOLULU III

3:30–4:50 PM
ASTRONOMICAL IMAGING: 2
Jacques Beckers, *Presider*
National Optical Astronomy Observatories

3:30 PM Page 38
MD1 **Innovations in the Phasor Diagram that Give Lower Ultimate Quantum Noise,** Lawrence N. Mertz, *Lockheed Palo Alto Research Laboratory.* Assembling the phasor diagram recursively in polar rather than Cartesian coordinate representation results in lower ultimate quantum noise for interferometric star tracking and speckle imaging.

3:50 PM Page 41
MD2 **Photon-Statistics Limitations in Precision Astrometry,** Aden B. Meinel, Marjorie P. Meinel, *Jet Propulsion Laboratory.* The limit of absolute position measurement of stars depends on the total number of photons collected and the associated statistical fluctuations in the spatial domain.

4:10 PM Page 45
MD3 **Statistical Limits of Fourier Transform Imaging in the γ-Ray Energy Range,** Gordon Hurford, Thomas Megeath, David Palmer, Thomas A. Prince, *California Institute of Technology.* Fourier Transform imaging and position sensitive γ-ray detectors make feasible astronomical telescopes with arc-second resolution. We discuss statistics-limited imaging with these techniques.

4:30 PM Page 50
MD4 **Quantum Noise Simulations for a Synthetic Aperture X-Ray Telescope,** Lawrence N. Mertz, G. H. Nakano, J. R. Kilner, *Lockheed Palo Alto Research Laboratory.* Quantum noise is examined for an imaging system where the photons are detected in the Fourier domain instead of the more familiar image domain.

PREFUNCTION AREA

5:00–6:00 PM **REFRESHMENTS**

HONOLULU III

8:30–10:30 AM
X-RAY AND RADIONUCLIDE IMAGING
Robert F. Wagner, *Presider*
Center for Devices and Radiological Health

8:30 AM Page 56
TuA1 **Quantum Limits in γ-Ray Imaging,** H. H. Barrett, *U. Arizona.* Various figures of merit for the performance of γ-ray imaging systems are reviewed, and the influence of quantum noise on each is considered. **(Invited paper)**

9:00 AM Page 59
TuA2 **Fundamental Statistical Limitations to X-Ray Quantum Detection,** Rodney Shaw, Majid Rabbani, *Eastman Kodak Company.* The photographic recording of x-ray quanta, either directly or via a screen, involves inefficiencies which are analyzed in terms of their statistical fluctuations. **(Invited paper)**

9:30 AM Page 63
TuA3 **Detection and Localization of Quantum-Limited Events from Radionuclide Labeled Materials by Computer-Enhanced Video Microscopy,** R. K. Traub, *U.S. Army Medical Research;* N. J. Pressman, J. K. Frost, P. K. Gupta, R. L. Showers, G. W. Gill, D. L. Cook, J. K. Frost, Jr., *Johns Hopkins U.* Enhanced microscope-video acquisition of radionuclide decompositions quantitatively determines single events. High spatial resolution of nuclide distribution has been demonstrated.

9:50 AM Page 67
TuA4 **Strip Beam Digital Radiography using a Kinestatic Charge Detector,** F. A. DiBianca, D. J. Wagenaar, J. E. Fetter, C. R. Tenney, M. J. Bolz, J. E. Vance, *U. North Carolina–Chapel Hill;* D. L. McDaniel, P. Gransfors, *General Electric Medical Systems Group.* Operating principles, theory, and early experimental results are presented on a kinestatic charge detector for digital radiography. Spatial contrast and temporal resolution are discussed. **(Invited paper)**

10:10 AM Page 70
TuA5 **Low Contrast Detection Limits X-Ray Screen-Film Imaging Systems,** J. W. Motz, M. Danos, *U.S. National Bureau of Standards.* The detection limits of typical fluorescent screen-film imaging systems for low contrast x-ray signals at the image plane have been estimated as a function of the x-ray exposures from 0.1 to 4.0 milliroentgens.

10:30–10:50 AM **BREAK**

HONOLULU III

10:50–12:10 PM
LASER SPECTROSCOPY
James C. Tsang, *Presider*
IBM T. J. Watson Research Center

10:50 AM Page 76
TuB1 **Multichannel Raman Spectroscopy of Monolayers on Surfaces using a CCD Detector,** Cherry A. Murray, *AT&T Bell Laboratories.* A backthinned, liquid nitrogen cooled CCD detector has been used to obtain high-quality unenhanced laser Raman scattering spectra from organic monolayers on surfaces. **(Invited paper)**

11:20 AM Page 80
TuB2 **Subpicosecond Light Scattering with a Microchannel Plate Photomultiplier,** J. A. Kash, J. C. Tsang, *IBM T. J. Watson Research Center.* Subpicosecond optical spectroscopy with an imaging microchannel plate photomultiplier is described. Requirements for low noise and high linearity, plus constraints on detector cost and ease of use, are discussed. **(Invited paper)**

11:50 AM Page 84
TuB3 **Imaging System Requirements for Turbulence and Combustion Diagnostics,** Marshall B. Long, *Yale U.* Quantitative imaging techniques have become an important tool for studying turbulence and combustion. The unique detector requirements and some typical experimental configurations are discussed.

12:10–1:30 PM **BREAK**

HONOLULU III

1:30–2:50 PM
PHOTON CORRELATIONS AND STATISTICS: 1
G. Michael Morris, *Presider*
University of Rochester

1:30 PM Page 90
TuC1 **Quantum-Limited Imaging in Vision,** Bahaa E. A. Saleh, *U. Wisconsin-Madison.* An overview of current activities in the theory of detection and recognition of quantum-limited images by the visual system is presented. Comparison with quantum-limited machine vision is held. **(Invited paper)**

2:00 PM Page 93
TuC2 **Use of Optical Dead-Time Effects to Generate Antibunched and Sub-Poissonian Photoelectron Statistics,** E. Jakeman, *Royal Signals & Radar Establishment, U.K.* Methods for generating analog and genuine nonclassical light with antibunched/sub-Poissonian photon statistics by the use of detection-triggered optical shutters are described. **(Invited paper)**

TUESDAY, APRIL 1, 1986—Continued

2:30 PM Page 96
TuC3 **Dead-Time Correction of Photon Correlation Functions,** Klaus Schatzel, *U. Keil, F. R. Germany.* Dead-time correction procedures are described for both direct distortions of correlograms for short lag-times and distortions due to count rate saturation effects.

2:50–3:30 PM **BREAK**

HONOLULU III

3:30–4:50 PM
PHOTON CORRELATIONS AND STATISTICS: 2
Harrison H. Barrett, *Presider*
University of Arizona

3:30 PM Page 102
TuD1 **Imaging a Randomly Translating Object using Triple Correlation,** J. Christopher Dainty, M. J. Northcott, *Imperial College, U.K.* The triple correlation of detected photons has been used to reconstruct a sharp image of a randomly translating object at very low light levels.

3:50 PM Page 106
TuD2 **Image Classification at Low Light Levels,** Miles N. Wernick, G. Michael Morris, *U. Rochester.* Two-class feature extraction transformations are implemented using photon-limited input images produced by a 2-D photon-counting detector. Reliable classification is shown to result from a sparse sampling of the input image.

4:10 PM Page 110
TuD3 **Photon-Limited Scene Matching using Histogram Analysis,** David A. Zweig, C. J. Morgan, *Perkin-Elmer Corporation.* Photon-limited scenes are analyzed using their high-light level histograms. The histograms are shown to identify scenes using fewer photons than a correlation filter.

4:30 PM Page 114
TuD4 **Exact Variance-Stabilizing Transformations for Image-Signal-Dependent Exponential and Rayleigh Noise,** Paul R. Prucnal, Evan L. Goldstein, *Columbia U.* Exact variance-stabilizing transformations for families of exponential and Rayleigh random variables are derived. These render signal-dependent noise signal-independent, thus allowing classical image estimators to be used.

PREFUNCTION AREA

5:00–6:00 PM **REFRESHMENTS**

WEDNESDAY, APRIL 2, 1986

HONOLULU III

8:30–10:00 AM
OPTIMAL PROCESSING
B. Roy Frieden, *Presider*
University of Arizona

8:30 AM Page 120
WA1 **Estimation in Quantum-Limited Conditions,** Donald L. Snyder, Michael I. Miller, *Washington U.* A point-process model for quantum-limited measurements is described; it includes the effects of signal and noise statistics and what we term translations and deletions. **(Invited paper)**

9:00 AM Page 124
WA2 **Quantum Statistics Basis for Maximum Entropy Restoration,** Bernard H. Soffer, *Hughes Research Laboratories;* Ryoichi Kikuchi, *U. Washington.* The maximum entropy method, using physical statistics, chooses the most probable estimate consistent with limited measurements. Thermodynamic analogies and the degree of confidence are discussed. **(Invited paper)**

9:30 AM Page 128
WA3 **Statistical Aspects of Low-Dose Electron Microscopy,** Hedzer A. Ferwerda, C. H. Slump, *State U. Groningen, The Netherlands.* Object reconstruction from noisy images is studied by direct methods as well as by maximum likelihood estimation and hypothesis testing when prior information is available. **(Invited paper)**

10:00–10:30 AM **BREAK**

HONOLULU III

10:30 AM–12:00 M
IMAGE RESTORATION
Bahaa E. A. Saleh, *Presider*
University of Wisconsin–Madison

10:30 AM Page 134
WB1 **Restoration of Photon-Limited Images,** B. Roy Frieden, *U. Arizona.* Extremely weak object sources may be restored optimally by combining Bayesian estimation with the known physics of statistical image formation. Computer simulations are shown. **(Invited paper)**

11:00 AM Page 138
WB2 **Origins of Linear and Nonlinear Recursive Restoration Algorithms,** Edward S. Meinel, *Aerospace Corporation.* Several linear and statistically based nonlinear restoration methods are written as recursive algorithms. The linear algorithms are shown to be related to the nonlinear methods.

11:20 AM Page 142
WB3 **Effect of Nonnegativity Constraints on Detectability,** Kenneth M. Hanson, *Los Alamos National Laboratory.* It is demonstrated that under certain circumstances the use of a nonnegativity constraint in tomographic reconstruction from noisy projections can improve the detectability of objects.

11:40 AM Page 146
WB4 **New Restoration Techniques for Images Degraded by Poisson Noise,** Shiaw-Shiang Jiang, Alexander A. Sawchuck, *U. Southern California.* Images degraded by Poisson noise are restored by a noise updating repeated Wiener filter. Performance is improved compared with adaptive noise-smoothing algorithms using local image statistics.

12:00 M **ADJOURN**

CORAL III BALLROOM

5:00–6:30 PM **CONFERENCE RECEPTION**