



G4 CCD Camera

User's Guide



Version 3.2

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Table of Contents

Introduction.....	4
G4 Camera Overview.....	6
CCD and Camera Electronics.....	8
CCD Chip.....	9
Model G4-9000.....	10
Model G4-16000.....	10
Camera Electronics.....	10
Model G4-9000.....	11
Model G4-16000.....	11
Cooling and power supply.....	12
Power Supply.....	13
Mechanical Specifications.....	15
Camera head dimensions.....	16
Telescope adapters.....	20
Off-Axis Guider Adapter (OAG).....	22
Attaching camera head to telescope mount.....	23
Camera head color variants.....	24
Camera Maintenance.....	25
Desiccant exchange.....	25
Changing the silica-gel.....	26
Changing the Telescope Adapter.....	28
Power Supply Fuse.....	28

Introduction

Thank you for choosing the Moravian Instruments CCD camera. G4 series of CCD cameras were developed for imaging under extremely low-light conditions in astronomy, microscopy and similar areas. Design of this series inherits from G2 and G3 cameras, with which they share precise electronics providing uniform frames without artifacts and extremely low read noise limited only by CCD detector itself. Also the robust construction, rich software support and easy manipulation are the same. However, G4 camera head is large enough to contain detector up to 37×37 mm.

Internal filter wheel is not available for G4 cameras, because a filter wheel capable to carry 50×50 mm square filters is too big.

There are external Filter wheels with 5 or 7 positions for 50×50 mm square filters are available for G4 cameras.

The G4 cameras are designed to work in cooperation with a host Personal Computer (PC). As opposite to digital still cameras, which are operated independently on the computer, the scientific slow-scan, cooled cameras usually require computer for operation control, image download, processing and storage etc. To operate the camera, you need a computer which:

1. Is compatible with a PC standard.
2. Runs a modern 32 or 64-bit Windows operating system.

Drivers for 32-bit and 64-bit Linux systems are also provided, but camera control and image processing software, supplied with the camera, requires Windows operating system.

3. Provides at last one free USB port.

G4 cameras are designed to operate with USB 2.0 high-speed (480 Mbps) hosts. Although they are fully backward compatible with USB 1.1 full-speed (12 Mbps) hosts, image download time can be somewhat longer if USB 1.1 connection is used.

A simple and cheap device called USB hub can expand number of available USB port. Typical USB hub occupies one computer USB port and offers four free ports. Make sure the USB hub is USB 2.0 high-speed compatible.

But keep on mind that if more USB devices connected to one hub need to communicate with a host PC, USB hub shares its single up link line to the host PC. Although G4 cameras can operate through a USB hub, it can negatively affect the camera performance, like download time etc. It is recommended to connect other USB devices through USB hub (e.g. the mouse) and to provide the camera a direct USB connection to the host PC.

4. Alternatively it is possible to use the Gx Camera Ethernet Adapter. This device can connect up to four Gx cameras of any type (not only G4, but also G0, G1, G2 and G3) and offers 1 Gbps and 10/100 Mbps Ethernet interface for direct connection to the host PC. Because the PC then uses TCP/IP protocol to communicate with the cameras, it is possible to insert e.g. WiFi bridge or other networking device to the communication path.

The G4 cameras need an external power supply to operate. It is not possible to run the camera from the power lines provided by the USB cable, which is common for webcams or very simple imagers. G4 CCD cameras integrate highly efficient CCD chip cooling, shutter and possibly filter wheel, so their power requirements significantly exceed USB line power capabilities. On the other side separate power source eliminates problems with voltage drop on long USB cables or with drawing of laptop batteries etc.

Also note the camera must be connected to some optical system (e.g. the telescope) to capture images. The camera is designed for long exposures, necessary to acquire the light from faint objects. If you plan to use the camera with the telescope, make sure the whole telescope/mount setup is capable to track the target object smoothly during the exposure.

G4 Camera Overview

G4 cameras do not allow usage of internal filter wheel as they require large 50×50 mm filters. External filter wheel is then the only option for G4 camera.

There are two sizes of the external filter wheel available for the G4 cameras:

- Medium “M” size wheel for 5 square filters 50×50 mm
- Large “L” size wheel for 7 square filters 50×50 mm

Components of G4 Camera system include:

1. G4 camera head capable to control External Filter Wheel
2. External Filter Wheel “M” size (5 positions)
3. External Filter Wheel “L” size (7 positions)
4. G0 Guider camera
5. G1 Guider camera
6. Canon EOS bayonet adapter for Canon compatible lenses
7. Off-Axis Guider with M68×1 thread
8. 1.75” dovetail rail for G4 camera head
9. Gx Camera Ethernet Adapter (x86 CPU)
10. Gx Camera Ethernet Adapter (ARM CPU)

Camera Ethernet Adapter allows connection of up to 4 Gx cameras of any type on the one side and 1 Gbps Ethernet on the other side. This adapter allows access to connected Gx cameras using routable TCP/IP protocol over practically unlimited distance.

11. 5-positions filter wheel “M” for 50×50 mm filters
12. 7-positions filter wheel “L” 50×50 mm filters

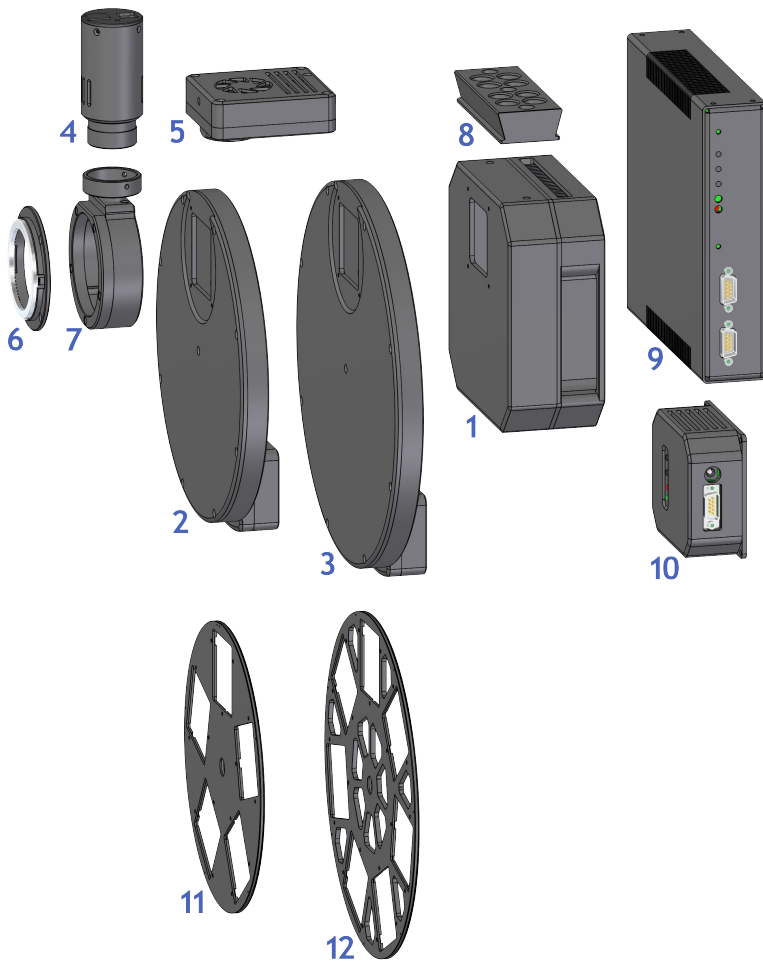


Illustration 1: Schematic diagram of G4 camera system components

CCD and Camera Electronics

G4 series of CCD cameras are manufactured with “Full Frame” CCD sensors manufactured by OnSemi (formerly Kodak)

Almost all Full Frame CCD detector area is exposed to light. This is why these detectors provide high quantum efficiency. Modern FF CCD detectors are suitable also for scientific applications, even if equipped with so-called Anti Blooming Gate (ABG – a gate, which prohibits blooming of the charge to neighboring pixels when image is over-exposed) with linear enough response to light within the full dynamic range.

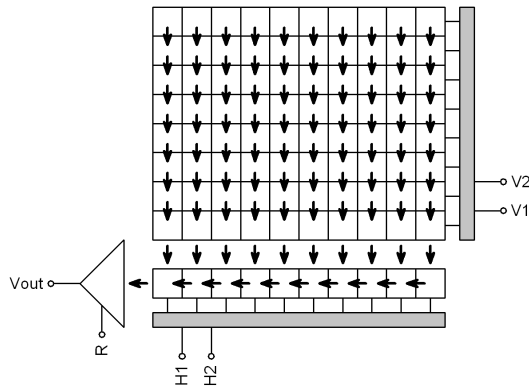
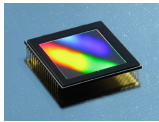
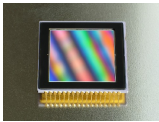


Illustration 2: “Full Frame” CCD schematic diagram

G4 camera models:

Model	G4-9000	G4-16000
CCD chip	KAF-09000	KAF-16803
Resolution	3056×3056	4096×4096
Pixel size	12×12 μm	9×9 μm
CCD area	36.8×36.8 mm	36.9×36.9 mm
ABG	Yes	Yes
Color mask	No	No



CCD Chip

Quantum efficiency (sensitivity) of CCD detectors used in G4 cameras depends on the particular camera model.

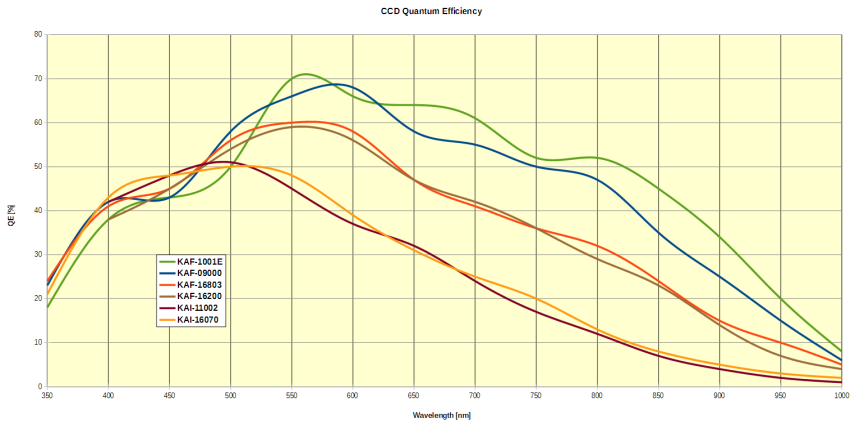


Illustration 3: Quantum efficiency of CCD detectors used in G3 and G4 cameras

Inherent dark current of these detectors is quite low compared to other CCD detectors, suitable for scientific applications, which results into very good signal/noise ratio.

Model G4-9000

G4-9000 uses 9 MPx CCD OnSemi KAF-09000.

Resolution	3056×3056 pixels
Pixel size	12×12 μm
Imaging area	36.8×36.8 mm
Full well capacity	Approx. 110 000 e-
Dark current	0.5 e ⁻ /s/pixel at 0°C
Dark signal doubling	7 °C

Model G4-16000

G4-16000 uses 16 MPx CCD OnSemi KAF-16803.

Resolution	4096×4096 pixels
Pixel size	9×9 μm
Imaging area	36.9×36.9 mm
Full well capacity	Approx. 100 000 e-
Dark current	0.3 e ⁻ /s/pixel at 0°C
Dark signal doubling	6.3 °C

Camera Electronics

16-bit A/D converter with correlated double sampling ensures high dynamic range and CCD chip-limited readout noise. Fast USB interface ensures image download time within seconds.

Maximum length of single USB cable is 5 m. This length can be extended to 10 m by using single USB hub or active USB extender cable. Up to 5 hubs or active extenders can be used in one connection.

Gx Camera Ethernet Adapter device allows connection of up to four Gx cameras of any type through Ethernet interface and TCP/IP network. Because

TCP/IP protocol can be routed, the distance between camera and host PC can be virtually unlimited.

ADC resolution	16 bits
Sampling method	Correlated double sampling
Read modes	Preview
	Low-noise
Horizontal binning	1 to 4 pixels
Vertical binning	1 to 4 pixels
Sub-frame readout	Arbitrary sub-frame
Computer interface	USB 2.0 high-speed
	USB 1.1 full-speed compatible

Binning can be combined independently on both axes.

Image download time and system read noise depends on the CCD chip used in particular camera model.

Model G4-9000

Gain	1.5 e-/ADU (1×1 binning)
	1.7 e-/ADU (other binnings)
System read noise	10 e- (Low noise)
	11 e- (Preview)
Full frame download	15.7 s (Low noise)
	10.9 s (Preview)

Model G4-16000

Gain	1.6 e-/ADU (all binnings)
System read noise	11 e- (Low noise)
	12 e- (Preview)
Full frame download	27.8 s (Low noise)
	19.2 s (Preview)

Cooling and power supply

Regulated two-stage thermoelectric cooling is capable to cool the CCD chip from 42 to 47 °C below ambient temperature, depending on the camera type. The Peltier hot side is cooled by a fans. The CCD chip temperature is regulated with ± 0.1 °C precision. High temperature drop and precision regulation ensure very low dark current for long exposures and allow proper image calibration.

G4 cameras are available in two variants, differing in the cooling performance:

- **Standard** cooling cameras achieve temperature difference up to 42 °C Under environment temperature.
- **Enhanced** cooling cameras can regulate temperature up to 47 °C under environment temperature. Compared to standard variant, enhanced cooling cameras are somewhat bulkier due to bigger heat sink, slightly heavier and somewhat noisier because of more powerful fans.

The camera head contains two temperature sensors – the first sensor measures directly the temperature of the CCD chip. The second one measures the temperature of the air cooling the Peltier hot side.

The cooling performance depends on the environmental conditions and also on the power supply. If the power supply voltage drops below 12 V, the maximum temperature drop is lower.

CCD chip cooling	Thermoelectric (Peltier modules)
Standard cooling ΔT	47 °C below ambient maximum 42 °C below ambient typical
Enhanced cooling ΔT	50 °C below ambient maximum 45 °C below ambient typical
Regulation precision	± 0.1 °C
Hot side cooling	Forced air cooling (two fans) Optional liquid coolant heat exchanger

Maximum temperature difference between CCD and ambient air may be reached when the cooling runs at 100% power. However, temperature cannot be regulated in such case, camera has no room for lowering the CCD temperature when the ambient temperature rises. Typical temperature drop can be achieved with cooling running at approx. 85% power, which provides enough room for regulation.



Illustration 4: Comparison of the standard (left) and enhanced (right) cooling cameras

Power Supply

The 12 V DC power supply enables camera operation from arbitrary power source including batteries, wall adapters etc. Universal 100-240 V AC/50-60 Hz, 60 W “brick” adapter is supplied with the camera. Although the camera power consumption does not exceed 55 W, the 60 W power supply ensures noise-free operation.

Camera head supply	12 V DC
Camera head power consumption	15 W without cooling
	52 W maximum cooling
Power connector	5.5/2.5 mm, center +
Adapter input voltage	100-240 V AC/50-60 Hz
Adapter output voltage	12 V DC/5 A
Adapter maximum power	60 W

1. Power consumption is measured on the AC side of the supplied 12 V AC/DC power supply. Camera consumes less energy from 12 V power supply than state here.
2. The camera contains its own power supplies inside, so it can be powered by unregulated 12 V DC power source – the input voltage can be anywhere between 10 and 14 V. However, some parameters (like cooling efficiency) can degrade if the supply drops below 12 V.
3. G4 camera measures its input voltage and provides it to the control software. Input voltage is displayed in the Cooling tab of the CCD Camera control tool in the SIPS. This feature is important especially if you power the camera from batteries.



Illustration 5: 12 V DC/5 A power supply adapter for G3 and G4 CCD Camera

Warning:

The power connector on the camera head uses center-plus pin. Although all modern power supplies use this configuration, always make sure the polarity is correct if you use own power source.

Mechanical Specifications

Compact and robust camera head measures only 154×154×65 mm (approx. 6×6×2.6 inches) for the model with standard cooling. Enhanced cooling increases camera depth by 11 mm. The head is CNC-machined from high-quality aluminum and black anodized. The head itself contains USB-B (device) connector and 12 V DC power plug, no other parts (CPU box, USB interface, etc.), except a “brick” power supply, are necessary. Another connector allows control of optional external filter wheel. Integrated mechanical shutter allows streak-free image readout, as well as automatic dark frame exposures, which are necessary for unattended, robotic setups.

Mechanical shutter	Yes, blade shutter
Shortest exposure time	0.2 s
Longest exposure time	Limited by chip saturation only
Head dimensions	154×154×65 mm (G4 with standard cooling)
	154×154×76 mm (G4 with enhanced cooling)
Back focal distance	16,5 mm (G4 without filter wheel)
	33.5 mm (G4 with external filter wheel)
Standard cooling head weight	1.6 kg (G4 without filter wheel)
	2.5 kg (G4 with “M” external filter wheel)
	2.8 kg (G4 with “L” external filter wheel)
Enhanced cooling head weight	1.8 kg (G4 without filter wheel)
	2.7 kg (G4 with “M” external filter wheel)
	3.0 kg (G4 with “L” external filter wheel)

Camera head dimensions

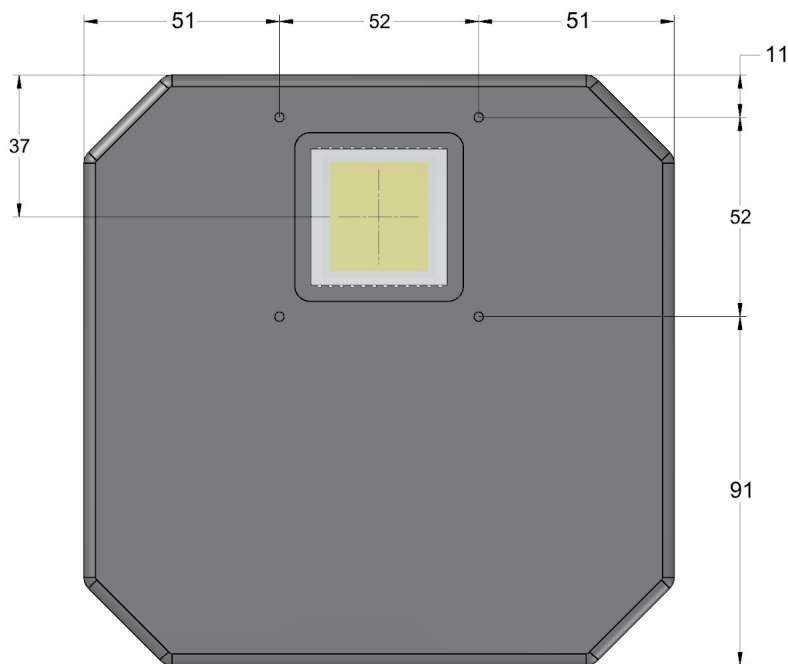


Illustration 6: G4 camera head front view

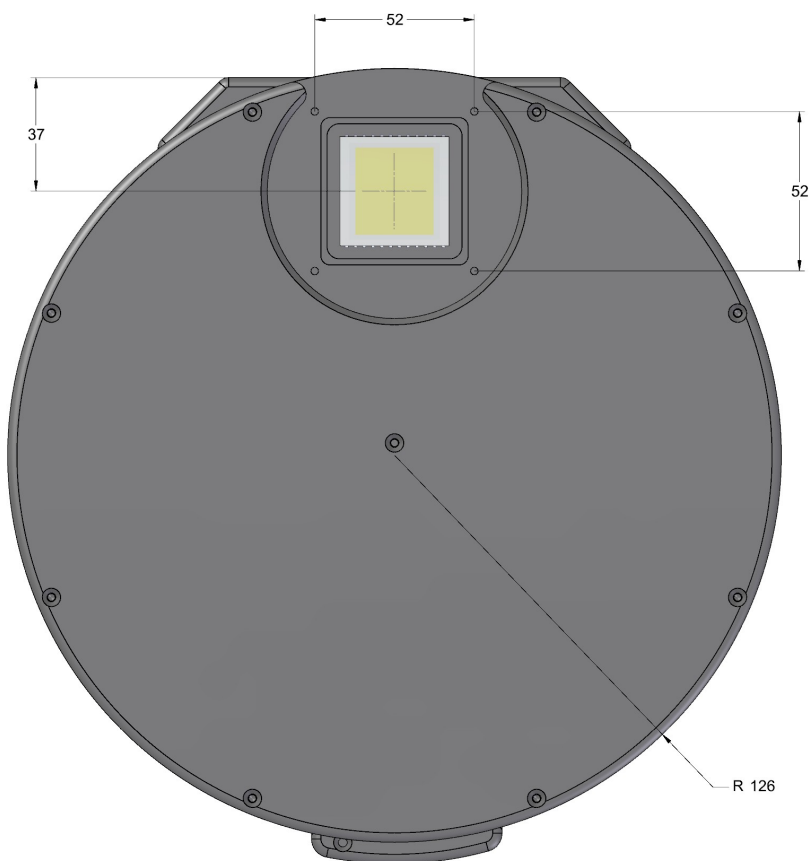


Illustration 7: G4 camera head with “L” size external filter wheel front view

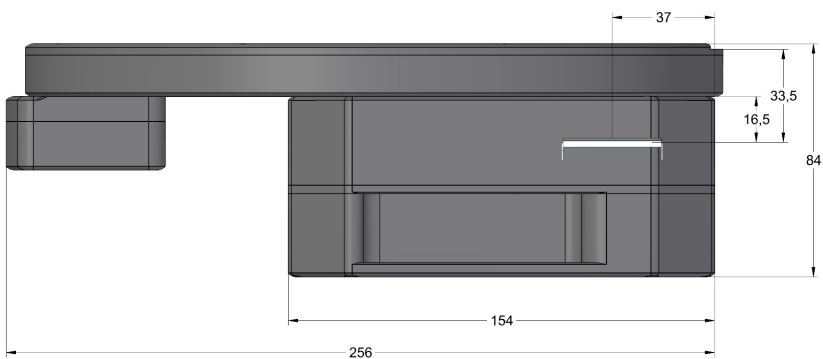


Illustration 8: G4 camera head with standard cooling and “L” size external filter wheel side view

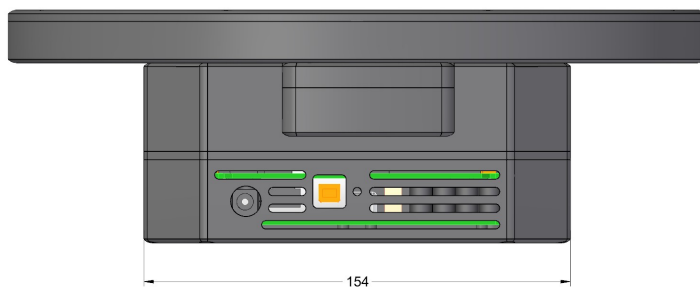


Illustration 9: G4 camera head with standard cooling and “L” size external filter wheel bottom view

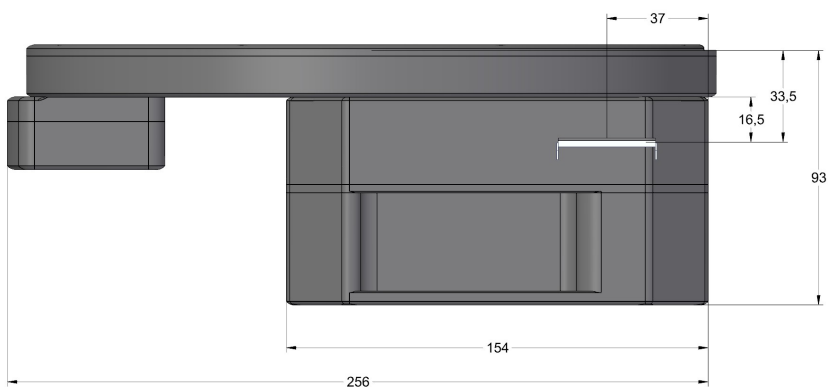


Illustration 10: G4 camera head with enhanced cooling and “L” size external filter wheel side view

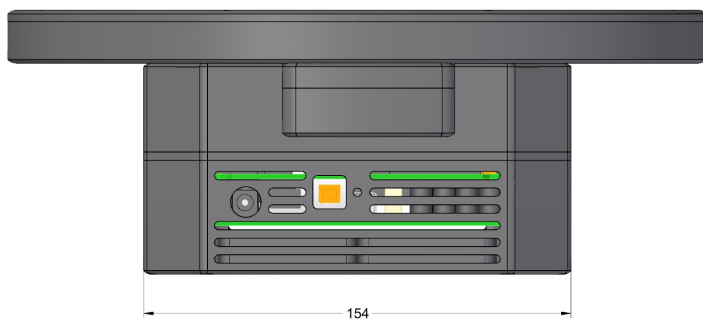


Illustration 11: G4 camera head with enhanced cooling and “L” size external filter wheel bottom view

Telescope adapters

The G4 cameras are supplied with standard M68×1 threaded adapter. The adapter itself is 14 mm thick and it contains 8 mm of the M68 thread. So the back focus distance is:

- 30.5 mm if the adapter is used on camera without filter wheel
- 47.5 mm if the adapter is used on camera with external filter wheel

It is also possible to use two-piece variant of the M68×1 adapter. The first part, attached to the camera head, offers 4.5 mm long outer thread M68×1. The second part is a 12 mm thick nut with inner M68×1 thread, screwed to the outer thread. So the user can choose to use outer thread (without a nut) or 7.5 mm of inner M68×1 thread (when the nut is screwed in). The back focal distance is of course longer in the second case.



Illustration 12: M68×1 adapter for G4 camera with a nut

Another option for G4 camera is Canon EOS lens adapter, all other standards (2" barrel, T-thread, ...) cause vignetting in the case of G4 cameras, because the detectors used measure 52 mm diagonally.

M68×1 adapter



Adapter with inner M68×1 thread

Two-piece M68×1 adapter		Adapter with both inner and outer M68×1 thread
Canon EOS lens adapter		Standard Canon EOS bayonet adapter
3" Wynne adapter		Adapter for 3" coma-corrector ASA Wynne, intended for G4-OAG.
3" Wynne adapter		Adapter for 3" coma-corrector ASA Wynne.
3" Paracorr BIG adapter		Adapter for 3" coma-corrector TeleVue Paracorr BIG, intended for G4-OAG.
3" Paracorr BIG adapter		Adapter for 3" coma-corrector TeleVue Paracorr BIG, intended for attaching to EFW with M68×1.

The EOS adapter ensures the 44 mm back focal distance when used with the external filter wheel. If it is used on the camera without filter wheel, a spacer must be used between the camera head and the adapter.

Because of camera mass, the EOS adapter is not suitable for attaching of camera to the telescope or lens. Bayonet attachments use ring-shaped spring, which is not strong enough to ensure proper position of the camera relative to

the optical axis. This adapter should be used to attach smaller and lighter lenses to the camera instead.

Adapters are attached to the camera body using four M3 (3 mm metric) screws. Threaded holes on the camera body are placed on the corners of 52 mm square. Custom adapters can be made upon request.

G2 and G3 cameras use smaller 44 mm threaded hole square on the camera head for mounting adapters, so adapters for G2/G3 series and G4 series are not compatible.

Off-Axis Guider Adapter (OAG)

G4 camera can be optionally equipped with Off-Axis Guider Adapter. This adapter contains flat mirror, tilted by 45° to the optical axis. This mirror reflects part of the incoming light into guider camera port. The mirror is located far enough from the optical axis not to block light coming to the main camera sensor, so the optics must be capable to create large enough field of view to illuminate the tilted mirror.

Because of the above described reasons the G4-OAG is manufactured with M68×1 threaded adapter. G4-OAG is compatible with external filter wheels. Adapter back focal distance is 61.5 mm.

If the OAG has to be used on camera with internal filter wheel, it is necessary to insert a spacer between OAG and camera head compensating BFD difference. Similar, but thicker spacer must be used when OAG is mounted to camera without filter wheel at all.

OAG guider port is compatible with G0 and G1 cameras. It is necessary to replace the CS/1.25" adapter with short, 10 mm variant in the case of G1 cameras. Because G1 cameras follow CS-mount standard, (BFD 12.5 mm), any camera following this standard with 10 mm long 1.25" adapter should work properly with the G4-OAG.



Illustration 13: G3-OAG on the camera head

Attaching camera head to telescope mount

G4 cameras are equipped with two “tripod” 0.250-20UNC threads on the top side of the camera head. This thread can be used to attach 1.75 inch “dovetail bar” (Vixen standard). It is then possible to attach the camera head, e.g. equipped with photographic lens, directly to various telescope mounts supporting this standard.



Illustration 14: 1.75" bar for standard telescope mounts

Camera head color variants

Camera head is available in several color variants of the center plate. Visit manufacturer's web pages for current offering.



Illustration 15: G4 camera color variants

Camera Maintenance

The G4 camera is a precision optical and mechanical instrument, so it should be handled with care. Camera should be protected from moisture and dust. Always cover the telescope adapter when the camera is removed from the telescope or put the whole camera into protective plastic bag.

Desiccant exchange

The G4 camera cooling is designed to be resistant to humidity inside the CCD chamber. When the temperature decreases, the copper cold finger crosses freezing point earlier than the CCD chip itself, so the water vapor inside the CCD chamber freezes on the cold finger surface first. Although this mechanism works very reliably in majority of cases, it has some limitations, especially when the humidity level inside the CCD chamber is high or the chip is cooled to very low temperatures.

This is why a cylindrical container, filled with silica-gel desiccant, is placed inside the camera head. This cylindrical chamber is attached to the insulated cooled CCD chamber itself.

Warning:

High level of moisture in the CCD chip chamber can cause camera malfunction or even damage to the CCD chip. Even if the frost does not create on the detector when the CCD is cooled below freezing point, the moisture can be still present. It is necessary to keep the CCD chamber interior dry by the regular exchange of the silica-gel. The frequency of necessary silica-gel exchanges depends on the camera usage. If the camera is used regularly, it is necessary to dry the CCD chamber every few months.

It is possible dry the wet silica-gel by baking it in the oven (not the microwave one!) to dry it again. Dry the silica-gel for at last one or two hours at temperature between 120 and 140 °C.

The silica-gel used in G4 cameras changes its color according to amount of water absorbed – it is bright yellow or orange when it is dry and turns to

transparent without any color hue when it becomes wet. It is recommended to shorten replacement interval if the silica-gel is completely transparent upon replacement. If it is still yellow-orange, it is possible to prolong the replacement interval.

Note:

The silica-gel ability to absorb moisture depends on the ambient temperature. If the camera is located in the environment with below freezing point temperatures, drying of the CCD cold chamber can take up to several days.

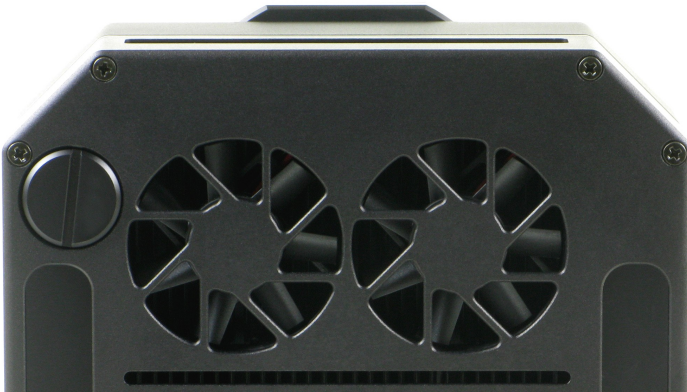


Illustration 16: Silica-gel container is accessible from the camera back side

Changing the silica-gel

The desiccant container design depends on the camera revision:

- G4 cameras revision 1 have the container accessible from the back side of the camera head. The slotted desiccant chamber cap can be unscrewed e.g. by a coin. Pour out wet silica-gel and fill the chamber with a dry one. The desiccant chamber can be filled with a hot silica-gel without a danger of damaging of the container.

The desiccant container can be left open without the fear from contamination of CCD chamber interior by dust. There is a very faint stainless steel grid between the CCD chamber and the desiccant container, so dust particles cannot enter the chamber itself. It is even

recommended to keep the desiccant container cap off for a couple of hours when the camera is in the room with low humidity. This helps drying the CCD chamber interior and prolongs the silica-gel exchange interval.

- G4 revision 2 cameras supplied in 2016 and later are equipped with a redesigned desiccant containers. New containers are no longer a fixed part of the camera body with only a removable cap, but the whole container can be unscrewed. The main advantage of this design is the ability to exchange silica-gel without the necessity to remove the camera from the telescope, which was necessary to be able to pour-out the silica-gel and then to pour it in.

Silica-gel is held inside the container with a perforated cap. This cap is also screwed into the container body, so it is easy to exchange the silica-gel inside the container after it is worn out or damaged e.g. by too high temperature etc.

The container itself does not contain any sealing (the sealing remains attached to the CCD cold chamber inside the camera head), it consists of aluminum parts only. So it is possible to heat the whole container to desired temperature without risking of the temperature-induced sealing damage.

This design also allows usage of some optional parts. First it is a threaded hermetic cap, which allows sealing of the dried container when it is not immediately attached to the camera head. And the second one is an alternate (somewhat longer) desiccant container, modified to be able to be screw in and tightened (as well as released and screwed out) without any tool.

The sealed cap as well as the tool-less container are not supplied with the camera, they are supplied only as optional accessory.

- The G4 cameras with Enhanced Cooling are equipped with a bigger heat sink and thus also thicker back shell. This requires usage of the longer desiccant containers. Both container variants (the standard one and also the tool-less variant) are supplied in two lengths. Shortened containers for standard cameras and longer ones for Enhanced Cooling cameras.



Illustration 17: Optional cap, containers with a slot and containers for tool-less manipulation, versions for the standard and enhanced cooling cameras

Changing the Telescope Adapter

The camera head contains four threaded holes in the corners of the 52 mm square. The telescope adapter is attached by four bolts. If you want to change the adapter, simply unscrew these bolts and replace the adapter with the new one.

Power Supply Fuse

The power supply inside the camera is protected against connecting of inverted-polarity power plug or against connecting of too-high DC voltage (above 15 V) by a fuse. If such event happens and the cooling fans on the back side of the camera do not work when the camera is connected to proper power supply, return the camera to the service center for repair.