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THORLABS

EDU-MINT1/M - November 26, 2018

Item # EDU-MINT1/M was discontinued on November 26, 2018. For informational purposes, this is a copy of the website content at that time and is valid only for the stated product.

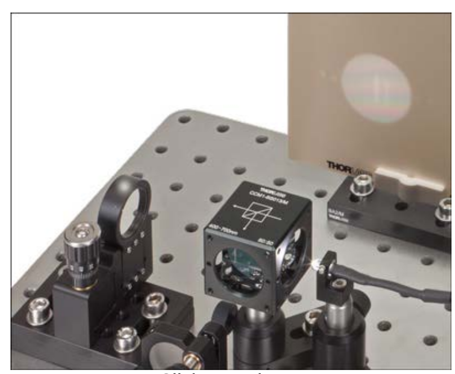
MICHELSON INTERFEROMETER EDUCATIONAL KIT

Hide Overview

OVERVIEW

Michelson Interferometer Educational Kit

- Designed for Educational, Demonstration, and Classroom Use
- Complete Photonics Kit Includes All Hardware Except Variable Power Supply for the Thermal Expansion Experiment (12 VDC, 2 A)
- Extensive Manual and Teaching Materials Provided
- Easy to Assemble and Use
- Choose from Educational Kits Containing Imperial or Metric Components


Click to Enlarge
White Light Interference Generated with the Michelson Interferometer Educational Kit

Download Manual and Educational Materials

Experiment

- Build and Examine the Properties of a Michelson Interferometer
- Examine the Second Output of the Interferometer
- Use the Interferometer as a Sensitive Spectrometer
- Generate White Light Interference
- Learn how the Interference Pattern is Affected by the Coherence Length of the Source
- Use the Interferometer to Measure the Physical Properties of Materials
    - Refractive Index of Plexiglas® Plates
    - Thermal Expansion Coefficient of an Aluminum Rod

Thorlabs' Michelson Interferometer Demonstration Kit highlights several ways that an interferometer can be used to take highly sensitive measurements. A laser and LEDs allow students to explore the concept of interference and examine how the coherence length of different light sources will affect the interferometer output. The interferometer can be aligned to produce white light interference using the included white LED, as shown in the photo to the right. Students can also use the lab setup to determine the refractive index of Plexiglas plates and the thermal expansion coefficient of an aluminum rod.

Thorlabs Educational Products

Thorlabs' line of educational products aims to promote physics, optics, and photonics by covering many classic experiments, as well as emerging fields of research. Each educational kit includes all the necessary components and a manual that contains both detailed setup instructions and extensive teaching materials. These 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: Each educational kit contains both the English and German language versions of the manual, as well as US-, UK-, European-, and Chinese-style power cords. The power supplies and other electronic devices in both the metric and the imperial kit accept voltages of 230 VAC and 120 VAC. Some power supplies include a switch for selecting the mains voltage. See the respective manuals for details. Please contact Tech Support if you need a different cord style or power supply. The educational kits can be made portable using the CPS1 5 VDC Battery Pack (sold separately) to power the laser diode module or LEDs. As with all products on our website, taxes are not included in the price shown below.

Hide Experiments

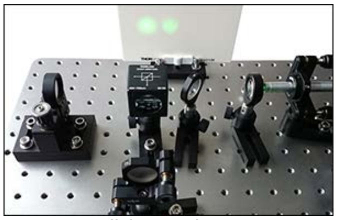
EXPERIMENTS

Thorlabs' Michelson Interferometer Kit allows students to build a basic Michelson Interferometer and use their system to measure physical properties of a laser source and several materials. The kit includes all of the components needed to create a functioning interferometer including light sources, mirrors, a beamsplitter cube, and screen. The manual (available on our website and included with each kit) includes an explanation of the underlying theory behind each experiment as well as detailed instructions. A summary of the experiments supported by the kit is provided below.

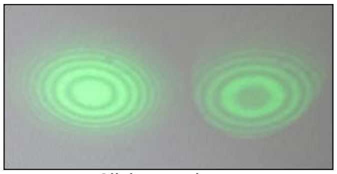
Michelson Interferometer

Students begin by building and aligning the interferometer so that they can observe the interference generated by the path length difference in the interferometer arms. The basic setup consists of a green laser source on a kinematic mount, a beamsplitter, one mirror mounted on a translation stage, a second mirror in a kinematic mount on a fixed post, and a screen, as shown in the schematic in Figure 1.

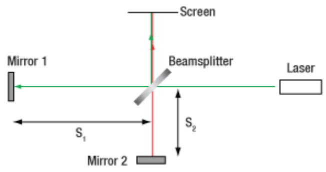
A common misconception among students is that light from the system is lost when destructive interference is observed on the viewing screen. To address this, an additional beamsplitter plate is included to allow students to observe the second output of the interferometer, i.e., the light that travels back towards the laser output, as shown in Figure 2. Students can see that when a bright spot is observed at the center of the interference pattern from the primary interferometer output, the secondary interferometer output has a dark spot at the center (see Figure 3). The light is simply re-distributed, not lost from the system.



Click to Enlarge
Figure 2. The kit includes a second beamsplitter that allows students to observe the output of the interferometer in the direction of the laser and compare it to the main output of the interferometer.



Click to Enlarge
Figure 3. A closeup of both interferometer outputs, as they appear on the screen in Figure 2. The output that propagates towards the laser is on the right, while the output that propagates perpendicular to the input laser is on the left.



Click to Enlarge
Figure 1. A Schematic of the Beam Path in a

Wavelength Measurement and Using the Interferometer as a Spectrometer

The kit guides students through an experiment that allows them to determine the wavelength of the included laser source, and then measure the wavelength difference between two spectral peaks in the laser's emission profile. To perform the first experiment, students count the number of light-dark-light transitions that occur as the mirror is moved a specified distance using a translation mount with a micrometer drive. Then, the wavelength can be calculated using the equation:

$$\lambda = \frac{2\Delta x}{N}$$

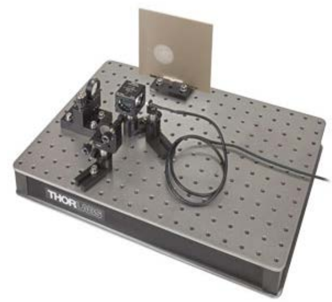
where Δx is the distance that the mirror is moved, N is the number of transitions, and λ is the wavelength of the laser.

Next, students can use the interferometer to determine the wavelength split of the peaks of the laser emission profile. Since the laser emits simultaneously at several different wavelengths, each wavelength will produce its own interference pattern. At certain path length differences between the interferometer arms, the interference patterns from two wavelength peaks will overlap perfectly and be visible with good contrast between the dark and light fringes. At certain distances, however, the bright fringes of one interference pattern will overlap with the dark fringes of the other interference pattern, producing a pattern with poor contrast. By measuring the change in path length difference as the contrast shifts from poor, to good, and back to poor, students can calculate the wavelength difference between the two peaks in the laser's emission spectrum.

Coherence Length and White Light Interference

A Michelson Interferometer provides an intuitive way to explore the concept of coherence length: in this context, the coherence length of a source corresponds to the maximum difference in path length between the interferometer arms that still allows interference to be observed. In this kit, students can use their setup to measure the coherence length of red and white LEDs, using the setup shown in Figure 4. After installing an LED in the interferometer, students adjust the position of one mirror until the interference pattern is close to disappearing. The coherence length should be approximately two times the difference between the positions of the two mirrors. They can then calculate an estimated coherence length from the wavelength and bandwidth of the source using the following equation:

$$\Delta L_c \cong \frac{\lambda_0^2}{\Delta\lambda}$$



Click to Enlarge
Figure 4. The kit includes a white light LED that can be used to observe white light interference, allowing students to explore the concept of coherence length.

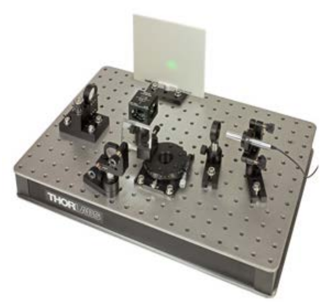
where ΔL_c is the coherence length, λ_0 is the center wavelength, and Δλ is the bandwidth, in order to compare their experimental results with theory.

After aligning their setup using the laser and red LED, students can place the included white LED in the setup to generate white light interference.

Determining the Refractive Index of a Material

The kit includes two Plexiglas® plates, 8 mm and 12 mm thick, so that students can use the interferometer to measure the refractive index of this material. A Plexiglas plate is placed into one of the interferometer arms perpendicular to the beam path (see Figure 5). Since the plate has a different index of refraction than the surrounding air, light passing through the interferometer arm with the plate will see a different effective optical path length than light in the other interferometer arm. If the plate is rotated, the thickness of the material in the beam path increases; as a result, the optical path length experienced by light traveling along that arm of the interferometer also changes. The change in optical path length can be determined by counting the number of light-dark-light transitions in the center of the interference pattern as the plate is rotated through a given angle. The refractive index, n, of the material can be calculated using the following equation:

$$n = \frac{\left(\frac{N\lambda}{2t} + \cos\alpha - 1\right)^2 + \sin^2\alpha}{2\left(-\frac{N\lambda}{2t} - \cos\alpha + 1\right)}$$



Click to Enlarge
Figure 5. Rotating a Plexiglas plate in one interferometer arm allows the refractive index to be measured.

where N is the number of light-dark-light transitions, λ is the wavelength of the laser light, t is the thickness of the Plexiglas plate, and α is the rotation angle of the plate. A detailed description of how to derive this equation based on the interferometer geometry is provided for students in the manual.

Measuring the Coefficient of Thermal Expansion

Click to Enlarge

Figure 6. One mirror of the interferometer is mounted on the end of an aluminum rod that is wrapped in a heater. The rod temperature is monitored, allowing the coefficient of thermal expansion to be calculated using the temperature change and total number of fringes that move out of the center of the interference pattern as the rod expands.

The final experiment enabled by the kit allows the thermal expansion coefficient of an aluminum rod to be measured using the kit. The rod is wrapped in a foil heater and mounted with a mirror attached to one end, as shown in Figure 6.* This assembly takes the place of the mirror at the end of one of the interferometer arms, and the setup is aligned so that interference is visible. A temperature sensor is inserted into the back end of the aluminum rod, allowing the rod temperature to be recorded. The resistive heater is connected to a voltage source, heating the rod and causing it to expand; this, in turn, causes the mirror position to shift. Students count the number of dark-light transitions that occur at the center of the interference pattern during this process, which corresponds to the change in the optical path length caused by the expansion of the rod due to heating. The coefficient of thermal expansion, α, can be calculated from the number of light-dark-light transitions and temperature change as follows:

$$\alpha = \frac{N\lambda}{2\, L_0\, \Delta T}$$

where N is the number of light-dark-light transitions, λ is the wavelength of the light source, L_0 is the original length of the rod, and ΔT is the temperature change.

*The necessary variable power supply to drive the heater is not provided in the kit.

Hide Kit Components

KIT COMPONENTS

Michelson Interferometer Educational Kit Components

Thorlabs' Michelson Interferometer Educational Kit is available in imperial and metric versions. In cases where the metric and imperial kits contain parts with different item numbers, metric measurements are indicated by parentheses unless otherwise noted.

	EDU-MINT1	EDU-MINT1/M	

Description	Item #	Item #	Qty.
Basic Interferometer Components			
Steel Breadboard, 12" x 18" (30 cm x 45 cm)	B1218FX	B3045AX	1
Rubber Damping Feet, Set of 4	RDF1		1
Collimated Laser Diode Module, 532 nm, Class II	CPS532-C2		1
5 VDC Regulated Power Supply with Phono Plug	LDS5[a]	LDS5-EC[a]	1
Ø1" Unthreaded Adapter for Ø11 mm Components	AD11NT		1
Ø1" Kinematic Mirror Mount	KM100		2
Ø1" Protected Silver Mirror	PF10-03-P01		2
Z-Axis Translation Mount	SM1ZP	SM1ZP/M	1
Height Spacer, 2" x 3" x 0.25" (50 mm x 75 mm x 6.25 mm)	BA2S5	BA2S5/M	1
Base, 2" x 3" x 3/8" (50 mm x 75 mm x 10 mm)	BA2	BA2/M	2
Plastic Viewing Screen	EDU-VS1	EDU-VS1/M	1
Ø1" Lens Mount	LMR1	LMR1/M	1
Ø1" N-BK7 Bi-Convex Lens, f = 50.0 mm	LB1471		1
Non-Polarizing Beamsplitter Cube, 400 - 700 nm	CCM1-BS013	CCM1-BS013/M	1
1.5" (30 mm) Long Universal Post Holder	UPH1.5	UPH30/M	4
Ø1/2" Post, 1.5" Long	TR1.5	N/A[b]	4
Ø12.7 mm Post, 30 mm Long	N/A[c]	TR30/M	2
Ø12.7 mm Post, 40 mm Long	N/A[c]	TR40/M	2
Components to Observe 2nd Interferometer Output			
Ø1" Economy Beamsplitter	EBS1		1
Ø1" Lens Mount	LMR1	LMR1/M	1
Ø1/2" (Ø12.7 mm) Post, 1.5" (40 mm) Long	TR1.5	TR40/M	1

- Our Michelson Interferometer Kits can be made portable using the CPS1 5 VDC Battery Pack (sold separately) to power the laser diode module or LEDs.
- This item is not included in the metric kit.
- This item is not included in the imperial kit.

Description	EDU-MINT1 Item #	EDU-MINT1/M Item #	Qty.
Refractive Index Measurement			
High-Precision Rotation Mount	PR01	PR01/M	1
General Purpose Plate Holder	FP01		1
Plexiglas Plate, 8 mm Thick	-		1
Plexiglas Plate, 12 mm Thick	-		1
Interference with LEDs			
Red LED with USB Connector, 635 nm[a]	-		2
White LED with USB Connector[b]	-		2
LED Mount	LEDMF		2
1.5" (40 mm) Long Universal Post Holder	UPH1.5	UPH40/M	2
Ø1/2" (Ø12.7 mm) Post, 1.5" (40 mm) Long	TR1.5	TR40/M	2
5 VDC Regulated Power Supply with USB	DS5[c]		1
72" USB 2.0 Type-A Extension Cable	USB-C-72		1
Ruler, 12" (30 cm)	-		1

Thermal Expansion Setup			
Mirror Holder for Ø1" Optics	MH25		1
Ø1" Aluminum Mirror	ME1-G01		1
Aluminum Post, Ø12.7 mm x 90 mm Long	-		1
Right-Angle Post Clamp	RA90	RA90/M	1
Ø1/2" (Ø12.7 mm) Post, 2" (50 mm) Long	TR2	TR50/M	1
1.5" (40 mm) Long Post Holder	PH1.5	PH40/M	1
Base, 1" x 2.3" x 3/8" (25 mm x 58 mm x 10 mm)	BA1S	BA1S/M	1
Digital Thermometer	-		1
Sensor	-		1
Foil Heater with 10 kΩ Thermistor	HT10K		1
Crocodile Clip to Banana Plug Cable	-		1
Electrical Tape	-		1

- This item consists of the LED631E LED connected to a 150 Ω resistor and a USB cable.
- This item consists of the LEDWE-15 LED connected to a 91 Ω resistor and a USB cable.
- Our Michelson Interferometer Kits can be made portable using the CPS1 5 VDC Battery Pack (sold separately) to power the laser diode module or LEDs.

Imperial Kit: Included Hardware and Screws

Description	Item #	Qty.
3/16" Balldriver for 1/4"-20 Cap Screws[a]	BD-3/16L	1
1/8" Hex Key[a]	-	1
3/32" Hex Key[a]	-	1
1/16" Hex Key[a]	-	1
1/4-20 Cap Screw, 1/4" Long	SH25S025[b]	2
1/4-20 Cap Screw, 3/8" Long	SH25S038[b]	1
1/4-20 Cap Screw, 1/2" Long	SH25S050[b]	4
1/4-20 Cap Screw, 5/8" Long	SH25S063[b]	9
1/4-20 Cap Screw, 3/4" Long	SH25S075[b]	4
8-32 Cap Screw, 1/4" Long	SH8S025[c]	3
8-32 Cap Screw, 3/8" Long	SH8S038[c]	1
8-32 Cap Screw, 5/8" Long	-	3
#1/4 Washer	W25S050[d]	15
1/4" Counterbore Adapter Ring for 8-32 Screws	SD1[e]	4

- Additional balldrivers and hex keys are available here.
- This kit contains the number of screws indicated in the Qty. column. Replacement screws, which are sold in packages of 25, are available by ordering the Item # listed.
- This kit contains the number of screws indicated in the Qty. column. Replacement screws, which are sold in packages of 50, are available by ordering the Item # listed.
- This kit contains the number of washers indicated in the Qty. column. Replacement washers, which are sold in packages of 100, are available by ordering the Item # listed.
- This kit contains the number of counterbore adapters indicated in the Qty. column. Replacement adapters, which are sold in packages of 10, are available by ordering the Item # listed.

Metric Kit: Included Hardware and Screws

Description	Item #	Qty.

5 mm Balldriver for M6 Cap Screws[a]	BD-5ML	1
3 mm Hex Key[a]	-	1
2 mm Hex Key[a]	-	1
1.5 mm Hex Key[a]	-	1
M6 Cap Screw, 8 mm Long	-	2
M6 Cap Screw, 10 mm Long	SH6MS10[b]	1
M6 Cap Screw, 12 mm Long	SH6MS12[b]	4
M6 Cap Screw, 16 mm Long	SH6MS16[b]	9
M6 Cap Screw, 20 mm Long	SH6MS20[b]	4
M4 Cap Screw, 6 mm Long	SH4MS06[c]	3
M4 Cap Screw, 10 mm Long	SH4MS10[c]	1
M4 Cap Screw, 16 mm Long	SH4MS16[c]	3
M6 Washer	W25S050[d]	15
M6 Counterbore Adapter Ring for M4 Screws	SD1[e]	4

- Additional balldrivers and hex keys are available here.
- This kit contains the number of screws indicated in the Qty. column. Replacement screws, which are sold in packages of 25, are available by ordering the Item # listed.
- This kit contains the number of screws indicated in the Qty. column. Replacement screws, which are sold in packages of 50, are available by ordering the Item # listed.
- This kit contains the number of washers indicated in the Qty. column. Replacement washers, which are sold in packages of 100, are available by ordering the Item # listed.
- This kit contains the number of counterbore adapters indicated in the Qty. column. Replacement adapters, which are sold in packages of 10, are available by ordering the Item # listed.

Hide Interferometry and LIGO

INTERFEROMETRY AND LIGO

Gravitational Wave Detection with Michelson Interferometers

A recent application of the Michelson interferometer that attracted a lot of international attention is gravitational-wave detection. Gravitational waves are oscillations in spacetime curvature produced by colliding black holes, neutron stars, and other astrophysical processes that involve a dense concentration of mass-energy moving at relativistic speeds. A network of laser interferometers has been constructed in several countries to detect these waves. This includes the Laser Interferometer Gravitational-wave Observatory (LIGO) in the United States, VIRGO in Italy, GEO600 in Germany, and KAGRA in Japan. All of these experiments consist of a Michelson interferometer with kilometer-scale arm lengths. The mirrors are suspended and free to swing in the plane of the interferometer. A passing gravitational wave will shrink the mirror-beamsplitter distance in one arm of the interferometer while stretching that distance in the other arm. The oscillating shrinking/stretching pattern induced by the passing wave is recorded as an oscillating signal in the photodetector.

On September 14, 2015 the twin LIGO detectors (in Washington state and Louisiana) made the first direct detection of a gravitational wave. The signal (which was measured with high confidence in both detectors) was produced by an orbiting pair of black holes that merged together about a billion light years away. This signal caused the LIGO mirrors to move by about 10^{-18} meters, or nearly one-thousandth the diameter of a proton. Michelson interferometers can thus perform some of the most sensitive length measurements possible. LIGO and its partner observatories are vastly more complicated than the interferometer in this kit, but the fundamental physical principle behind their operation is Michelson interferometry.

Click to Enlarge
Loud music with a strong bass line causes fluctuations in the interference pattern.

Once the Michelson interferometer is assembled, it can be used as a simple classroom demonstration of the operating principles behind gravitational-wave detectors like LIGO, Virgo, and GEO600. In those kilometer-scale interferometers the mirrors are free to swing in the plane of the interferometer in response to passing gravitational waves. Those waves shrink one arm of the interferometer while stretching the other. In our kit interferometer, the mirrors do not swing, but the effect of a gravitational wave can be mimicked by a local vibration of the table top or an acoustic source. This will change the relative length between the two arms, resulting in an oscillation of the fringe pattern and a change in brightness of the central maximum.

More information about LIGO and the detection of gravitational waves can be found here:
LIGO Scientific Collaboration Homepage

LIGO Laboratory Homepage
Advanced LIGO Project Homepage

We cordially thank the LIGO collaboration, in particular Marc Favata, Nancy Aggarwal, and Maggie Tse, for this addition to the webpage.

Hide Kit Comparison

KIT COMPARISON

Interferometer Demonstration Kit Comparison

Thorlabs offers three demonstration kits that make use of an interferometry setup. Each kit is designed to target a different topic and includes accessories to support the experiments described in the kit manual. The EDU-MINT1 interferometer kit is designed to explore the experimental uses of a Michelson Interferometer, while the EDU-BT1 and EDU-QE1 analogy demonstrations are designed to explore concepts in quantum mechanics. Due to the nature of the experiments in the EDU-MINT1 kit, an intrinsically damped breadboard is included to minimize vibrations as students interact with the setup. This added feature supports some of the more challenging experiments, especially the wavelength measurement and white light interference exercises. The other two demonstration kits are built on lighter, aluminum breadboards as the experiments outlined in these kits require less interaction with the setups and vibration is therefore less of an issue. The table below outlines the key features and educational topics addressed by each kit to aid in choosing the best option for your classroom.

Interferometer Type	**Michelson**		**Mach-Zehnder**
Kit Item #	**EDU-MINT1(/M)**	**EDU-BT1(/M)**	**EDU-QE1(/M)**
Description	**Michelson Interferometer Demonstration Kit**	**"Bomb Tester" Demonstration Kit**	**Quantum Eraser Demonstration Kit**
Kit Photo (Click to Enlarge)			
Underlying Concept	Use a Michelson Interferometer as a Sensitive Instrument for Measuring Physical Properties	Explore the "Bomb Tester" Thought Experiment with an Analogy Demonstration	Explore the Dual Particle/Wave Nature of Light with an Analogy Demonstration
Light Sources	Laser (Class 2), Red LED, White LED	Laser (Class 2)	Laser (Class 2)
Breadboard	Steel Breadboard, 12" x 18" (30 cm x 45 cm) with Intrinsic Damping to Decrease the Effect of Vibrations	Aluminum Breadboard, 12" x 12" (30 cm x 30 cm)	Aluminum Breadboard, 18" x 24" (45 cm x 60 cm)
Other Accessories	Additional Beamsplitter to Observe Second Interferometer Output Plexiglass Plates and Rotation Mount for Refractive Index Measurements Aluminum Rod, Heater, and Thermometer for Thermal Expansion Coefficient Measurement	Detector for Measuring the Probability of Different States in the Analogy Experiment	Polarizers to Observe the Effect of Polarization on the Interference Pattern
	• Build and Examine the Properties of a Michelson Interferometer • Examine the Second Output of the Interferometer • Use the Interferometer as a Sensitive Spectrometer	• Photons Create an Interference Pattern in a Michelson	• Photons Create an Interference

Educational Aspects	Generate White Light Interference • Learn how the Interference Pattern is Affected by the Coherence Length of the Source • Use the Interferometer to Measure the Physical Properties of Materials 　◦ Refractive Index of Plexiglas® Plates 　◦ Thermal Expansion Coefficient of an Aluminum Rod	Interferometer • Examines the Principle of Interaction-Free Quantum Measurement • "Marking" a Photon with Path Information Destroys the Interference Pattern	Pattern in a Mach-Zehnder Interferometer • Demonstrates Complementarity of Particle/Wave Duality of Light • Polarization "Marks" and "Erases" Each Photon's Path Information

Upgrading Kits

Upgrading the EDU-MINT1(/M) to perform like the EDU-BT1(/M) is simple; the only additional components are a photodetector and necessary mounting hardware. See the links below for the list of items required for this upgrade.

[APPLIST]
[APPLIST]

Hide

Part Number	Description	Price	Availability
EDU-MINT1/M	**Michelson Interferometer Educational Kit, Metric**	**$2,700.96**	**Lead Time**
EDU-MINT1	**Michelson Interferometer Educational Kit, Imperial**	**$2,700.96**	**Lead Time**