The Products

2.1 Functional Principle of Pyroelectric Detectors

The core of a pyroelectric detector is the pyro chip. This consists of a crystalline material with special properties. Crystals consist of oppositely charged components, the ions arranged in a regular structure, the crystal lattice. With many crystals, the negative and positive centres of charge do not coincide in the crystal lattice. This is referred to as polarisation. Pyroelectric crystals with a single polar axis also have a rare asymmetry in the world of crystals. As a result, its polarisation changes with the temperature. Sensor technology utilises this pyroelectric effect. For this purpose, a thin pyroelectric crystal (pyroelectric material) is coated with electrodes vertical to the polar axis. An absorbent layer (black layer) is applied on the upper electrode of the crystal. If infrared radiation strikes this layer, the pyroelectric material heats up and surface charges result. If the radiation is switched off, charges of reverse polarity result. The charges are very small, however. Before they can equalise again by the final internal resistance of the crystal, extremely low-noise and low leakage current field-effect transistors (JFET) or operational amplifiers (OpAmp) convert the charges to a signal voltage.

Since a pyroelectric element only reacts to changes in the infrared radiation, a pyroelectric detector normally has to be operated with a modulated source. An exception to this are measurement objects that emit rapidly changing radiation, such as flames.

Unlike quantum detectors, such as photodiodes, thermal detectors have a very broad spectral sensitivity. Pyroelectric detectors are sensitive for radiation starting from the ultraviolet range (100 nm), via the visible and infrared wavelength range through to terahertz waves (1,000 µm). This is on condition that the pyroelectric crystal has a suitable absorption layer. This absorbs the incident radiation in the wavelength range of interest almost completely. Owing to its appearance, it is often described as a black layer.

All pyroelectric materials are operating physically as well as piezoelectrically. For this reason, the pyroelectric chip of a detector reacts to structure-borne and airborne noise like a microphone or acceleration sensor. This phenomenon is described as microphonic effect or acceleration sensitivity. The airborne sound influence even suppresses the sealed detector housing. InfraTec minimises the effect of the disturbing structure-borne noise by a patented micromechanical chip holder (low micro). As a result, the interference voltage drops to a few percent in all three directions.

Since the pyroelectric detector is sensitive for temperature changes, the change of the ambient temperature also affects the measurement signal and shifts the operating point. Thermal compensation reduces this effect by a factor of about 20. To get this optically inactive pyroelectric elements are connected to the active pyroelectric elements inversely phased.

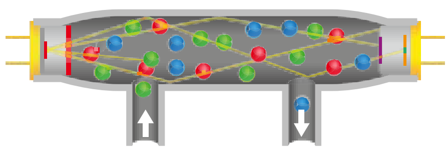
2.2 Typical Applications

2.2.1 Non-dispersive Infrared (NDIR) Gas Detection Technology

Many methods are available today for detecting the concentration of gases. They vary, on the one hand, by the physiochemical principle used, and on the other, by their application characteristics, such as detection limits or cross-sensitivities. The NDIR principle has particular benefits there, where the detection of the slightest traces is not necessary, but instead robust devices with long-term stable properties are needed, such as in process measurement technology or for the gas alarm as a component of the personal protective equipment.

Many gases absorb infrared radiation. The cause is the stimulation of molecular vibrations. These are linked to characteristic wavelengths, and the more molecules that are available, the more radiation is absorbed. Thus, it is possible to deduce the type and concentration of the gas from the absorption spectrum. This simplest measuring device consists of a wideband, pulsed source of radiation, a gas cell, a filter and a wideband infrared sensor. Just a special light bulb is often sufficient as a source of radiation. The filter lets exactly the type of radiation pass through that the gas to be detected absorbs. A narrow bandpass filter is mostly used, which is matched exactly to one characteristic absorption band (e.g. 4.26 µm for CO_2). The decrease in the detector signal is thus a measurement for the increase in the gas concentration.

Thermal detectors, such as thermopiles or pyroelectric detectors, are normally used as wideband sensors. The latter generate a signal proportional to the incident radiant power. They are characterised by high sensitivity with low temperature coefficients and have very wideband spectral sensitivity due to their absorptive coating. For this reason, they are very well suited for radiometric tasks such as with NDIR gas detection technology. Quantum detectors, such as photodiodes, are unsuitable in most cases due to their very limited spectral sensitivity.



10075_GaskuevetteA multi channel detector is often used for gas detection, where one channel is used as a reference in order to compensate for ageing or drift effects of the measuring section. A filter is used for this, in whose passband there are no absorption bands of the gases, which occur or could occur in the mixture (e.g. 3.95 µm). The filters are already integrated into the cap at the factory. Typical fields of application include safety technology (detection of explosive or toxic gases), medical technology (diagnostic respiratory gas analysis or anaesthesia) and process measuring technology (optimisation of combustion processes).

2.2.2 Flame Detection

For monitoring environments, in which fires occur and can spread relatively easily, industrial flame detectors are used. Flames that are typical for the burning of organic materials, emit radiation in the carbon dioxide absorption band range of 4.3 µm with a flicker frequency of about 1 Hz to 10 Hz. Both properties can be utilised for detecting a flame when using a pyroelectric detector. This ensures a high level of selectivity and prevents false alarms, e.g. due to sunlight, electric arcs or other infrared sources. Combined with a high degree of sensitivity and long durability, pyroelectric detectors have distinct benefits that no other detector principle offers for flame detection. In the simplest case, a single channel detector equipped with a wideband filter can detect the radiation emitted from the flame in the spectral range from 4.0 to 4.6 µm. The downstream electronics also evaluate the flicker frequency. An additional increase in detection reliability and selectivity can be achieved by the use of multiple spectral ranges, particularly within such ranges emitted by combustion products. Multi channel detectors are particularly suitable for this purpose. Attention is paid to high sensitivity, fast response time and large field of view, especially in the case of flame detectors. For this reason, current mode detectors, such as the LME-335 or LMM-244 are particularly suitable for this application.

For flame detection the emission of radiation by the gas is used, whereas with gas detection technology, it is absorption**.** Both effects occur even at the same wavelengths. In the flame, the stimulation of the molecular vibrations occurs due to thermal energy of the combustion process. The stimulated molecules then emit the energy as radiation, whereupon they return to the initial state. In gas detection technology, in contrast, the molecules are first in the initial state, are stimulated by the absorbed radiation and return again to the initial state by discharging heat. This amount of heat is very small, nevertheless.

2.2.3 Further Application Areas

Apart from these two main application areas – gas detection technology and flame detection – you can use pyroelectric detectors in a variety of other applications for recording or measuring infrared radiation.

Pyrometry

Thanks to the long-term stability of the lithium tantalate used, pyroelectric detectors are also suitable for contactless temperature measurement. In this process, either the entire radiation generated by the measurement object or the ratio between two adjacent, narrow spectral ranges is analysed. This enables conclusions to be drawn about the temperature of the measurement object. Owing to the special properties of pyroelectric detectors, these are mostly used in very high quality pyrometers.

Spectroscopy

Thermal detectors are characterized by a constant sensitivity over an extremely wide spectral range. Therefore they are ideal for use in spectrometers. Specially designed for this application our detectors combine wideband, permeable entry windows, with a metal black coating of the pyro chip developed by InfraTec, which produces a particularly even function of the spectral absorption.

Aerospace

Due to their extremely high quality, robustness and long-term stability, customised InfraTec detectors are also used in aerospace, e.g. for the alignment of satellites. Devices used in spacecrafts must meet very high standards regarding their reliability. The basis for this is highly reliable assembly and packaging technology. Compliance with the specifications of the customer is checked by means of demanding qualification tests on evaluation models that simulate extreme environmental impacts. Afterwards, the detectors not only have to work, but have to meet all specified properties. Detectors from InfraTec have been used successfully in spaceflight applications for many years already.

2.3 Product Groups

Our detectors are assigned to the product groups listed here according to their design and application area.

Single Channel Detectors

Detectors for gas analysis, flame detection and radiometry

- Housing types TO18 and TO39
- Voltage or current mode
- Signal processing with JFET or operational amplifier
- Thermally compensated (optional)
- With special chip holder for reducing the microphonic sensitivity (optional)

Planar Multi Channel Detectors

Detectors for gas analysis and flame detection

- Two, three or four spectral channels in one housing
- Low channel crosstalk (< 0.1 %)
- Signal processing with JFET or operational amplifier
- Thermally compensated (optional)
- With special chip holder for reducing the microphonic sensitivity (optional)

PYROMID® Multi Channel Detectors

Dual and quad channel detectors for gas analysis

- Integrated beam splitter in the detector or micromechanical frame for compact design
- One common aperture opening for all channels
- Inside filter, common entry window
- Low channel crosstalk (< 0.1 %)
- Signal processing with JFET or operational amplifier

Special Detectors

Highly specialised single channel detectors for applications in spectroscopy analytical instruments

- High electro-optical performance
- Short response time (optional)
- Large active area (optional)
- Spectrally flat black metal layer as an option

PyrIQ® – Detectors With Digital Interface

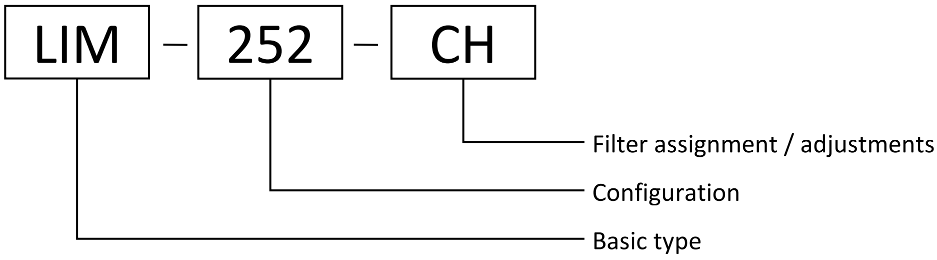
- Two or four spectral ranges
- Housing types TO39 and TO8
- Optional with robust aperture for all channels
- Integrated amplification and AD/conversion
- Readout and parameterization via I^2C interface

The Products

InfraTec Type Description and Article Identification

Type description

- Describes detector type and infrared filter used
- Attached to detector for identification



Basic types

- LIE LiTaO$_3$ & InfraTec & single channel detectors
- LME LiTaO$_3$ & reduced microphonic effect & single channel detectors
- LRE LiTaO$_3$ & micromechanical Frame & single channel detectors
- LIM LiTaO$_3$ & InfraTec & multi channel detectors
- LID LiTaO$_3$ & InfraTec & multi channel detectors & digital interface

- LMM LiTaO$_3$ & reduced microphonic effect & multi channel detectors
- LRM LiTaO$_3$ & micromechanical frame & multi channel detectors
- LRD LiTaO$_3$ & micromechanical frame & digital interface

Configuration

- Three-digit numerical sequence describing the design of the basic type in more detail
- The last number indicates the number of channels for the multi channel detectors

Filter codes

M	B	R	H	C	G	F	T	D	Z	E	I	K	L	W	N	U
Ref	Ref	Ref	Ref	CH_4	HC	Fla	CO_2	CO_2	CO_2	CO_2	CO	CO	NO	H_2O	NO_2	SO_2

Ref = Reference, HC = (Hydrocarbons), Fla = Flame

Details in chapter 2.4.3 Filters and Windows – Standard Narrowband Filters.

Examples

- LIM-252-CH Detectors with standard IR filters bear the filter code in the sequence of the channels at the end of the name
- LIE-202-X005 Detectors of a customized design end with X, followed by a three-digit number

Article number

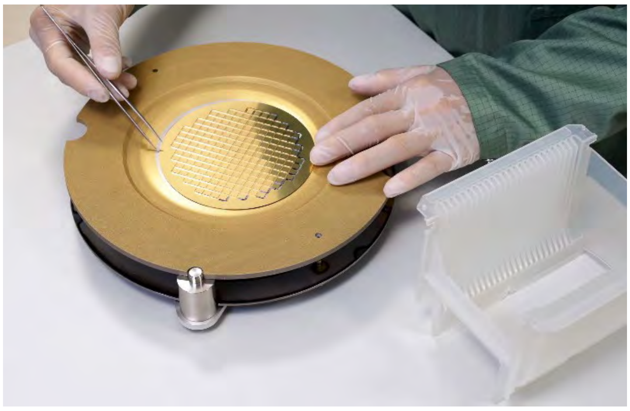
- A unique article number is assigned to each type description
- This one is listed on the data sheet and is used in order processes

Serial number

- Every single detector bears a unique serial number
- This enables conclusions to be drawn about its manufacturing conditions and measured values of the electro-optical test at the end of production

2.4 Filters and Windows

2.4.1 Basic Principles



The window of a detector is its interface to the optical system. It has to protect the internal components from environmental influences, while letting the spectral part of the infrared radiation relevant for the function pass through. For this purpose, very infrared-transparent materials are used. Since there is no ideal material for all applications, it is necessary to weigh up which properties are particularly important on a case-by-case basis. The transparency ranges, i.e. the spectral ranges, in which the window practically does not absorb, are very different. On the other hand, the different position of the absorption edge can be utilised specifically if radiation of a higher wavelength should not be detected. This is referred to as blocking. If necessary, windows can be provided with an anti-reflective coating (ARC). As a result, the transmission in a selected spectral range is improved considerably, which is important particularly in the case of materials with a high refractive index such as silicon, since reflection losses at the interfaces increase with the rising refractive index.

A window is referred to as filter if its transparency range is further limited by additional measures. Here, we differentiate between absorption filters and interference filters. The former are mostly used only in the visible range. InfraTec only uses interference filters. For this layer stacks of two dielectric materials with a different refractive index are applied alternately to a substrate made from a very infrared-transparent material on one side or both sides. Interference effects lead to a wavelength-dependent extinction or enhancement of the incident electromagnetic wave. Thus, different spectral ranges of higher and lower transmission result, which is used for producing various types of optical filters and anti-reflective coatings.

The Products

Depending on the application, the filter must let radiation pass through different spectral ranges, which concerns their position as well as their limitation after only one or both sides. A longwave pass (LWP) only lets radiation pass though above a limit wavelength (cut-on). A shortwave pass (SWP), on the other hand, cuts off from a certain limit wavelength (cut-off). For example, silicon with an anti-reflective coating can act as a longwave pass, and calcium fluoride can act as a shortwave pass owing to the position of its absorption edge. A bandpass can be regarded as a combination of a long and short pass, where the transmission ranges overlap in such a way that a passband is formed. Depending on the width of this band, the filter is referred to as a wide bandpass (WBP) or narrow bandpass (NBP). The latter are particularly important for the gas analysis.

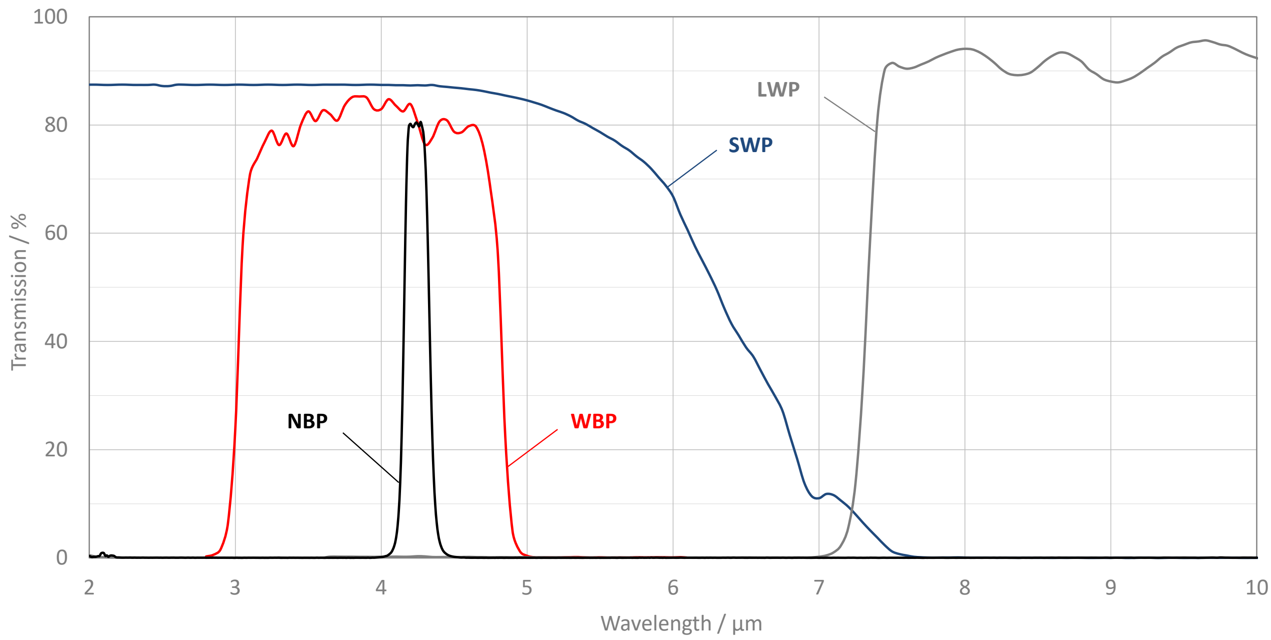


Diagram 1: Presentation of different bandpass filters

2.4.2 Bandpass Parameters

The transmission range of a bandpass is characterised by the centre wavelength CWL, half power bandwidth HPBW and peak transmission T_{pk}. The peak transmission should not fall below a value of 70 % so that the detector signal does not become too low. With the cut-on and cut-off wavelength ($\lambda_{cut-on}, \lambda_{cut-off}$) the transmission is exactly half of the peak transmission.

$$T(\lambda_{cut-off}) = T(\lambda_{cut-on}) = \frac{T_{pk}}{2} \qquad HPBW = \lambda_{cut-off} - \lambda_{cut-on} \qquad \lambda_{cut-off} > \lambda_{cut-on}$$

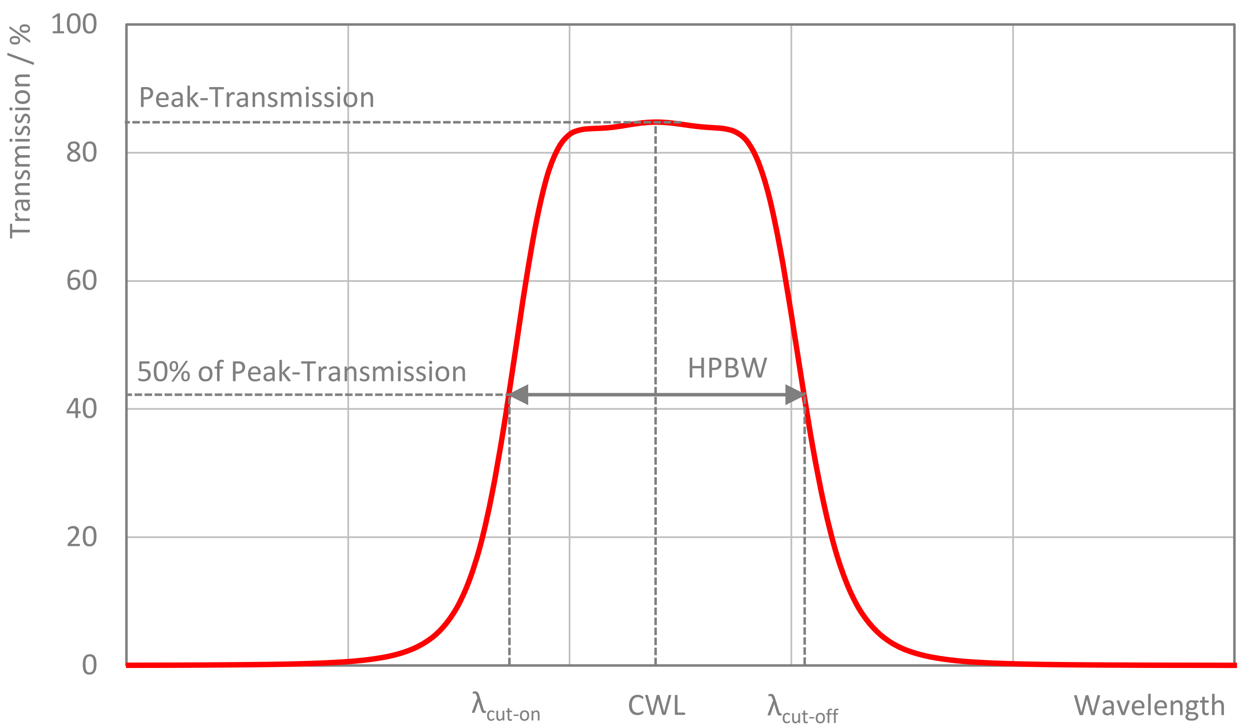


Diagram 2: Transmission range of a bandpass filter

The centre wavelength indicates the "middle" of the bandpass and is calculated from the cut-on and cut-off wavelengths[1]:

$$CWL = \frac{\lambda_{cut-on} + \lambda_{cut-off}}{2}$$

Outside the passband, in the blocking range, the transmission of the filter should be as little as possible < 0.1 … 1%, since additional, otherwise disturbing signal parts result. Since these parts are not affected by the value to be measured, with which the bandpass is aligned, a transmission in the blocking range reduces the measuring sensitivity of the application.

[1] InfraTec uses for the definition of CWL the wavelength, not the wavenumber.

2.4.3 Standard Narrowband Filters

Narrowband filters are particularly well suited for the gas analysis thanks to their low half power bandwidth. Thus, even closely adjacent absorption bands of different gases can be clearly separated. The gas specified in the table corresponds to the typical application of the filter. In individual cases, however, it can make sense to use another gas band and thus a customised filter. The choice of filter always essentially depends also on which gases in what concentration exist in the mixture to be measured. This applies not only but especially to the reference filter. Hence, there is also a choice of several different standard filters for some gases.

When using the filters, it should be noted that the blocking, depending on the application, does not extend sufficiently wide in the longwave range for all filters (e.g. > 15 µm). Therefore an additional blocking element for the longwave range can be necessary in some cases.

Designation (CWL / HPBW)	Gas	Code	Tolerance of CWL / nm	Tolerance of HPBW / nm	Diagram
NBP 3.09 µm / 160 nm Reference	-	**M**	± 30	± 20	7
NBP 3.72 µm / 90 nm Reference	-	**B**	± 30	± 20	7
NBP 3.90 µm / 90 nm Reference	-	**R**	± 30	± 20	7
NBP 3.95 µm / 90 nm Reference	-	**H**	± 30	± 20	7
NBP 3.33 µm / 160 nm Methane	CH_4	**C**	± 20	± 20	7
NBP 3.40 µm / 120 nm HC[2]	HC	**G**	± 30	± 20	7
NBP 4.30 µm / 600 nm Flame	Flame	**F**	± 30	± 30	8
NBP 4.26 µm / 90 nm CO_2 narrow	CO_2	**T**	± 20	± 20	5
NBP 4.26 µm / 180 nm CO_2 standard	CO_2	**D**	± 20	± 20	5
NBP 4.27 µm / 170 nm CO_2 high AOI	CO_2	**Z**	± 30	± 20	5
NBP 4.45 µm / 60 nm CO_2 long path	CO_2	**E**	± 20	± 20	5
NBP 4.66 µm / 180 nm CO centred	CO	**I**	± 40	± 20	6
NBP 4.74 µm / 140 nm CO flank	CO	**K**	± 20	± 20	6
NBP 5.30 µm / 180 nm NO	NO	**L**	± 40	± 20	8
NBP 5.80 µm / 100 nm H_2O	H_2O	**W**	± 50	± 20	8
NBP 6.20 µm / 120 nm NO_2	NO_2	**N**	± 50	± 20	8
NBP 7.30 µm / 200 nm SO_2	SO_2	**U**	± 40	± 30	8

We will gladly answer your questions regarding the choice of filter at any time. On request we will offer more filters.

[2] Hydrocarbons

The Products

2.4.4 Standard Crystal Windows

Designation (incl. thickness)	Code	Material	Transmission > 80 %	Diagram
CaF_2 0.4 mm	**60**	Calcium fluoride	UV ... 10.5 µm	9
CaF_2 0.7 mm	**61**	Calcium fluoride	UV ... 10 µm	9
CaF_2 1.0 mm	**62**	Calcium fluoride	UV ... 10 µm	9
BaF_2 0.4 mm	**63**	Barium fluoride	UV ... 13.5 µm	10
BaF_2 1.0 mm	**64**	Barium fluoride	UV ... 13 µm	10
CsI 0.8 mm	**65**	Caesium iodide*	UV ... 50 µm	12
KBr 0.8 mm	**66**	Potassium bromide*	UV ... 30 µm	12
Sapphire 0.4 mm	**68**	Sapphire	UV ... 5.5 µm	11
Sapphire 0.6 mm	**69**	Sapphire	UV ... 5.5 µm	11
Sapphire 0.6 mm	**69-S**	Sapphire (soldered)	UV ... 5.5 µm	11
Si uncoated 0.5 mm	**70**	Silicon	1 ... 50 µm**	12

* With moisture protective coating
** Transmission approx. 50 %

2.4.5 Standard Silicon Windows

Designation	Code	Properties	Transmission > 70 %	Diagram
Si ARC 2 – 5 µm	**10**	Anti-reflecting coating	2 ... 7 µm	13
Si ARC 3 – 6 µm	**11**	Anti-reflecting coating	3 ... 7 µm	13
Si ARC 3 – 10 µm	**12**	Anti-reflecting coating	3 ... 12 µm	13
Si WBP 3 – 5 µm	**13**	Wideband pass	3 ... 5 µm	14
Si WBP 8 – 14 µm	**14**	Wideband pass	8 ... 14 µm	14
Si LWP 5.3 µm	**15**	Long pass	6 ... 15 µm	15
Si LWP 6.5 µm	**16**	Long pass	7 ... 14 µm	15
Si LWP 7.3 µm	**17**	Long pass	8 ... 11 µm	15