# HoloSpec
# Imaging Spectrograph
# Operations Manual

**2004945 R6**

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An Endress+Hauser Company

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**CAUTION.** Performing procedures, using controls, or adjusting the spectrograph other than as specified in the manual may result in hazardous radiation exposure.

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## Important Symbols Used in This Manual

**CAUTION: THIS SYMBOL IS USED TO IDENTIFY IMPORTANT OPERATING INSTRUCTIONS.**

**WARNING: THIS SYMBOL IS USED TO ALERT THE USER TO THE DANGER OF EXPOSURE TO HAZARDOUS VISIBLE LASER RADIATION.**

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## Preface

This manual contains information for users concerning the *HoloSpec* spectrographs.

**Caution**: Read this manual carefully before using a *HoloSpec* spectrograph for the first time.

**Warning:** Performing procedures, using controls, or adjusting the spectrograph other than as specified in the manual may result in hazardous radiation exposure.

# HoloSpec Imaging Spectrograph

## 1 Introduction

The *HoloSpec* line of holographic imaging spectrographs from Kaiser Optical Systems, Inc. (Kaiser) features significant advances in high-performance spectroscopy. The *HoloSpec* spectrographs use *Volume Phase Holographics* (*VPH*) in an axial transmissive spectrograph configuration to provide superior imaging, excellent spectral resolution, high efficiency, low scatter, and unsurpassed throughput.[1] All of these features are offered in a system that is compact and simple to set up, operate, and maintain.

The *HoloSpec* is available in the following two versions:

- The *HoloSpec f*/1.8i incorporates optics for pre-filtering the light before it enters the heart of the spectrograph. A holographic *SuperNotch-Plus* filter is included with the *HoloSpec f*/1.8i for filtering out light at the laser wavelength.
- The *HoloSpec f*/1.8 is offered without the prefiltering optics and is ideal for applications in which pre-filtering is either performed remotely or not required.

### 1.1 The VPH System

Kaiser first introduced *Volume Phase Holographics* technology in its line of holographic notch filters for spectroscopic spectrographs. These notch filters serve as laser-blocking filters in Raman and fluorescence spectroscopy. The same technology used to produce holographic notch filters has been applied to the production of high-quality transmission gratings. *VPH* gratings are tuned to satisfy the conditions of Bragg diffraction for any wavelength between 400 and 1070 nm and therefore provide maximum efficiency at the wavelength of interest. In contrast, gratings in conventional spectrographs are often blazed far from the wavelength of interest, resulting in poor efficiency.

The lenses used in the *HoloSpec* spectrographs are made with one of three antireflection coatings, each optimized for a particular spectral region:

- visible (VIS), 500–700 nm
- near-infrared (NIR), 750–1100 nm

The *HoloSpec* spectrographs are designed to be easy to use. A snap-in input adapter system permits you to switch between input sources quickly and easily. The optical axis of the unit is exactly three inches above the table, allowing you to use many standard optical components. Recessed rubber pads on the feet of the spectrograph prevent the spectrograph from slipping on virtually any surface. The unit may be secured to an optical table using the clamps provided with the spectrograph. You can access the inside of the *HoloSpec* easily by releasing the two quick-release latches and removing the cover.

The *HoloSpec f*/1.8i incorporates a pre-filter stage including a pre-aligned holographic notch filter tuned to the selected excitation wavelength. The holographic *SuperNotch-Plus* filter included with the *HoloSpec f*/1.8i attenuates the laser wavelength by more than six orders of magnitude yet allows collection of data at Stokes shifts as low as 100 $cm^{-1}$.

[1] Battey, D.E.; Slater, J.B.; Wludyka, R.; Owen, H.; Pallister, D.; Morris, M.D., Appl. Spectrosc., 47**,** 1913 (1993).

The slits (Table A.5) used with the *HoloSpec* spectrographs are easily interchanged, allowing you to vary resolution for a variety of experimental needs. The slits, *VPH* grating, and holographic *SuperNotch-Plus* filter are all easily replaced.

Superlative light-gathering capability in a spectrograph requires a low *f*/# (fast optics). The *VPH* transmission grating produces a 90° fold, allowing *f*/1.8 optics to be placed very close to the grating while minimizing vignetting. The fast, on-axis, multi-element optics used in the design of the *HoloSpec* provide excellent imaging capabilities.[2] Hundreds of clearly separated channels, each with high spectral resolution, can be produced simultaneously.[3] Scattered light is minimized by smooth, sinusoidal refractive index profile of the *VPH* grating.

The *HoloSpec* may be easily attached to many major CCD cameras and photodiode arrays with available adapter plates.

Kaiser's *HoloSpec* offers a number of features that deliver superior performance and ease of use for many conventional and unique spectroscopic applications. High construction standards and versatile, rugged components ensure that *HoloSpec* spectrographs will perform exceptionally well under a variety of conditions and meet the most demanding spectroscopic needs.

[2] Tedesco, J.M.; Owen, H.; Pallister, D.M.; Morris, M.D., Anal. Chem., 65**,** 441A (1993).
[3] Jorgenson, R.C.; Siegfried, M.C., Proc. SPIE, 3603**,** 313 (1999).

# 2 Specifications and Optical Performance

Figure 2-1 through Figure 2-4 show the interior of the *HoloSpec f*/1.8i and the *HoloSpec f*/1.8.

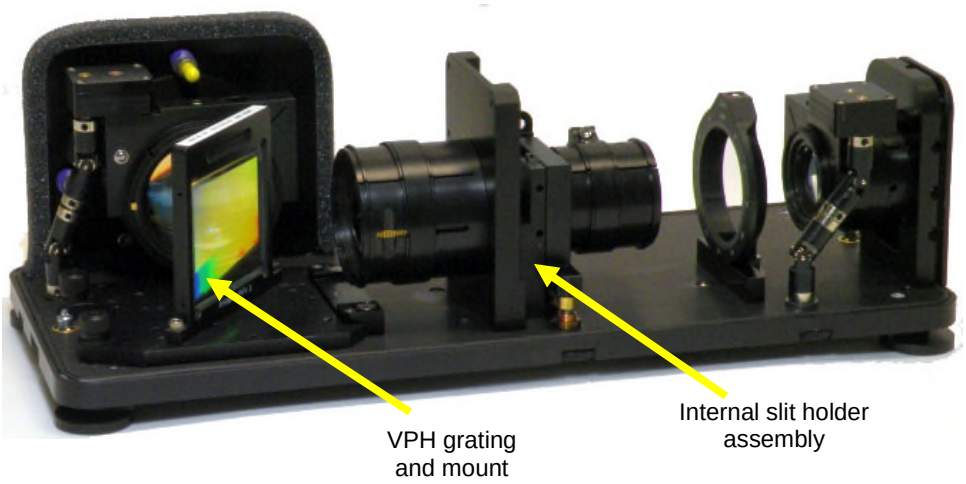


Figure 2-1. Interior of the *HoloSpec f*/1.8i, showing the *VPH* grating and mount and the internal slit holder assembly.

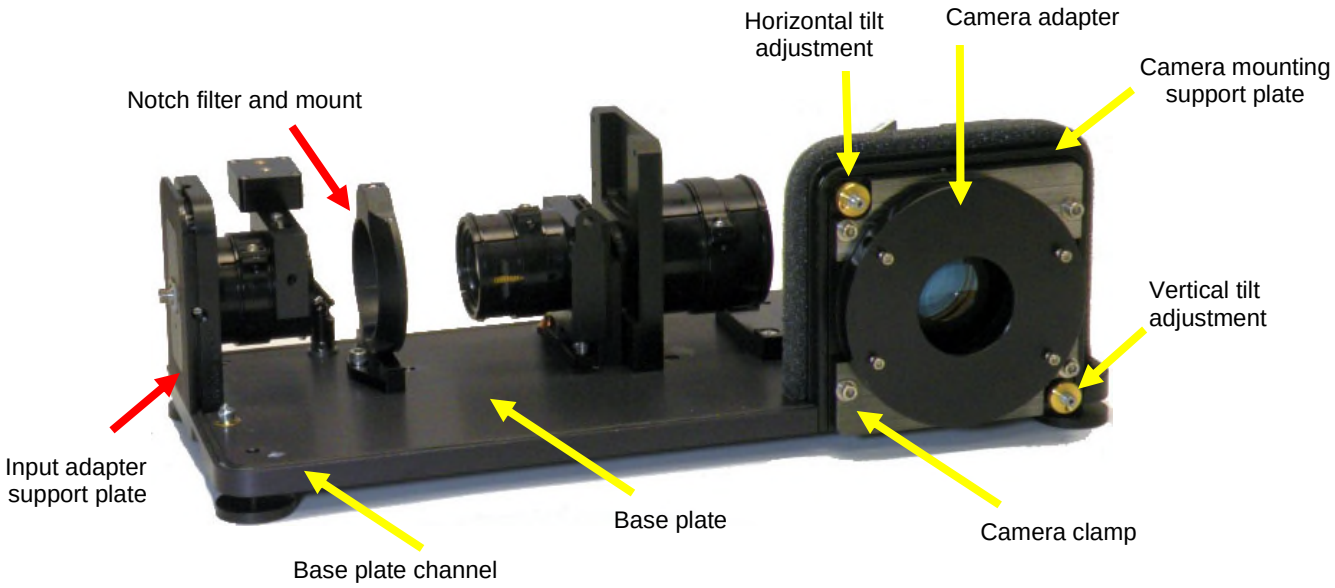


Figure 2-2. Interior of the *HoloSpec f*/1.8i, showing the input adapter support plate, base plate, notch filter and mount, base plate channel, horizontal tilt adjustment, vertical tilt adjustment, and camera mounting support plate.

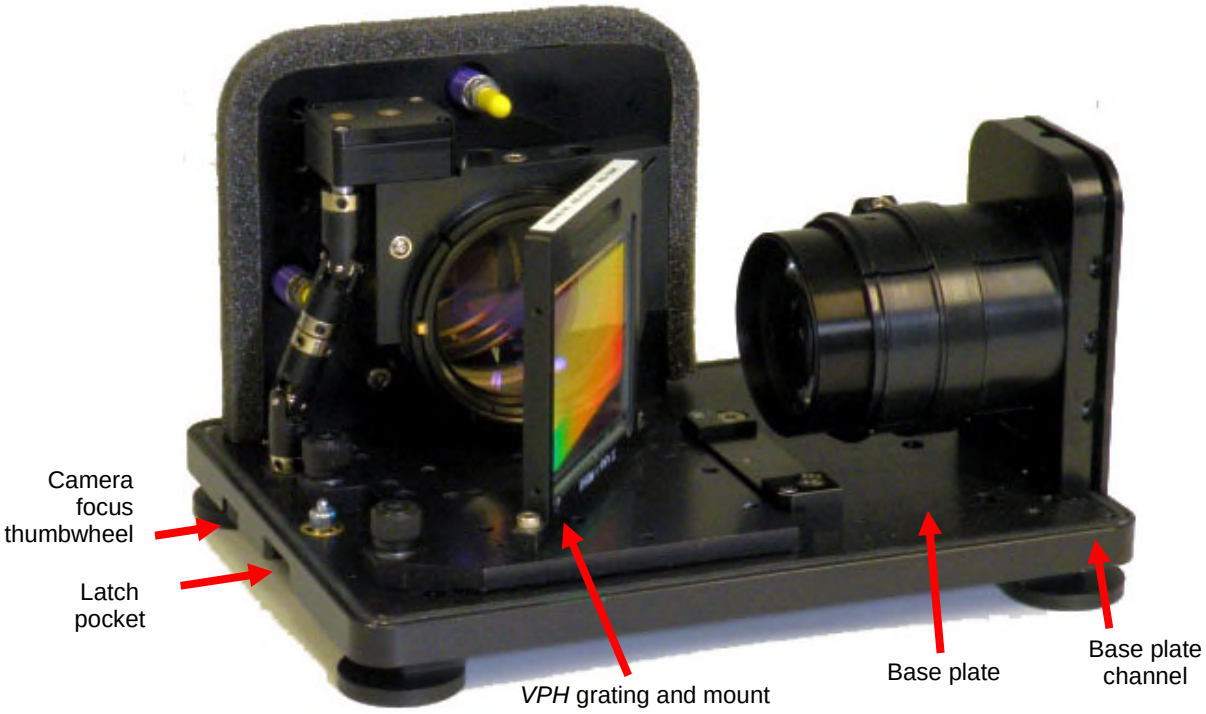


Figure 2-3. Interior of the *HoloSpec f*/1.8, showing the camera focus thumbwheel, latch pocket, *VPH* grating and mount, base plate, and base plate channel.

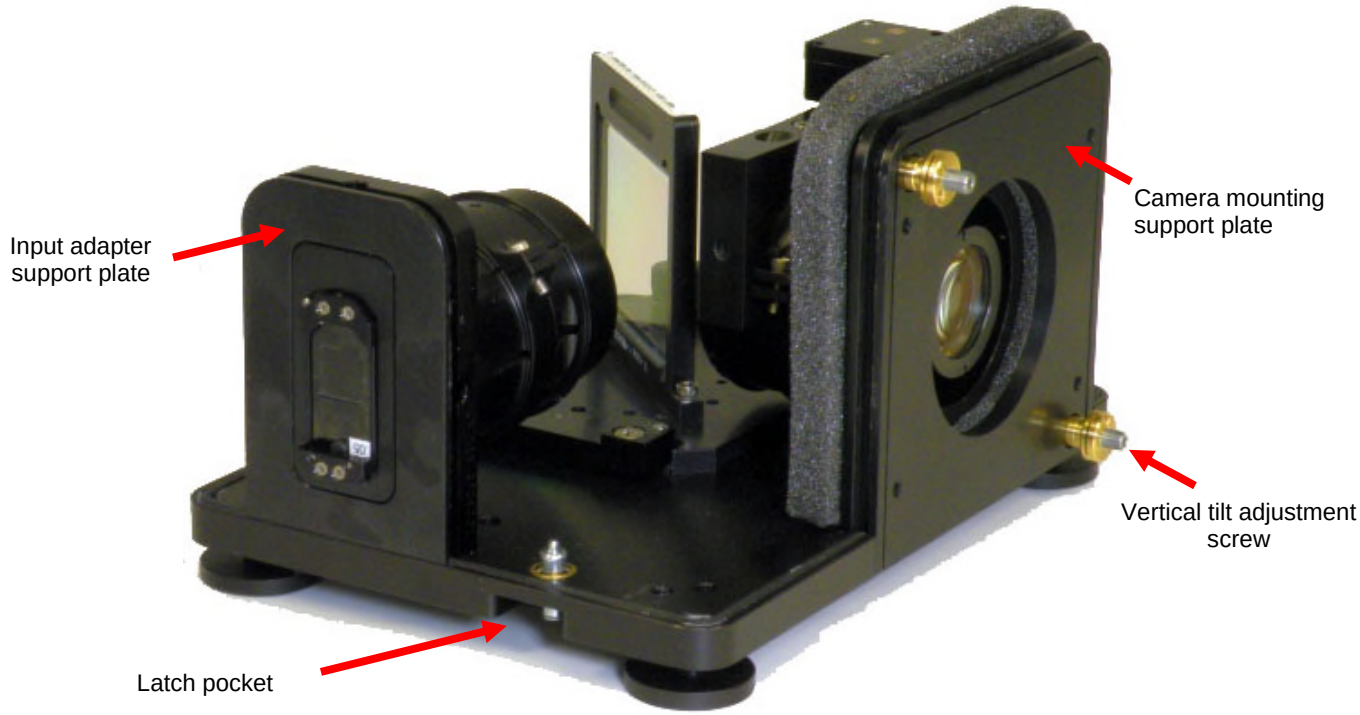


Figure 2-4. Interior of the *HoloSpec f*/1.8, showing the latch pocket, input adapter support plate, camera mounting support plate, horizontal tilt adjustment screw, and vertical tilt adjustment screw.

## 2.1 Specifications

| | |
|---|---|
| **Focal Length** | 85 mm |
| **Weight** | |
| *HoloSpec f*/1.8i | 18 lbs |
| *HoloSpec f*/1.8 | 11 lbs |
| | |
| **Dimensions** | |
| Length | *HoloSpec f*/1.8i: 17-1/2 in. (44 cm)<br>*HoloSpec f*/1.8: 10 in. (25 cm) |
| Width | 8 in. (19 cm) |
| Height | 6.5 in. (17 cm) |
| | |
| **Magnification** | |
| Ratio of output focal length to input focal length | |
| NIR | 85/75 |
| VIS | 75/75 |

### 2.1.2 Spectral Coverage

The spectral coverage varies with the grating used. Table A.1 in Appendix A lists the holographic gratings available for the *HoloSpec* spectrographs, along with their spectral coverage (based on a 25-mm detector width) and linear dispersion (at the center of the output plane). Gratings to achieve different spectral coverage and linear dispersions are available on a custom basis.

### 2.1.3 Resolution

The resolution is a function of the slit width and the pixel size of the detector. Resolution can be determined by dividing the average reciprocal linear dispersion of the grating by the size of a pixel and multiplying by the width of the slit. The data in the example below are found in Appendix A.

**Example:**
**532 Low Frequency Stokes grating with 50-$\mu$m slit:**
**2.4 cm$^{-1}$/pixel × 1 pixel/26 $\mu$m × 50 $\mu$m = 4.6 cm$^{-1}$**

### 2.1.4 Slit Height

The slits provided with the *HoloSpec* spectrographs are 8 mm high. However, the optics are well corrected over a height of 16 mm, so the spectrograph can be used over 16 mm vertically without a slit. Restriction apertures for the slit are available for use with certain custom transmission gratings, such as the *HoloPlex* gratings.

### 2.1.5 Aperture Ratio

Table 1 shows the aperture ratios of the *HoloSpec* spectrographs.

Table 1. Aperture ratio based on 25-mm image plane width.

| | With visible-coated optics | With NIR-coated optics |
|---|---|---|
| ***HoloSpec f*/1.8i** | *f*/1.8 across image plane | *f*/1.4 at center of image plane<br>*f*/1.8 at edges of image plane |
| ***HoloSpec f*/1.8** | *f*/1.8 across image plane | *f*/1.4 at center of image plane<br>*f*/1.8 at edges of image plane |

## 2.2 Curvature in Image of Slit

The image of a straight slit through any spectrograph using a plane grating will result in a curved image, in most cases parabolic.[4] This happens because rays from different positions along the length of the slit are incident on the grating with different amounts of obliqueness.

Due to the short focal length of the *HoloSpec* spectrographs, the amount of obliqueness for rays at the top and bottom of the slit is significantly larger than for spectrographs with long focal lengths. As an example, Figure 2-5 shows the horizontal displacement for rays from different vertical positions along the slit with respect to a ray at the center of the slot. This curve applies to a *HoloSpec* with the Raman grating HSG-532-LF. Visible and fluorescence gratings exhibit less curvature. See Appendix C for more details.

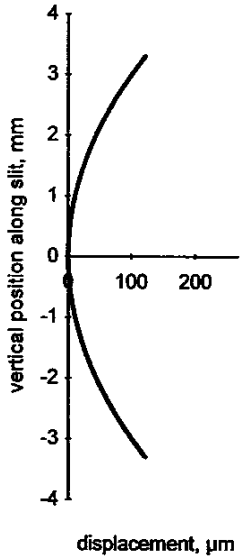


Figure 2-5. Horizontal displacement of rays with respect to vertical position along the slit for grating HSG-532-LF.

[4] James, J.F. and Sternburg, R.S., *The Design of Optical Spectrometers,* Chapman and Hall Ltd., London, England, (1969)

For rays covering approximately the central 3 mm of the slit, displacement from the central ray is less than 25 $\mu$m, and this region can be binned with no degradation in resolution for most CCD cameras. However, spectra gathered using a larger vertical section of the CCD must be binned into separate regions and shifted the appropriate number of pixels before summing in order to prevent loss of resolution.

# 3 Unpacking and Handling

Unpack the *HoloSpec* carefully. Keep the packing materials for possible future storage, return or reshipment. Examine the exterior and interior of the spectrograph for any signs of damage in shipment. If damage has occurred, immediately contact Kaiser for assistance.

The *HoloSpec* has been designed and manufactured to the highest standards to meet the most demanding spectroscopic needs. It can be operated in any orientation. Despite its durability, you must take the following precautions:

- When removing or replacing the spectrograph cover, do not force it over the support plates. The cover will slide smoothly into place when properly aligned.
- Do not adjust any of the lenses other than those specified in the installation procedures. All focus and alignment operations for installation or operation of the spectrograph are controlled by thumbwheels. All other lens alignments are set at the factory and should not be adjusted.

All holographic notch filters and transmission gratings provided with the spectrograph are encapsulated between glass plates and can be handled in the same manner as a typical lens. Filters and gratings may be cleaned using standard lens-cleaning methods and materials, as directed in the cleaning instructions for holographic filters and gratings (Appendix A).

**Caution**: Handle the slit only by its metal carrier. Do not touch the thin substrate into which the slit is cut.

# 4 Installation and Operation

## 4.1 Preparing the HoloSpec for Use

The following steps are necessary to prepare the *HoloSpec* for use:

1. Attach the camera.
2. Install the slit (HoloSpec f/1.8i: Section 4.3; HoloSpec f/1.8: Section 4.11).
3. Install the VPH grating (Section 4.4).
4. HoloSpec f/1.8i only: Install the holographic SuperNotch-Plus filter (Section 4.5).
5. HoloSpec f/1.8i only: Install the aperture input adapter (Section 4.6).
6. HoloSpec f/1.8i only: Align the pre-filter section (Section 4.7 and 4.8).
7. Focus and align the camera (Section 4.10).

## 4.2 Spectrograph Cover

The spectrograph cover is secured to the base of the spectrograph by means of two quick-release latches located in pockets underneath the base plate at both ends of the unit. When the cover is locked in place on the base plate, the latch buttons sit firmly in the latch receptacles. When the cover is unlocked, the latch buttons hang beneath the latch receptacles.

**To remove the spectrograph cover**

1. Locate the latch pockets at both ends of the spectrograph (Figure 2-4). Disengage the latch buttons by pushing upward against them until they slip out of their receptacles. It is not necessary to lift the spectrograph to disengage the latch buttons.
2. After the latch buttons are disengaged, lift the cover off the base (Figure 4-1). Grooves located on the input adapter support plate at the end of the spectrograph and in the camera mounting support plate at the rear of the spectrograph guide the cover off the base plate.

**To replace the spectrograph cover**

1. Align the cover with the grooves on the input adapter support plate and the camera-mounting support plate.
2. Lower the cover into place on the spectrograph's base plate by sliding it along these grooves. Do not force the cover into position; it will slide smoothly when properly aligned in the guides. When replaced properly, the cover will fit snugly into the gasket-lined channel around the perimeter of the base plate.
3. Secure the cover by re-engaging the latches. Lock the latches by pushing up on the latch buttons, seating them firmly in the latch receptacles.
4. When re-engaging the latch button at one end, apply slight hand pressure to the spectrograph cover over that end to help the locking mechanism.


Figure 4-1. The cover slides easily over the *HoloSpec* frame.

## 4.3 Internal Slit (HoloSpec f/1.8i only)

Three slits are included with the *HoloSpec f*/1.8i to allow you to vary the spectrograph's resolution.

**To install a slit in the internal slit holder**

1. Make sure that the slit-locking setscrew (Figure 4-2) is loosened. If not, loosen it using a 0.035" Allen key.
2. Grasp the selected slit near its top (untapered) edge. Align the locating pin toward the grating and away from the input plate.
3. Push the top of the slit down until it stops and the locating pin at the top of the slit is below the top of the internal slit holder.
4. Tighten the slit-locking setscrew.

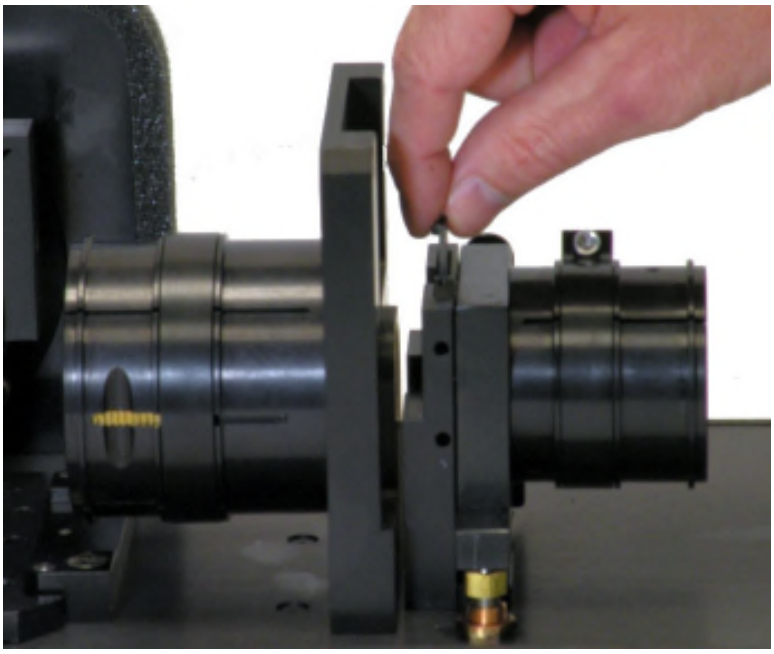

Figure 4-2. Installing the slit.

**To remove a slit from the internal slit holder**

A tool for removing the internal slit from the *HoloSpec f*/1.8i is included. It attaches to the side of the internal slit holder assembly (Figure 2-1) for storage.

1. Loosen the slit-locking setscrew (Figure 4-3) using a 0.035" Allen key.
2. Orienting the tool as shown in Figure 4-3, place the hole in the tool over the round locating pin near the top of the slit.
3. Slowly lift the tool and slit straight up.

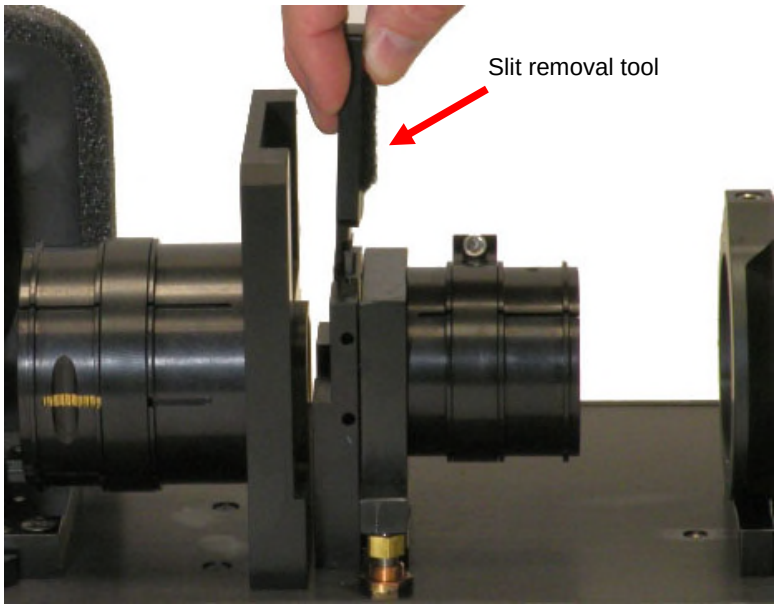


Figure 4-3. Removing the slit.

## 4.4 Installing and Removing the *VPH* Grating

The *VPH* grating is designed to fit easily into the spectrograph section of the *HoloSpec*.

**To install a *VPH* grating**

1. The holographic grating must be free of fingerprints and lint to provide maximum efficiency. If necessary, clean the grating using standard lens-cleaning methods and materials before installing it (Appendix B).
2. Being careful not to touch the surface of the grating, grasp the grating at the top of its mounting frame with one hand and by the sub-base near the screws (Figure 4-4) with the other hand.
3. Lower the entire assembly into position as shown in Figure 4-4.
4. Snap the tongue of the grating assembly sub-base into the groove of the grating clamp located beneath the collimating lens.
5. Tighten the two large sub-base screws.

**To remove a *VPH* grating**

Loosen the large sub-base screws and pull the grating assembly away from the grating clamp beneath the collimating lens.

> **Caution**: Holographic gratings are aligned at the factory. Do not remove the grating screws that hold the grating onto the sub-base. Tampering with them will misalign the grating.

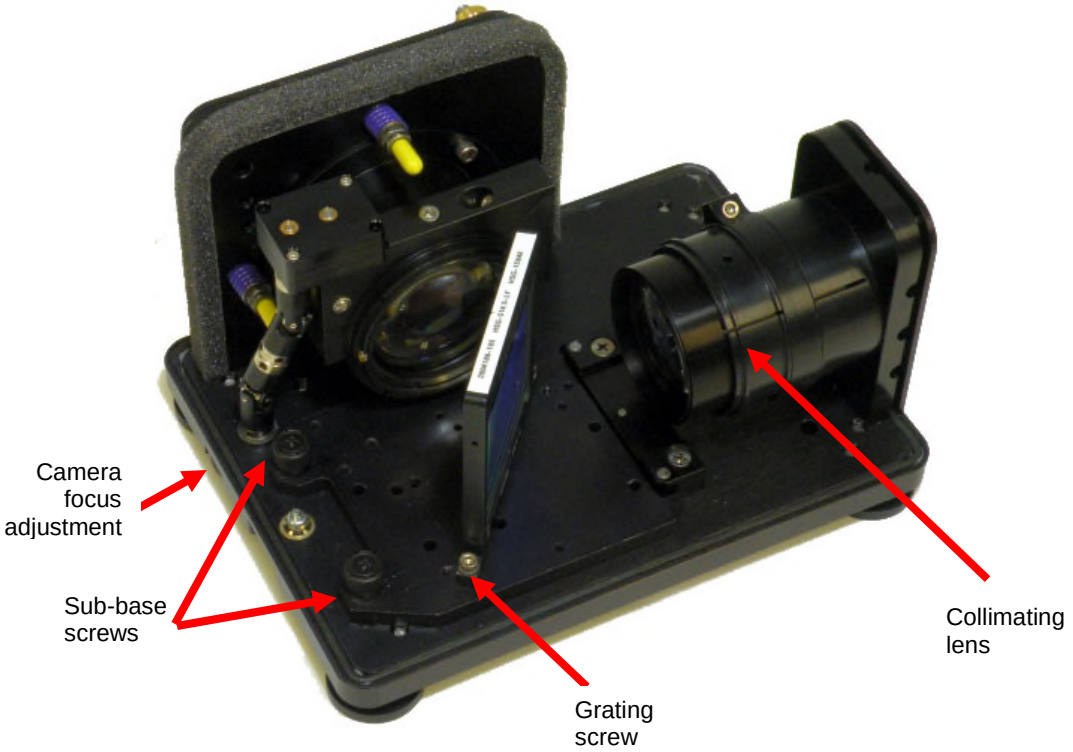


Figure 4-4. Installing a *VPH* grating.

## 4.5 Notch Filter (HoloSpec f/1.8i only)

A 2"-diameter holographic notch filter, contained in a mounting ring, is easily installed in the notch filter mounting assembly located in the pre-filter section of the spectrograph. The notch filter must be free of fingerprints and lint to provide maximum efficiency. If necessary, clean the filter using standard lens-cleaning methods and materials before installing it.

**To install a holographic notch filter**

1. Grasp the filter by the mounting ring (Figure 4-5).
2. Pull up on the spring-loaded knob.
3. Slide the filter into the filter mount, making sure that the lip of the filter mounting ring seats firmly against the filter mount.
4. Gently release the spring-loaded knob.
5. Tighten the setscrew using a 0.05" Allen key or ball driver.

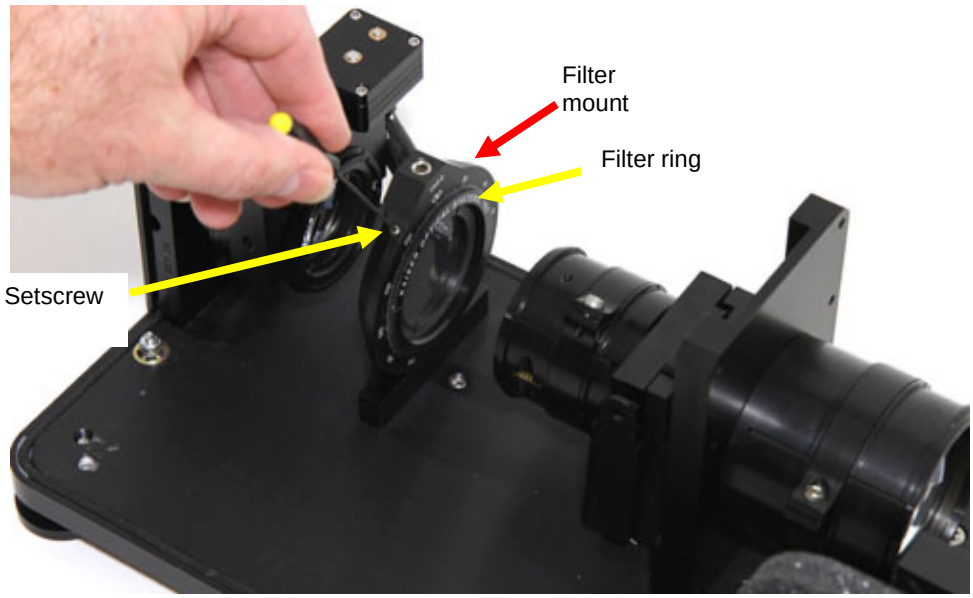


Figure 4-5. Installing or removing the notch filter.

**To remove a holographic notch filter**

1. Loosen the setscrew (Figure 4-5) using a 0.05" Allen key or ball driver.
2. Grasp the filter by the lip of the mounting ring.
3. Pull up on the spring-loaded knob.
4. Remove the filter-mounting ring from the filter mount.
5. Gently release the spring-loaded knob.

**Caution:** Use care when removing the notch filter to avoid damaging the lenses located on either side of the filter mount.

## 4.6 Input Adapter

Five basic types of input adapters are available for use with the *HoloSpec*: aperture, fiber (FC, SMA, or linear fiber array), and external slit (Figure 4-6). The aperture input adapter is standard with the *HoloSpec f*/1.8i or *HoloSpec f*/1.8. The external slit adapter holds a slit in the input adapter support plate and is standard with the *HoloSpec f*/1.8 and optional with the *HoloSpec f*/1.8i.

All adapters are installed or removed in the same manner, by snapping them into or out of the input adapter support plate (Figure 4-7).


Figure 4-6. Available input adapters.

**To install an input adapter**

1. Insert the bottom lip on the rear surface of the input adapter over the ledge located at the bottom of the input adapter support plate (Figure 4-7).
2. Align the bottom edge of the input adapter and the input adapter support plate so that they are parallel with each other. Push down until the input adapter snaps into place over the ball plunger.
3. Push firmly inward at the top edge of the input adapter until it snaps into place in the input adapter support plate.

Figure 4-7. Installing the input adapter.

**To remove an input adapter**

1. Apply thumb pressure to the center of the lower edge of the input adapter until the top edge snaps out of the input adapter support plate.
2. Lift the input adapter out of the input adapter support plate.

## 4.7 Aligning the Pre-Filter with Fiber and External Slit Input Adapters (*HoloSpec* f/1.8i only)

1. Install the input adapter (fiber or external slit) according to the procedure described in Section 4.6.
2. Remove the internal slit (Section 4.3).
3. Illuminate the slit or fiber with a spectral line source, such as a spectral calibration lamp (e.g., neon or argon) or a fluorescent lamp.
4. Loosen the lens strap clamp (if necessary) (Figure 4-8).
5. Adjust the pre-filter section focus by turning the slit focus thumbwheel (SF) to minimize the spectral line width.
6. Tighten the lens strap clamp to 25 inch-pounds (Figure 4-8). Don't over tighten.
7. Insert a 25-µm slit, or the smallest available slit, in the internal slit holder using the procedure described in Section 4.3.
8. Adjust the lateral image position by turning the image adjust thumbwheel to attain maximum peak height of a spectral line.

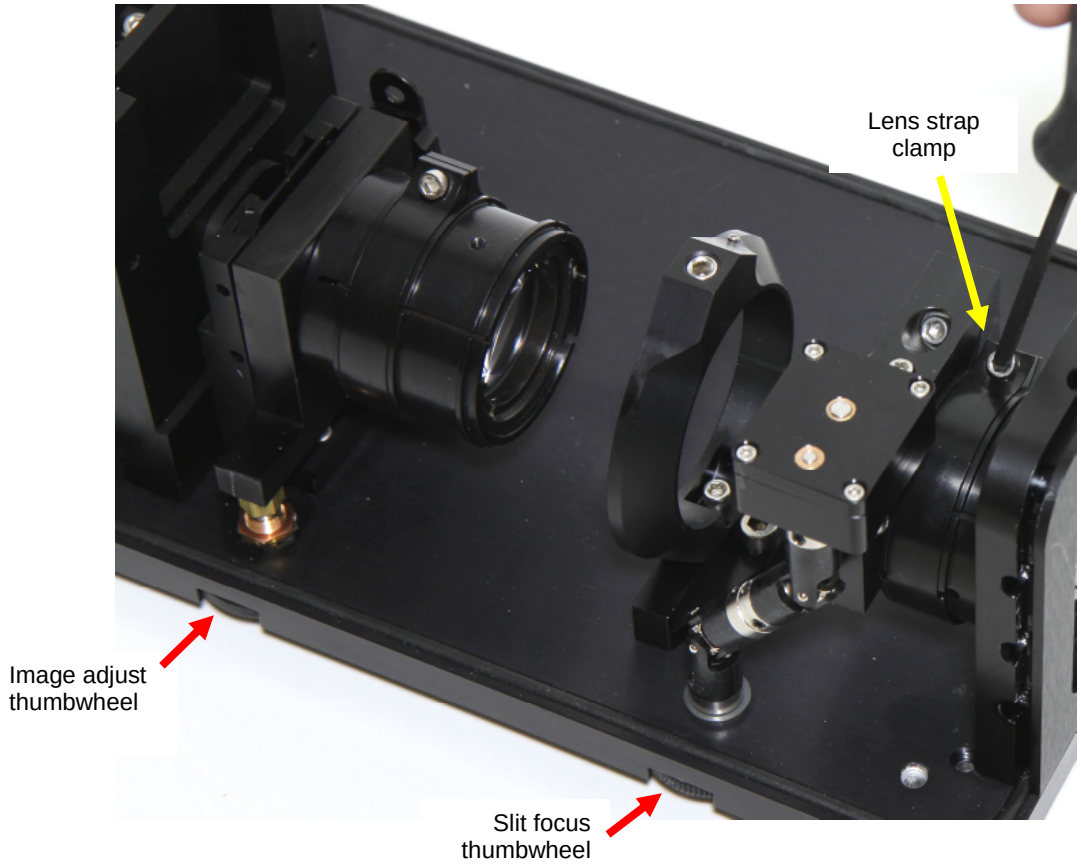


Figure 4-8. Loosen or tighten the lens strap clamp.

## 4.8 Focusing the System to the Fiber and External Slit Input Adapters (*HoloSpec* f/1.8 only)

1. Install the input adapter (fiber or external slit) according to the procedure described in Section 4.6.
2. Illuminate the slit or fiber with a spectral line source, such as a spectral calibration lamp (e.g., neon or argon) or a fluorescent lamp.
3. Loosen the lens strap clamp (if necessary) (Figure 4-8).
4. Adjust the focus by turning the camera focus thumbwheel (SF) to minimize the spectral line width.
5. Tighten the lens strap clamp to 25 inch-pounds (Figure 4-8). Don't over tighten.

## 4.9 Aligning the Pre-Filter with the Aperture Input Adapter (*HoloSpec* f/1.8i only)

The aperture input adapter is intended to be used with user-supplied collection optics. Before performing this procedure, use the image adjust thumbwheel (Figure 4-8 and Figure 4-9) to adjust the user-supplied collection optics so that the sample is imaged approximately into the plane of the exterior surface of the adapter support plate, at the center of the aperture in the aperture input adapter. Small errors in the axial and lateral positions of the image of the sample can be

compensated for with the slit focus thumbwheel and the image adjust thumbwheel. Small errors in the lateral position of the image of the sample can be fixed by following this procedure:

1. Install the aperture input adapter (Section 4.6).
2. Remove the slit from the internal slit holder (Section 4.3).
3. Illuminate the sample with the laser.
4. Loosen the lens strap clamp (if necessary) (Figure 4-8).
5. Adjust the slit focus thumbwheel (Figure 4-8) until the sample is focused in the detector. Note that because the image of the sample will be dispersed in the horizontal direction, the spectrograph should be focused so that the vertical extent of the image of the sample is minimized.
6. Tighten the lens strap clamp (if necessary) (Figure 4-8).
7. Insert the smallest available slit in the internal slit holder (Section 4.3).
8. Adjust the image adjust thumbwheel (Figure 4-8) until the signal level observed on the detector is maximized.

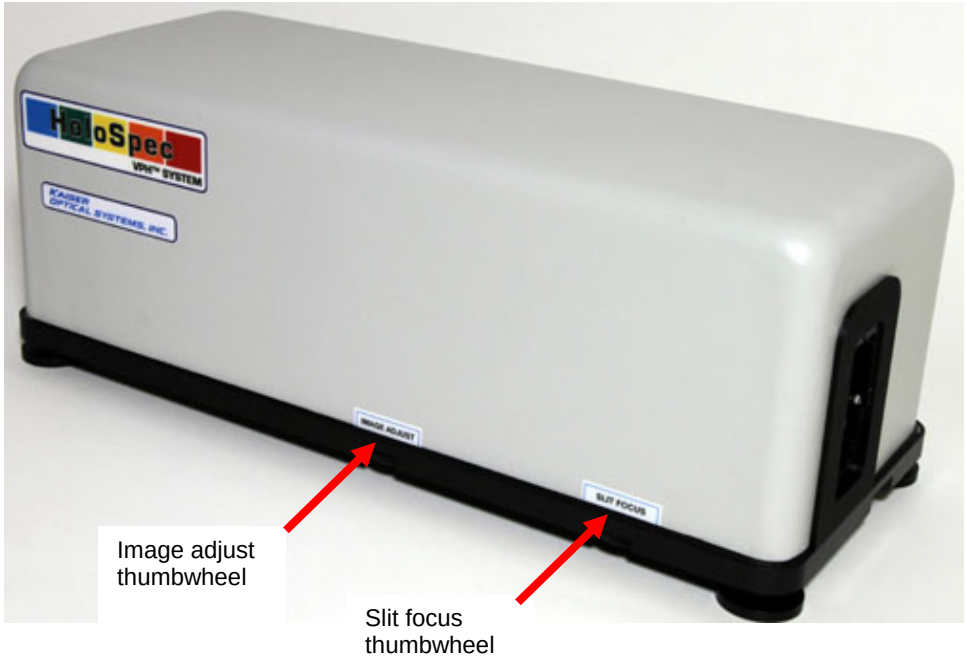


Figure 4-9. Locations of the image adjust thumbwheel and the slit focus thumbwheel.

## 4.10 Camera

When focusing and aligning the camera, use the smallest available slit, preferably 25-$\mu$m. All focus and alignment adjustments are performed with the camera focus, horizontal tilt, and vertical tilt adjustment screws (Figure 4-10).

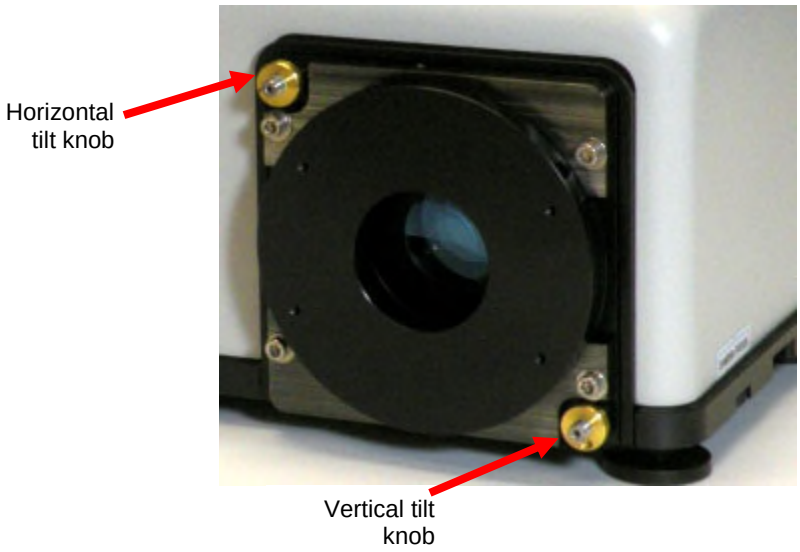


Figure 4-10. The camera mount, including the horizontal tilt knob with its setscrew, vertical tilt knob, and camera focus thumbwheel.

**Caution:** Do not make adjustments other than those controlled by the camera focus thumbwheel, vertical and horizontal tilt adjustment screws. Other lens settings are pre-adjusted at the factory.

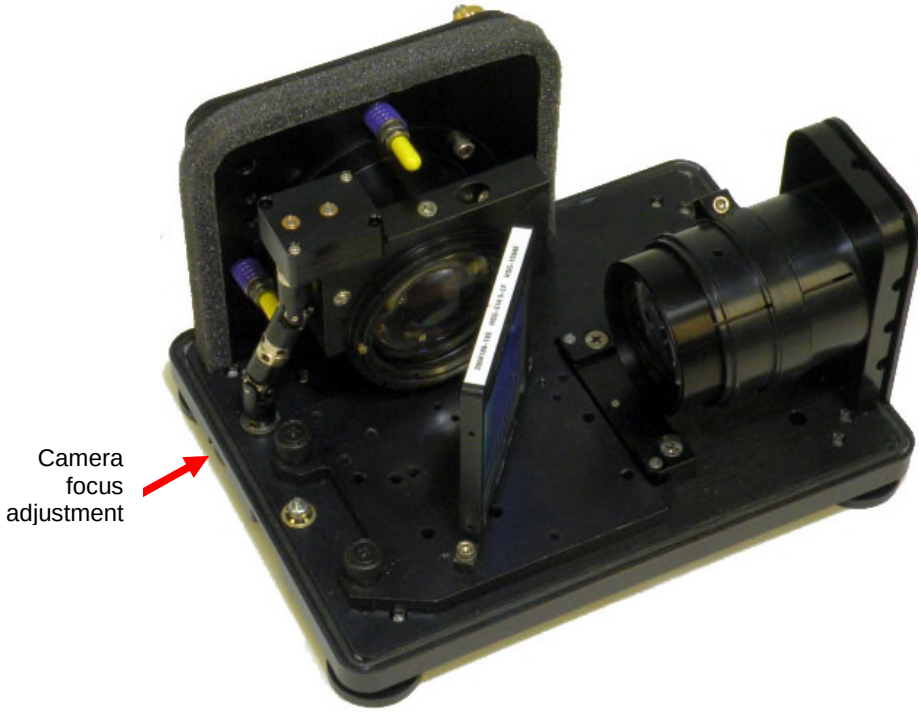


Figure 4-11. Camera focus adjustment.

1. Insert the smallest available slit into the internal slit holder (HoloSpec f/1.8i, Section 4.3) or external slit input adapter (HoloSpec f/1.8, Section 4.11), if it's not already in place.
2. Illuminate the slit with a light source that has spectral lines, such as a spectral calibration lamp or a fluorescent lamp. Make sure that the acceptance aperture is filled as uniformly as possible. The light source should be mounted so that the spectrograph is illuminated in as similar a way as possible to normal operation; otherwise the spectral data will show inaccurate band shapes and band centers. Normally, this means that you should mount the light source along the spectrograph's optical axis.
3. If you are using a CCD as your detector, bin the CCD in two zones, taking a stripe at the top and bottom of the image of the slit. If you are using a one-dimensional array, such as a photodiode array, skip to step 5.

> **Note**: **Before adjusting the horizontal or vertical tilt adjustment screws (Figure 4-10), loosen the setscrews that lock the adjustment screws.**

4. Loosen the lens strap clamp (if necessary) (Figure 4-12).
5. Adjust the camera focus thumbwheel (Figure 4-11) and vertical tilt adjustment screw (Figure 4-10) until spectral lines located near the center of each stripe are simultaneously in focus (i.e., line width is minimized).
6. Adjust the camera focus thumbwheel (Figure 4-11) and horizontal tilt adjustment screw (Figure 4-10) until spectral lines located at the left and right of the detector are simultaneously in focus.
7. Tighten the lens strap clamp (if necessary) (Figure 4-12).

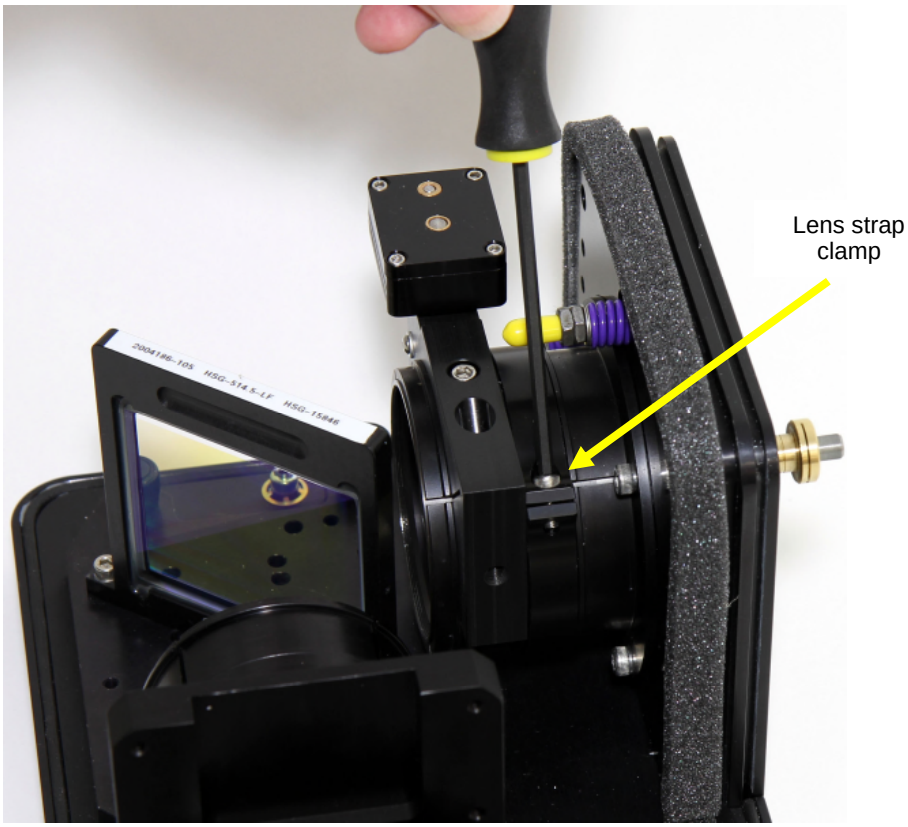


Figure 4-12. Adjusting the lens strap clamp.

## 4.11 External Slit Input Adapter

The external slit adapter holds a slit in the input support plate. An external slit adapter is standard with the *HoloSpec f*/1.8 and is optional with the *HoloSpec f*/1.8i.

**Caution**: Handle the slit only by its metal carrier—do not touch the thin substrate into which the slit is cut.

**To insert a slit into the external slit input adapter**

1. Insert the end of the slit with the round tab into the bottom end of the external slit input adapter, as shown in Figure 4-13.
2. Push down on the slit until it seats itself in the bottom end of the external slit input adapter.
3. Push the slit forward until it snaps into place. Make sure that the slit is seated properly.

Figure 4-13. Inserting a slit into an input adapter.

**To remove a slit from the external slit input adapter**

1 Gently push on the button on the back.

**Caution**: When removing the slit, the force of the push button and the ball plungers may throw the slit from the input adapter. Take care to avoid dropping the slit.

When or if the external slit input adapter is replaced with another input door, it is necessary to verify the system focus per section 4.8.

# 5 Warranty Information

Kaiser Optical Systems, Inc. (Kaiser) warrants that the product will be free from defects in materials and workmanship when delivered to you, and will perform in accordance with Kaiser specifications on the date of delivery and under normal usage for a period of one year from the date of delivery. Kaiser makes no warranty or representation with respect to the quality, performance, merchantability, or fitness for a particular purpose of this product. In no event will Kaiser be liable for direct, indirect or consequential damages resulting from any defect in the product or manual even if advised of the possibility of such damages. In particular, but not exclusively, Kaiser shall have no liability for any business interruption, loss of business profits, manufacturing degradation loss or property or personnel.

Kaiser Optical Systems, Inc. will provide telephone consultation for this product during normal U.S. East Coast business hours 8:00 A.M. to 5:00 P.M. Under no circumstances does telephone consultation affect the terms of any warranty agreement.

If the product fails to meet the standards set out in the warranty, Kaiser will, at its discretion, repair or replace it. You must contact Kaiser or appropriate dealer to obtain the following information: a Return Material Authorization (RMA) number, information regarding any applicable charges, and the address to which the product must be sent. No merchandise will be accepted by Kaiser for any reason without an accurate RMA clearly displayed on the shipping label or documentation of the returned merchandise.

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This warranty does not include damage, misuse, negligence, improper installation, unauthorized repair, or adjustments conducted by non-Kaiser-authorized operators. Removal of the laser enclosure constitutes immediate termination of the Kaiser-offered warranty.

The warranties and remedies set out above are exclusive and in lieu of all other warranties of merchantability, fitness for a particular purpose, and any other warranty whether express, implied, or statutory. No Kaiser dealer, value-added reseller, agent, or employee, other than an officer of the company, is authorized to make modification, extension, or addition to this warranty. In the event that any portion of these warranties and remedies are deemed unenforceable, the remaining portions will continue to apply and be enforceable.

# Appendix A. Options

Tables A.1 through A.8 list the available gratings, filters, slits, CCD camera adapters, and linear fiber array adapters for the *HoloSpec* spectrographs.

Model numbers for standard Raman gratings (Table A.1) are HSG-*XXX*-*YY*, where *XXX* is the excitation wavelength in nanometers, and *YY* is SA for Stokes/anti-Stokes, LF for low frequency and HF for high frequency. For example, the part number for a Raman grating for low-frequency coverage with 532-nm excitation is HSG-532-LF.

**Table A.1. Raman Gratings: Model Number, Spectral Coverage ($cm^{-1}$, relative to excitation), Average Reciprocal Linear Dispersion ($cm^{-1}$/pixel), and Part Number.**

| Excitation Wavelength (nm) | Stokes/Anti-Stokes Grating | Low-Frequency Stokes Grating | High-Frequency Stokes Grating |
|---|---|---|---|
| 514.5 | HSG-514.5-SA<br>–1054 to 1577 $cm^{-1}$<br>2.7 $cm^{-1}$/pixel<br>2004370-517 | HSG-514.5-LF<br>–204 to 2317 $cm^{-1}$<br>2.6 $cm^{-1}$/pixel<br>2004370-516 | HSG-514.5-HF<br>2290 to 4491 $cm^{-1}$<br>2.2 $cm^{-1}$/pixel<br>2004370-515 |
| 532 | HSG-532-SA<br>–980 to 1559 $cm^{-1}$<br>2.6 $cm^{-1}$/pixel<br>2004370-520 | HSG-532-LF<br>–29 to 2388 $cm^{-1}$<br>2.4 $cm^{-1}$/pixel<br>2004370-519 | HSG-532-HF<br>2265 to 4387 $cm^{-1}$<br>2.1 $cm^{-1}$/pixel<br>2004370-518 |
| 632.8 | HSG-632.8-SA<br>–1150 to 1026 $cm^{-1}$<br>2.2 $cm^{-1}$/pixel<br>2004370-523 | HSG-632.8-LF<br>–2 to 2027 $cm^{-1}$<br>2.1 $cm^{-1}$/pixel<br>2004370-522 | HSG-632.8-HF<br>1958 to 3735 $cm^{-1}$<br>1.8 $cm^{-1}$/pixel<br>2004370-521 |
| 647 | HSG-647-SA<br>–983 to 1127 $cm^{-1}$<br>2.1 $cm^{-1}$/pixel<br>2004370-526 | HSG-647-LF<br>–33 to 1955 $cm^{-1}$<br>2.0 $cm^{-1}$/pixel<br>2004370-525 | HSG-647-HF<br>1877 to 3620 $cm^{-1}$<br>1.8 $cm^{-1}$/pixel<br>2004370-524 |
| 752 | HSG-752-SA<br>–984 to 1173 $cm^{-1}$<br>2.2 $cm^{-1}$/pixel<br>2004370-529 | HSG-752-LF<br>–34 to 1979 $cm^{-1}$<br>2.0 $cm^{-1}$/pixel<br>2004370-528 | HSG-752-HF<br>1901 to 3622 $cm^{-1}$<br>1.7 $cm^{-1}$/pixel<br>2004370-527 |
| 785 | HSG-785-SA<br>–1000 to 1072 $cm^{-1}$<br>2.1 $cm^{-1}$/pixel<br>2004371-506 | HSG-785-LF<br>–34 to 1894 $cm^{-1}$<br>2.0 $cm^{-1}$/pixel<br>2004371-505 | HSG-785-HF<br>1794 to 3446 $cm^{-1}$<br>1.7 $cm^{-1}$/pixel<br>2004371-504 |
| 830 | HSG-830-SA<br>–980 to 987 $cm^{-1}$<br>2.0 $cm^{-1}$/pixel<br>2004371-509 | HSG-830-LF<br>14 to 1831 $cm^{-1}$<br>1.8 $cm^{-1}$/pixel<br>2004371-508 | HSG-830-HF<br>1752 to 3306 $cm^{-1}$<br>1.6 $cm^{-1}$/pixel<br>2004371-507 |

Model numbers for fluorescence (HFG) and visible (HVG) gratings (Table A.2) are simply HFG-*XXX* and HVG-*XXX*, where *XXX* is the excitation wavelength in nanometers.

**Table A.2. Fluorescence and Visible Gratings: Spectral Coverage and Linear Dispersion.**

| Model | Spectral Coverage (nm) | Linear Dispersion (nm/pixel) | Part number |
|---|---|---|---|
| HFG-539.5 | 411.4 to 667.6 | 0.26 | 2004373-514 |
| HFG-550 | 419.4 to 680.6 | 0.26 | 2004373-502 |
| HFG-600 | 457.6 to 742.4 | 0.29 | 2004373-504 |
| HFG-650 | 495.7 to 804.3 | 0.31 | 2004373-506 |
| HFG-730.8 | 557.3 to 904.3 | 0.35 | 2004373-508 |
| HFG-750 | 571.9 to 928.1 | 0.36 | 2004373-510 |
| HFG-850 | 648.2 to 1051.8 | 0.41 | 2004373-512 |
| HVG-590 | 384.5 to 795.5 | 0.42 | 2004372-502 |
| HVG-800 | 521.3 to 1078.7 | 0.56 | 2004372-504 |
| HVG-821 | 535.0 to 1107.0 | 0.58 | 2004372-506 |

**Table A.3. Holographic Notch Filters.**

| Model | Description |
|---|---|
| HNPF-632.8AR-2.0 | 2.0" Holographic *SuperNotch-Plus* Filter, 632.8 nm (AR) |
| HSPF-532.0AR-2.0 | 2.0" Holographic *SuperNotch-Plus* Filter, 532 nm (AR) |
| HSPF-785.0AR-2.0 | 2.0" Holographic *SuperNotch-Plus* Filter, 785 nm (AR) |
| HSPF-514.5AR-2.0 | 2.0" Holographic *SuperNotch-Plus* Filter, 514.5 nm (AR) |
| HSPF-632.8AR-2.0 | 2.0" Holographic *SuperNotch-Plus* Filter, 632.8 nm (AR) |

**Table A.4. Optical Specifications of *SuperNotch-Plus* Filters.**

| | |
|---|---|
| Laser Attenuation<br>Optical density (averaged over entire clear aperture) | > 6.0 |
| Spectral Bandwidth<br>Wavenumbers between O.D. 0.3 or 50% transmission points<br>Nanometers between O.D. 0.3 or 50% transmission points | < 350 $cm^{-1}$ |
| Spectral Edgewidth<br>Wavenumbers between O.D. 0.3 and O.D. 4.0 points<br>Nanometers between O.D. 0.3 and O.D. 4.0 points | < 150 $cm^{-1}$ |
| Available Wavelength Range | 488–1400 nm |

**Table A.5. Slits.**

| Model Number | Slit Width (microns unless otherwise indicated) | Part Number |
|---|---|---|
| SLIT-25 | 25 | 6001215 |
| SLIT-50 | 50 | 6001221 |
| SLIT-83 | 83 | 2004331-511 |
| SLIT-100 | 100 | 6001216 |
| SLIT-167 | 167 | 6001217 |
| SLIT-250 | 250 | 6001218 |
| SLIT-416 | 416 | 6001219 |
| SLIT-500 | 500 | 6001222 |
| SLIT-833 | 833 | 6001223 |
| SLIT-1000 | 1000 (1.00 mm) | 6001212 |
| SLIT-1670 | 1670 (1.67 mm) | 6001213 |
| SLIT-2000 | 2 mm | 303-20-400 |
| SLIT-4000 | 4 mm | 303-20-461 |

**Table A.6. Linear Fiber Array Adapters.**

| Model | Description | Part Number |
|---|---|---|
| LFAI-10 | 0.397" Linear Fiber Array Input Adapter Assembly (10 mm) | 2004204-502 |
| LFAI-12 | 0.475" Linear Fiber Array Input Adapter Assembly (12 mm) | 2004204-503 |
| LFAI-12.7 | 0.502" Linear Fiber Array Input Adapter Assembly (12.7 mm) | 2004204-504 |

**Table A.7. SMA Adapter.**

| Description | Part Number |
|---|---|
| SMA Input Adapter | 2004058-501 |
| SMA plunger only | 2003113 |

**Table A.8. Adapter Kits for Mounting CCD Cameras to *HoloSpec* Spectrographs.**

| Model | Part Number |
|---|---|
| Andor DV or DU series | 2005721-501 |
| C-Mount | 2005459-501 |
| Hamamatsu PMA-100 | 2005462-501 |
| Photometrics CH250 water-cooled | 2005433-501 |
| Photometrics CH250 air-cooled | 2005434-501 |
| Photometrics CH260 | 2005460-501 |
| Photometrics CH270 | 2005455-501 |
| Photometrics PXL | 2005461-501 |
| Princeton $LN_2$-cooled, with shutter | 2005430-501 |
| Princeton $LN_2$-cooled, no shutter | 2005431-501 |
| Princeton ICCD PentaMAX | 2005432-501 |
| Princeton NTE, no shutter | 2005439-501 |
| Princeton RTE, no shutter | 2005456-501 |
| Santa Barbara Spectrograph Group ST-6 | 2005436-501 |
| Thermo Oriel | 2005721-501 |
| Wright Spectrographs, TE-cooled | 2005437-501 |

# Appendix B. Cleaning Holographic Filters and Gratings

If you need to remove the holographic filter from its filter-mounting ring for cleaning, use the following procedure to avoid damage:

1. Wear finger cots or rubber gloves to avoid leaving fingerprints.
2. Remove the notch filter from the filter mount as shown in Figure 4.5. Be careful not to touch the surface of the notch filter; grasp it only by the filter-mounting ring.
3. Invert the filter-mounting ring and tap its front surface gently on a surface protected with optical tissues.
4. Follow the directions below, as appropriate. When replacing the notch filter in the filter mount, make sure that the words "Kaiser Optical Systems, Inc." face toward the slit and transmission grating.

Before cleaning, examine the element to determine the type of contamination that is present. It is important to know the types of contaminants and the correct method to remove the contaminant without adversely affecting the surface quality.

### Dust, Dirt, or Lint

Carefully remove dust and dirt particles with compressed air or nitrogen or by blowing with a rubber hand syringe. Do not touch the surface. Loosen particles by gently brushing with a camelhair brush, and blow the particles away.

### Oil, Grease, or Fingerprints

These contaminants are easily removed immediately after contamination. Use a soft tissue and acetone.

### Saliva or Water Spots

Use a water-based cleaning agent to loosen water or saliva spots, followed by acetone to remove the cleaning agent.

## Appendix C. Slit Curvature

The following is a sample calculation of the displacement of a ray impinged on a slit 4.000 mm above the optical axis. The general equation is

$$y = f_{output} \tan\left( \sin^{-1}\left\{ \sin\alpha - \frac{\lambda}{d} \right\} - \sin^{-1}\left\{ \sin\alpha - \frac{\lambda}{d\cos\left[ \tan^{-1}\left( \frac{x}{f_{input}} \right) \right]} \right\} \right) \quad (1)$$

where

$\alpha$ = input angle (45.00°)

$\lambda$ = wavelength (784.8 nm)

$x$ = vertical position along input slit (–4.000 to +4.000 mm)

$y$ = displacement from diffracted axis

$f_{input}$ = focal length of input lens (85.00 mm)

$f_{output}$ = focal length of output lens (85.00 mm)

$d$ = grating fringe spacing ($6.076 \times 10^{-4}$ mm)

The following is a sample calculation of the displacement from the diffracted axis of a ray with a wavelength ($\lambda$) of 784.8 nm striking the top of the input slit ($x$ = +4.000 mm). For the purposes of this calculation, the focal length will be assumed to be 85.00 mm. The calculation will be performed in segments of equation 1, starting with

$$d\cos\left[ \tan^{-1}\left( \frac{x}{f_{input}} \right) \right] = (6.083\times10^{-4}\,mm)\cos\left[ \tan^{-1}\left( \frac{4.000\,mm}{85.00\,mm} \right) \right] \quad (2)$$
$$= 6.076\times10^{-4}\,mm$$

Working out further,

$$\sin^{-1}\left( \sin\alpha - \frac{\lambda}{6.076\times10^{-4}\,mm} \right) = \sin^{-1}\left( \sin 45.00^{o} - \frac{7.848\times10^{-4}\,mm}{6.076\times10^{-4}\,mm} \right) = -35.77 \quad (3)$$

and

$$\sin^{-1}\left( \sin\alpha - \frac{\lambda}{d} \right) = \sin^{-1}\left( \sin 45.00^{o} - \frac{7.848\times10^{-4}\,mm}{6.083\times10^{-4}\,mm} \right) = -35.67 \quad (4)$$

Inserting these values into equation (1),

$$y = f_{output} \tan\left[(-35.67) - (-35.77)\right] = (85.00\,mm)\tan\left[(-35.67) - (-35.77)\right] \\ = 0.1484mm \approx 0.15\,mm \tag{5}$$

For these conditions, the displacement of the ray at the top of the slit is approximately 0.15 mm.