Channel Photomultipliers - New Technology for More Accurate and Efficient Photon Detection

Introduction

Science and industry are continuously discovering new applications for technology that measures and analyzes light emitted at levels so low that detection of single photons is required. For decades, researchers have relied heavily upon glass photomultiplier tubes (PMTs), especially for detecting light in the ultraviolet and visible regions. PMTs and other photon counting devices have enabled fundamental advances in fields ranging from genomics and biomedical research to health diagnostics, hygiene monitoring, environmental protection, and metallurgy. However, PMTs have severe limitations, and as photon counting and low light level applications grow in number and sophistication, so does the need for more precise and efficient instruments. This is why PerkinElmer has introduced its line of Channel Photomultipliers (CPMs), which exceed the capabilities of PMTs by eliminating many disadvantages.

The Technology

CPMs operate according to the same general principles as PMTs, but are built from different materials and lack the PMT's internal parts. Photons enter both devices through an entrance window and hit the photocathode. Inside the photocathode the photons are converted into electrons, which are emitted into the vacuum. These electrons are accelerated by an electrical field through a multi-curved path through the vacuum chamber toward an anode. In a PMT, electrons hit specially coated and separately charged metal dynodes on their way through the glass vacuum tube, and these dynodes emit secondary electrons. The electrons travel to the next dynode, which emit still more electrons, and the multiplication is repeated up to approximately ten times to produce a gain on the order of one million. Finally the electrons are collected and read out at the anode.

A CPM works in much the same way, but without the PMT's multi-element dynode structure. Instead, the device contains a single hollow tube internally coated with a semiconductor. On the way from the photocathode to the anode, the electrons hit the curved channel walls several times, and at each collision with the channel wall several secondary electrons were created.

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Technology cont.

Like an avalanche, more and more electrons are generated at each collision. Every electron emitted from the photocathode can multiply up to a gain of 100 millions or more. Since a CPM contains no dynodes, there is no need for a voltage divider network, which is required to bias the PMT´s dynodes.

The simplified structure of the CPM accounts for the instrument's considerable advantages over the PMT. Both devices are sensitive in the range from vacuum ultraviolet up to the near infrared and can detect photons at high speed in sample sizes up to several centimeters. The CPM, however, operates with far less "background noise" - the current generated by the device itself in absence of photocathode illumination. In the PMT, emissions from both the photocathode and the dynodes produce significant dark current. In the CPM, the vacuum channel is virtually silent, and dark counts originate from the photocathode alone. Also, in the CPM, there is no leakage current of the kind that results from voltage applied to dynodes. Hence, a CPM's background level is generally one or two orders of magnitude lower than in a PMT. This results in a high dynamic range and significantly better detection limits. Since the CPM operates with a monolithic semiconducting channel, there is no glass bulb to discharge, which might create sudden "bursts" in the background signal, thus, the CPM´s background noise is extremely stable. The device can operate with a low and stable background in both photon-counting mode and DC-analog mode. The CPM is more reliable than the PMT, because it is 50 times more immune to external magnetic fields. No expensive magnetic shielding is required.

Unlike the PMT, the CPM can apply an incorporated electronic shutter, which prevents excessive illumination and enables time-resolved measurements. This is especially important for applications like fluorescence or luminescence when samples are activated with short-time high light flash lamps or lasers and might overexpose the detector. PMTs require mechanical shutters, which are far slower and wear out.

From a practical standpoint, a CPM is smaller, more rugged and less breakable than a glass PMT. The tube is completely encapsulated and shock resistant. Since the CPM has no internal dynodes, vibration resulting in "microphonics" will not disturb the signal. This is particularly important when using handheld or movable devices.

Applications

CPMs can be used in a wide variety of applications. Examples include:

Health diagnostics and biomedical research - Researchers can use CPMs in conjunction with fluorescence and luminescence techniques to examine light reactions in amino acids, antibodies, proteins, genes, etc. In high-throughput screening (HTS), several CPMs can be arranged in a multi-channel array that corresponds to a multi-titer plate.

Hygiene monitoring - Chemiluminescence methods enable food companies to detect the minutest levels of bacteria in products and equipment.

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Metallurgy - Emission spectroscopy allows scientists to analyze within seconds the properties of metals and helps steel manufacturers insure that the contents of steel are exactly the same for all elements. Pollution monitoring - CPMs enables companies and government agencies to detect very small traces of contaminants in water, oil, air, etc.

Basic physics - CPMs have applications in neutrino physics; they can be used with calorimeters and Cherenkov imagers; and can read-out optical fibers and scintillators.

Product Variety

PerkinElmer CPMs are available in three sizes: 1/3, 1/2 and 3/4 inches. The company offers 8 different photocathodes, four different window materials, and three different module types, including photon counting and analogue-DC modules. PerkinElmer continues to develop the technology to meet the needs of science and industry worldwide.

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