The PentaMAX Camera

The Princeton Instruments PentaMAX System is a high performance 5 MHz 12 bit cooled CCD camera. By incorporating very good cooling and state of the art electronics, this camera achieves record low noise levels. Images can be transferred to the computer via a high speed serial link for display and storage, while simultaneously being displayed on a standard video monitor.

The Princeton Instruments PentaMAX Camera combines both high speed and high precision readout in a single camera. The high speed mode collects 12 bit images at a readout rate of 2.5 or 5 million pixels per second (2.5 or 5 MHz). Instantly switch to precision mode to collect lower noise data at 1 MHz. CCD arrays up to 4K × 4K are supported. Frame transfer CCDs in this camera can sustain up to 150 frames per second with binning.

Data is transferred directly to the memory of the computer via a high speed link and DMA. A frame buffer with standard video (RS-170 or CCIR) output is also incorporated. The PentaMAX Camera offers high performance thermoelectric cooling, to support long exposure times and to minimize readout noise.

The PentaMAX Camera is a fully integrated package, containing analog and digital electronics, thermoelectric cooler with air and water options, and timing hardware in a single, shielded housing. The latest advances in surface-mount technology allow a small package without compromising many of the advanced hardware programming features found in other Princeton Instruments systems.

Dual Speed Operation

Read noise of CCD arrays always increases with pixel rate, so it is often necessary to trade off temporal resolution for high dynamic range. This is sometimes accomplished by operating a high speed A/D at slower readout rates, but the readout noise of these A/Ds limits the overall dynamic range. The PentaMAX Camera has been designed specifically to solve these experimental problems without compromise.

The PentaMAX Camera incorporates two complete analog channels including separate A/D converters to provide optimum signal to noise ratios for both 1 MHz and either 2.5 or 5 MHz readout. Switching between the two channels is completely under software control, for total experiment automation.

The Princeton Instruments PentaMAX Camera. Dual A/D channels, thermoelectric cooling, and timing hardware are all found in this integrated package.

High Speed Supported Through the Whole System

The performance of a high speed CCD camera is a function of many factors in addition to the A/D rate These include the ability of the CCD to be read out at high speeds and the ability to transfer the data to computer RAM in real time. This camera system provides high speed in each of these categories, so the total system provides high throughput.

To achieve high camera speed, the CCD array itself must support high pixel rates. This generally requires a dual stage output amplifier on the array. Since not all scientific CCD arrays have this, not all scientific CCD arrays can be read out at MHz rates.

For the PentaMAX Camera, PI has selected only CCD arrays that can maintain high pixel rates (see the CCD chart on the following page or contact your regional salesperson for the latest information on this list).

High data rates require high speed data transfer. The PentaMAX Camera provides data transfer at full speed and resolution direct to the memory of the computer operating the camera. This high speed DMA is available for IBM AT compatible computers. Support for Sun and Silicon Graphics, Inc computers is provided by adapters, as found on pages 101 and 102.

Camera focusing and alignment require the highest possible readout rate. To support this, the digital data must be displayed in real time with minimum delay, a feat that becomes increasingly difficult through the computer at these high pixel rates. The PentaMAX is therefore available with a built-in frame buffer and standard video output circuitry. This allows data to be seen as soon it is read from the CCD. This is a major advance over earlier cooled CCD camera designs, and it is a part of our approach of providing a whole system compatible with high speed.

Computer Interface

The PentaMAX Camera can be interfaced to Sun, Silicon Graphics, Inc, MacIntosh and IBM AT compatible computers (requires an EISA bus for high speed data transfer). An EISA computer can support a sustained readout rate of over 5 million pixels/sec. Contact the factory to ensure computer compatibility, or for a list of compatible computer models.

All PentaMAX Cameras are available with interfaces to EISA bus IBM AT compatible computers. Because this interface transfers data immediately into the memory of the computer, information is available immediately for analysis. Data transfer is accomplished through a high speed serial or fiber optic cable. With the optional fiber optic output, digital data can be transferred to a computer up to 2 kilometers away. Since the output signal is already digitized, no signal degradation occurs.

Sophisticated CCD Readout

Extremely flexible readout of the CCD is supported through a new electronic design. Readout modes supported include full resolution, simultaneous multiple subimages, and nonuniform binning. Arbitrary, software defined regions of interest can also be tested without having to digitize all the pixels of the array. Completely flexible exposure, also set through software, is supported as described below.

CCD Manufacturer	Pixels	Image Area, mm	See Page
Kodak	768 × 512	6.91 × 4.6	32
Kodak	1317 × 1035	8.98 × 7.04	34
Kodak	2033 × 2044	18.4 × 18.3	36
Kodak	3072 × 2048	27.6 × 18.4	37
Kodak	4096 × 4096	36.9 × 36.9	37
EEV	512 × 512 (FT)	7.7 × 7.7	28
EEV	288 × 384 (FT)	6.3 × 8.4	31

These CCD arrays are available in the Princeton Instruments PentaMAX Camera. Contact your sales representative for information on other CCDs.

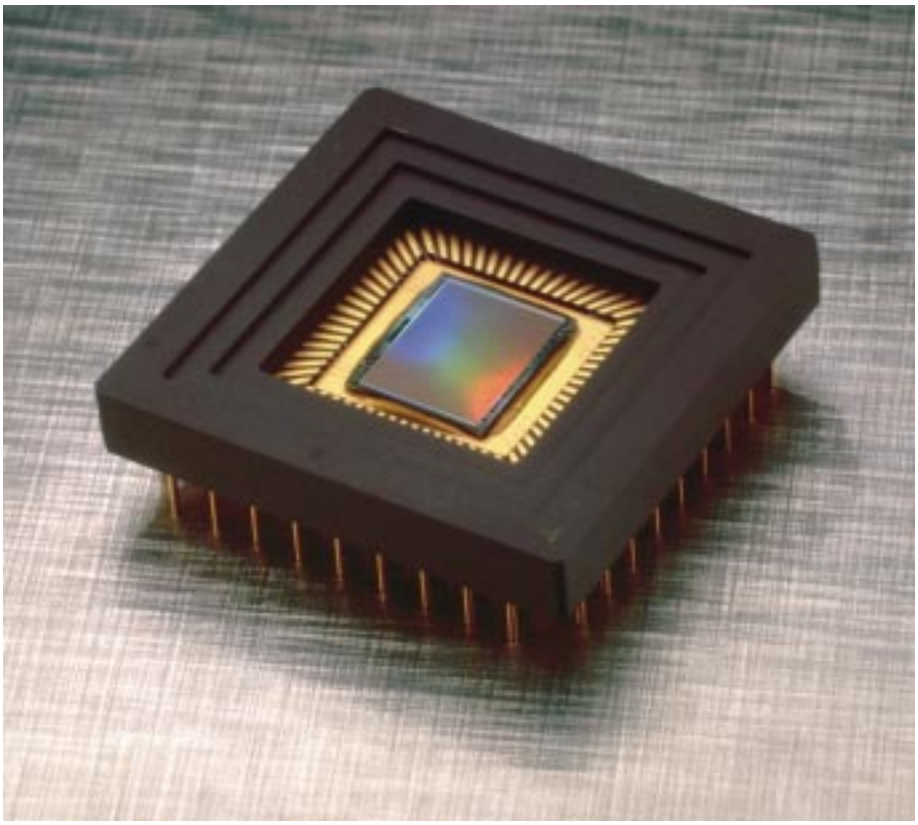
Temperature Control

As with all Princeton Instruments cameras, the PentaMAX cools the CCD to minimize thermal noise and maximize sensitivity.

By advanced mechanical design, we are able to achieve lower CCD temperatures with air cooling than other manufacturers achieve with water cooling. With water cooling, we can go even lower. Because about 1% of pixels on a CCD have anomalously high dark current, extra cooling power is required to achieve the flattest possible background level.

An LCD display, unique to this system, shows either the actual or the target temperature. You can now monitor the precise temperature of the CCD array, and begin work as soon as you have reached the target temperature. This thermal stability is most important for the repeatability of experiments, when, for example, a background image is taken for subtraction from later data. Once cooling has been achieved the CCD temperature is thermally regulated to within ±0.040°C.

Heat dissipation for the thermoelectric cooling system is provided by either forced air or water circulation. For maximum flexibility, all models come equipped for both of these options. Air cooling provides maximum convenience and is sufficient for many applications requiring only short exposures. Water cooling allows the CCD to be operated at lower temperatures, for minimum dark current when acquring images with longer exposure times.

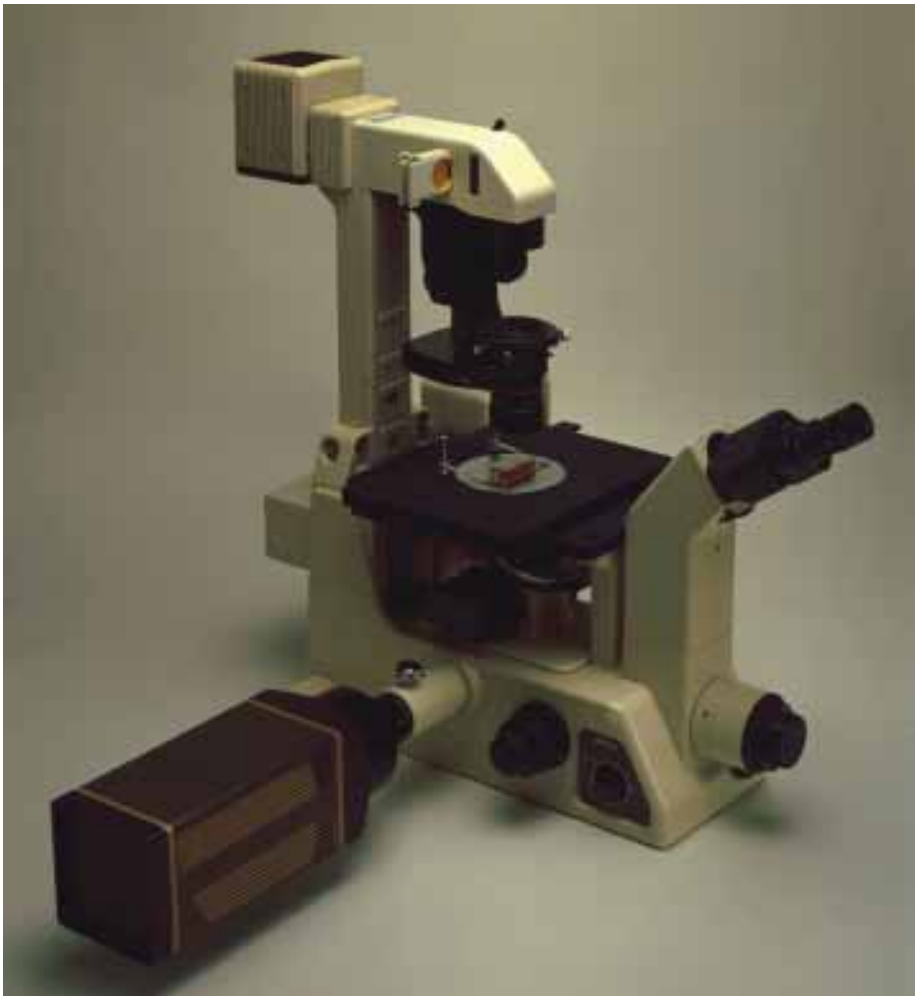


All CCD arrays available in the PentaMAX Camera can be read at rates of several million pixels per second. Kodak KAF-1400 array shown.

Standard Video Output

The PentaMAX Camera is available with a digital scan converter for standard composite video output (choice of RS-170 or CCIR standards). Data can be transferred to the computer, to the video subsystem, or to both simultaneously. Because the video system includes a digital frame store, low frame rates can be used to achieve high sensitivity without incurring image flicker. Higher frame rates can also be accomodated easily by this system.

Not all pixels digitized need to be displayed by the video monitor. Thus on a large CCD, where the CCD resolution exceeds the capability of the video output, selected pixels can be written to the video buffer while all the pixels are written to the computer. Thus the video buffer can show the whole



The PentaMAX system is ideal for applications requiring a high frame rate and a high dynamic range. Nikon Diophot 300 courtesy of Micron Optics, Parsippany, NJ.

CCD array at partial resolution, or part of the CCD array at full resolution.

Charge binning in the camera hardware can also be used to match the resolution of a CCD to that of the video buffer, with a corresponding increase in sensitivity of the CCD array.

Video output also allows data from this extremely sensitive cooled camera to be recorded on video tape and other media, when a very large number of frames must be stored. It also provides easy integration of images from this camera with those taken by other cameras.

The video display provides 8 bit gray scale resolution, which exceeds the capability of most monitors. Since the CCD data have a dynamic range of 12 bits or more, a downloadable look up table (LUT) is available to map the desired portion of the 12 bit range from the camera to the video visible range. The mapping can be nonlinear (for compression or gamma correction) or even reversed (for negative video) if the user so desires.

Triggering

The PentaMAX Camera can run with or without external triggering. In an external trigger mode, the camera hardware is programmed to collect images once a trigger is received. Data collection is therefore not dependent on software speed limitations. Any number of frames can be programmed to be collected by the camera without software intervention.

This camera can also be used to trigger other experimental equipment, for full experimental control via software. A signal from the camera as the exposure begins starts the experiment. Programs created under Princeton Instruments WinView software package can process images as they are collected or store them for later processing.

The mechanical shutter built into the camera can also be synchronized in a number of ways depending on the ambient light of the experiment.

Shuttering

PentaMAX Cameras incorporate a fast mechanical shutter to keep light from the CCD array during readout. The small size and mechanical isolation of the shutter allows it to be operated at several Hz for rapid sequences of images. If necessary, the shutter can be temporarily disabled by the user.

Advanced System Design

To meet all its high speed requirements, this camera uses a somewhat different system configuration from Princeton Instruments camera systems based on Model ST-130, ST-133, or ST-138 Camera Controllers.

In the PentaMAX System all signal processing occurs in the camera head, and digital data is then sent directly to the computer. An available fiber optic interface for this camera allows separation of camera and computer by as much as 2 kilometers.

Power for the system is provided by a separate module which can be located up to 3 meters from the camera head (further with a special cable). This module also displays the current CCD temperature, to facilitate immediate image collection as soon as the CCD reaches the desired operating temperature.

Information Updates

This camera system, one of the newest from Princeton Instruments, is subject to continuous improvements. All data in this description should therefore be considered preliminary.

Contact your local sales representative or the factory for the latest information on specific PentaMAX Camera parameters, including available CCDs.