



ICCD Gating

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Introduction

In recent years, rapid developments in the field of intensifier technology coupled with advancements in CCD technology have allowed ICCD cameras to be used in spectroscopy and imaging applications involving transient phenomena at ultra-low-light levels. Detection and time resolution of low light are two unique strengths of ICCDs. Low-light detection is achieved by high amplification of incoming photons by the intensifier, whereas time resolution is possible due to the fact that the intensifier can be switched on and off (gated) in very short intervals.

Principle of Operation

The construction of an image intensifier tube is shown in Figure 1. The intensifier consists of a photocathode, a microchannel plate, and a phosphor screen. A fraction (called the *quantum efficiency*, or QE) of the photons incident on the photocathode is converted into electrons. Single photoelectrons are converted into clouds of electrons by the microchannel plate (MCP), which acts as a distributed electron multiplier. The electrons released from the MCP then strike the fluorescent screen (phosphor) and cause it to emit far more light than was incident on the photocathode. In the traditional configuration, the voltage between the photocathode and the input of the MCP is used to switch the intensifier on and off. If the photocathode is electrically biased more positively than the MCP, electrons will not enter the MCP and the intensifier is gated off. If the photocathode is negatively biased, electrons will be accelerated toward the MCP and the intensifier is turned on.

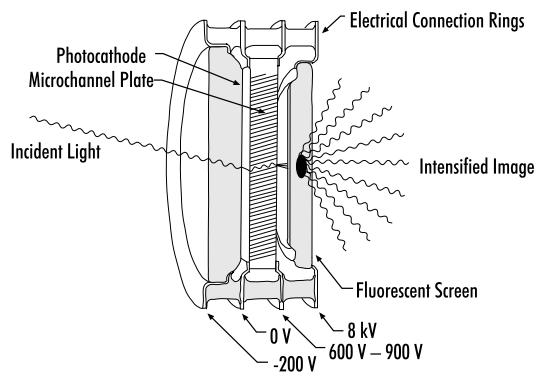


Figure 1. Construction of an image intensifier tube.

Fast- and Slow-Gate Intensifiers

Photocathode material is deposited on the inside face of the front window of the intensifier. Electrically, this can be represented as a resistor-capacitor network. Due to its high resistance (thereby high RC constant) photocathode material by itself does not allow fast gating. To overcome this limitation, a nickel underlayer is deposited on the front window, which lowers the resistance and allows fast gating. With the Ni layer, intensifiers can be gated faster than 2 ns. But, due to the Ni layer, the sensitivity (QE) of the system is lowered. Intensifier manufacturers' data indicate that the reduction in QE can be as much as 40%. Slow intensifier tubes, on the other hand, do not have this Ni layer and thus have no QE loss. They can, however, have minimum gate widths up to 25 ns or more.

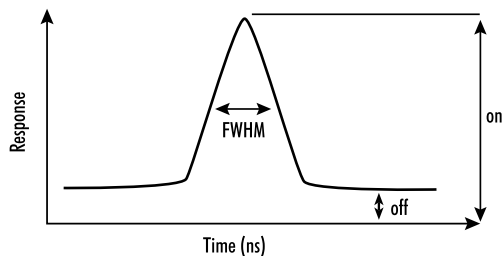


Figure 2. On/off ratio and FWHM.

Gating performance of an ICCD is measured in terms of the minimum width and on/off ratio. The minimum width of gating is specified by the *full width at half maximum* (FWHM) of the gate pulse. Typical FWHM values range from nanoseconds to tens of nanoseconds. *On/off ratio*, the ratio of light output when the intensifier is electrically turned on and off, is a direct measure of the quality of the gating (see Figure 2). A high on/off ratio is necessary to eliminate the background and to faithfully reproduce the transient phenomenon. In the visible region, an on/off ratio exceeding 10⁶:1 is typically achieved. In the UV region, the on/off ratio is typically much poorer (10⁴:1). However, with a new gating technique called MCP Bracket Pulsing on/off ratios in the UV region can be improved dramatically (10⁷:1).

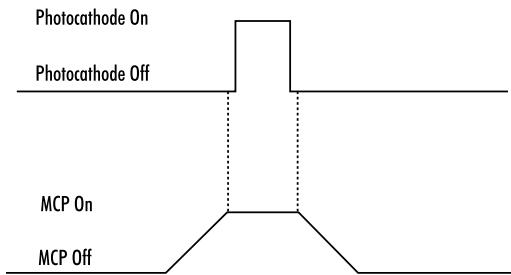


Figure 3. MCP Bracket Pulsing.

MCP Bracket Pulsing™

As explained earlier, only a fraction of incident photons is absorbed by the photocathode. The rest then pass through it and strike the input side of the MCP. This leakage is not damaging in the visible region because photons do not have sufficient energy to generate electrons at the face of the MCP. At UV wavelengths though, photons are energetic enough to occasionally release a photoelectron from the MCP. Once into the MCP, undesired photoelectrons are multiplied into charge clouds, which in turn generate photons from the phosphor. This effect reduces the on/off ratio in the traditional configuration (where MCP is continuously on) to approximately 10⁴:1.

However, if the MCP is biased "off" (along with the photocathode) during the time the intensifier is required to be off, the multiplication of the electrons is prevented, and the on/off ratio will exceed 10⁷:1. Implementing this strategy in an ICCD camera requires two high-voltage pulse generators in the camera: one for the photocathode and one for the MCP. Because of the high power requirement, the MCP gating generator is slower, so it must be given a 500-ns "head start" on the optical pulse. It takes another 500 ns to turn it off. In other words, the gating of the MCP "brackets" the gating of the photocathode, as shown in Figure 3.

Generating the early warning is not always easy; many experiments don't provide a timing pulse 500 ns before the laser pulse. In such situations, an "anticipator" is used to "predict" the arrival of the optical pulse.

Anticipator

If the light source (typically a laser) is pulsed at a constant frequency, advanced timing generators (such as the PTG™) can measure the interpulse interval and activate the MCP a user-selectable time before the next laser pulse is expected.

MCP Gating

The ability to gate the MCP on and off gives rise to an additional technique, known as MCP gating, which addresses the need to have the same QE as that of slow-gate tubes, but with shorter gate widths. The lower resistance of the two sides of the MCP allows the MCP to be gated more quickly than a slow-gate photocathode. This technique gives gate widths of < 10 ns (better than slow-gate tubes), but does not compromise the QE of the system. It is an excellent solution for applications that are light starved and do not need the fastest gate speed.

Contact Roper Scientific, Inc. for more information:

3660 Quakerbridge Road Trenton, NJ 08619
tel: 609.587.9797
fax: 609.587.1970
email: info@roperscientific.com
web: www.roperscientific.com

3440 East Britannia Drive Tucson, AZ 85706
tel: 520.889.9933
fax: 520.573.1944
email: info@roperscientific.com
web: www.roperscientific.com

530 Main Street Acton, MA 01720
tel: 978.263.3584
fax: 978.263.5086
email: mail@acton-research.com
web: www.roperscientific.com