



SKDAV Spectroscopy Kit

User Guide



















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Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

| Symbol | Description |
|---|--|
|  | Direct Current |
|  | Alternating Current |
|  | Both Direct and Alternating Current |
|  | Earth Ground Terminal |
|  | Protective Conductor Terminal |
|  | Frame or Chassis Terminal |
|  | Equipotentiality |
|  | On (Supply) |
|  | Off (Supply) |
|  | In Position of a Bi-Stable Push Control |
|  | Out Position of a Bi-Stable Push Control |
|  | Caution: Risk of Electric Shock |
|  | Caution: Hot Surface |
|  | Caution: Risk of Danger |
|  | Warning: Laser Radiation |
|  | Caution: Spinning Blades May Cause Harm |

Chapter 2 Safety

All statements regarding safety of operation and technical data in this instruction manual will only apply when the unit is operated correctly.



WARNING



This unit must not be operated in explosive environments.



WARNING



Make sure you use appropriate laser safety glasses during setup and operation.

Chapter 3 Introduction

Dichroic atomic vapor spectroscopy (DAVS) was first demonstrated in Helium in 1994 and has subsequently been demonstrated for a variety of elements, including Rubidium, Cesium and Potassium. The DAVS scheme is fairly simple: a magnetic bias field is applied to a gas cell. The two circular polarizations of a probe beam are detected differentially, creating an error signal suitable for laser locking. Chapter 5 offers a detailed discussion of the DAVS scheme.

DAVS is an attractive technique for many experiments, because of its simplicity, wide capture range, low power requirements and steep signal slope. Furthermore, no modulation of the laser frequency is necessary for the DAVS scheme to operate, eliminating power loss to side-bands and the need for expensive electro-optic modulators.

As a teaching tool, it allows a straightforward demonstration of the Zeeman effect. By adding or removing the magnetic bias field, the frequency shift of the atomic transitions can be quickly visualized, and the polarization dependence of the shift can be shown.

The Thorlabs *SKDAV* kit offers a proven set of components to construct a compact, fiber coupled spectroscopy setup. Easy to mount permanent magnets with optimized field strength facilitate setting up the dichroic atomic vapor spectroscopy and will save users time when adding such a stabilization technique to their Experiment. The *SKDAV/M* kit provides the same functionality with metric components. Both can easily be integrated with Thorlabs tunable laser kits or third-party tunable source to stabilize the laser frequency.

A preassembled version of the setup is available upon request. Please contact us at applications@thorlabs.com.

Chapter 4 Setup and Operation

4.1. Overview

Figure 1 shows a top view of the SKDAV kit when properly aligned. Light is coupled into the setup using an optical fiber. A *F220FC-780* collimates the light, which is then passed through a calcite polarizer in order to guarantee good polarization purity. The light then passes the magnet and vapor cell assembly. The quarter wave plate following the cell maps the circular polarizations onto linear polarizations, which are then separated using a Wollaston prism. The two polarizations exit the prism with an angle of roughly 20 degrees. Two folding mirrors are used to steer these beams onto the two photodiodes of the *PDB210A* balanced detector. An optional 1" square mirror is used to fold the beam path – this allows the complete setup to fit onto a 10x12" breadboard (part number *MB1012* for imperial, *MB2530/M* for metric setups, not included).

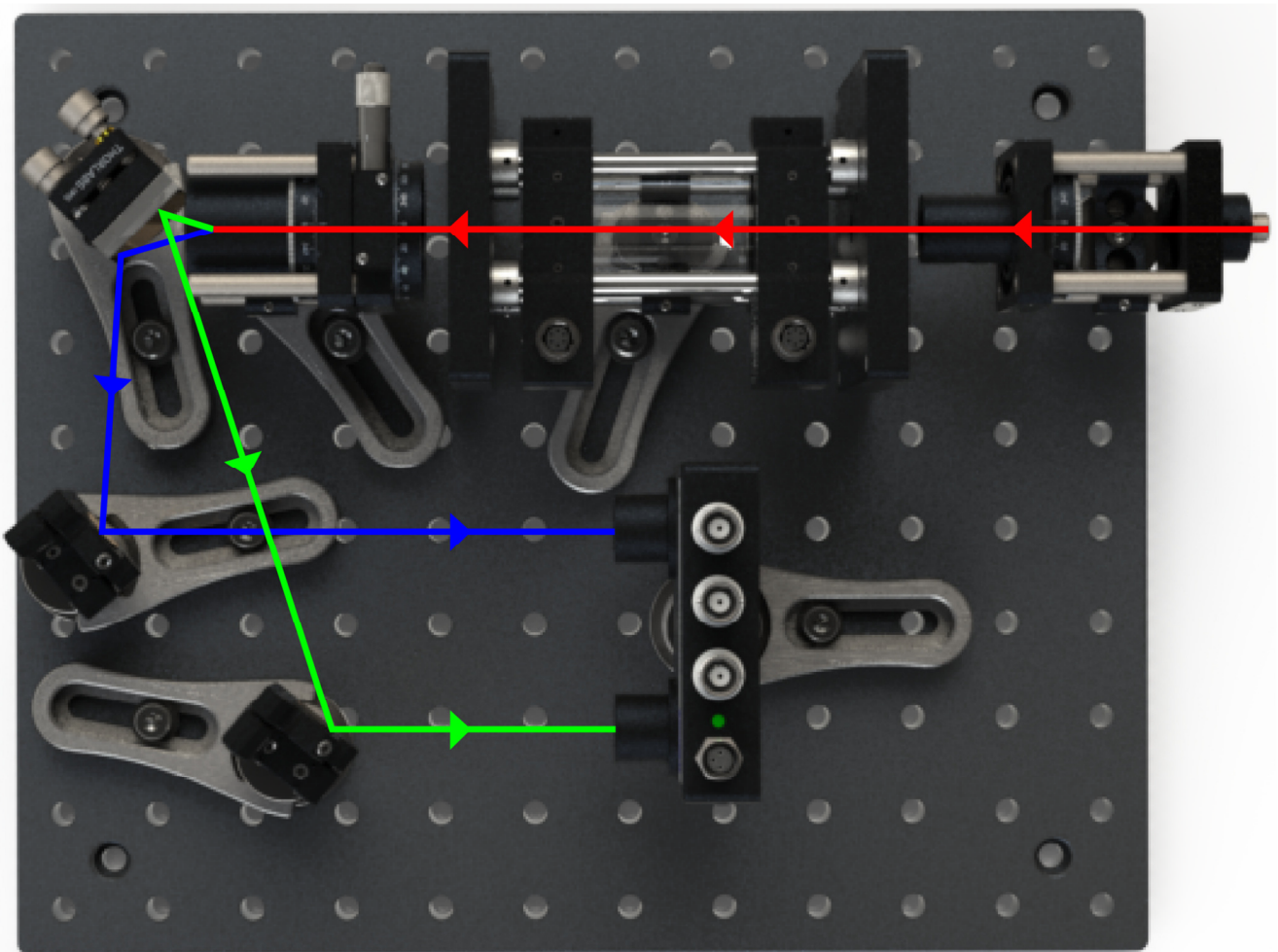


Figure 1 The Thorlabs SKDAV kit assembled on an MB1012 breadboard (not included). The red line designates the initially s-polarized beam crossing the vapor cell. The green and blue lines represent the right- and left circular components of the beam after passing the vapor cell.

4.2. Basic Setup

The following instructions detail the setup of the SKDAV spectroscopy kit. These instructions and Figure 1 refer to the kit as set up with a minimum footprint. For teaching labs, it is advisable to leave more space between components to give easy access to individual optics.

4.2.1. Assembling the fiber input

The first step is to assemble the fiber input. The complete assembly is depicted in Figure 2a.

- Mount the *AD11F* adapter in a *CP02* cage plate such that the set screws in the *A11F* face up, and secure the position with a *SM1RR* retaining ring on the front face of the adapter
- Insert the *F220FC-780* fiber collimator into the adapter. Rotate it so that the alignment notch faces left (looking at the fiber input) and secure it using the *AD11F*'s set screw.
- Remove the 4-40 set screws from four *ER2* cage rods and mount them in the *CP02* cage plate so that they are flush with the *CP02*, protruding in the direction that the collimator lens faces.
- Mount the *GL5-B* in the *SM05PM5*, and secure it using the set screw. Mount an *SM1A6* adapter in a *CRM1* cage rotation mount and secure it using an *SM1RR* retaining ring. Next, mount the *SM05PM5* in the *SM1A6* so that it points in the opposite direction from the angle scale on the rotation mount.
- Install the *CRM1* onto the 4 *ER2* rods, so that the polarizer points away from the fiber collimator.
- Rotate the Polarizer, so that the line indicator on the *SM05PM5* is horizontal.
- Mount an *RS075* (*RS19/M* for metric kits) post together with an RS5M post spacer directly to your table or breadboard, and attach the collimator assembly on top. Please refer to Figure 1 to get an idea about how to lay out the components before proceeding.

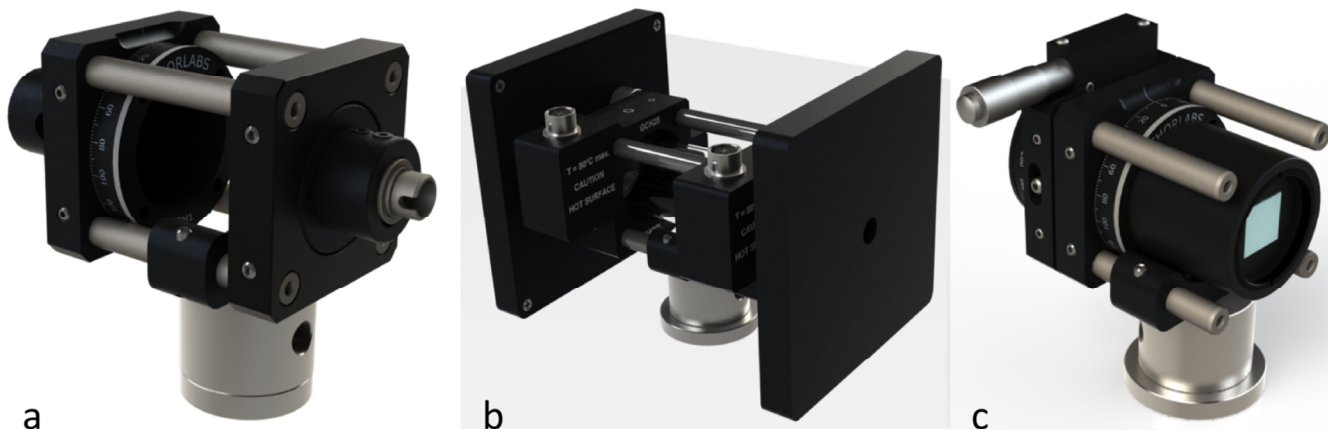


Figure 2 Sub-assemblies used in the SKDAV kit: a) fiber collimator and Glan-Taylor polarizer b) gas cell heater with bias magnets and c) quarter wave plate and Wollaston prism.

4.2.2. Mounting the vapor cell

- Attach a *BE1* post base adapter to an *RS075* (*RS19/M*) post, and mount the *GCH25-75* gas cell heater on top of it.
- Add four *ER05* cage rods to the ends of the *ER3* rods connecting the two ends of the gas cell heater. Rearrange the cage rods so that roughly $\frac{1}{4}$ "of them protrudes from each side of the gas cell heater. Remove the protruding 4-40 set screws.

- Install the vapor cell in the cell heater according to the GCH25-75 instruction manual.
- Attach an *SK-MAGNET* magnet cell to each end of the gas cell holder. The complete assembly is depicted in Figure 2b.
- Position the vapor cell assembly in your setup, such that the beam exiting the fiber collimator passes both apertures in the magnet cells, and secure it in place using a *CF125* clamp.

4.2.3. Mounting the output prism assembly

- Mount the *WP10-B* Wollaston prism in the *SMA1L10* lens tube using two *SM1RR* retaining rings (Obtain the 2nd *SM1RR* from the *CRM1* used in the subsequent steps). Using the *SPW602* spanner wrench, set the first retaining ring 0.65" into the lens tube. The second retaining ring should be flush with the end of the lens tube. The input side of the Wollaston prism, as indicated by the single beam engraved on its housing, should face the external threads of the lens tube.
- Remove the 4-40 set screws from two *ER2* cage rods. Mount a *CRM1P* and a *CRM1* back to back to each other on the *ER2* rods using the bottom two mounting holes. Leave a small gap between the mounts, so that both can rotate freely. Position the rods such that they are flush with the surface of the *CRM1P*.
- Install the *WPQ05M-780* quarter wave plate in the *CRM1P* and secure it with an *SM1RR* retaining ring. Loosen the *CRM1P*'s set screw to disengage the micrometer, and rotate the wave plate so that its fast axis is set to 45 degrees with respect to the *CRM1P*'s edges.
- Tighten the *CRM1P* set screw so that the micrometer is engaged. Test that you can rotate the wave plate back and forth using the micrometer. If it doesn't rotate, the *CRM1* is mounted too close to the *CRM1P*.
- Install a *CP02B* onto the cage rods, and mount it onto an *RS075 (RS19/M)* post. Attach a *BE1* pedestal post adapter to the bottom of the post and position the assembly in your setup and secure it using a *CF125* clamp.
- Install the lens tube containing the Wollaston prism in the *CRM1* cage rotation mount. You should observe two beams exiting the Wollaston prism. Rotate the prism so that the beams define a plane parallel to your breadboard or table, and lock the *CRM1*. The complete assembly is shown in Figure 2c.

4.2.4. Mounting the square mirror

- Use epoxy (item number *G14250*, included) or optical adhesive to mount the *PFSQ10-03-M01* mirror to the front surface of the *KMS* mount.
- Attach a *BE1* base adapter to an *RS1 (RS25/M)* post, and mount the *KMS* to the post once the adhesive has cured.
- Use a *CF125* clamp to mount the mirror at roughly 45° as close to the Wollaston prism as possible, so that the beam passing closer to the *SM1L10* still clears it, without being clipped (refer to Figure 1 for a diagram of the beam path).

4.2.5. Mounting the folding mirrors

- Mount two *PF05-03-M01* mirrors in *KS05* mounts.
- Attach *BE1* base adapter to two *RS1 (RS25/M)* posts and mount the *KS05*s on the posts using the included *AE8E25E (AE4M6M)* adapters.
- Position the two mirrors so that they direct the two beams coming from the square mirror in parallel, 2 inches apart, and secure them using *CF125* clamps.

4.2.6. Mounting the balanced detector

- Mount the *PDB210A* detector on an *RS075 (RS19/M)* post, with an *RS5M* post spacer and add a *BE1* pedestal adapter to the bottom.
- Attach two *SM05L05* lens tubes to the *PDB210A* photodiode inputs.
- Use a *CF125* clamp to mount the balanced detector downstream from the two folding mirrors, so that the two beams impinge on the two photo diodes.

4.3. Aligning the SKDAV kit

Check that the *LDS1212* power supply is set to the correct voltage level for your country. Failure to set the correct voltage can damage the power supply and the balanced detector!

- Attach the *LDS1212* power supply to the balanced detector, and check that the detector turns on (i.e. the green LED on top lights up).
- Couple a small amount of power, roughly 500 μW into a polarization maintaining optical fiber. For a Rubidium setup, Thorlabs part number *P1-780PM-FC-5* is a suitable fiber; for Potassium, *P1-630PM-FC-5* may be used. When using 3rd party fiber cables, ensure that the slow axis of the fiber is aligned with the connector key.
- Attach the fiber to the fiber collimator and rotate the fiber input assembly so that the beam passes through the center of both magnets.
- Rotate the Wollaston prism so that the two output beams run parallel to the breadboard surface. It is helpful to remove the square mirror for this step.
- Replace the square mirror if you removed it for the previous step. Align the mirror so that both beams clear the lens tube, and so that the bisecting line of the two beams runs at roughly 90 degrees to the axis of the vapor cell.
- Place the two folding mirrors such that they are roughly in line with the photodiodes of the balanced detector. Now move them parallel to the vapor cell, so that they each reflect one of the beams. Rotate the mirrors so that they roughly steer their respective beam onto the photodiode they are lined up with, and affix them using the *CF125* clamps.
- At this point, ensure that your laser is not on resonance with the vapor cell and attach a voltmeter or oscilloscope to the monitoring outputs of the balanced detector. Use the folding mirrors to maximize the output signal of both photodiodes. If the signals are close to or exceeding 10V, reduce the optical input power. After maximization, rotate the quarter wave plate so that the monitoring signals are roughly of equal magnitude. If you have to rotate the wave plate more than a few degrees, your laser is likely in resonance with the atomic vapor.
- Connect your voltmeter or oscilloscope to the RF output of the balanced detector and null the output using the quarter wave plate.

Your *SKDAV* system is now aligned. If you set your laser to scan over a resonance of your gas, you will be able to record a spectrum similar to the one shown in Figure 3. You can now adjust the input power to optimize the signal.

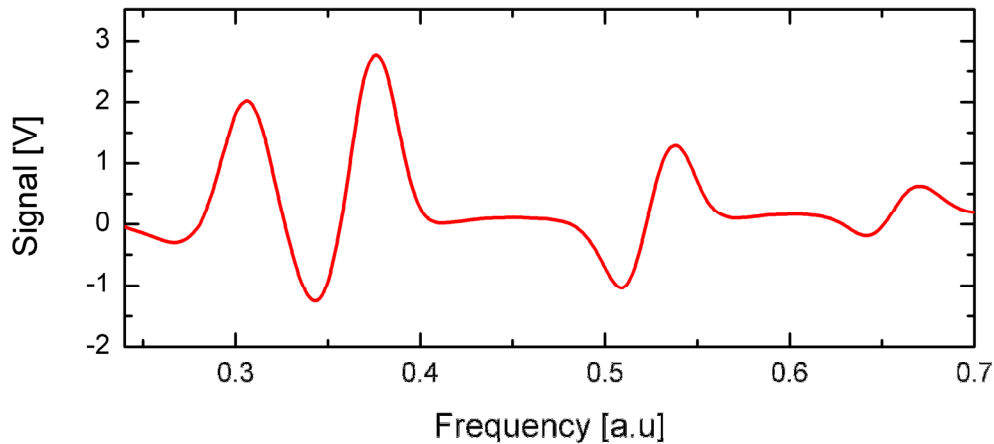


Figure 3 DAVS signal of the Rubidium D2 lines, recorded using a Thorlabs TLK-L780M tunable laser kit.

4.4. Temperature stabilization of the vapor cell

The Thorlabs SKDAV spectroscopy kit allows the heating and temperature stabilization of the included vapor cells. For this purpose, two 6-pin Hirose connectors are available on the gas cell assembly.

The Thorlabs TC200 temperature controller (not included) can directly interface with the connectors. Please refer to the TC200 user manual for setup instructions.

For use with 3rd party controllers, the pin-out for the gas cell heater connectors are defined in Figure 4. The mating connector is Hirose part number HR10A-7P-6PC(73), and can be procured from various electronics suppliers (e.g. DigiKey part number HR1665-ND).

The sensor employed in the spectroscopy system is a TH100PT platinum resistive sensor. The sensor response is given by

$$R(t) = 100\Omega \cdot \left(1 + 3.9083 \cdot 10^{-3} \frac{1}{^\circ\text{C}} t - 5.775 \cdot 10^{-7} \frac{1}{^\circ\text{C}^2} t^2 \right)$$

Here, R(t) is the temperature dependent resistance of the sensor, and t is the temperature in degrees Celsius.



| Pin | Function |
|-----|---------------------------|
| 1 | Heater |
| 2 | Heater Return |
| 3 | Reserved |
| 4 | Temperature Sensor |
| 5 | Temperature Sensor Return |
| 6 | Reserved |

Figure 4 The gas cell heater connector employs a Hirose 6-pin connector. The pin out is given on the right.

Chapter 5 Theory of Operation

Dichroic Atomic Vapor Spectroscopy is based on the Zeeman shift in ground state atoms to generate a signal suitable for laser locking. In the absence of a magnetic field, the absorption of an atomic vapor is independent of the polarization of the excitation source. This is shown by the red line in Figure 5. If a magnetic field is applied along the propagation axis of the probe beam, the left (right) circularly polarized light will be absorbed at lower (higher) frequencies, as denoted by the green (blue) lines of Figure 5.

To create the DAVS signal, the two polarization signals are detected independently from one another. In practice, one uses a quarter wave plate. The wave plate, with its slow axis oriented at 45 degrees maps the left and right circularly polarized light onto the linear s- and p-states, respectively.

The s- and p-polarization are then split using a Wollaston prism and detected independently. The two signals are subsequently electronically subtracted from one another to generate the DAVS signal, which is plotted in pink in Figure 5.

The zero-crossing of the DAVS signal allows for direct stabilization of a laser's frequency to the signal using a servo loop, without using electronic offsets.

By rotating the quarter wave plate, the two polarizations can be weighted differently. This consequently tunes the position of the zero crossing, and thus the frequency of a laser locked to the signal. Furthermore, the zero-crossing is independent of laser power fluctuations, aiding the stability of the lock. The SKDAV kit includes a micrometer-driven rotation mount for the quarter wave plate, which facilitates small shifts in laser frequency.

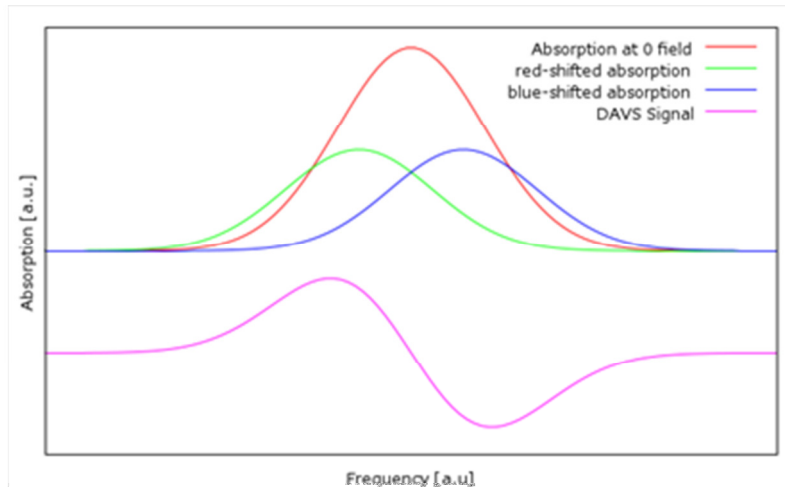


Figure 5 Origin of the DAVS signal. With no magnetic bias field, a Doppler-broadened absorption profile (red line) is observed. When applying a bias field, the Zeeman shift can be observed by polarization – one signal is shifted red (green line), the other blue (blue line). By differentially detecting the signals, the DAVS signal (purple line) is generated.

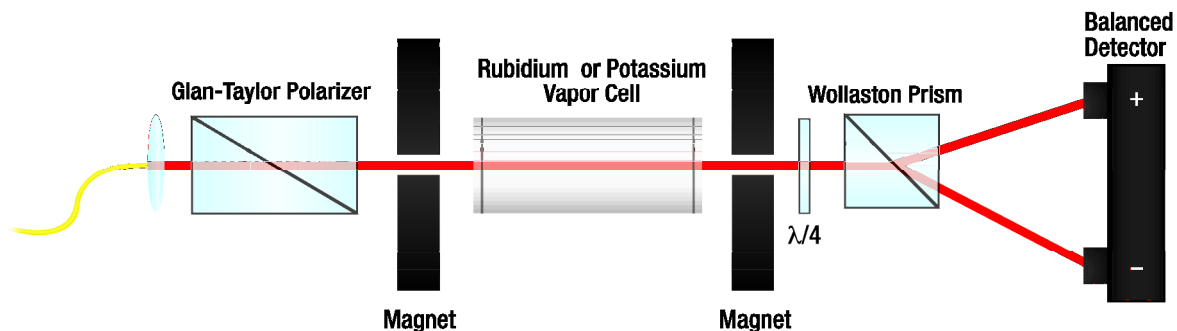


Figure 6 Schematic representation of the Thorlabs SKDAV kit. The input light is polarized with high purity by a Glan-Taylor polarizer. After passing the vapor cell, the two circular components of the beam are mapped onto the two photo diodes of a balanced detector, using a quarter wave plate and a Wollaston Prism.

Chapter 6 Troubleshooting

| Issue | Resolution |
|---|---|
| There is no spectroscopy signal present | <ul style="list-style-type: none"> • Ensure that your laser is on-resonance using a wavemeter or spectrum analyzer, and that it is scanning over a few GHz. Alternatively, you can use a camera to observe fluorescence emitted by the vapor cell when the laser is on resonance. • Check that the power supply is connected to the balanced detector, that the power supply is turned on and set to the correct voltage setting for your region. • Ensure that there is light coupled into the input fiber, and that it has the correct polarization. |
| The spectroscopy signal is small | <ul style="list-style-type: none"> • Increase input power |
| The spectroscopy signal shows artifacts and is distorted | <ul style="list-style-type: none"> • Decrease input power |

Chapter 7 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return “end of life” units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out “wheelie bin” logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated



Wheelie Bin Logo

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:

- Pure OEM products, that means assemblies to be built into a unit by the user (e. g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

7.1. Waste Treatment is Your Own Responsibility

If you do not return an “end of life” unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

7.2. Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

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