Quantar Technology
3300/2400 Series Imaging Detector Systems

3300/2400 Technical Description June 1999

Shown: 3300 Series Detector Head, 2401B Position Analyzer

MAJOR FEATURES

- Ultimate, single-event-counting sensitivity, detects individual charged-particles and energetic photons including electrons, positrons, ions, energetic neutrals, EUV and soft x-rays. Open-face detector head specifically designed for use in high-vacuum environments.
- Position-sensitive, 1-D and X-Y, with up to 1024 x 1024 channels (pixel) spatial digitization. Better than 60 micron FWHM spatial resolution.
- Displays XY event data on detector in real-time on conventional oscilloscope in X-Y mode.
- Extremely low detector noise combined with single-event, pulse-counting detection means higher S/N ratio and better data in detector-noise limited applications.
- Capture more signal with 18 mm, 25 mm, 40 mm, 75 mm and 80 x 100 mm active collection areas to match field-of-view. Fully UHV-compatible.
- Fast data acquisition with count rates from less than one count/second to 100,000 counts/sec (other models up to 1 million counts/sec).
- Optional 100 psec FWHM single-event time-resolution combined with spatial imaging available using MCP and external timing electronics.
- Easy-to-use, complete systems to meet application needs including detector heads, readout electronics, powerful data collection/display hardware and software, options and accessories.
- Proven, dependable product design and support. High-quality materials, design and fabrication.
- Used by satisfied customers worldwide in a wide range of applications including XPS, EELS, LEED, SIMS, Imaging TOF MS, soft x-ray, EUV.

INTRODUCTION

The efficient detection of particle and photon flux has represented a major instrumentation challenge since the beginning of science. Today, scientific, analytical and industrial research demands even higher detector performance as many efforts focus on observation of inherently weak signal-generating processes, smaller areas, spatially-resolved analysis and the need to gather data quickly and minimize exposure and of damage-sensitive sample materials. Simply, there is the need to make more spatially-resolved measurements, more accurately, faster and at lower levels than ever before.

Quantar Technology's 3300/2400 Series *Multichannel/ Multipixel* Imaging^{TM} Detector Systems are position-sensitive, quantum-limited, charged-particle and photon detectors designed primarily for these kinds of scientific applications.

These high performance detectors are ideal solutions in a wide range of 1-D parallel multichannel spectroscopy and 2-D X-Y imaging applications.

Complete systems include MCP/RAE detector heads (3300 Series Sensors), signal processing and readout electronics (2400/2500 Series Position Analyzers) and PC-based data collection and display hardware and software (2200 Series Software and associated hardware boards and other multiparameter data systems).

SYSTEM PERFORMANCE

3300 Series MCP/RAE Sensors (detector heads) utilize MCP (microchannel plate) imaging electron multipliers followed by a charge-division position-encoding anode. These detectors provide true, single-event, position-sensitive detection of electrons, positrons, positive and negative ions, neutral particles and EUV and soft X-ray photons (10-200 nm) in vacuum environments. Higher energy X-rays (>2 KeV) can also be detected directly by MCP's with decreasing efficiency at higher energies.

Combined with extremely-low detector MCP background dark count (typically less than 10 counts/sec over entire active area for 25mm MCP's), this approach offers extremely high signal-to-detector-background ratio measurements, especially useful in relatively low count-rate applications, where signals of interest would otherwise be obscured by noise.

Detector heads are fabricated using precision alumina ceramic and gold-plated stainless steel for maximum UHV compatibility (vacuum pressures of better than 10^{-6} are typically required for operation of these detectors).

For optical photon detection, the 2600 Series *Mepsicron-II*^{tm} Imaging Detector Systems are also available for true single-photon detection and imaging in the 180-900 nm range (UV-VIS-near IR). These are permanently vacuum-sealed, intensifier-like imager tubes and incorporate an optically-sensitive photocathode on a transparent faceplate. The remainder of the system is identical to that described above.

These optical detectors are an excellent choice for ultra-low count-rate optical applications such as Raman scattering, fluorescence and luminescence spectroscopy and imaging, and astronomy. Using external timing electronics, both single-photon time-resolved and imaging capabilities can be simultaneously combined using this unique detector, a powerful and unusual capability. For more information on this optical version, see the 2600 Series *Mepsicron-II* ^{tm} Technical Description.

SYSTEM OPERATION

In operation, single incoming events (particles or photons) impact the MCP surface and result in an electron cascade, the gain depending on the number and type of MCP's, the bias voltage and the MCP configuration. The MCP's operate in a gain-saturated mode to ensure a relatively constant gain from event-to-event to optimize position determination. Detection efficiency for various types of particles and photons is determined primarily by the MCP surface response or by applied enhancement coatings.

The resulting charge packet from the MCP stage is electrostatically focused on the charge-division anode. Four pulse signals are processed by separate charge-sensitive preamplifiers, shaper amplifiers and discriminators. The X and Y spatial coordinates of each detected event, corresponding to a single incoming particle or photon, are then computed from the ratio of charge pulse amplitudes. The X and Y position is output in analog format for real-time display on an analog CRT XY monitor (such as a 2-channel oscilloscope operated in X-Y mode) and in digitized format (see options) for use in digital data collection systems.

By accumulating single events for a user-determined period of time, spectra and images are developed from the integration of these single events.

SPATIAL RESOLUTION

3300 Series Sensor heads are available in several configurations with circular active diameters of 18 mm, 25 mm, 40 mm, 75 mm and a nominal rectangular size of 80 x 100 mm (74 x 93 mm actual useable area). Custom sizes are available to meet specialized application requirements. Special features are available, such as 6 mm diameter clear center holes through the entire detector to accommodate coaxial electron or ion guns.

Standard and high spatial-resolution versions are available. Standard resolution versions achieve 100 resolution elements (1/100 of active dimension) across each axis. High-resolution versions achieve 400 resolution elements (1/400 of active dimension).

These versions differ primarily in the number of MCP stages and the corresponding electron gain. In these systems, FWHM spatial resolution (position blur or point-spread distribution for the reported position of a statistically large number of events) is the result of event-to-event position jitter caused by slight variations in the computed spatial position of successively imaged events. For fixed noise, higher MCP gain reduces the effect of this position jitter, improving fractional position resolution.

Measured spatial resolution can also be affected by the spatial sampling intervals of the digitized output. Digital output options are available with either 8-bit (256 channels), 9-bit (512 channels) or 10-bit (1024 channels) equally spaced along the X and Y axis. Generally, the number of digital channels (and therefore the digital output option) should be chosen to provide at least 2X finer spatial sampling than the required spatial resolution. For example, for a desired spatial resolution of 100 resolution elements across the active detector dimension, at least 200 points, preferably more, should be digitally sampled. Higher ADC resolution options, however, reduce the maximum achievable count rate due to longer system dead time.

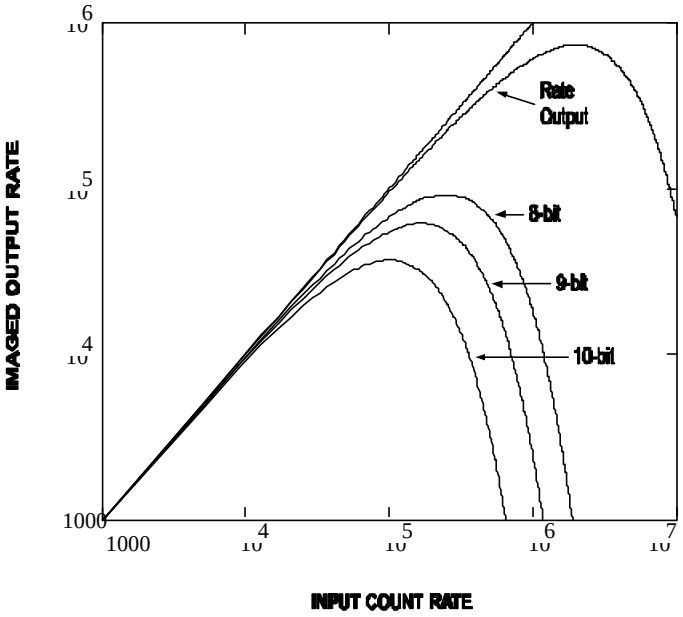
COUNT RATE CAPABILITY

Each detected event is processed separately and occupies a fixed amount of signal processing time. Only one event can be processed simultaneously. This fixed time period is required for position calculation and preamp/shaper baseline recovery to ensure accurate spatial position calculations of subsequently-occurring event.

The basic paralyzable dead time of the Model 2401B Position Analyzer, including the preamplifiers, is 4 microseconds per detected event, and applies to both the analog-only output version and the 8-bit digitized output option. This dead time is increased to 6 microseconds for 9-bit digitized output, and to 10 microseconds for 10-bit digitized output (the added time is non-paralyzable). Digitization is performed by fast, highly-linear 130 MHz clock rate, Wilkinson-type ADC's.

A fast "look-ahead" channel is incorporated for pulse-pile-up detection and event rejection. If a second event is received by the charge-sensitive amplifier within the dead time (in Fsec) of a prior event, either one or both of the events are vetoed from further processing to ensure optimum spatial position calculation accuracy. A separate RATE output signal (500 nsec dead time) is derived from this channel for use in dead time corrections of count rate and to monitor input count rate. A front panel meter monitors this RATE signal, MCP gain and dead-time loss percentage.

For perfectly time-periodic input counts, the 4 Fsec dead time translates to a maximum output count rate of 250,000 cts/sec. For Poisson-distibuted time-of-arrival statistics encountered in typical applications, this maximum output rate is reduced due to the arrival of closely-time-spaced events that are lost from processing and the effect on maximum output count rate is shown below.



DYNAMIC COUNTING RANGE

In a single-event-counting detector, the time-integrated dynamic counting range is limited only by available digital storage memory. Each event count is stored as a single count, with no crosstalk or other interaction with adjacent channels or pixels. This characteristic is particularly advantageous when detecting spectra or images with spectral or spatial features of significantly differing intensities. In the 2200 Series data system, data memory counting range is typically 16 bits deep (65,000 counts per pixel) but can be selected to be 32 bits deep (4,000,000,000 counts).

TIME-RESOLVED CAPABILITY

There are several methods to obtain time-resolved event data with these detectors, depending on the application.

The Model 2401B Position Analyzer can be electronically gated to exclude unwanted events from the output data using an external TTL-level signal on the VETO GATE input, with a time-resolution of approximately 500 nsec.

Using conventional external single-event pulse timing equipment (amplifier/CFD/TAC), event position data can be "time-tagged" using the MCP bias recharge pulse signal relative to a reference pulse from, for example, a laser source. Digitized representations of this time can then be written to a data system together with the event XY position data or used in an external coincidence system to exclude unwanted events. Time resolution of better than 100 psec FWHM has been achieved using this method.

DATA COLLECTION AND DISPLAY

Real-time event positions can be readily displayed on an analog XY CRT monitor (oscilloscope in XY mode) using the 0-5V analog X and Y axis position pulses. Each event is displayed as a momentary bright dot on the CRT in its proper image position. This display mode is extremely useful for real-time spectral and image alignment and diagnostics.

These analog position pulses can also be displayed using a one or two-dimensional multichannel analyzer (MCA) with an integral pulse-height analyzer ADC.

Units equipped with digitalized output options produce TTL-level, positive-true, 8 or 9 or 10 bit position addresses for both X and Y axis, accompanied by a digital strobe signal. These signals can be then read directly by a computerized data system. Alternatively, the digital position data can be captured by an auto-incrementing (add-one), dual-ported histogramming memory. This memory has a dedicated memory channel for each spatial position in the spectra or image. Under software control, the memory can start and maintain an accumulation and data can be simultaneously read out into a PC-based data system and the computer display screen updated. This histogramming memory approach avoids PC-bus limitations and enables significantly higher data rates to be realized than can be achieved with direct readout into a PC.

Quantar Technology offers several fully-integrated data system configurations with histogramming memories of different sizes to match application requirements, and both 1-D spectral and 2-D imaging DOS-based software. See 2200 Series Data Sheet for additional detail. Also available are PC-based, 3-parameter Multiparameter Data Systems for X-Y-T data collection and display.

ACCESSORIES

Quantar can provide HV bias power supplies and divider networks for MCP biasing, time-resolving subsystems, special cables, vacuum flanges, isolated mounting ring options to enable mounting accelerating, collection or retarding grids in front of the input MCP and other accessories upon request.

APPLICATIONS

Quantar Technology's detector systems are being successfully used worldwide and have proven useful in a wide range of spectroscopic and imaging applications in scientific and analytical instrumentation fields including:

- **!** Parallel multichannel electron spectroscopy, XPS, EELS
- **!** Secondary-ion imaging mass spectrometers (SIMS),
- **!** Imaging TOF-SIMS
- **!** Sector-type mass spectrometers
- **!** LEED, ESDIAD (electron-stimulated ion angle) and SARIS (angle-resolved ion TOF MS) imaging
- **!** Soft x-ray fluorescence multichannel spectroscopy
- **!** Raman multichannel spectroscopy and imaging
- **!** Fluorescence and luminescence spectroscopy/imaging
- **!** Space science and astronomy
- **!** Neutron imaging (with scintillator)
- **!** Biomedical applications

Quantar Technology invites inquires regarding possible applications.

TECHNICAL SPECIFICATIONS

3300 SERIES MCP/RAE SENSORS

Description: Open-face, MCP-based, position-sensitive detector heads for particle and EUV/X-ray detection on standard or coated (e.g. CsI, KBr) MCP surface, in vacuum. Fully UHV-compatible.

Sensor head active area diameter: 18 mm, 25 mm, 40 mm and 75 mm circular; 74 x 93 mm rectangular. Special sizes available upon request.

Spatial position resolution: 100 (standard) or 400 (high resolution) effective resolvable elements across active area diameter.

Spatial position linearity: typically within 5% of true position (of sensor active dimension). Fixed pattern.

Background count rate: typically less than 10 events per second integrated over entire image.

Bias voltage requirements: microchannel plates and RAE position encoder must be biased by external 2 kV (3 kV for high resolution versions) power supply and resistive biasing network.

Physical dimensions: See outline drawing available upon request. Shipping weight: Approx. 5 lbs (3 kg).

MODEL 2401B POSITION ANALYZER

Description: Pulse-position processor, 2 axis (X, Y) , includes separate modular 4 channel charge-sensitive preamplifier/shaper with added fast look-ahead channel, plus main electronics module (19" rack mount unit) containing signal processing, metering, edge-gating and power supply circuits. Two preamp gain options are available to match MCP/RAE sensor head types.

Deadtime per event: Depends on spatial digitization resolution; 4 Fsec per detected event (basic analog only model and 8-bit digitized option model), 6 Fsec (9-bit) and 10 Fsec (10 bit) digitized option models. Correspond to maximum output count rates of 60,000 to 100,000 counts/sec with 67% dead time loss with Poisson-distributed event arrival times. See dead time plot.

Pulse-pair resolution: 300 nsec. A second event arriving more than 300 nsec but less than 1 Fsec after a prior event are both vetoed from processing; a second event arriving more than 1 Fsec but less than the total dead time after a prior event is vetoed from processing but the first event is processed; events separated by more than the total dead time are both processed. If two events arrive within 300 nsec (and combined amplitude does not exceed upper discriminator setting), both are counted together as a single event with a calculated position between the true positions. Incoming count rates should be adjusted so the probability of near- simultaneous events is minimal.

Inputs: Four low-level charge signals from MCP/RAE sensor (detector head).

X and Y analog position outputs: approximately 0.5 to 4.5 VDC linearly proportional to coordinate position of event on sensor. Analog strobe output and Z-axis blanking output (for XY monitor) activated when valid data is present on analog XY outputs. Quiescent analog X and Y position output voltage is 2.5 volts.

X and Y digitized outputs: TTL-level, positive-true logic outputs, internal 50 pin ribbon connector, external 50-pin Amphenol-type connector. Includes digital strobe.

Front panel edge-gating controls enable selection of rectangular active area for data acquisition.

Other inputs/outputs: Veto Gate Input; Sum (diagnostic gain output), Analog Rate (for remote count rate meter), Analog Strobe, Z-axis Blanking, Rate, and Busy outputs. 1D/2D data switch selector on digitized options. Switch-selectable front-panel meter monitors Count Rate, Input Level (MCP Gain) and Dead-Time Loss %.

Accessories included: 8 ft (3.3m) preamp cable, XYZ cables, 18" (0.5m) preamp input cables (RG188), rack adapters, manuals.

Power requirements: Switch-selectable, 100/120/200/240 VAC, ±10%, 50-60 Hz, 50 watts.

Physical dimensions: preamp module, 2"H x 5W" x 7"D (51 x 127 x 178mm). Electronic rack unit, 5-1/4"H x 17"W x 18"D (133 x 432 x 560mm). Net wt: 20 lbs (9 kg). Ship weight: 30 lbs (14 kg). CE-marked versions available for European installations.

2200 SERIES DATA COLLECTION SYSTEM

Description: Functions as a one or two dimensional, PC-based multichannel analyzer (multiparameter MCA). Requires at least 286 type processor, EGA compatible color graphics adapter/monitor and ISA-type available expansion slot for IO card. Accepts digitized position data from Model 2401B.

Consists of Histogramming Memory (Model 2412A or 2415B), Parallel IO Card (Model 2420B), 11001A Data Cable and MCA Software (either 1D or combined 1D/2D version). Histogramming Memory board is installed in Model 2401B.

The Model 2412A Histogramming Memory has maximum 12 -bit input address (4096 addressable counting channels) and is suitable for 1D spectroscopy or limited 2D imaging (e.g. 6- bits x 6-bits).

The Model 2415B Histogramming Memory has maximum 20-bit input address (1,048,000 addressable counting channels) and is suited for up to full 10-bit x 10-bit imaging. The counts in each channel in the RAM memory are auto-incremented when a corresponding digital event address is received. Memory is dual-ported to enable simultaneous readout by the host computer during data accumulation. Data is transferred to the PC via the Model 2420B Parallel IO Card.

The Model 2251A MCA Software enables control of data accumulation, display, file storage and retreival, and operations such as image collapses from 2D to 1D, image and spectral arithmetic, spectral peak-fitting and printing to selected printers. The 1D program is available separately. See the Model 2251A Technical Data brochure for complete information.

Warranty: Quantar Imaging Detectors are covered by a limited 12-month warranty. Certain exceptions apply.

Quantar Technology holds US patents or exclusive patent licenses on several MCP/charge encoder imaging technologies. MCP's are subject to special limitations and must be stored under vacuum conditions to prevent damage.

Quantar Technology Incorporated
2620A Mission Street
Santa Cruz, CA 95060-5703
Tel: 831-429-5227 FAX: 831-429-5131