EDU-FOP1 - July 06, 2020

Item # EDU-FOP1 was discontinued on July 06, 2020. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

FOURIER OPTICS EDUCATIONAL KIT

OVERVIEW

Fourier Optics Kit

The Fourier Optics Kit allows students to manipulate the image on the camera by filtering the pattern in the Fourier plane. Here we show how to manipulate the image of cross lattice using a variable, rotatable slit.

- Designed for Educational, Demonstration, and Classroom Use
- Complete Photonics Kit Includes All Hardware and Tools (Computer Not Included)
- Includes Extensive Manual for Easy Assembly and Use
- Choose from Educational Kits Containing Imperial or Metric Components

Download Manual and Educational Materials

Educational Kit Details

- Understand the Principles of Fourier Optics Using a 4f Optical Setup
- Manipulate Images of 14 Chrome-on-Glass Microstructured Patterns
- Investigate Formation and Manipulation of Images in the Context of a Microscope
- Demonstrate Various Image Processing Techniques

In an imaging system, such as a microscope, image formation can be understood as the interference of light diffracted by the sample and collected by the objective lens. The Fourier transform of the object is projected onto the back focal plane of the lens, otherwise known as the Fourier plane, a fact not described by simple geometric optics. The image of the object, which is formed by a second lens, can be altered in a variety of ways by manipulating the pattern in the Fourier plane. The study of Fourier optics allows students to enhance their understanding of Fourier transforms and image formation.

In this kit, an etched, chrome-on-glass target with fourteen different patterns serves as the object. A beamsplitter and lens project the pattern from the Fourier plane onto a screen for direct viewing. Students alter the patterns in the Fourier plane using a chrome-on-glass mask, rotating slit, or iris. The extensive manual provides mathematical and theoretical background material as well as many exercises for students to demonstrate the various optical effects that can be achieved with Fourier Optics.

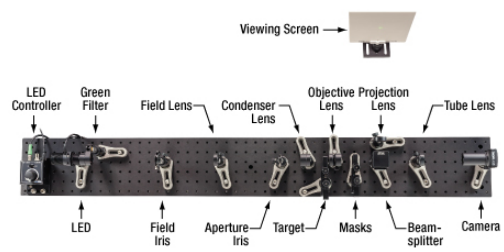
Thorlabs Educational Products

Thorlabs' educational line of products aims to promote physics, optics, and photonics by covering many classic experiments, as well as emerging fields of research. Each kit includes all the necessary components and a manual that contains both detailed setup instructions and extensive teaching materials. These educational lab kits are being offered at the price of the included components, with the educational materials offered for free. Technical support from our educational team is available both before and after purchase.

Purchasing Note: Both English and German language manuals/teaching information are available for this product. The imperial educational kit contains the English manual and US-style power cord. The appropriate manual and power cord will be included in the metric kit based on your shipping location. The power supplies and other electronic devices in both the metric and the imperial kit accept voltages from 100 to 230 VAC. Please contact Tech Support if you need a different language, cord style, or power supply. As with all products on our website, taxes are not included in the price shown below.

E X P E R I M E N T

Thorlabs' Educational Fourier Optics Kit is designed for classroom, lab, and other educational uses. As shown in Figure 1, the kit is a horizontal, 4f microscope setup with a perpendicular arm after the objective lens to allow direct viewing of the Fourier transform pattern created by the object. The CMOS viewing camera at the end of the setup must be connected to a PC to view the final image. The setup allows students to see the manipulations in the Fourier pattern and observe the resulting image simultaneously.



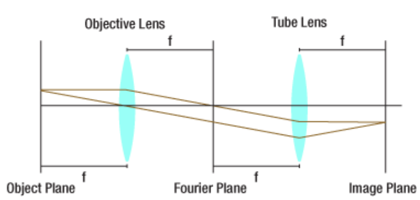
Click to Enlarge
Figure 1. Horizontal Microscope Assembly from the Fourier Optics Kit

The manual accompanying the kit contains theoretical and mathematical background material for introducing students to the main concepts of Fourier transforms, Fourier optics, and basic microscope theory. The manual also provides detailed setup instructions and a series of exercises ranging from simple to complex that allow students to explore image manipulation through Fourier optics.

Building a 4f Setup with LED Illumination

The first exercise in the kit has students assembling a 4f setup, shown in Figure 2, with LED illumination. The setup also serves as a horizontal infinity-corrected microscope. The system uses Kohler illumination techniques to create uniform illumination with independently adjustable intensity and spot size. The simplified nature of the setup allows students to see all of the working principles of a microscope and a 4f system clearly, as none of the optics are hidden in a microscope body or objective housing. The preliminary exercises introduce students to the function of the individual lenses before the full system is assembled.

When the full system is complete, an illuminated target (Figure 3) etched with various patterns is placed in the objective plane, and the resulting image is projected by the tube lens onto the camera which is in the image plane. A beamsplitter placed in the infinity space between the Fourier plane and the tube lens projects the pattern from the Fourier plane onto a viewing screen.



Click to Enlarge
Figure 2. Schematic of a 4f Setup

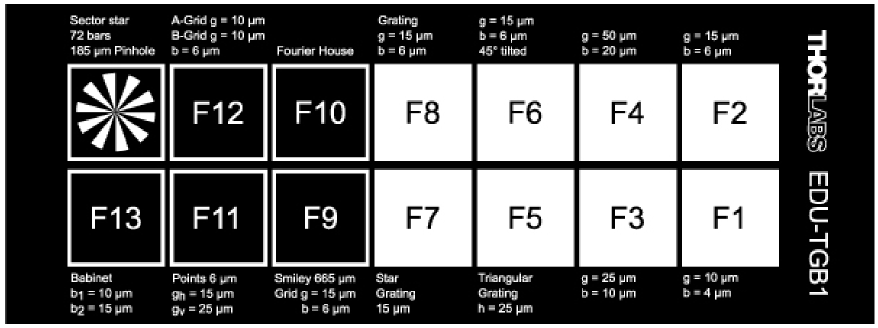
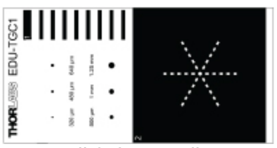


Figure 3. Diagram of Chrome-on-Glass Target Supplied with Fourier Optics Kit: Click on the numbered sections to see a detailed drawing of the pattern in each section. The white text along the edges of the slide is etched into the glass, but all other lines and dimensions shown in the detailed drawings are provided for reference only and do not appear on the actual slide. Black areas indicate chrome coating, and white areas indicate clear glass.

Manipulating Images

The majority of the exercises in the manual show students how to use Fourier optics to manipulate the final image projected on the camera. Various masks, slits, and irises are placed in the beam path at the Fourier plane before the beamsplitter so the changes to the pattern can be observed on the screen. The camera simultaneously displays the change in the final image. Students learn which portions of the Fourier transform pattern carry information about each part of the image.



Click for Details

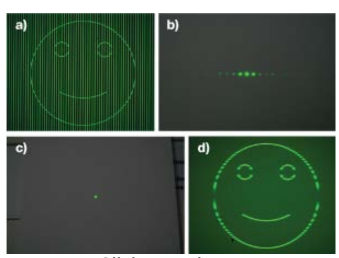
Figure 4. Diagram of Chrome-on-Glass Mask Supplied with Fourier Optics Kit

The custom-etched, chrome-on-glass target supplied with the kit offers fourteen different patterns and images convenient for Fourier filtering. The target features four cross gratings each with a different lattice constant, a triangle grating, a star grating, a series of houses composed of differently angled line gratings, overlapping letters, and a smiley face behind bars. Click on Figure 3 above to see the full layout of the target and detailed dimensions for each target section.

The kit also comes with a custom-etched, chrome-on-glass mask specifically designed to filter patterns in the Fourier plane. The mask features a series of dots of various sizes for masking the main maximum of a Fourier pattern, precision-aligned bars for masking every other maxima in a line pattern, and a custom star-shaped pattern designed to block out every other maxima in the Fourier transform pattern of the triangle lattice seen in Figure 7. Figure 4 shows the details of the mask.

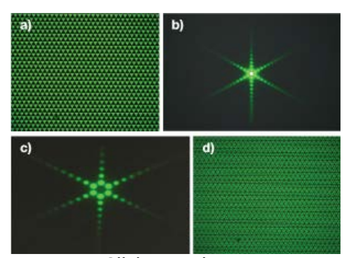
The optical exercises range from simple filtering of a cross lattice to create diagonal lines, as seen in Figure 5, to separating a smiley face from prison bars (Figure 6). Students also explore other optical concepts such as Babinet's principle which states that, apart from the zeroth order, diffraction patterns of complementary structures are identical. Using a dot mask, students can block the zeroth order of the diffraction pattern of a lattice of complementary green and black triangles (Figure 7). When the zeroth order is blocked, all information on the difference between the triangles is lost, and the resulting image shows nothing but green triangles.

Students will also complete exercises demonstrating imaging effects such as soft focus (the removal of higher diffraction orders) and edge highlighting (the blocking of low orders). The kit also includes custom diffractive optical elements which project images into the Fourier plane instead of into the image plane. There is also an exercise demonstrating why microscope imaging is diffraction limited.



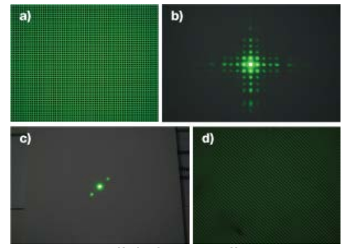
Click to Enlarge

Figure 6. A smiley face behind bars (a) generates a Fourier pattern of dots (b). When a slit is used to block all but the zeroth order of the pattern (c), the bars disappear and the smiley is free (d).



Click to Enlarge

Figure 7. Babinet's Principle is demonstrated with a triangle grating (a). The zeroth order of the pattern (b) is blocked with a dot mask (c), and the resulting image (d) shows a matrix of identical triangles.



Click for Details

Figure 5. A cross-lattice target (a) creates a pattern in the Fourier plane (b). A diagonal slit masks part of the Fourier pattern (c), and the resulting image is diagonal lines (d).

ALTERNATE SETUPS

Alternate Setups for the Fourier Optics Kit

We offer two alternative setups to the standard Fourier Optics Kit as custom orders. First, we offer a setup on an optical rail for ease of alignment and adjustment. Second, we offer a compact version of the kit modified for use with a laser light source instead of an LED.

Click to Enlarge

The rail configuration of the Fourier Optics Kit easily aligns all the elements along a single optical axis.

Rail Configuration

The majority of the optical components in this setup need to be positioned along a single axis. For situations like these, some educators prefer to limit the degrees of freedom by using an optical rail. For convenience, we created a rail-based configuration with our XT34 rails and the XT34TR1 carriers.

The rail system, by locking all of the elements onto a single horizontal line, eliminates the need for precise positioning in the lateral direction, which is advantageous for students with little optical lab experience. A rail-based system also reduces the time required to set up and adjust the experiment. However, the standard EDU-FOP1(/M) kit gives students the opportunity to learn how to align a complex optical system on a breadboard as is typical of a lab environment.

If you are interested in purchasing the Fourier Optics Kit on a rail, please contact Tech Support.

Laser Configuration

A Fourier Optics setup can use a laser for illumination instead of an LED. This choice comes with a few advantages and a few disadvantages.

Click to Enlarge

The laser configuration of the Fourier Optics Kit allows for a more compact setup with higher intensity in the Fourier plane.

Advantages:

Laser illumination provides much higher intensity for the diffraction pattern in the Fourier plane. A laser exceeds the intensity of an LED substantially, so the Fourier plane will be much easier to observe.

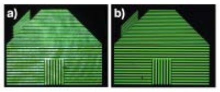
The use of a laser also eliminates the need for several components. Thus, the setup becomes more compact and simpler to adjust. This can be helpful when students either have little time or little experience in setting up optical experiments. Our CPS532-C2 laser diode module has a beam diameter large enough to illuminate the target without requiring beam-expanding optics and is ideally suited for use in this experiment.

Disadvantages:

There are three main disadvantages that come with switching from an LED set up for Koehler illumination to a laser.

First, the analogy with a standard microscope is reduced. Since the collecting and field lenses as well as the field and aperture irises are missing from the setup, any demonstrations involving Koehler illumination and aperture manipulation will be impossible.

A second disadvantage is that the image of the laser's intensity profile is projected onto the camera. Since laser modules do not have a homogeneous intensity pattern, artifacts will appear in the images of the targets. For example, one of our



Click to Enlarge
Image with Laser Source (a)
vs. Image with LED Source (b)

CPS532-C2 laser diode modules produces a bright ring-shaped structure in the left half of every pattern. The image to the left shows a comparison between laser and LED illumination. Since each laser diode module differs slightly, each laser configuration setup will show different artifacts.

Finally, experiments that study the role of coherence (as discussed in section 9.1 of the manual) are not possible.

If you are interested in purchasing the Fourier Optics Kit with a laser source instead of the LED, please contact Tech Support.

COMPONENT LIST

Fourier Optics Kit Components

Thorlabs' Fourier Optics Educational Kits are available in imperial and metric versions. In cases where the metric and imperial kits contain parts with different item numbers, metric part numbers and measurements are indicated by parentheses unless otherwise noted.

Item #	Description	Qty.
Mechanical Components		
MB648 (MB15120/M)	Aluminum Breadboard, 6" x 48" (15 cm x 120 cm)	1
RDF1	Rubber Feet, Set of Four	2
PH2 (PH50/M)	2" (50 mm) Post Holder	11
BE1 (BE1/M)	Pedestal Base Adapter	11
CF125	Clamping Fork	13
TR2 (TR50/M)	Ø1/2" Post, 2" (50 mm) Long	12
TR1.5 (TR30/M)	Ø1/2" Post, 1.5" (30 mm) Long	2
EDU-VS1 (EDU-VS1/M)	Viewing Screen	1
BA2 (BA2/M)	Mounting Base	1
PH1.5 (PH30/M)	1.5" (30 mm) Post Holder	1

PH2E (PH50E/M)	2" (50 mm) Pedestal Post Holder	4
Targets and Masks		
-	XY Mount for 1" to 3" Rectangular Optics	2
-	Micro-Structured Target, Chrome on Glass	1
VA100 (VA100/M)	Variable Slit	1
RSP1D (RSP1D/M)	Rotation Mount for Ø1" Optic with Adjustable Zero	1
SM1A6	Threaded Adapter, Internal SM05 to External SM1	1
SM05T2	Threaded Adapter, External SM05 to SM05	1
-	Micro-Structured Masks, Chrome on Glass	1
-	Diatoms Slide	1
FP01	Plate Holder	1
-	Inverse Fourier Target	1
-	Set of Labels	1

Item #	Description	Qty.
Light Source and Collimation		
MCWHL5[a]	Cool White LED, 1000 mA	1
LEDD1B	LED Driver	1
KPS101[b]	Power Supply	1
SM1RC (SM1RC/M)	Ø1.2" Slip Ring	1
SM1V10	SM1 Adjustable Lens Tube, 0.81" Adjustment	1
ACL2520U-A	Aspheric Condenser Lens, f = 20.1 mm	1
SM1RRC	Extra-Thick SM1 Retaining Ring	1
Optical Components		
TRF90 (TRF90/M)	90° Flip Mount	1
FB550-40	Bandpass Filter, 550nm, FWHM 40 nm	1
LMR1 (LMR1/M)	Ø1" Lens Mount	5
ID12 (ID12/M)	Iris, 12 mm Max Aperture, on TR3 (TR75/M) Post	2
ID25 (ID25/M)	Iris, 25 mm Max Aperture, on TR3 (TR75/M) Post	1
AC254-150-A	Ø1" Achromatic Doublet, f = 150 mm	2
SM1L05	SM1 Lens Tube, 1/2" Long	1
AC254-050-A	Ø1" Achromatic Doublet, f = 50 mm	1
SM1V05	SM1 Adjustable Lens Tube, 0.31" Adjustment	1
AC254-030-A	Ø1" Achromatic Doublet, f = 30 mm	1
KCP05 (KCP05/M)	Optic Mount Centering Plate	1
BS028	Beamsplitter Cube, 90:10 Reflection:Transmission	1
CCM1-4ER (CCM1-4ER/M)	Housing for Beamsplitter Cube	1
DCC1645C	CMOS Color Camera, 1280 x 1024 Pixels	1
SM1M20	Ø1" Lens Tube, 2" Long	1
SM1EC2B	Snap-On Plastic Dust Caps for SM1 Lens Tubes, 5 Pack	1
LB1901	Ø1" N-BK7 Bi-Convex Lens, f = 75.0 mm	1
LMR1AP	Alignment Plate for Ø1" Fixed Lens Mounts	1

Imperial Kit: Included Hardware and Screws

Item #	Description	Qty.	Item #	Description	Qty.
BD-3/16	3/16" Balldriver	1	SH25S038[c]	1/4"-20 Cap Screw, 3/8" Long	16
-	5/64" Hex Key	1	SH25S050[c]	1/4"-20 Cap Screw, 1/2" Long	8

-	9/64" Hex Key	1	SH25S063[c]	1/4"-20 Cap Screw, 5/8" Long	2
SPW606	SM1 Spanner Wrench	1	SH8S025[c]	8-32 Cap Screw, 1/4" Long	2
-	Ruler, 12" (30 cm)	1	-	#1/4 Washer	17

Metric Kit: Included Hardware and Screws

Item #	Description	Qty.	Item #	Description	Qty.
BD-5M	6 mm Balldriver	1	SH6MS10[c]	M6 Cap Screw, 10 mm Long	16
-	2 mm Hex Key	1	SH6MS12[c]	M6 Cap Screw, 12 mm Long	8
-	3 mm Hex Key	1	SH6MS16[c]	M6 Cap Screw, 16 mm Long	2
SPW606	SM1 Spanner Wrench	1	SH4MS06[c]	M4 Cap Screw, 6 mm Long	2
-	Ruler, 30 cm (12")	1	-	M6 Washer	17

- This previous-generation item is no longer available for individual purchase. For a replacement, please see the MCWHL6 Mounted LED.
- A location-specific adapter ships with the power supply based on your location.
- Screws may be reordered in larger quantities using these part numbers. The quantity shown in the table is the quantity of individual screws provided in the kit.

SOFTWARE

Software Download

We recommend operating this Fourier Optics Kit with the ThorCam™ software packages. A guide to software installation and settings can be found in the manual.

Gwyddion
The kit also makes use of Gwyddion, a popular program for image manipulation. The software package can be downloaded here.

ThorCam™ Camera Software

Version 3.4.1

The entire software package can be downloaded here.

Software

ACKNOWLEDGEMENTS

We would like to thank Kurt Thorn, formerly a Professor at the University of California, San Francisco, for his collaboration in the development of this kit. The prototype of the setup was published in his blog and used in an instructional video about Abbe differaction.

We cordially thank Anna Burvall from the KTH Royal Institute of Technology, Sweden, for sharing the idea for the Babinet field.

We would also like to thank Prof. Wilfried Sommer, head of the Institute for Subject-Related Methodology, for the Fourier house materials. The Institute for Subject-Related Methodology in Kassel is closely affiliated to Alanus University and has a strong link to the division for teaching materials of the Bildungswerk Beruf und Umwelt: http://www.lehrerseminar-forschung.de/shop/geraete/physik.html?klasse=3

We thank the team of the undergraduate lab of the Freie Universität Berlin for their idea for the quantitative measurements detailed in Chapter 9 of the manual.

Do you have ideas for an experiment that you would like to see implemented in an educational kit? Contact us through Tech Support; we'd love to hear your ideas.

Part Number	Description	Price	Availability
EDU-FOP1/M	Customer Inspired! Fourier Optics Educational Kit, Metric	$4,960.33	Lead Time
EDU-FOP1	Customer Inspired! Fourier Optics Educational Kit, Imperial	$4,960.33	Lead Time