BrightView XUV-2000
IMAGE CONVERTER/INTENSIFIER

BrightView provides real-time, two-dimensional visible images of radiation with wavelengths below 250 nm in the VUV to x-ray range of energies. This open-tube device is also well suited for particle detection over its entire 40 mm diameter active area.

- ***MCP Imaging.*** BrightView utilizes a microchannel plate (MCP) intensifier with a phosphor screen imaging surface and a glass or fiberoptic element to transfer the visible image to the atmosphere side of the device. It is convenient for CCD camera or film recording.

  One, two, or three MCPs may be stacked for gains of up to 1×10^4, 1×10^6, and 5×10^7.

- ***High Resolution.*** Resolution is better than 40 µm (>12 line pairs/mm) at highest voltages; BrightView provides more than 10^3 minimum-resolution "pixels" across the faceplate diameter.

- ***Grazing Incidence Access.*** The MCP is held approximately 34 mm above the sealing surface of the flange. A 1 cm wide slot in the MCP holder allows the incident light to strike the active MCP area at true grazing incidence angles (0°). It is ideal for Rowland circle spectrometer applications.

- ***Bakeable UHV Assembly.*** BrightView is ultra-high-vacuum compatible. The imaging components are mounted on a 4.5 in. OD copper gasket vacuum flange (ISO 64 mm flange). For vacuum purity, the unit may be baked under vacuum at 200°C; a 350°C bakeout option is available.

- ***Side Mounted Connectors.*** All user connections are made on the atmosphere side of the unit, after installation. All power attachments are conveniently available at the side, out of the way of the image-recording accessories.

- ***Many Available Options.*** Options include photocathode coating for wavelength sensitivity, a special pumped chamber for independent operation, and image recording by CCD camera system for laboratory convenience or film-pack for maximum information.

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1 UNIT DESCRIPTION

BrightView is an image converter of unmatched performance, flexibility, and ruggedness. It provides a laboratory aid for continuous, real-time observation of visible images formed from radiation in the UV to x-ray region of the spectrum. Applications range from recording images generated by VUV, x-ray, or charged-particle sources to counting pulses from such sources. BrightView is ideal as the detector for spectrographic applications and has been explicitly designed for use in Rowland circle grazing-incidence spectrometers. Other uses include imaging UV laser beams and, with minor modifications, crystal alignment using Laue backscattering techniques. The principle of BrightView operation is discussed in section 6.

The standard BrightView configuration consists of two subassemblies, as diagrammed in Figures 1, 2, and 3. The central *imaging subassembly* is a microchannel plate (MCP) attached to the image-transfer element that conveys the image formed in the vacuum to the recording device in the laboratory. The imaging subassembly is attached to the *ultra-high vacuum (UHV) flange subassembly* for convenient laboratory use. The unit can be obtained with the laboratory flange or with the imaging subassembly alone. A variety of standard options are available. They are summarized in section 3.2.

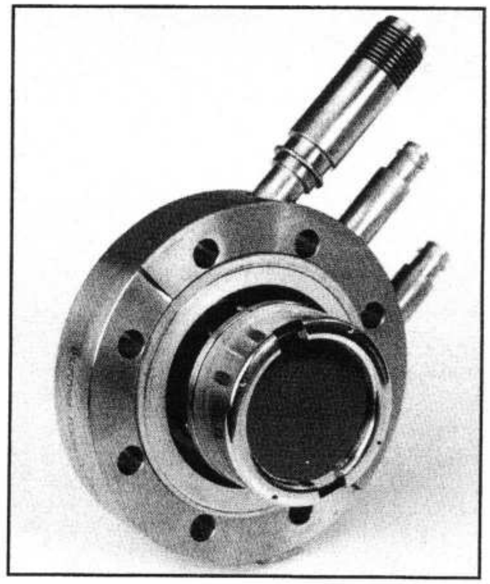
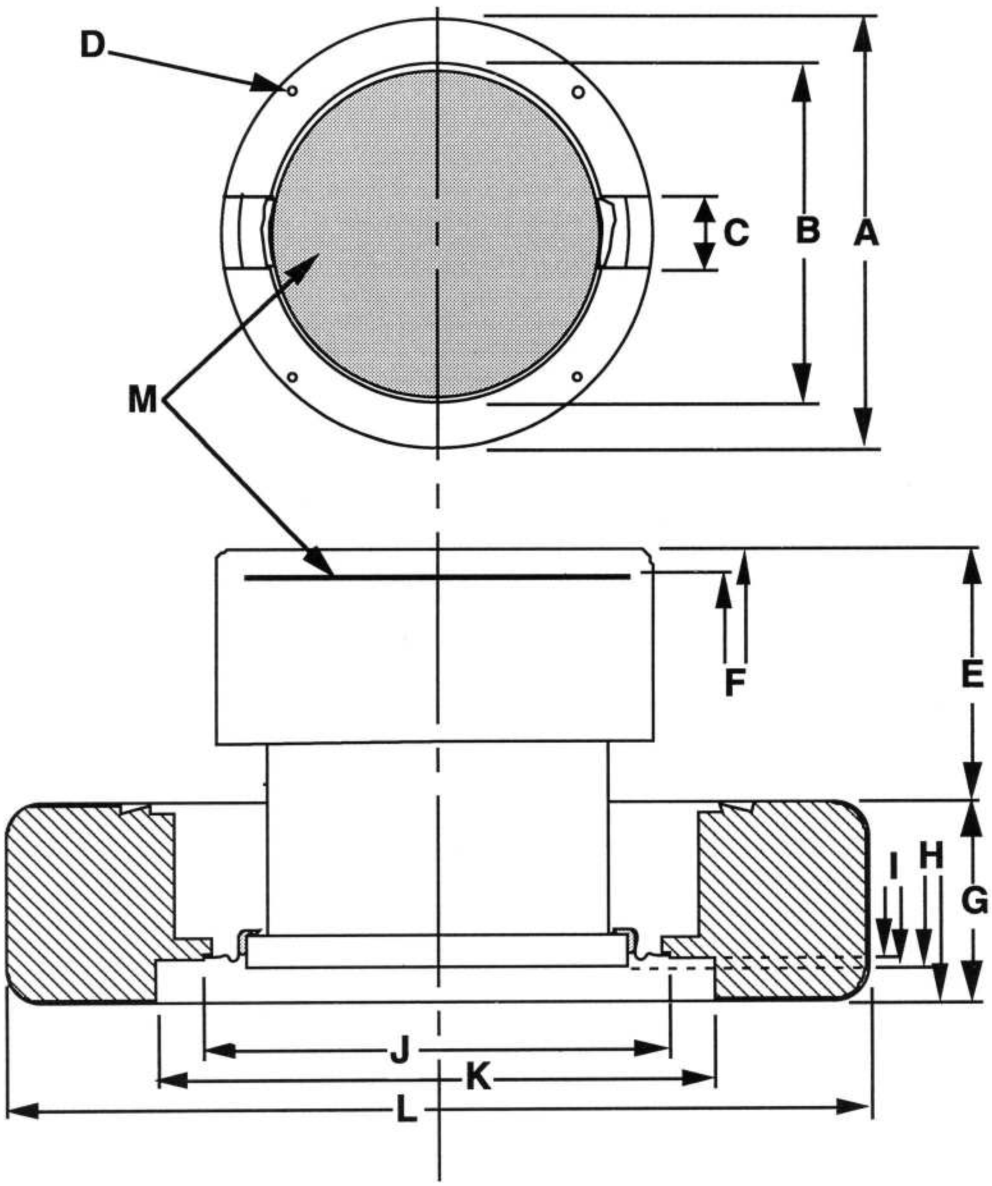


Figure 1. Standard configuration of BrightView.

1.1 Imaging Subassembly

Self-Aligning Electrodes. The imaging subassembly contains the MCP, which is housed in the KMS-proprietary Self-Aligning Electrode (SAE) assembly. The SAE assembly is located at the end of the image-transfer element. The SAE assembly guarantees that the MCP gain stage and the phosphor image plane are held in good alignment to ensure uniform image resolution across the active surface. The rigidity provided by the cylindrical SAE design gives the unit high resistance to mechanical vibration and shock. The SAE design also provides a high degree of electrical safety in laboratory use. The outer cylindrical electrode completely encloses the other high-voltage electrodes; it may be kept at ground potential to eliminate accidental arcing. The SAE assembly has four tapped holes on its top so that the user can mount components above the MCP. Such components might include an accelerating screen for charged-particle collection or filters to screen the MCP from unwanted portions of the spectrum.



A Diameter of outer electrode 57.2 mm (2.25 in.)

B Diameter of open area in electrode 43.7 mm (1.72 in.)

C Grazing incidence slot 9.5 mm (0.375 in.)

D 4 holes on 53.6 mm circle: tapped 2-56

E Outer electrode-sealing surface 34.4 mm (1.35 in.) *Nominal: 1 MCP*

F Electrode-MCP 3.2 mm (0.13 in.)

G Flange thickness 25.4 mm (1.00 in.)

H Recess of fiber-optic faceplate 4.3 mm (0.17 in.)

I Faceplate to flange 1.3 mm (0.05 in.)

J Expansion gasket diameter 69.85 mm (2.750 in.)

K Flange recess diameter 76.2 mm (3.00 in.)

L Outer diameter 114 mm (4.5 in.)

M MCP: 40 mm active area

Figure 2. Cross-section diagram of BrightView (actual size).

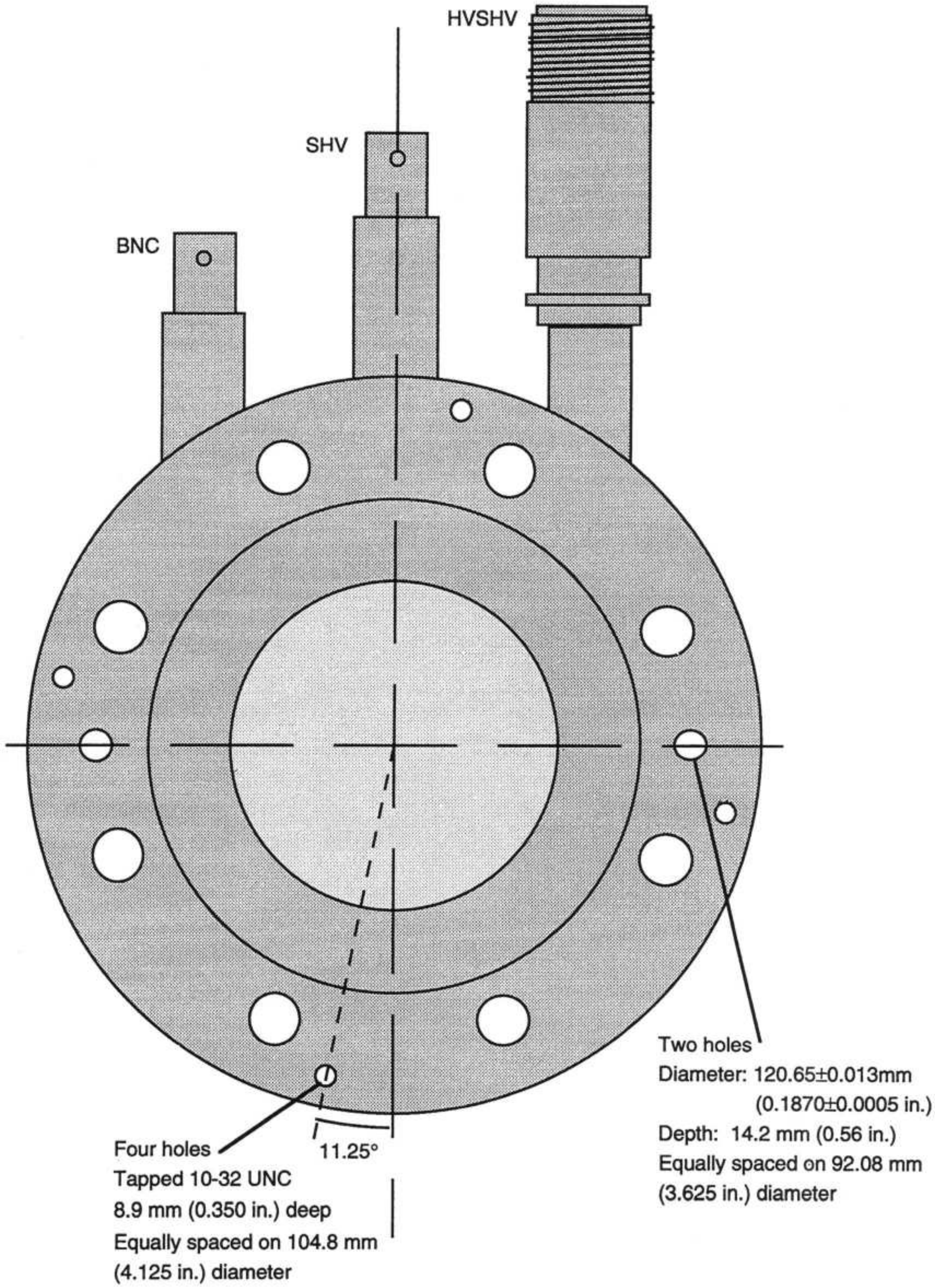


Figure 3. Flange drawing (actual size).

Image-Transfer Element. There are two options for transferring the image to a recording device. (1) *Normal.* An inexpensive transparent glass post may be used for applications that use lens coupling of the visible image to an external camera. The image, which is generated deep inside the subassembly, is relayed by a lens to the camera. (2) *Special.* For applications that must use film to retain the full image contrast and spatial resolution, the element is a high-quality fiberoptic post that transfers the image plane to the rear (atmosphere) side of the unit. A film pack is then used to record the image.

Bonding Techniques. The image-transfer element is permanently bonded to a gasket that is welded into the mounting flange subassembly. The bonding method of choice depends on application. (1) *Normal.* A NASA-validated low-outgas sealant that may be safely baked to 200°C is used. (2) *Special.* For extreme UHV requirements, the imaging element is bonded to the gasket by a glass frit seal that can withstand bake-out temperatures up to 350°C.

All power connections are made to the image-transfer subassembly approximately halfway between the SAE electrode and the gasket. *This imaging subassembly weighs 430 g with the fiberoptic option.* An application using the imaging subassembly alone is shown in Figure 4.

Figure 4. The BrightView imaging subassembly has been used as an imaging element in a special Bragg spectrograph.

1.2 UHV Flange Subassembly

The mounting flange subassembly is provided for laboratory convenience. It is a standard copper gasket UHV flange with an outer diameter of 4.5 in. (the ISO 63 mm standard flange). This flange is a stainless steel ring welded to the image-transfer gasket. Three power feedthroughs extend from the side of the flange, as shown in Figure 3. These feedthroughs are a BNC connector, an SHV connector and a special "high voltage SHV" connector designed to withstand the (up to) 8 kV that may be applied to the unit. All mating cable connectors are supplied with the unit. The flange is constructed with a nonstandard thickness so that BrightView can be attached to a larger reducing flange without interference between the voltage connectors and the mated flange.

The standard mounting flange weighs an additional 1140 g. It has a number of convenient features. On the atmosphere side of the assembly are four threaded holes for the attachment of a recording device (such as a camera assembly, linear photodiode array, or film pack). Two holes for alignment pins are provided to ensure alignment of the recording device. To assist users who wish to attach their own components around the MCP and electrodes, four tapped holes are provided in the flange on the vacuum side (not shown in Figure 3).

BrightView can be ordered (a) with its standard flange, (b) with a different flange, (c) without its mounting flange (SAE electrode and image-transfer element only), or (d) in a self-contained vacuum enclosure for use with x-rays above approximately 5 keV.

2 SPECIFICATIONS

Table 1. BrightView Specifications.

Size	4.5 in. (OD) copper seal flange (ISO 63 mm). Active surface is 31.2 mm above vacuum sealing surface.	Standard configuration.
Weight	1.57 kg (3.5 lb) 0.43 kg	Standard configuration. Fiberoptic imaging subassembly.
Temperature	200°C normal 350°C optional	Choose low-outgas seal option. Choose glass frit option.
Connectors	BNC SHV HVSHV	For ground. For low V. For high V.
Detector	MCP elements in a stack 1, 2 ("chevron"), or 3 ("Z")	Multiple plates cause a slight reduction in spatial resolution.
Power Supply	Two required: n kV and $(6+n)$ kV n = number of MCPs	User choice for gain.
Storage	Shipped under vacuum.	For long-term storage, place unit in pumped chamber.
Features	All user power connections are made in atmosphere. Choice of voltage connection scheme. Easy attachment of user components. Grazing incidence access to MCP. Multiple MCP stack for high gain.	Side-mounted feedthroughs. Mating connectors included. Configure unit to user's needs. Threaded holes for mounting, guide holes for alignment. pins Selectable orientation. 1 MCP standard.

3 ACCESSORIES AND OPTIONS

BrightView has many accessory items and options to tailor the unit for special needs. Standard and special accessories are available to complement the instrument. Standard and special options to the basic unit must be selected when the unit is ordered. These are discussed below. Contact the Manager of KMS X-Ray and Specialty Instruments for further information and for price lists.

3.1 Accessories

The following items are available to work with the XUV-2000 BrightView unit. Certain accessories are custom designs to meet special user needs.

- ***CCD Camera Mount*** [model XUV-2000CC]. The mount attaches to the C-mount lens of most CCD cameras for the most convenient image recording. It works well with the KMS VIA image-acquisition system.

- ***Video Image Acquisition System (VIA)*** [model VIA-100, 200 or 300]. VIA is a complete image data acquisition and analysis system that coordinates well with other external data acquisition and control facilities available to the user. It is designed to accept external triggers and synchronize an event to be imaged with the correct image frame from the camera.

  Images from up to three independent cameras can be acquired, displayed, stored, and passed through a network for final archiving and analysis. VIA also provides local image-analysis capability for immediate use; it is the ideal solution for the analysis and archiving of BrightView images. VIA is supplied with the computer, monitors, frame-grabber board, and the single camera needed for one BrightView system (XUV-2000CC mount required).

- ***Film Pack*** [model XUV-2000FP]. The single-picture 35 mm film holder is designed to acquire images with the highest possible spatial resolution and dynamic range in intensity. The film is pressed directly against the fiberoptic faceplate (not coupled by a lens) for maximum image fidelity. The faceplate has a grounded conductive transparent film to eliminate static when the film is removed for development. (Requires the fiberoptic "-FO" option for the image-transfer element, as discussed in section 3.2.)

  The film pack uses either regular 35 mm camera film or special film that has special retaining holes at the ends instead of the usual edge sprocket holes. KMS can supply properly punched film without edge holes so that a complete 35 mm of image can be recorded with best quality. The film pack holds the filmstrip for one image and is loaded and unloaded in a darkroom.

- ***Vacuum Pumped Enclosure.*** This custom enclosure is designed to the user's specifications for special vacuum and power feedthroughs. It is useful for reduced weight, minimal size, and for attachment to systems that have poor vacuum quality or that are frequently vented to atmospheric pressure. (*KMS will be pleased to develop the vacuum chamber to fit special requirements.*)

3.2 Options

Table 2. Standard Options for BrightView.

Option Code	Option	Customer Specification
 F **R** **P**	**Power attachment** *Ground front of MCP* Ground rear of MCP Ground phosphor screen	Specify per section 5.
M*n*	**Number of microchannel plates** *n* MCP plates in unit *n = 1 standard,* = 2 * or = 3 *	Spatial resolution degrades slightly with each plate. See section 6.
 200 **350**	**Bakeout option** *200˚C bakeout* 350˚C bakeout *	Specify seal of image-transfer element to the weld ring, as discussed in section 1.1.
 GL **FO**	**Image-transfer element** *Glass* Fiberoptic *	Specify type, as discussed in section 1.1. Fiberoptic has transparent conductive coating.
 KNi **KAu** **KCsI** **KMgF**	**Photocathode** *Ni or NiCr photocathode* Gold * Cesium iodide * Magnesium fluoride *	Specify material to be applied to front surface of MCP detectors.
 P20 **P11**	**Visible phosphor screen** *Green, several ms decay* Blue, tenths of ms decay	Specify for image color, brightness, and persistence. Others are available.
GIϕ	ϕ degrees *Default: arbitrary angle*	Specify angle between grazing incidence slot and the central voltage feedthrough; GB0 means they are parallel.
 STD **IA**	**BrightView configuration** *Flange and imaging subassembly* Imaging assembly only, no flange	Specify per sections 1.1 and 1.2.

Italicized options are the default choice.

* These options provided at extra charge. Contact KMS for quotation.

4 ORDER INFORMATION

Order BrightView by specifying the part number (220100) and the option codes desired. The order is coded as follows:

220100-oc-oc-...-S#

where

220100 = BrightView part number

oc = standard option codes (any number of these codes may be included)

= number of special options

Any number of standard option codes from the list in Table 2 may be included. If a particular code is not written, the default (italicized items in Table 2) will be assumed. Note that if the "GIϕ" code is not included, the unit will be shipped with the grazing incidence slot at an arbitrary angle.

The **S#** suffix specifies the number of *special* options included. The order should be placed with each special option listed in 1, 2, 3 order and with the relevant KMS Price Quotation number listed.

Example 1. BrightView with rear-grounded voltage leads, two MCPs with CsI photocathode coatings, and two additional special options.

```
BrightView P/N  220100-R-M2-KCsI-S2

1.   KMS Quotation XSI491200   Special P46 phosphor
2.   KMS Quotation XSI491200   Extra tapped hole on electrode
                               per customer drawing
```

Example 2. Default order.

```
BrightView part number 220100
```

The default order above is exactly the same as the detailed order below (for a unit with an arbitrary slot angle).

```
BrightView P/N 220100-F-M1-200-GL-KNi-P20-STD
```

5 POWER CONNECTIONS

BrightView can be configured to distribute voltages to its components in one of three ways. The diagram of Figure 5 shows the three connection schemes, labeled **"-F,"** **"-R,"** and **"-P."** Table 3 shows the details of these option schemes.

Specify a particular option:

The **-F** option should be used if high-voltage safety is a concern.

The **-R** option should be specified to allow for completely independent operation of two power supplies.

The **-P** option is suggested if electrical current or pulse counting is desired in addition to imaging.

-F *Front of MCP is grounded.* The outer electrode, which encloses the other electrodes, is attached to the BNC connector and should be attached to laboratory ground. This is the safest connection scheme since the vacuum system sees only grounded components and no arcing will occur.

Certain operational difficulties are present. The order of switching the two voltages ON and OFF is critical, and the user should interlock the system so that the proper sequence is maintained. To ensure that no excess voltages are generated, V_{mcp} should be the first voltage on and the last turned off.

-R *Rear of MCP is grounded.* The two power supplies are completely independent. Either supply may be switched on or off at will.

-P *Phosphor is grounded.* The phosphor is attached directly to the current or pulse-measuring detector (at 50 Ω from actual ground). This is useful when the current or pulses from the MCP must be measured. The visible image of the data is still available at the faceplate.

Here again, power supply control poses a problem. The voltage on Ⓐ and Ⓑ should be reduced is so that $|V_a - V_b| \leq V_{mcp}$.

If no option is specified, KMS will ship the unit in the -F configuration.

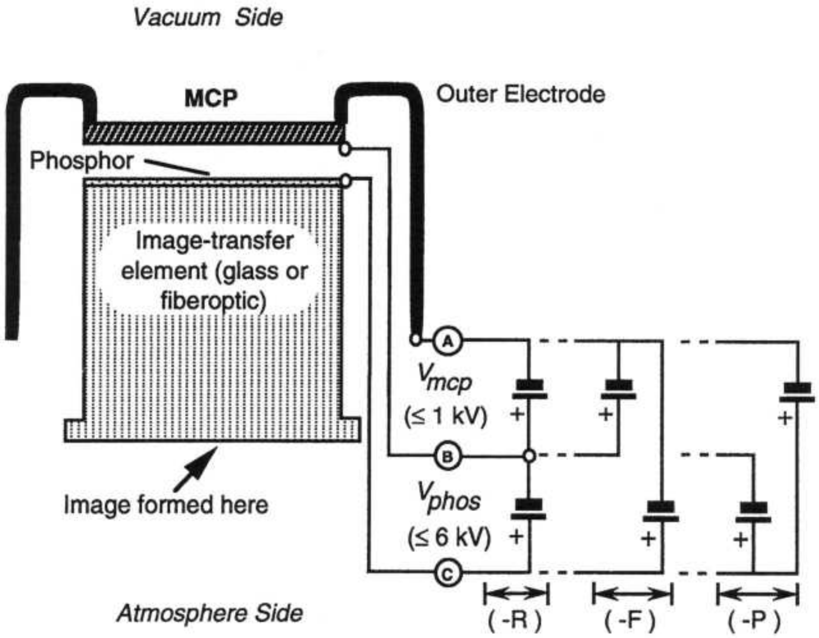


Figure 5. Voltage connections.

Table 3. Power Connection Options.

Option	Ⓐ	Ⓑ	Ⓒ	Feature
-F	BNC 0 V	SHV $+V_{mcp}$	HVSHV $+V_{mcp}+V_{phos}$	No HV danger to user vacuum system.
-R	SHV $-V_{mcp}$	BNC 0 V	HVSHV $+V_{phos}$	Safest power supply operation.
-P	HVSHV $-V_{mcp} - V_{phos}$	SHV $-V_{phos}$	BNC 0 V	Pulse counting with visible images.

Ⓐ Connects to the outer electrode and front surface of the MCP.

Ⓑ Connects to the rear surface of the MCP.

Ⓒ Connects to the visible phosphor on the image-transfer element.

6 PRINCIPLE OF OPERATION

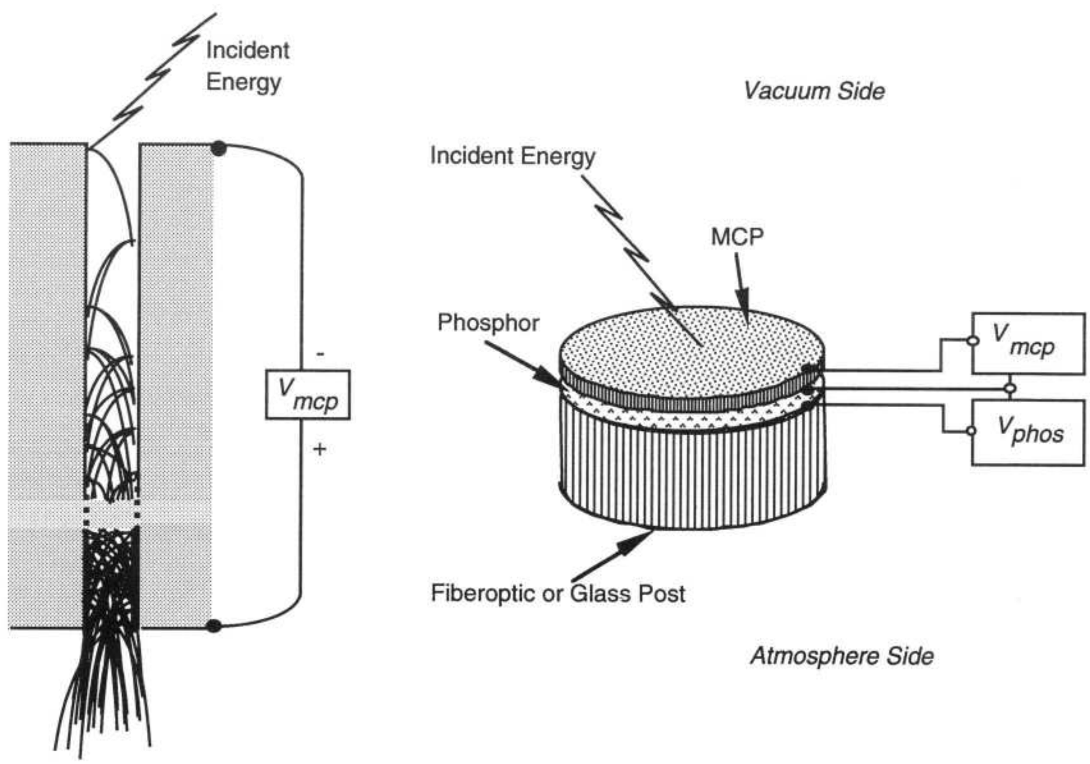
Figure 6 shows a schematic of an image converter.[1] Shown are the MCP, the electrodes, the phosphor screen, and the image-transfer element.

1. Incident radiation (or particles) strike the MCP, which is made of many 10 µm (diameter) channels.

2. The incident energy causes an electron discharge in the channel (refer to Figure 6a). The electrons are accelerated through the MCP by the voltage V_{mcp} applied across the plate (connections (A) and (B) of Figure 5).

3. The burst of electrons leaves the MCP and accelerates across the gap between the MCP and the phosphor coating on the image-transfer element (refer to Figure 6b). The accelerating voltage is V_{phos} applied across the gap (connections (B) and (C) of Fig. 5).

4. The electron bursts make the phosphor glow, and the visible phosphor image is transferred to the atmosphere side of the image-transfer element.



(a) MCP discharge channel

(b) Image converter

Figure 6. Principle of operation.

6.1 Quantum Efficiencies

Photons. The response of an MCP to incident radiation is a function of the photocathode coating on its front surface. Most coatings have a peak quantum efficiency response at about 60 nm (20 eV), have *QE* above 10% to nearly 0.1 nm (to approximately 10 keV), and have nearly constant response[2] of 2 to 8% up to even 10^{-3} nm (1 MeV). MCP units have also been used for wavelengths exceeding 250 nm, although with low efficiency. The MCP and most photocathode coatings are blind at visible wavelengths. The *QE* may be extended in various regions by using a special photocathode material, either applied to the surface of the MCP or on a screen between the photon source and the MCP. The photocathode is chosen to enhance the secondary emission above that of the bare plates, and many materials have been examined.[3] Among the most favored are CsI, Au, and MgF. Hard x-ray response can be improved by matching a material's K_α edge to the photon energy.

Particles. The literature[4] shows that an MCP has a *QE* of about 1.0 for particle energies above about 3 keV ("threshold" depends on particle mass). For lower energies, it is recommended that an accelerating screen be placed in front of the MCP.

6.2 MCP Gain Due to V_{mcp}

The gain of the MCP (electrons out of MCP per incident photon or particle) is, in general, a complicated function of V_{mcp}. Simplified analysis[5] follows the secondary emission process down a channel and shows $G = (A\,V_{mcp}/2\alpha V_o^{1/2})^{(4V_o\alpha^2/V_{mcp})}$, where $\alpha = L/d$ is the channel length-to-diameter ratio and V_o and A are properties of the emitting material. G has a maximum (and is insensitive to the exact value of α) when $\alpha = A\,V_{mcp}/3.3V_o^{1/2}$. Many commercial plates, when operated at $V_{mcp} = 1$ kV, have $\alpha \approx 40$. (Although this is a property of the material, plates are made with $\alpha \equiv 40$ as the standard value.) For MCP materials that have the correct A and V_o, the gain is exponential in V_{mcp}: $G = exp(0.185\ A^2V_{mcp})$. Figure 7a shows an example[6] measured at KMS of an exponential response to V_{mcp}. There are other scaling "laws" for gain. Eberhardt[7] has proposed $G = V_{mcp}^{\kappa}$ with κ a constant. He showed that κ values between approximately 8 and 12 are a good fit to most experimental data. Figure 7b shows an example done at KMS with another MCP where the fit cannot be exponential, but $\kappa = 8.6$ is a good value. MCP gain is an empirical function, depending on the individual plates, whose value at full voltage is about 10^4. For a unit with two

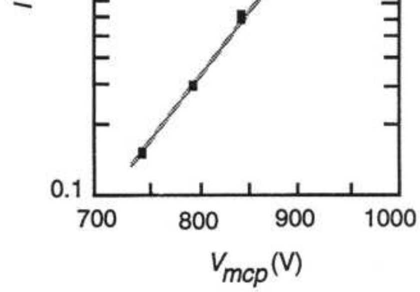


Figure 7a. MCP gain is exponential in V_{mcp}.

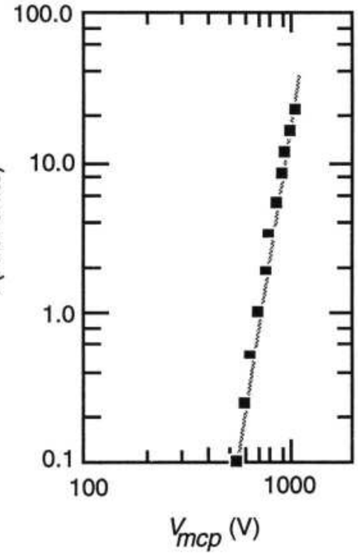


Figure 7b. MCP gain is well fit by a power law.

or three plates, the gain can flatten and saturate as the voltage approaches the maximum value and all available electrons are removed with each channel firing. *Note:* all plates in multiple-plate units should be made from the same batch and matched in all ways.

The MCP gain rises above one for $V_{mcp} \approx 450$ V. The maximum allowed V_{mcp} is a function of the vacuum pressure. MCP manufacturers advise that, for pressure above 10^{-5} Torr, the DC voltage should be kept below 700 V. For pressures below 3×10^{-6} Torr, V_{mcp} may be as high as 1 kV. Under no circumstance should V_{mcp} ever exceed 1 kV per plate. The MCP gain varies significantly from one plate to the next, but it is usually between 3×10^3 and 10×10^3. When the MCP is first manufactured, the gain is always high due to adsorbed gas molecules on the channel walls. During a discharge, these ionize and accelerate to the MCP front surface. The back-flowing ions cause second and third discharges, which cause a gain enhancement that disappears as the plate is used and the molecules are removed. To avoid this initial gain change, some users[8] "scrub" the plate by illuminating it with a UV or electron source and operating the plate in continuous discharge for extended periods of time. The gain drops quickly to a nearly constant value. That "equilibrium" gain will continue to decrease, although much more slowly, as a function of increasing number of pulses delivered. This has also been attributed to scrubbing.

6.3 Light Output Due to V_{phos}

Figure 8 shows that, for a fixed value of V_{mcp} (constant gain), the light output from the phosphor increases with increasing V_{phos}. Figure 8a shows data for P-11 phosphor settled on the fiberoptic plug; the reference line is V^3_{phos}. Figure 8b shows data for P-20 phosphor spray-deposited on the fiberoptic; the reference line is $V^{1.2}_{phos}$ *Note:* The power law scaling is an empirical observation *only* and is included here for quick estimates of response.

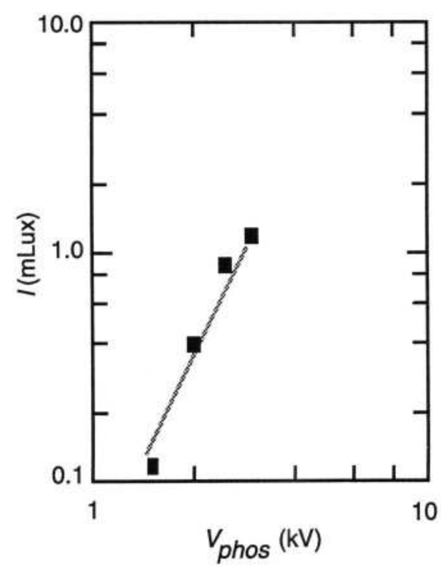


Figure 8a. Light output vs. V_{phos} for P-11.

There is a limit to the maximum V_{phos} allowed before arcing will occur. The gap between the MCP and the phosphor is 0.75 mm wide and, for pressures below approximately 2×10^{-6} Torr, V_{phos} may

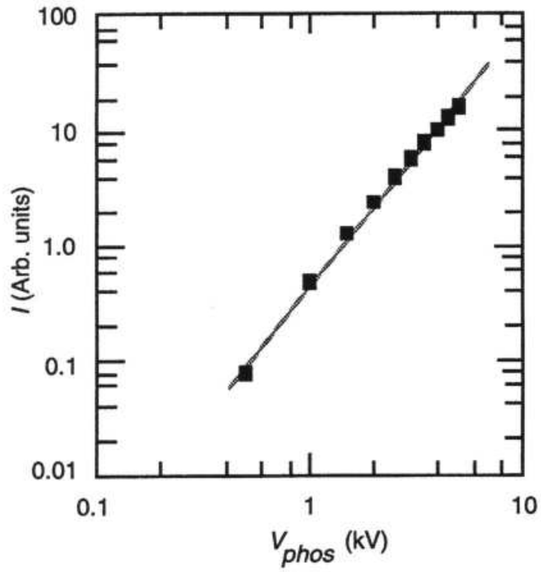


Figure 8b. Light output vs. V_{phos} for P-20.

be has high as 5.5 kV. Proper voltage technique must be employed if such high values are to be used without arcing. The BrightView user manual explains proper "voltage-forming" technique in detail.

6.4 Minimum Resolution

The minimum resolution of the image is usually defined by the Rayleigh Criterion: two points are at the minimum resolution distance if the minimum intensity between them is no higher than 80% the peak intensity of the spots.

In Figure 9, the minimum resolution is shown to be 35 μm for V_{mcp} = 1 kV and V_{phos} = 5 kV. An equivalent number is the number of line-pairs-per-mm (lppm) visible at minimum resolution. A bright line and a dark line are used as a set; therefore, the pair take up twice the minimum resolution distance. The 35 μm value for a "minimum-resolution element" (mre) corresponds to 14.3 lppm. This corresponds to 1142 mre across the BrightView diameter. The recorded resolution is normally limited by the camera used to acquire the image.

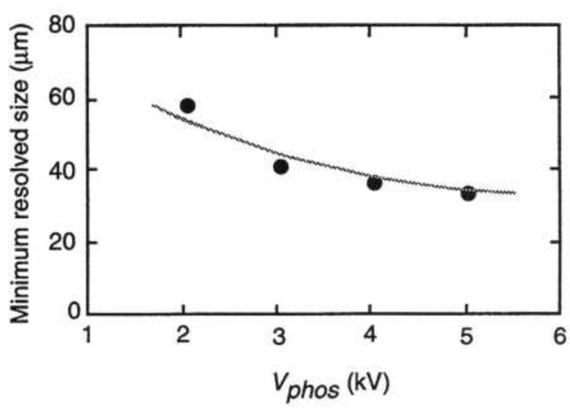


Figure 9. The minimum resolved spot size decreases with V_{phos}.

The minimum resolution is limited by the spacing between channels in the MCP and the thermal spread of the electron cloud in the acceleration gap between the MCP and the phosphor. Tests at KMS indicate that the minimum resolution follows the predictions of this simple model and that the diameter of the mre decreases as approximately $V_{phos}^{-1/2}$.

When the assembly contains more than one plate, each plate contributes to an increase in the minimum resolution size. One should expect an increase in the mre size by approximately a channel-to-channel spacing distance. An assembly of two stacked plates, each with 12 μm channels and 15 μm spacing, would have its mre diameter increased to 50 μm (compare with the 35 μm single-plate value).

6.5 Count-Rate Considerations

The flat surfaces of an MCP are coated with a metallic conductor, usually NiCr. These top and bottom surfaces form electrodes to establish the accelerating ***E*** field in the channels when a bias voltage V_{mcp} is applied. With the application of V_{mcp}, a current I_{mcp} will flow along the surface of every channel from the top electrode to the bottom electrode. This is usually referred to as the strip current and is limited by the resistance of all channels connected in parallel. After a discharge has drained the electrons from a channel, it is I_{mcp} that resupplies electrons for the next discharge. The recharge time τ_r is controlled by the channel capacitance and is proportional to the *RC* recharge time constant for a channel. An event that occurs sooner than τ_r will cause a discharge at a lower than normal gain.

Various MCP parameters must be estimated in order to estimate τ_r, and therefore the maximum count rate $\nu_{max} = 1/\tau_r$ for a channel or f_{max}, the maximum count rate, for the entire plate.

6.5.1 Channel density. The channels are arranged in an essentially hexagonal close-packed array with channel diameter given by d_c, and the center-to-center separation given by L_{cc}. If the centers are connected by triangles, each triangle will intersect 1/6 the area of three separate channels, accounting for half of the total area of an equivalent single channel. The best estimate for the number of channels in the plate is half the MCP area divided by the triangle area. The number of channels per square centimeter N_c is

$$N_c = \frac{2}{\sqrt{3}} \frac{1}{L_{cc}^2} .$$

A typical value for N_c when $L_{cc} = 15\ \mu\text{m}$ ($d_c = 12\ \mu\text{m}$) is $N_c = 5.1 \times 10^5\ \text{cm}^{-2}$.

6.5.2 Channel resistance. The total resistance between the faces of the plate R_{mcp} is V_{mcp}/I_{mcp}. When V_{mcp} is 1 kV, the strip current will fall between 10 and 110 μA; the specific value depends on the particular plate being measured. This wide variation is due to the chemical reduction processing that is done during manufacturing of the plate. It is possible to specify high-, medium-, or low-current plates; however, there is no guarantee that a plate from one batch will have the same I_{mcp} as an otherwise identical plate from a different batch.

For the purposes of the calculation, we will use a low typical value for a circular 40 mm diameter active area plate of 2 μA/cm^2 (approximately 25 μA total current). The typical plate resistance is $R_{mcp} = 400\ \text{M}\Omega$ for each cm^2 of active area (or 31 MΩ for the entire plate). This corresponds to a channel resistance of $R_c = R_{mcp} N_c = 2 \times 10^{14}\ \Omega$.

6.5.3 Signal current and count rate. It is well known that if the signal discharge current I_d is too large, the MCP channels will become strongly depleted in charge and the gain G will rapidly decrease from its nominal value. Normal user practice limits the input flux so that I_d is less than 10% of I_{mcp}. (Some users allow I_d to rise higher because total signal rate is more important to them than highest gain.) Because the total discharge current is the average charge of a discharge times the discharge rate (count rate) f_{max}, the maximum count rate for the entire plate will be

$$f_{max} = \frac{0.1\ I_{mcp}}{eG}.$$

A single-channel plate with $G = 10^4$ and $I_{mcp} = 2\ \mu A/cm^2$ will have a maximum counting rate $f_{max} = 1.3 \times 10^8\ s^{-1}\ cm^{-2}$. This is shown in Figure 10. Shown by gray highlights are the typical gain values obtained with a single-channel plate or with a stack of two or three plates. The right edge of each gray area is the upper limit to the expected gain.

Note that the maximum depletion of charge in a channel will occur at the output of the last MCP in a stack. At the highest gain possible, this will represent a large fraction of the available charge. It should be expected that, for multiple-plate stacks, the recharge time will become 5 to 10 *RC* time constants; the gain must become reduced at high rates. This means that the gain G is a function of f_{max}. For stacks with two or three MCP elements, the maximum count rate achieved by a realistic assembly is significantly below that indicated by the gray regions of Figure 10. This

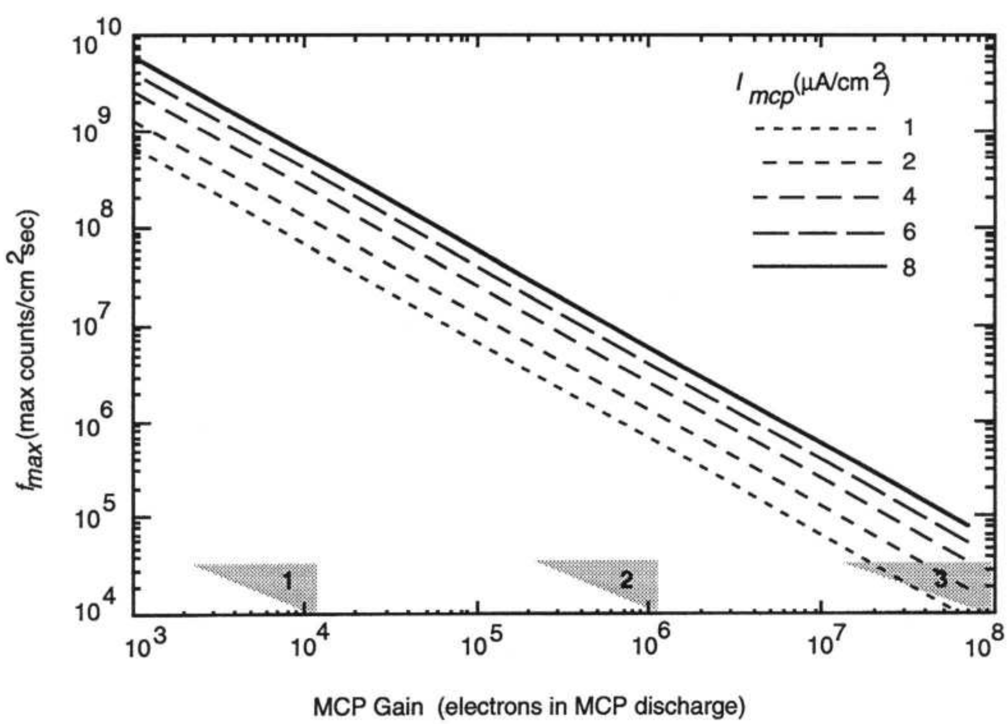


Figure 10. The maximum MCP count rate depends on the gain and the strip current. The gray regions show typical gain for a stack of one, two, or three plates.

emphasizes that multiple-layer assemblies are meant for low-count-rate, single-event detection. For high count rates, specify a single high-current plate and use current or imaging techniques to record the data.

When the charge depletion in a channel remains low (i.e., for single plates) the maximum discharge rate of one of the N_c channels is $v_{max} = f_{max}/N_c$. For the representative case, $v_{max} = 255\ s^{-1}$ and the channel recharge time is $\tau_r = 3.9$ ms. It is interesting to note that the channel capacitance for this case is 1.6×10^{-5} pf, yielding a value of 8.2 pf for the entire plate.

Higher count rates can be achieved by reducing the gain for the assembly. For a single plate, the gain rises from 1 at $V_{mcp} \approx 450$ V to approximately 10^4 at $V_{mcp} \approx 1$ kV, or approximately one decade per 175 volt increment. This scaling can be seen also in Figure 7. Although the plate current I_{mcp} changes, it is only linear in bias. This means that if the plate bias is reduced from 1 kV to 0.9 kV, the gain will drop by slightly more than 3× and f_{max} will increase by a factor of 2.7.

6.6 Signal Detection

The previous section gave an estimate for the upper bound of the count rate. Such high fluxes are not difficult to detect and record. The problem arises when the goal is to measure single counts. A single MCP provides at most 10^4 electrons per pulse, a signal too small to detect by "usual" methods of either electronic or imaging techniques.

6.6.1 Electronic detection. The BrightView unit should be configured with the "**-P**" option (see section 5). The charge from a pulse should go from the anode to a discriminator to convert the pulse into a logical TRUE pulse and to reject spurious noise from laboratory pickup. It is then sent to the recording circuits, such as scalors. In order to obtain a charge pulse large enough for reliable discriminator operation, BrightView should have two or three MCPs in a chevron or Z stack (the names are derived from the orientation of the MCP channels for successive plates).

An MCP is a charge source, not a voltage or current source. The voltage presented at the discriminator depends on the capacitance of the circuit between the MCP and the detector. A >50 mV signal has been obtained for a pulse from a Z stack connected by 1 m of 100 Ω (low capacitance) coaxial cable. This has proven satisfactory even in a high-noise environment.

6.6.2 Imaging detection. The flash from a single event is clearly visible to a dark-adapted human eye when a BrightView unit is operated at the highest voltages, with one MCP and with the P-20 phosphor. However, the intensity of a single scintillation is below the noise threshold of a normal CCD camera. Table 4 compares several options for obtaining a usable signal: (a) add one or two MCP plates for enhanced gain, (b) use an intensified camera, or (c) use a cooled camera.

Discussion of the criteria for the proper choice of a camera (or even film) is beyond the scope of this brochure. However, it should be noted that a CCD camera that is well matched to BrightView should be the frame-transfer type with at least 1024 × 1024 pixels (non-interlaced). The best cameras have at most 10- or 11-bit dynamic range without cooling, but most frame-grabber boards offer only an 8-bit "gray scale" range.

Table 4. Options for Low-Count-Rate Imaging.

	ADDITIONAL PLATES	INTENSIFIED CAMERA	CRYOGENIC CAMERA
COST	***Least expensive***	***Expensive***	***Most expensive***
SIGNAL/NOISE RATIO	***Good*** BrightView in high-quality vacuum	***Reduced***	***Good*** Ultra-low noise
SPATIAL RESOLUTION	***Reduced*** 15-20 μm per plate	***Reduced*** Limited by intensifier stage	***CCD normal*** Normal pixel size
DYNAMIC RANGE	***Shifted*** f_{max} reduced, but f_{min} reduced to 1	***Unchanged*** f_{max} reduced f_{min} reduced	***Increased*** f_{max} unchanged f_{min} reduced

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