PIKE TECHNOLOGIES

POLARIZATION

Polarizers may be used to detect oriented samples and for measurement of thin films on reflective substrates. PIKE Technologies offers several crystal forms of polarizers and automated versions for transmission, reflection and ATR sampling covering the Vis, NIR, mid-IR and far-IR regions.

Manual Polarizers
7 different offerings for mid-IR, NIR and far-IR spectroscopy

Automated Polarizers
Motorized polarizers for precision and efficient measurements

THEORY AND APPLICATIONS INCLUDED

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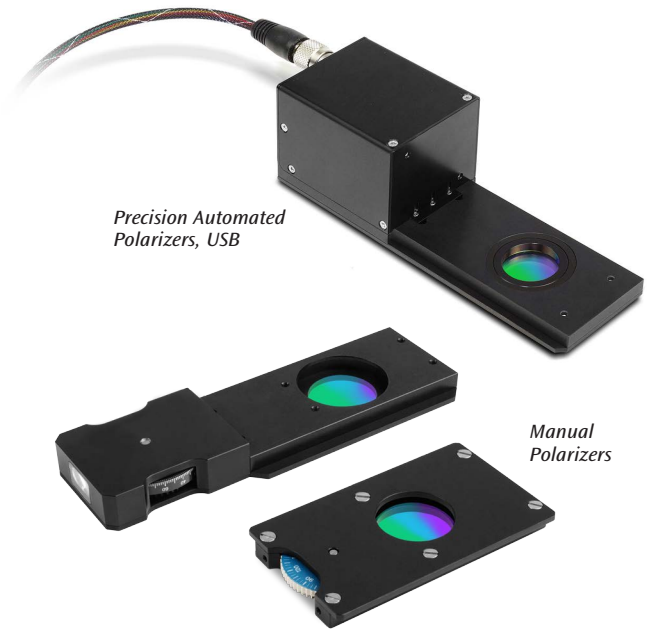
Polarizers –
Manual and Automated Versions for Molecular Spectroscopy



Precision Automated Polarizers, USB

Manual Polarizers

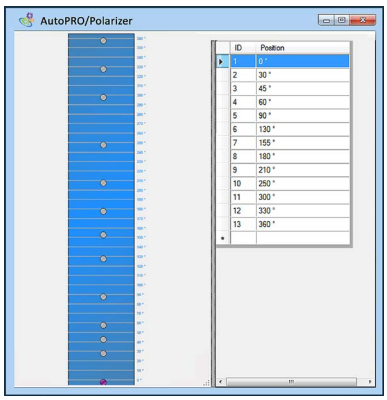
Features

- **Convenient, slide-mount design for all FTIR spectrometers**
- **Compatible with many PIKE Technologies accessories**
- **Available in manual and automated versions**
- **Elements for NIR, mid-IR, and far-IR applications**

PIKE Technologies polarizers are used for a wide variety of spectroscopy applications. Manual or automated versions are available covering the NIR, mid-IR and far-IR regions. New to our offerings is a NIR nanowire polarizer with ultra-high contrast. All polarizers fit into a standard 2" x 3" slide mount and are compatible with FTIR spectrometers. Polarizer elements are 25 mm in diameter and, with mount, have a 20-mm clear aperture.

The polarizers are also compatible with many PIKE Technologies accessories including the 80Spec, VeeMAX, and AGA specular reflectance accessories. If you would like to add mounting to any of our accessories, including ATR, please contact us.

PIKE automated polarizers provide specifications identical to our manual versions, plus they are fully computer controlled, making many previously labor-intensive applications feasible. With the automated polarizer an analysis program can be set up through PIKE AutoPRO software to automatically collect all spectra at user-specified polarizer settings.



PIKE AutoPRO software configured for the automated polarizer.

There are two manual polarizer types available. The short form has 5-degree scale resolution and the long form (Precision) offers the more precise, 1-degree scale. Automated polarizers are also available to address various sample compartment and accessory configurations. The automated polarizers offer the added benefit of increased setting reproducibility with accuracy to +/- 0.5 degree.

Specifications

Element Type	ZnSe, KRS-5, Ge, CaF_2, Glass BaF_2, Polyethylene
Element Diameter	25 mm
Clear Aperture Diameter	20 mm
Dimensions (W x D x H)	
Manual	50 x 86 x 9 mm (NIR glass manual polarizers are 17-mm thick)
Precision Manual	50 x 142 x 9 mm
Automated Precision	50 x 146 x 55 mm

Ordering Information

Manual Polarizers

(select based upon spectral range and performance requirements)

Part Number	Description
090-1000	Manual Polarizer, ZnSe
090-1200	Manual Polarizer, KRS-5
090-1500	Manual Polarizer, Ge
090-1400	Manual Polarizer, BaF_2
090-1600	Manual Polarizer, Polyethylene
090-1300	Manual Polarizer, CaF_2
190-2002	Manual Polarizer, Glass
090-3000	Precision Manual Polarizer, ZnSe
090-3200	Precision Manual Polarizer, KRS-5
090-3500	Precision Manual Polarizer, Ge
090-3400	Precision Manual Polarizer, BaF_2
090-3600	Precision Manual Polarizer, Polyethylene
090-3300	Precision Manual Polarizer, CaF_2
190-2000	Precision Manual Polarizer, Glass

Note: All manual polarizers are mounted into a 2" x 3" plate for use with the FTIR spectrometer slide sample holder or the appropriate sampling accessory. Contact us for a mount for your PIKE ATR accessory.

Automated Polarizers

(select based upon spectral range and performance requirements)

Part Number	Description
090-5000	Precision Automated Polarizer, ZnSe, USB
090-5100	Precision Automated Polarizer, KRS-5, USB
090-5400	Precision Automated Polarizer, Ge, USB
090-5300	Precision Automated Polarizer, BaF_2, USB
090-5500	Precision Automated Polarizer, Polyethylene, USB
090-5200	Precision Automated Polarizer, CaF_2, USB
190-2005	Precision Automated Polarizer, Glass, USB

Notes: All automated polarizers are mounted into a 2" x 3" plate for use with the FTIR spectrometer slide sample holder or the appropriate sampling accessory. The automated polarizers include the PIKE Technologies Motion Control Unit and AutoPRO software for fully automated operation. Contact us for short form automated polarizers.

Infrared Polarizers – *Theory and Applications*

Polarizers are valuable tools used for spectroscopic analysis of sample orientation and for measuring thin films on reflective surfaces. This overview presents basic polarization theory and highlights some useful polarization applications.

For the purposes of discussing polarizers, light is considered an electric field with a magnitude oscillating in time. Light propagating along the z axis can be described as a combination of electric vectors in x and y axis. Linearly polarized light may be thought of as consisting of an x and a y component with different relative magnitudes. For example, if the y component is close to zero, the light is considered fully polarized in the x direction.

Polarizers are devices that split unpolarized light into two orthogonal components; one of the linearly polarized components is transmitted, the other is reflected, redirected or absorbed. The most important features of a good polarizer are brightness, contrast and durability. Brightness and contrast can be described by two main parameters; K_1 and K_2.

K_1 = Transmission efficiency for normally incident polarized light whose electric field vector is perpendicular to the wire direction.

K_2 = Transmission efficiency for normally incident polarized light whose electric field vector is parallel to the wire direction.

For a 'perfect polarizer' $K_1 = 1$, which means full transmission of polarized light whose electric field vector is in the preferred direction and $K_2 = 0$, which means complete blockage of a beam of polarized light whose electric vector is perpendicular to the former. Other measures of performance deduced from K_1 and K_2 are

$$\text{Degree of polarization} = \frac{(K_1 - K_2)}{(K_1 + K_2)}$$

$$\text{Extinction Ratio} = \frac{K_1}{2K_2}$$

$$\text{Principal transmittance ratio or contrast} = \frac{K_1}{K_2}$$

Polarizers may be made from very fine conducting parallel elements or grid placed upon a suitable transparent base material. When the grid spacing is much smaller than the wavelength of light, the light with the electric vector parallel with the grid will be reflected and only the component with perpendicular electric vector will be transmitted (shown graphically on the right).

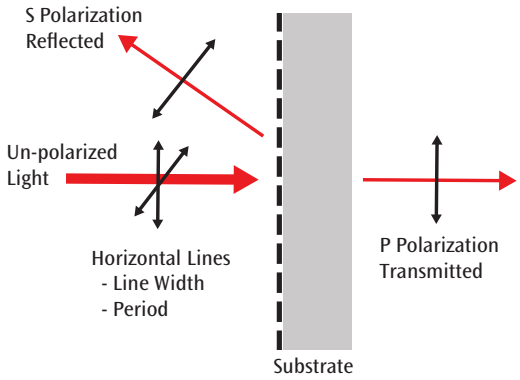
The overall transmission characteristic of the polarizer depends upon the substrate, but the polarization efficiency depends upon the period, line width and other design parameters of the polarizer.

In the mid-infrared range, the most practical and commonly used polarizers are ruled or holographic wire grid structures. The polarization effect comes from the same principle as the free standing wire grid, except the fine wires are formed on the surface of an infrared transmitting optical window material.

Polarization efficiency depends on smaller grid spacing than the wavelength and on the conductivity of the wires. In the case of a ruled polarizer, the surface of the optical element is created by a diamond needle to form very fine parallel lines, such as 1200 lines/mm, on the surface. The optical element is then placed into a vacuum chamber and this pattern is partially coated with aluminum or other evaporated metallic layer. The spacing between the evaporated thin lines has to be very small, typically a fraction of the wavelength. Ruled polarizers have good performance and are durable at high laser powers, but can only be made on hard, non-granular materials that can be ruled, such as ZnSe.

Holography is another method used to form the fine metallic wire pattern on the surface of the polarizer element. Two coherent laser beams are directed onto the surface of the optical element which is coated with a very thin layer of photo resist. The interference pattern formed at the intersection of the two beams is allowed to expose the photo resist. The lines in between the exposed photo resist are removed and then coated in a vacuum chamber similar to the ruled grating type. The advantage of holographic polarizers is that a wider variety of materials can be used such as the softer KRS-5. As mentioned earlier, the efficiency of the polarizer depends on the grid spacing formed among the wires. Holographic techniques allow more uniform grid patterns because the spacing is produced optically. Light scatter due to imperfections of ruled grooves are also reduced. If the grid spacing is smaller, the polarizer is more efficient. The spacing errors have also much less effect on the efficiency if the grid is much smaller than the wavelength. The trade-off with tighter grid is the reduction of the optical throughput. These parameters are carefully optimized in the design of the polarizer elements and the right polarizer can be selected for specific experimental conditions.

Specifications and performance characteristics of polarizers offered by PIKE Technologies are shown in Table 1.



Graphical representation of the polarization effect.

Table 1: Polarizer properties.

Polarizer Type	Application	Cutoff, cm^{-1} Spectral Range	Transmission Efficiency, K_1	Undesired Transmission, K_2	Degree of Polarization, $(K_1-K_2)/(K_1+K_2)$
ZnSe	Mid-IR, General Purpose	460	70%	1%	97%
KRS-5	Mid-IR, Wide-range	200	75%	0.25%	99%
Ge	Mid-IR, Highest Efficiency	5500–570	90%	0.25%	99%
Polyethylene	Far-IR, Widest Range	500–10	80%	4%	93%
CaF_2	NIR Applications	800	85%	1%	98%
Glass	Vis/NIR Broadband	20,000–3030	85%	0.05%	99%
BaF_2	Mid-IR	840	70%	0.1%	99%

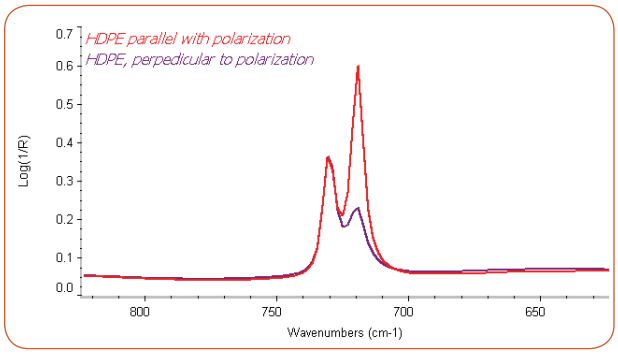
Notes: Efficiency values reported at 1000 cm^{-1} for mid-IR, at 3300 cm^{-1} for NIR, at 5000 cm^{-1} for glass Vis/NIR and 100 cm^{-1} for far-IR. All polarizers are holographic, wire grid for maximum performance.

The optical material substrate used to create the polarizers determines the wavelength range of the polarizer – such as ZnSe or KRS-5. Table 1 shows the K_1 values of PIKE Technologies polarizers. The maximum transmitted light is affected by the transmission of the materials and the scattering of the ruled and evaporated surfaces. Fresnel losses are determined by the refractive index and the performance of the anti-reflection coating on the element. The maximum transmission compared to a fully depolarized open beam is typically less than 50%. However, FTIR spectrometers produce slightly polarized beams, which in most cases are oriented in the vertical direction in the sample compartment. Thus the apparent transmission of a single polarizer oriented vertically and compared to open beam can be over 50%.

The other critical parameter of polarizers, the contrast, can be measured by crossing two polarizers and recording the throughput signal. For efficient polarizers in a practical spectroscopy setting, such as using a converging infrared beam in the sample compartment of an FTIR spectrometer, it is expected that the light level should be less than 1%. For selected high performance polarizers it can be better than 0.5%.

Polarizers are usually mounted in a plastic disc and placed in a rotating holder with an angle scale. This way, the angle of the polarizer orientation can be positioned with approximately 1 degree repeatability. Motorized polarizers are available with much better angular accuracy and precision. The automated polarizers are also very useful for conducting a series of experiments with different angle settings under complete computer control.

One of the main uses of infrared polarizers is to monitor molecular orientation in samples such as films and fibers. During manufacture polymers tend to orient along the axis of the mechanical stretching and this preferred orientation is retained after the material stops flowing. In some cases, polymers are a mixture of crystalline, more polarized, and amorphous, less polarized, forms of the material. In order to study orientation, polarized light is directed on the film or fiber. The polarized light electrical vector coinciding with the dipole of the infrared active moiety increases in absorption intensity, thereby revealing the band assignment and the orientation of the molecular group. Single crystals placed in the focus of polarized light also absorb selectively, depending on the orientation of the crystal.

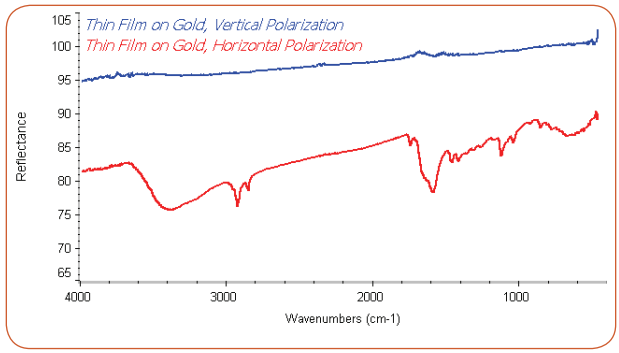


Spectra for high density polyethylene (HDPE) with parallel and perpendicular polarization demonstrate that this sample is oriented.

Polarizers can also be used in conjunction with attenuated total reflection (ATR). Even without polarizers, for any ATR that retains the orientation relative to the incoming infrared beam, there could be spectral differences noted when an oriented sample is placed with its direction along the optical axis or perpendicular to it. The phenomenon is related to penetration depth differences for the light components polarized parallel or perpendicular with the reflective surface (see ATR Theory and Applications).

Another important application of polarizers is the enhancement of the signal measuring thin films on polished semiconductors, metallic mirrors and other reflective surfaces.

Using large angle reflectance optics, the grazing angle reflectance of the thin films can be measured. Substantial signal enhancement can be achieved by using polarized light in conjunction with a grazing angle accessory. As an example, a thin oily deposit on a gold mirror can be measured with good signal-to-noise ratio by using polarized light with a specular reflectance accessory set at 80 degrees. Background spectra for each result were collected at the identical polarization angle as the sample. As seen in the spectra below, the light polarized such that the electric vector is perpendicular to the metallic mirror surface is enhanced. The spectrum measured with the polarization perpendicular to the surface (electric vector parallel with the surface) is not detected. The non-polarized light measurement is a combination of the two polarized measurements, showing a signal with less contrast than the red trace.



FTIR spectra with vertical and horizontal polarization.

Summary

Polarizers are highly useful spectroscopy sampling tools for the measurement of samples with molecular orientation, for measuring thin films on reflective surfaces and for molecular spectroscopic research.

Ordering Terms, Contact Information and Guarantee

Part Numbers and Price

The PIKE price list includes accessories that may be used with a variety of makes and models of spectrometers. Please specify the part number and description when ordering, including your instrument type and model number. Click here for a list of spectrometer and spectrophotometer instrument codes. When placing an order, substitute these codes for the final two digits (XX) in the accessory part number.

PIKE Technologies is continually extending the accessory product range. If you are unable to find a required item, please contact us to discuss your needs. We will be glad to assist.

Payment Terms

Purchase Order Number, cash in advance, MasterCard and Visa are acceptable. Payment is net 30 days, and shipments are FOB Madison, WI USA. Freight charges are prepaid and added to your invoice. If you wish to pay freight charges, please specify this on your order. Prepayment is required for international customers.

International Handling Fee

For orders placed from outside the United States or Canada, a handling fee of $40 will apply per order to cover the costs associated with the additional documentation and bank charges required for international shipments.

Ways to Order

Many products are available for purchase directly through our website. These items are marked on our website with a red shopping cart icon.

Please include the following information when placing an order: your name, phone number, product part number, quantity, ship to address, bill to address, purchase order number and spectrometer model on which the accessory will be used.

Orders may be placed via mail, phone, fax, e-mail or on our website. We accept Visa and Mastercard via phone and direct online purchases. For security purposes, do not send credit card information via e-mail. An electronic order form is available on our website (for P.O. Numbers only – do not use this form for credit card orders). There is no minimum order requirement. Please use the following addresses and phone/fax numbers when placing your orders:

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Madison, WI 53719
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(608) 274-0103 (FAX)
orders@piketech.com (E-MAIL)
www.piketech.com

Delivery

The delivery/shipment date is confirmed upon receipt of an order. Special requirements and custom accessories are subject to different lead times. Please contact us for price quotes and delivery information on these products.

Guarantee

All PIKE products are guaranteed to be free from defects in material and workmanship for a period of 12 months from the date of shipment. Should you be dissatisfied, or have any queries, please contact us immediately and we will promptly repair or replace the product at no charge.

Product Returns

Please contact PIKE to receive your Return Material Authorization (RMA) number if you wish to return any of our products. A restocking fee may apply. Customers are responsible for shipping charges for all returned products. For products under warranty, back-to-customer shipping charges will be covered by PIKE. Please do not return any products without obtaining the RMA number first.

Technical Assistance

PIKE Technologies offers comprehensive technical assistance. Please contact us via mail, phone, fax or e-mail with your questions.

International Distribution

PIKE Products are available worldwide. Call or send us an e-mail and we will provide you with an address of the sales office closest to your location. All exports are handled in accordance with the US Export Administration Regulations.

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Customer satisfaction is very important to all of us here at PIKE Technologies, Inc. We have hopefully made the ordering process very fast and easy for you. If you have any questions or concerns about our products or services, please don't hesitate to contact us. We will be happy to make adjustments to fit your needs.

Products and prices are subject to change without notification.

FTIR and UV-Vis Instrument Codes

When ordering a PIKE accessory, replace the XX or XXX portion of the product's part number with your spectrometer's instrument code below. For assistance, please contact a PIKE customer service representative at (608) 274-2721 or sales@piketech.com.

FTIR Instrument Codes (XX)

ABB Bomem	
FTLA2000-100 (Arid Zone)	80
Michelson 100, MB Series	81
MB 3000	82
Agilent	
Excalibur™, Scimitar™, FTS, 600-IR Series	10
Excalibur™, Scimitar™, 600-IR Series with recognition	13
Analect (See Hamilton Sundstrand)	
Bio-Rad (See Agilent)	
Bruker Optics	
IFS™, Vector™, Equinox™ Series.	50
Tensor™, Vertex™ with recognition (Quick-Lock)	51
Buck Scientific	
M500	65
Digilab (See Agilent)	
Hamilton Sundstrand AIT	
Diamond 20	60
Horiba	
7000 Series	35
Interspectrum	
Interspec 200-X	90
Jasco	
300/600 Series	56
400	57
4000/6000 Series	58
JEOL	
Winspec™ Series	46
Lambda Scientific	
Lambda FTIR 7600	66
Lambda FTIR 8600	64
Lumex	
INFRALUM FT-02, FT-08	67
Mattson (See Thermo Electron)	
Midac	
M Series	30
Nicolet (See Thermo Electron)	
Oriel	95
Optical Table	99
PerkinElmer	
1700 Series	70
Spectrum™ GX, 2000	71
Spectrum BX / RX, 1600, Paragon 1000	73
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Spectrum Two with recognition	75
Shimadzu	
8300, 8400 Series, IRPrestige™-21, IRAffinity-1s	15
IRPrestige™-21, IRAffinity-1s with recognition (QuickStart)	16
IRTracer™-100	18
IRTracer™-100 with recognition	19
Thermo Electron / Nicolet / Mattson	
Infinity, Galaxy, RS Series	20
Genesis™, Satellite, IR 300	21
Impact™ 400, Magna, Protege™, 500 / 700 Series	40
Avatar™, Nexus™, Nicolet™, iS™10, iS™50	40
Model 205/210	41
Nicolet iS™5	42
Avatar, Nexus, Nicolet Series with recognition (Smart)	47
Varian (see Agilent)	

UV-Vis Instrument Codes (XXX)

Agilent/Varian	
Cary 50	100
Cary 60	111
Cary 100, 300	110
Cary 4000, 5000, 6000i	120
Jasco	
600 Series	600
Optical Table	999
PerkinElmer	
Lambda 650, 750, 850, 950 and 1050	700
Lambda 25, 35, 45	730
Shimadzu	
1600 and 1700	200
1800 Series	210
2600	240
3600	220
Thermo Fisher Scientific	
Evolution 300/600	400
Evolution 200	410

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Application Notes

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