Gas Detection Limits

Awakening Your 6th Sense

LUMASENSE™
TECHNOLOGIES

About LumaSense Technologies

LumaSense Technologies, Inc. was founded in 2005 as the world's first company to focus exclusively on reducing preventable waste and inefficiency across our planet's most resource-intensive global industries. LumaSense delivers advanced sensing solutions to detect, reduce and prevent waste and inefficiency in resource-intensive industries including Global Energy, Industrial Materials and Advanced Technologies.

LumaSense enables customers worldwide to achieve predictable and sustainable improvements in process efficiency and waste reduction. These customers have processes that include generating and transmitting electricity; oil and gas refining; processing industrial materials like steel and glass; and manufacturing advanced technologies such as semiconductor, wafers and LEDs. LumaSense gives our customers a competitive edge by awakening their 6^{th} sense, which allows them to gain insight into their processes to see things before they happen.

Microphone technology is an important tool in measuring gases through the use of Photoacoustic Spectroscopy – also known as PAS. This is a unique technique offering the customer an outstanding degree of measurement stability with exceptional sensitivity. The LumaSense engineering department continually works to improve the PAS technique and to test its applications in new areas. This is how the knowledge accumulated at LumaSense is used to meet the needs of our customers.

Product development is always based on customer needs for specific solutions. Consequently, customers are an integral part of the development process. Not until we deliver user-friendly solutions that meet the customers' requirements for quick, efficient and reliable solutions to problems, do we at LumaSense consider the job done!

LumaSense's past, thus, bears witness to our never ending efforts at meeting the application demands of our customers. We feel confident that you, too, will benefit from the expertise we have built in this field. Our gas portfolio not only helps our customers achieve process efficiency and waste reduction, but also is capable of monitoring the world's most harmful and dangerous gases. Because our gas sensing solutions offer superior sensitivity over other gas detection techniques, our gas modules and instruments are particularly beneficial when the environment and human safety are involved.

Our know-how is the key to customer confidence!

Ask us – we may have the solution to YOUR problem!

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Since most gases have characteristic infrared absorption spectra, infrared spectroscopy is an excellent monitoring tool. LumaSense has a selection of INNOVA monitors exploring this technique – Infrared Photo Acoustic Spectroscopy (PAS) to provide very stable and sensitive gas monitors.

The selectivity of any infrared detection method is enhanced by selective irradiation with light of the desired wavelength. The range of optical filters is designed to provide you with the best options for choosing the optimal light wavelength range for the specific monitoring need.

Photoacoustic Gas Monitor – INNOVA 1412i is capable of simultaneous monitoring up to five component gases and water vapor in any air sample. The monitor is well suited and very efficient in both short and long time monitoring applications. At short time monitoring, the benefit is the portability, the minimal warm-up time and built-in data storage capability. In long time monitoring the PAS system is especially stable, and the multipoint sampling option and the data handling feature should be highlighted.

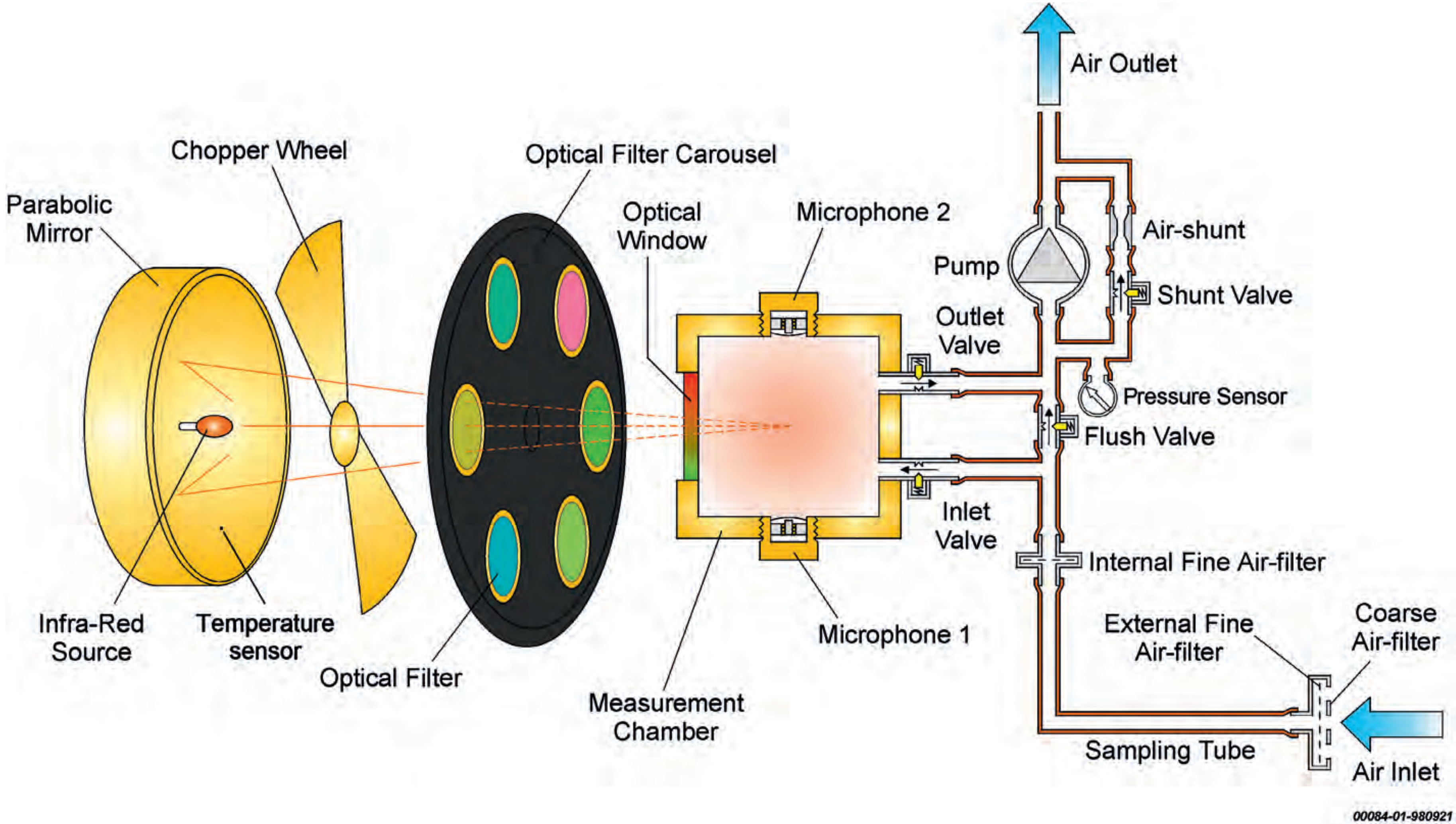
The INNOVA 1412i can be configured to perform almost any kind of monitoring task. A special optical filter is permanently installed and enables water vapor contribution to be measured separately during each measurement cycle. The instrument is, thus, able to compensate for water vapor interference. Any other gas, which is known to be present in the ambient air, can be compensated for in a similar way. By installing an optical filter to selectively measure the concentration of the interfering gas, the user can set up the 1412i to compensate for the interfering gas' contribution.

Photoacoustic Gas Monitor – INNOVA 1314i has the same specifications as the 1412i instrument, but it is housed in a rugged box that fits in a standard 19 inches rack.

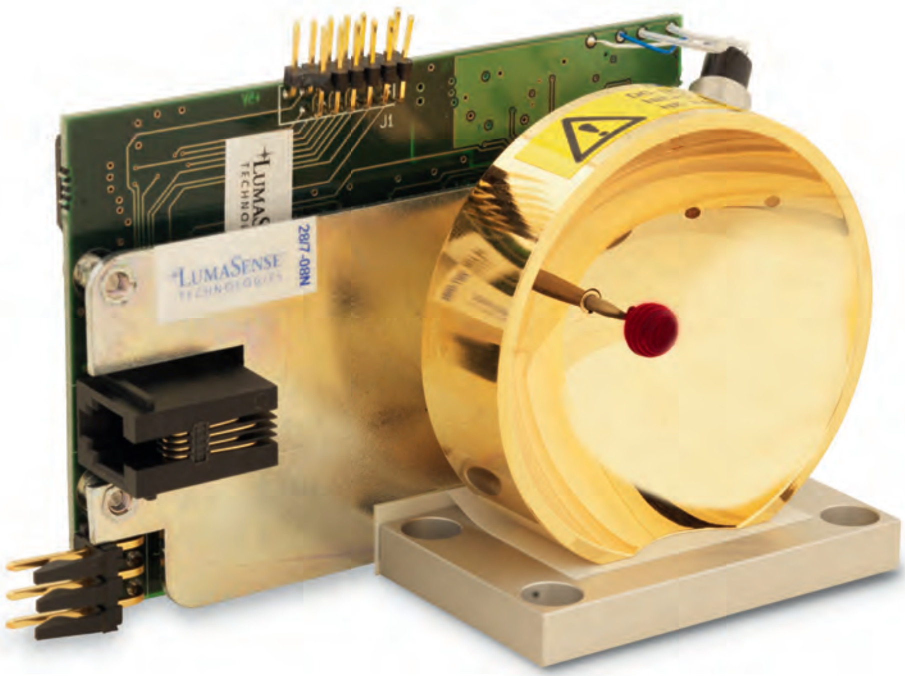
Included with the 1412i and the 1314i is user software. The software displays measurement data in a table or a graphical window and it uses a SQL 2005 database giving online access to measurement data from Microsoft® Excel.

PHOTOACOUSTIC GAS MONITOR – INNOVA 1412i

PHOTOACOUSTIC GAS MONITOR – INNOVA 1314i



PAS SYSTEM USED IN THE INNOVA INSTRUMENTS

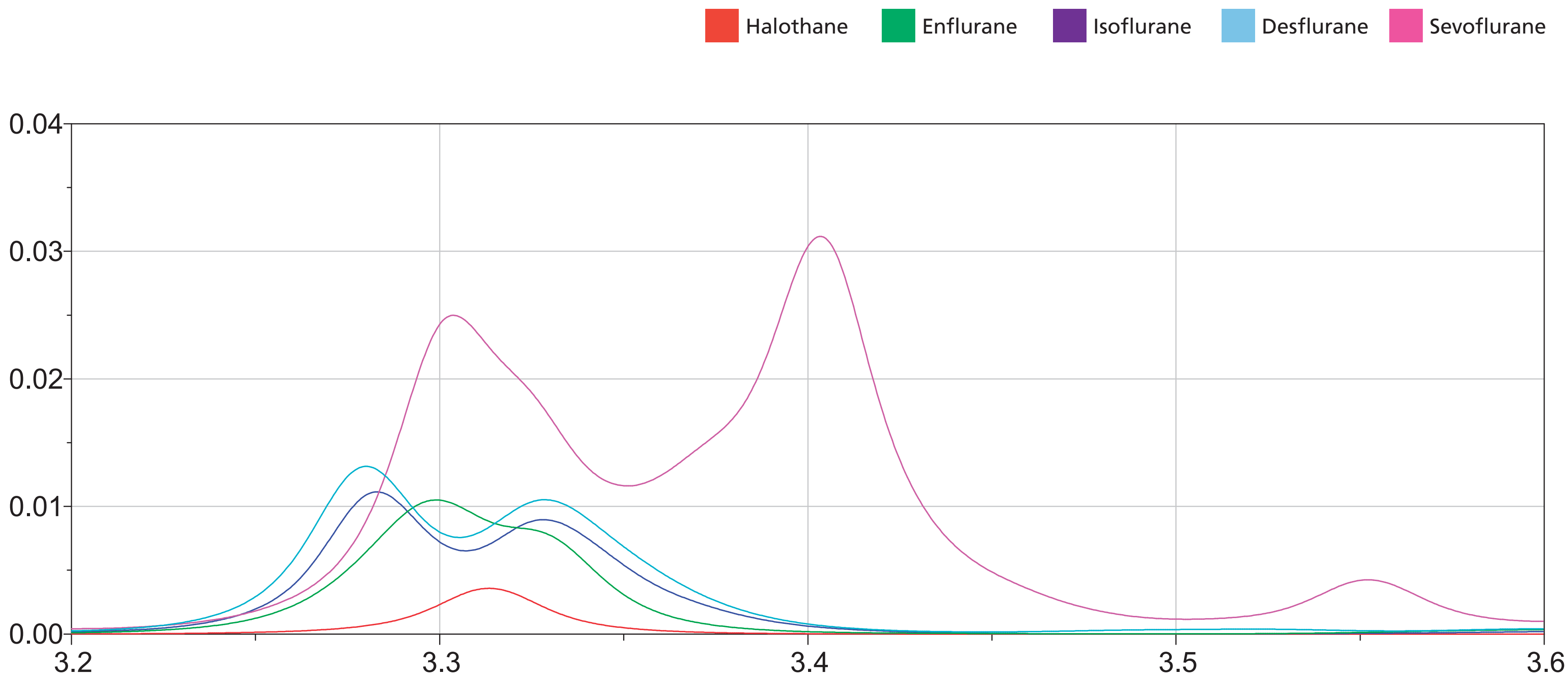


UNIT OF IR-SOURCE WITH ELLIPSOID MIRROR

UNIT OF PAS MEASUREMENT CELL

Infrared spectra

The ➔ C – H fundamental stretching vibration frequencies are always in the region from 3.2 to 3.6 μm. The infrared spectra for Halothane, Enflurane, Isoflurane, Desflurane, Sevoflurane in that region is shown in the figure below.



The optical filters

Optical filters used in INNOVA instruments display different characteristics, while sharing a basic design. Each filter comprises three separate infrared elements; a narrow-band pass element, a short-wave pass element and a wide-band pass element. The narrow-band pass element has very specific transmission characteristics. These are further defined by short-wave pass and wide-band pass elements, which prevent transmission of light at other wavelengths; as a result the optical filters have low leakage characteristics.

The narrow-band pass filter determines the center wavelength and bandwidth of the optical filter, and, thus, which gases can be detected. The ranges of optical filters span the entire "fingerprint" region (700 to 1350 cm^{-1}) plus the region between 2000 and 3000 cm^{-1} (see Fig. 1 and Table 3). The "gap" in the infrared spectrum between 1350 cm^{-1} and 2000 cm^{-1} is due to strong water absorption. This region is only suited for monitoring water vapor.

In the Table 3 the specifications for the 27 optical filters is summarized. The bandwidth is given as a percentage of the filter center wavelength. For example, the bandwidth of UA0987 becomes 3.4µm x 6,0% = 0.204µm.

Fig. 1 and Table 3 contain 4 special filters:

SB0527 is the standard filter for measurement of water vapor. The detection limit for this filter is 50 ppm.

UA6010 is a high sensitive filter for measurement of water vapor. The detection limit for this filter is 0.1 ppm. The main application is measurement of humidity in pure gases.

UA6009 is a high sensitive filter for measurement of carbon dioxide. The detection limit for this filter is 7 ppb. The main application is measurement of carbon dioxide in pure gases.

UA6008 is a dedicated filter for measurement of mustard gas. The detection limit for this filter is 0.1 ppm.

Choosing a filter:

Immunity to interfering species is perhaps the most important consideration in any gas detection application. Careful consideration of potential interference is therefore essential. Depending on the concentration and type of interfering gases and on the measurement range required, different filters may be selected in different applications in order to measure the same gas.

Table 3. Filter specifications

Optical filter Number	Filter Centre µm	Filter Centre cm^{-1}	Bandwidth %
UA0987	3.4	2950	6.0
UA0986	3.6	2800	3.0
UA0989	3.6	2750	1.5
UA6009	4.3	2347	2.0
UA0983	4.4	2270	1.3
UA0985	4.5	2215	2.0
UA0984	4.7	2150	3.0
SB0527	5.1	1985	2.0
UA6010	5.9	1700	5.9
UA0968	7.7	1291	5.5
UA0969	8.0	1254	5.5
UA0970	8.2	1217	5.5
UA6008	8.3	1210	3.0
UA0971	8.5	1179	6.0
UA0972	8.8	1139	6.0
UA0973	9.1	1101	6.0
UA0974	9.4	1061	6.5
UA0936	9.8	1020	6.5
UA0975	10.2	981	6.5
UA0976	10.6	941	7.0
UA0988	10.6	946	3.7
UA0977	11.1	900	7.0
UA0978	11.6	861	7.0
UA0979	12.2	822	7.5
UA0980	12.8	783	7.5
UA0981	13.4	746	7.5
UA0982	14.1	710	7.5

Dimensions:	
Diameter	31.00 mm
Height	5.15 mm
Operating Temperature	-20°C to +70°C
Relative Humidity	0% to 95% RH
Storage Temperature	-25°C to +70°C

All LumaSense optical filters comply with MIL-SC-48497A requirements.

Wavenumber/wavelength and bandwidth

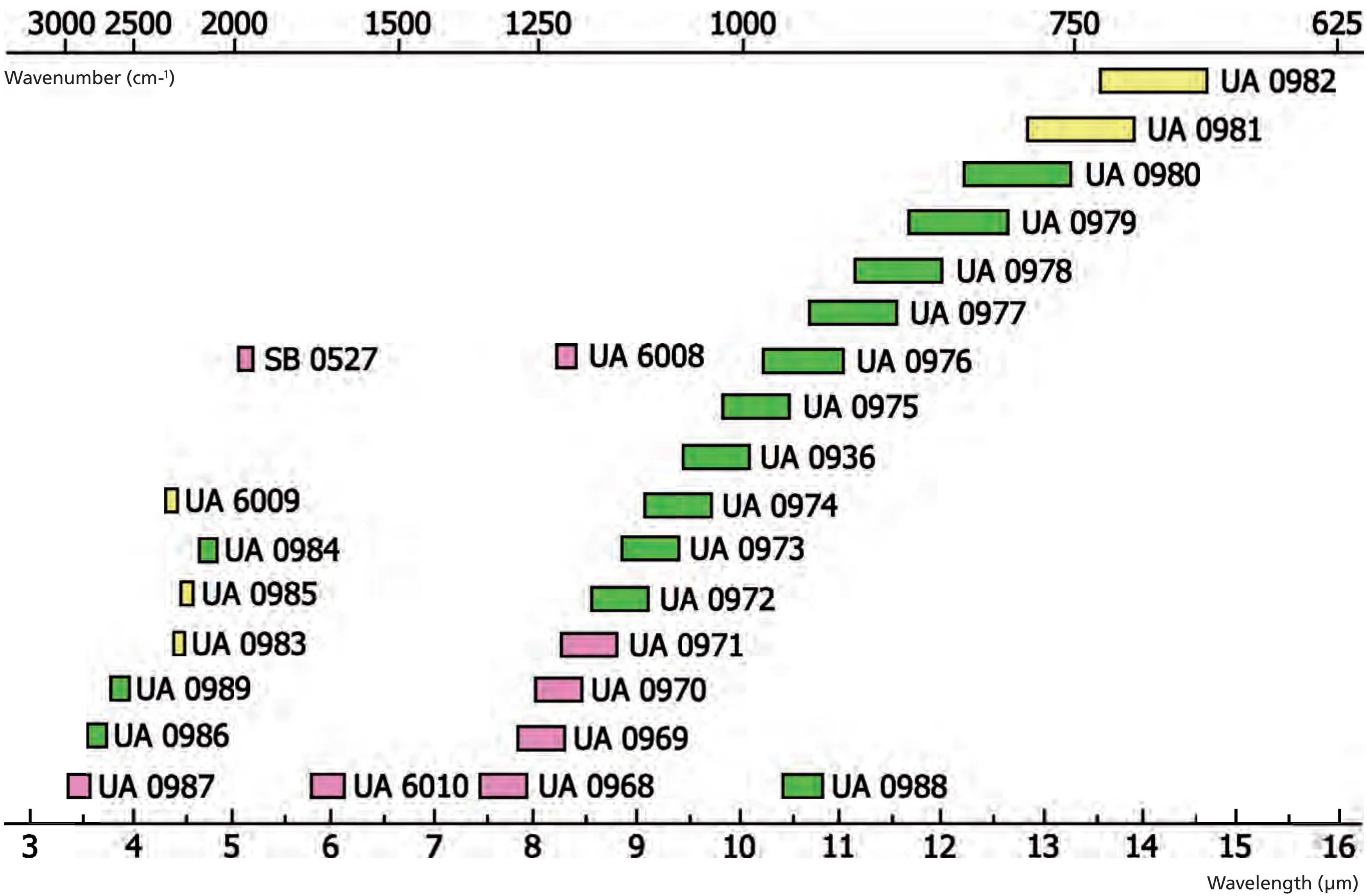


Fig. 1 Centre wavelength and half-power bandwidths of the optical filters

Information about this chart:
For each gas/vapor in the table below, one or more optical filters and corresponding detection limits are listed.

The interference caused by water vapor and carbon dioxide in ambient air is a problem inherent in all infrared methods of detection. The extent of this interference is dependent on the optical filter used. Some optical filters are more sensitive to these substances than others, and color-coding has been introduced to illustrate the sensitivity of the filters (details are given below).

Color coding of the optical filters used in the chart

These optical filters are sensitive to water vapor.
In these regions of the infrared spectrum, water vapor interferes heavily with all infrared technologies. However, the unique water compensation algorithm of the INNOVA gas monitors minimizes this effect, thus, expanding the usable range of infrared measurements.

These optical filters are sensitive to carbon dioxide.
Carbon dioxide interference can, however, be compensated for when using the 1412i and 1314i instruments. An optical filter can be installed in the monitors to measure the level of carbon dioxide and the instruments can then automatically compensate for the interference.

These optical filters are not affected by interference from carbon dioxide and water vapor.
If a gas is measured in clean ambient air using one of these optical filters, the listed detection limit will not be affected by the presence of carbon dioxide or water vapor, except if these are present in very high concentrations.

Notification used in the chart:

= **Measured detection limit – verified by LumaSense laboratory in Denmark.**

Normal = Calculated detection limit.

Detection limit: The minimum concentration of a substance that produces an observable response. For the INNOVA gas monitors, the "observable response" is equal to twice the noise signal on the measured concentrations when monitoring in dry air.

RELATIVE STRENGTH OF ABSORPTION BAND
vw = very week
w = week
m = medium
s = strong
vs = very strong

Sample Integration Time (SIT): To optimize each measurement task, providing faster response time or lower detection limits, the Photoacoustic Gas Monitor – INNOVA 1412i and the Photoacoustic Gas Monitor – INNOVA 1314i have the option of adjusting the SIT between 0.5 and 50 seconds.

SIT	0.5	1	2	5	10	20	50
DLF	3.2	2.2	1.6	1.0	0.7	0.5	0.3

Table 1. Detection Limit Factor as a function of Sample Integration Time

The DLF is the Detection Limit Factor. To get the detection limit at a given SIT one has to multiply the detection limit in the chart with the corresponding DLF:

Detection limit = Detection limit in chart x DLF

For more information look at the example on the back of this chart.

Dynamic range: The 1412i and 1314i instruments have very wide dynamic ranges of up to five orders of magnitude. This means that the measurement range is from the detection limit of a gas up to 100,000 times the detection limit at 5 SIT.

Note: This chart should only be used as a guide when choosing an optical filter for a specific measurement task. If more than one infrared absorbing gas is present in the air being monitored, this will frequently affect the choice of optical filter. Consequently, it is recommended that the local LumaSense representative is contacted for help in choosing the optimum filter configuration.

Detection limits in part per million at 20 ^{0}C, 1 atmosphere pressure and SIT=5 sec.

Optical filter number / Centre wavelength (in micrometer) / Centre wavenumber (in cm^{-1})

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
Acetaldehyde	C_2H_4O	44,05	0,1	0,08	0,07									0,2											
Acetic acid	$C_2H_4O_2$	60,05									0,04	0,03													
Acetic anhydride	$C_4H_6O_3$	102,09								0,04					0,05					0,1					
Acetone	C_3H_6O	58,08	0,1							0,07	0,06														
Acetonitrile	C_2H_3N	41,05	w		w										2,5	w				w					
Acetophenone	C_8H_8O	120,15								0,1									0,8					0,4	
Acetylene	C_2H_2	26,04																					0,3	0,3	0,3
Acrolein	C_3H_4O	56,06	0,1	0,1	m								0,2						0,1						
Acrylonitrile	C_3H_3N	53,06														0,3	0,2		0,2						
Allyl chloride	C_3H_5Cl	76,52	0,2							0,2									0,2					0,4	
1-Aminobutane	$C_4H_{11}N$	73,14	0,01	0,3										0,5	0,5								0,1		
Ammonia	NH_3	17,03												0,2			0,2		0,2						
Aniline	C_6H_7N	93,13	0,3							0,09					0,2									0,2	
Arsine	AsH_3	77,95					0,05	0,03									0,4		0,4						
Benzene	C_6H_6	78,11	0,1												0,7		21								0,3
Benzyl chloride / α-Chlorotoluene	C_7H_7Cl	126,58	0,1							0,1														0,3	0,1
Biphenyl	$C_{12}H_{10}$	154,21	m																	w					
Boron trifluoride	BF_3	67,81														0,2								0,07	
Bromoform / Tribromomethane	$CHBr_3$	252,73	vw									0,11	0,06	12											1,3
Bromomethane	CH_3Br	94,94	0,2						0,5																
1,3-Butadiene	C_4H_6	54,09	0,2													0,2			0,1	0,2					
Butane	C_4H_{10}	58,12	0,01	0,5																					
Butanethiol / Butyl mercaptan	$C_4H_{10}S$	90,19	s							s												m			
1-Butanol	$C_4H_{10}O$	74,12	0,01							0,2					0,08				0,5						
2-Butanol	$C_4H_{10}O$	74,12	s										m			m				m					
tert-Butanol / tert-Butyl alcohol	$C_4H_{10}O$	74,12	0,03										0,08							0,2					
Butanone / Methyl ethyl ketone (MEK)	C_4H_8O	72,11	0,04	1							0,2	0,07							0,5						
2-Butenal / Crotonaldehyde	C_4H_6O	70,09	m	m	s								s	0,2			s								
2-Butoxyethanol	$C_6H_{14}O_2$	118,17	0,01									0,05	0,04								0,4				
n-Butyl acetate	$C_6H_{12}O_2$	116,16	0,02							0,01				0,08	0,05										
sec-Butyl acetate	$C_6H_{12}O_2$	116,16	s							s				s				m							
tert-Butyl acetate	$C_6H_{12}O_2$	116,16	s							s		s													
Butyl acrylate	$C_7H_{12}O_2$	128,17	0,02	0,02							0,02			0,09											
tert-Butyl alcohol / tert-Butanol	$C_4H_{10}O$	74,12	0,03										0,08							0,2					
Butyraldehyde	C_4H_8O	72,11	s	s																				1	
Butyric acid	$C_4H_8O_2$	88,11	0,04										0,04	0,06											
Carbon dioxide	CO_2	44,01				5	70																	13	1,5
Carbon disulfide	CS_2	76,14					1	0,6																	
Carbon monoxide	CO	28,01					0,5	0,2																	
Carbonyl chloride / Phosgene	$COCl_2$	98,92																			0,02	0,02			
Carbonyl sulfide	COS	60,08	0,3					1													0,6				
Chlorobenzene	C_6H_5Cl	112,56												0,09	0,2										0,2
Chloroethane	C_2H_5Cl	64,51	0,04						0,1	0,2							0,6								
2-Chloroethyl ether	$C_4H_8Cl_2O$	143,01	0,03	0,4						0,4			0,02	0,02											
Chloroform	$CHCl_3$	119,38									0,09											0,3	0,04		
Chloromethane	CH_3Cl	50,49	0,2													2								0,6	
1-Chloro-1-nitropropane	$C_3H_6ClNO_2$	123,54	m							m								m			m				
Chloropicrin / Trichloronitromethane	CCl_3NO_2	164,38	w							0,3								0,4		0,03				s	
α-Chlorotoluene / Benzyl chloride	C_7H_7Cl	126,58	0,1							0,1														0,3	0,1
m-Cresol / 3-Methylphenol	C_7H_8O	108,14	0,07									0,05							0,3					0,3	
Crotonaldehyde / 2-Butenal	C_4H_6O	70,09	m	m	s									0,2			s								

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
Cumene / Isopropylbenzene	C_9H_{12}	120,19	m											m		0,7							m		
Cyanogen / Dicyan	C_2N_2	52,03					1,1	0,6																	
Cyanogen bromide	BrCN	105,92					0,1																		
Cyanogen chloride	CNCl	61,47					0,3	0,4																	
Cyclohexane	C_6H_{12}	84,16	0,008	0,2						0,9															
Cyclohexanone	$C_6H_{10}O$	98,14	s								0,2									m					
Cyclohexene	C_6H_{10}	82,14	0,02																	0,9					
n-Decane	$C_{10}H_{22}$	142,28	0,007						0,3																
1-Decene	$C_{10}H_{20}$	140,27	0,009						0,3										0,3						
Desflurane	$C_3H_2F_6O$	168,04									0,005		0,008												m
Deuterium oxide	D_2O	20,03		0,3						s				s											
Diamine / Hydrazine	N_2H_4	32,05													0,6	0,6					0,6				
Diaminoethane	$C_2H_8N_2$	60,10	0,04											0,7									0,1		
Diborane	B_2H_6	27,67										0,1	0,1												
o-Dichlorobenzene / 1,2-Dichlorobenzene	$C_6H_4Cl_2$	147,00	4												0,3									0,1	
m-Dichlorobenzene / 1,3-Dichlorobenzene	$C_6H_4Cl_2$	147,00	2											0,1									0,1	0,15	
p-Dichlorobenzene / 1,4-Dichlorobenzene	$C_6H_4Cl_2$	147,00												0,05	0,2							0,2			
1,1-Dichloroethane	$C_2H_4Cl_2$	98,96	0,2								0,2				0,1										0,09
1,2-Dichloroethane	$C_2H_4Cl_2$	98,96	0,2							0,1														0,3	
1,1-Dichloroethene	$C_2H_2Cl_2$	96,94												vs								0,09		m	
1,2-Dichloroethene (cis)	$C_2H_2Cl_2$	96,94							0,2												0,09	0,2			s
1,2-Dichloroethene (trans)	$C_2H_2Cl_2$	96,94										0,2									0,07	0,05			
Dichloromethane	CH_2Cl_2	84,93	0,6								0,5												0,1	0,08	
1,1-Dichloro-1-nitroethane	$C_2H_3Cl_2NO_2$	143,96													m						m				m
1,2-Dichloropropane	$C_3H_6Cl_2$	112,99	0,08									0,3				0,3								0,5	
Diethylamine	$C_4H_{11}N$	73,14	0,02										0,1											0,4	
2-(Diethylamino)-ethanol	$C_6H_{15}NO$	117,19	s									m			0,4										
Diethylen glycol dimethyl ether	$C_6H_{14}O_3$	134,17	0,01										0,02	0,02											
Diethylen glycol butyl ether	$C_8H_{18}O_3$	162,23	s	m										s	s					m					
Diethylentriamin	$C_4H_{13}N_3$	103,17	s		0,4							0,4			0,3							0,3			
Diethyl ether	$C_4H_{10}O$	74,12	0,02										0,02	0,08											
Diethyl ketone (DEK) / 3-Pentanone	$C_5H_{10}O$	86,13	0,01										0,1						0,2						
N,N-Dimethyl acetamide	C_4H_9NO	87,12	m								m					0,3	0,2								
Dimethylamine (DMA)	C_2H_7N	45,08	0,02	0,04									0,1										0,3		
2-(Dimethylamino)-ethanol	$C_4H_{11}NO$	89,14	s											vs							m				
N,N-Dimethylanilin	$C_8H_{11}N$	121,18	m									m				m									m
Dimethyl disulfide	$C_2H_6S_2$	94,20	s						s									0,6							
Dimethyl ester sulfuric acid (DMS)	$C_2H_6O_4S$	126,13	0,07													0,02	0,06					0,05			
Dimethylethylamine	$C_4H_{11}N$	73,14	s								0,2			0,2									0,8		
Dimethylformamide (DMF)	C_3H_7NO	73,09	0,1								0,3			0,06	0,07		3							0,9	
2,6-Dimethyl-4-heptanone	$C_9H_{18}O$	142,24	0,008							0,45				0,3											
1,1-Dimethylhydrazine	$C_2H_8N_2$	60,10	s												s			s				s			
Dimethylnitrosamine	$C_2H_6N_2O$	74,08	0,04							0,06						0,03									
Dimethyl sulfoxide	C_2H_6OS	78,13	0,3											0,07		0,6									
Dimethyl sulfate	$C_2H_6O_4S$	126,13	m									s				vs						0,06			
Dimethyl sulfide	C_2H_6S	62,13	s	0,4											0,7	0,6									
Dimethyl sulfite	$C_2H_6O_3S$	110,13	m								s						s							m	
Dinitrogen difluoride	N_2F_2	66,01															0,02	0,2							
Dinitrogen oxide / Nitrous Oxide	N_2O	44,01					0,03	0,5																	
1,4-Dioxane / 1,4-Diethylene oxide	$C_4H_8O_2$	88,11	0,02										0,02							0,07					
Diphenyl ether	$C_{12}H_{10}O$	170,21	m/w							s	s									s					
Dipropylnitrosamine	$C_6H_{14}N_2O$	130,19	0,03									0,1			0,05										
Enflurane	$C_3H_2ClF_5O$	184,49	0,1									0,007	0,005									0,08			
Epichlorohydrin	C_3H_5ClO	92,52	m										0,9								0,2				

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
Ethane	C_2H_6	30,07	0,02																			1			
Ethanethiol / Ethyl mercaptan	C_2H_6S	62,13	s														1		2						
Ethanol	C_2H_6O	46,07	0,03										0,2		0,08	0,08									
Ethanolamine	C_2H_7NO	61,08	0,09												0,1							0,7			
Ethene	C_2H_4	28,05	0,3														0,2			0,4					
2-Ethoxyethanol / Cellosolve	$C_4H_{10}O_2$	90,12	s										0,02		s				m						
2-Ethoxy ethylacetate	$C_6H_{12}O_3$	132,16	0,02						0,02		0,01								0,3						
Ethyl acetate	$C_4H_8O_2$	88,11	0,03							0,01					0,05						0,7				
Ethyl acrylate	$C_5H_8O_2$	100,12	0,04									0,02			0,06				0,2						
Ethylamine	C_2H_7N	45,08												0,2								0,07	0,09		
Ethyl benzene	C_8H_{10}	106,17	0,01												0,5									0,4	0,09
Ethylene glycol / Ethanediol	$C_2H_6O_2$	62,07	m												0,09						m				
Ethylene oxide	C_2H_4O	44,05	0,08							0,3										0,2	0,1				
Ethyl formate	$C_3H_6O_2$	74,08	0,03									0,03				0,4									
2-Ethyl-1-Hexanol	$C_8H_{18}O$	130,23	0,008												0,08		0,3								
Ethylhexyl acrylate	$C_{11}H_{20}O_2$	184,28	s									0,03				m			0,4						
5-Ethyl-2-methylpyridine	$C_8H_{11}N$	121,18	s												m							0,6			
Fluorobenzene	C_6H_5F	96,10	7								0,03													0,2	
Formaldehyde	CH_2O	30,03	0,1	0,04	0,1																				
Formic acid	CH_2O_2	46,03	0,01								0,2		0,04	0,02											
Freon 11 / Trichlorofluoromethane	CCl_3F	137,37												0,04	0,04						0,02				
Freon 12 / Dichlorodifluoromethane	CCl_2F_2	120,91										0,02	0,02							0,03					
Freon 12B2 / Dibromodifluoromethane	CBr_2F_2	209,82												0,08	0,1							0,1			
Freon 13 / Chlorotrifluoromethane	$CClF_3$	104,46									0,02	0,04		0,05											
Freon 14 / Tetrafluoromethane	CF_4	88,00								0,004	0,08														
Freon 21 / Dichlorofluoromethane	$CHCl_2F$	102,92	vw											0,01								0,02			
Freon 22 / Chlorodifluoromethane	$CHClF_2$	86,47	0,3										0,02	0,01									0,2		
Freon 23 / Trifluoromethane	CHF_3	70,01	m										0,007												
Freon 112 / 1,1,2,2-Tetrachloro-1,2-difluoroethane	$C_2Cl_4F_2$	203,83											s	s		s				s					
Freon 113 / 1,1,2-Trichloro-1,2,2-trifluoroethane	$C_2Cl_3F_3$	187,38	0,4								0,02	0,02			0,03							0,04			
Freon 114 / 1,2-Dichlorotetrafluoroethane	$C_2Cl_2F_4$	170,92									0,01		0,01								0,02				
Freon 115 / Chloropentafluoroethane	C_2ClF_5	154,47										0,001		0,003			0,001								
Freon 116 / Hexafluoroethane	C_2F_6	138,01								0,01				0,02											
Freon 134a / Tetrafluoroethane	$C_2H_2F_4$	102,03	0,05									0,01	0,04						0,2						
Freon 141b / 1,1-Dichloro-1-fluoroethane	$C_2H_3Cl_2F$	116,95															0,6						0,1		
Freon 152 / 1,2-Difluoroethane	$C_2H_4F_2$	66,05	0,08										0,002						0,09						
Freon152a / 1,1-Difluoroethane	$C_2H_4F_2$	66,05	vw									0,05	0,01												
Freon 1113 / Chlorotrifluoroethene	C_2ClF_3	116,47								0,07					0,04										
Freon 404a														0,2			0,1								
Furfural	$C_5H_4O_2$	96,08		0,2												0,1							0,2		
Furfuryl alcohol	$C_5H_6O_2$	98,10	m										s				0,1							s	
Glutaraldehyde	$C_5H_8O_2$	100,12		0,2	0,06																	0,7			
Halothane	$C_2HBrClF_3$	197,38	0,9									0,02	0,02									0,09			
1,1,1,2,3,3,3-Heptafluoropropane	C_3HF_7	170,03								0,005	0,007		0,02												
n-Heptane	C_7H_{16}	100,20	0,009	0,4																					
2-Heptanone	$C_7H_{14}O$	114,19	0,01	0,2								0,3													
3-Heptanone	$C_7H_{14}O$	114,19	m											m		m									
Hexachloroethane	C_2Cl_6	236,74																					s		
Hexafluorobenzene	C_6F_6	186,05														0,01	0,02								
Hexanal	$C_6H_{12}O$	100,16	0,02	m	s				0,2																
n-Hexane	C_6H_{14}	86,18	0,009	0,1							0,2														
Hexanoic acid	$C_6H_{12}O_2$	116,16	s									m						m							
Hexanol	$C_6H_{14}O$	102,17	0,02												s	s									
1-Hexene	C_6H_{12}	84,16	0,01																	0,2					

Detection limits in part per million at 20 °C, 1 atmosphere pressure and SIT=5 sec.

Optical filter number / Centre wavelength (in micrometer) / Centre wavenumber (in cm^{-1})

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
HFO 1234yf / 2,3,3,3-Tetrafluoropropene	$C_3H_2F_4$	114,04									vs	0,01		0,3					0,2						
Hydrazine / Diamine	N_2H_4	32,05													0,6	0,6					0,6				
Hydrogenchloride	HCl	36,46		0,4																					
Hydrogencyanide	HCN	27,03																						0,5	0,2
Hydrogensulfide	H_2S	34,08								14	22														
4-Hydroxy-4-methyl-2-pentanone	$C_6H_{12}O_2$	116,16	s										m						m						
Isobutyl acetate / 2-Methyl-1-propyl acetate	$C_6H_{12}O_2$	116,16	s								s					s									
Isobutyl alcohol / 2-Methyl-1-propanol	$C_4H_{10}O$	74,12	s	m											s				m						
Isoflurane	$C_3H_2ClF_5O$	184,49	0,3									0,005		0,008								0,1			
Isooctane / 2,2,4 Trimethylpentane	C_8H_{18}	114,23	0,009								0,4	0,5													
Isopentane / 2-Methylbutane	C_5H_{12}	72,15	0,006	0,4																					
Isophorone / 3,5,5-Trimethyl-2-cyclohexen-1-one	$C_9H_{14}O$	138,21	0,03	0,06						0,1			0,5							0,5					
Isoprene / 2-Methylbutadien	C_5H_8	68,12	0,1																0,4	0,3					
Isopropyl acetate / 2-Propyl acetate	$C_5H_{10}O_2$	102,13	m									s			s				m						
Isopropylbenzene / Cumene	C_9H_{12}	120,19	m											m		0,7							m		
Limonene	$C_{10}H_{16}$	136,23	0,01																	0,2	0,4				
Maleic anhydride	$C_4H_2O_3$	98,06									m				m					m					
Methane	CH_4	16,04	0,1						0,2	0,4															
Methanethiol / Methyl mercaptan	CH_4S	48,11	0,1											0,9		1									
Methanol	CH_4O	32,04	0,04								0,5				0,08		0,2								
2-Methoxyethanol	$C_3H_8O_2$	76,09	m	0,1									0,04	0,05											
Methoxyflurane	$C_3H_4Cl_2F_2O$	164,97	0,05							0,04				0,01								0,03			
1-Methoxy-2-propanol	$C_4H_{10}O_2$	90,12	s								0,06		0,02	0,04											
Methyl acetate	$C_3H_6O_2$	74,08	0,04							0,04					0,05										
Methyl acrylate	$C_4H_6O_2$	86,09	0,05								0,02			0,1			0,2								
Methylamine	CH_5N	31,06	0,04	0,2												0,6							0,2		
o-Methylanilin / o-Toluidine	C_7H_9N	107,15	0,05							0,1					0,4									0,1	
Methylbiphenyl	$C_{13}H_{12}$	168,23	s									m				m							s		
2-Methylbutadien / Isoprene	C_5H_8	68,12	0,1																0,4	0,3					
3-Methyl-1-butanol / Isoamyl alcohol	$C_5H_{12}O$	88,15	s	s											m										
3-Methyl-2-butanone / Methyl isopropyl ketone	$C_5H_{10}O$	86,13	0,02						0,2										0,5						
3-Methylbutyl acetate / Isoamyl acetate	$C_7H_{14}O_2$	130,19	0,02								0,01					0,1				0,9					
Methyl tert-butyl ether	$C_5H_{12}O$	88,15	0,01								0,04			0,05											
Methyl chloroformate	$C_2H_3ClO_2$	92,50									0,04	0,01	0,02									0,2			
Methylcyclohexane	C_7H_{14}	98,19	0,01							1															
Methyl ethyl ketone (MEK) / Butanone	C_4H_8O	72,11	0,04								0,2	0,07							0,5						
Methyl formate	$C_2H_4O_2$	60,05	0,03							0,03		0,02								0,3					
4-Methyl-3-heptanone	$C_8H_{16}O$	128,21	s											m			m								
Methylhydrazine	CH_6N_2	46,07	0,07	0,1																0,2			0,3		
Methyl iodide	CH_3I	141,94	0,3							0,2										1,3					
Methyl isobutyl carbinol / 4-Methyl-2-pentanol	$C_6H_{14}O$	102,17	s										m		m					m					
Methyl isobutyl ketone (MIBK)/ 4-Methyl-2-pentanone	$C_6H_{12}O$	100,16	0,02									0,08							0,1						
Methyl isopropyl ketone / 3-Methyl-2-butanone	$C_5H_{10}O$	86,13	0,02						0,2										0,5						
Methyl methacrylate	$C_5H_8O_2$	100,12	0,04									0,02							0,2				0,6		
4-Methyl-2-pentanol / Methyl isobutyl carbinol	$C_6H_{14}O$	102,17	s										m		m					m					
2-Methylpropane / Isobutane	C_4H_{10}	58,12	0,02										0,9												
2-Methylpropene	C_4H_8	56,11	0,02																	0,2	0,4				
1-Methyl-2-pyrrolidone / N-Methylpyrrolidone	C_5H_9NO	99,13	s						0,04		0,2			0,3											
Methylsalicylate	$C_8H_8O_3$	152,15	0,1								0,02	0,03									0,7				
α-Methylstyrene	C_9H_{10}	118,18	m																	s			0,5		s
2-Methylstyrene	C_9H_{10}	118,18	s														s			m			s		

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
Monomethylhydrazine	CH_6N_2	46,07	s													s			s					m	
Morpholine	C_4H_9NO	87,12	m	0,04											0,2								0,2		
Naphthalene	$C_{10}H_8$	128,17	0,07							0,5													0,06		
Nitrobenzene	$C_6H_5NO_2$	123,11													0,5						0,3				
Nitroethane	$C_2H_5NO_2$	75,07	m														m			m					
Nitrogentrifluoride	NF_3	71,00														0,2				0,02					
Nitromethane	CH_3NO_2	61,04												0,5						0,7					
1-Nitropropane	$C_3H_7NO_2$	89,09	m								m												m		
2-Nitropropane	$C_3H_7NO_2$	89,09	0,05											0,9							0,8				
Nitrosomorpholine	$C_4H_8N_2O_2$	116,12		0,2											0,09						0,9				
3-Nitrotoluene / m-Nitrotoluene	$C_7H_7NO_2$	137,14	w											0,3								0,3			
Nitrous Oxide / Dinitrogen oxide	N_2O	44,01					0,03	0,5																	
Nonane	C_9H_{20}	128,26	0,007						0,4																
Nonenal (Trans-2-nonenal)	C9H16O	140,22	0,03										0,2				0,5								
Octane	C_8H_{18}	114,23	0,007	0,2																					
1-Octanol	$C_8H_{18}O$	130,23	0,01											0,2		0,2									
1-Octene	C_8H_{16}	112,21	0,01						0,4										0,2						
Pentanal	$C_5H_{10}O$	86,13	0,02		s				0,3																
Pentane	C_5H_{12}	72,15	0,01	0,3																					
2-Pentanone	$C_5H_{10}O$	86,13	0,01									0,1	0,2						0,8						
n-Pentyl acetate / Amyl acetate	$C_7H_{14}O_2$	130,19	0,02	0,7						0,03					0,06										
Perfluoro-1,3-dimethylcyclohexane	C_8F_{16}	400,06									s						0,06			0,07					
Perfluoromethylcyclohexane	C_7F_{14}	350,05									s						0,03			0,1					
Phenol	C_6H_6O	94,11	0,6									0,008	0,1		0,4										
Phenylhydrazine	$C_6H_8N_2$	108,14	vw							m														m	
1-Phenylpropane	C_9H_{12}	120,19	0,02						0,6																s
Phosgene / Carbonylchloride	$COCl_2$	98,92																			0,02	0,02			
Phosphine	PH_3	34,00												0,3		0,5									
α-Pinene	$C_{10}H_{16}$	136,23	0,009											0,4									0,6		
Propadiene	C_3H_4	40,06	0,8																		0,1				
Propane	C_3H_8	44,10	0,02	0,4																					
1,2-Propanediol / Propylene glycol	$C_3H_8O_2$	76,09	s												0,01						m				
Propanoic acid	$C_3H_6O_2$	74,08	0,1										0,03			0,3									
Propanol	C_3H_8O	60,10	s	0,3											0,08										
2-Propanol	C_3H_8O	60,10	0,2									0,09	0,07						0,2						
Propene	C_3H_6	42,08	0,05														0,4			0,3					
n-Propyl acetate	$C_5H_{10}O_2$	102,13	m								s					m				m				w	
2-Propyl acetate / Isopropyl acetate	$C_5H_{10}O_2$	102,13	m									s			s				m						
Propylene glycol / 1,2-Propanediol	$C_3H_8O_2$	76,09	s												0,01						m				
Propylene glycol monomethyl ether acetate	$C_6H_{12}O_3$	132,16									0,01		0,02	0,03											
Propylene oxide	C_3H_6O	58,08	s										0,7									0,2			
Propyl nitrate	$C_3H_7NO_3$	105,09	s														s		s					m	
Propyne / Methylacetylene	C_3H_4	40,06	0,06							0,4															
Pyridine	C_5H_5N	79,10	0,4													0,7								0,3	
Sevoflurane	$C_4H_3F_7O$	200,06	0,08								0,006		0,01						0,2						0,3
Silane	SiH_4	32,12																s		m					
Silicon tetrafluoride	SiF_4	104,08													0,03	0,02									
Styrene	C_8H_8	104,15	0,1																0,3					0,3	
Sulfur dioxide	SO_2	64,06										0,4	0,3												
Sulfur hexafluoride	SF_6	146,06															0,009	0,006	0,004						
1,1,2,2-Tetrabromoethane	$C_2H_2Br_4$	345,65	vw									m								s				m	
1,1,2,2-Tetrachloroethane	$C_2H_2Cl_4$	167,85									0,2											0,1		0,06	
Tetrachloroethene	C_2Cl_4	165,83																	0,04	0,07			0,2		
Tetrachloromethane	CCl_4	153,82																				0,03	0,02		

Name	Brutto-formula	Molec.-weight	987 3.4 2950	986 3.6 2800	989 3.7 2750	983 4.4 2270	985 4.5 2215	984 4.7 2150	968 7.7 1291	969 8.0 1254	970 8.2 1217	971 8.5 1179	972 8.8 1139	973 9.1 1101	974 9.4 1061	936 9.8 1020	975 10.2 981	988 10.6 946	976 10.6 941	977 11.1 900	978 11.6 861	979 12.2 822	980 12.8 783	981 13.4 746	982 14.1 710
Tetraethylplumbane	$C_8H_{20}Pb$	323,44	s										0,2						s						
2,3,3,3-Tetrafluoropropene / HFO 1234yf	$C_3H_2F_4$	114,04									vs			0,3					0,2		0,4				
Tetrahydrofuran	C_4H_8O	72,11	0,01												0,09			0,5							
Tetrahydrothiophene	C_4H_8S	88,17	0,02									m									2				
Thionyl chloride	Cl_2OS	118,97								0,02	s														
Thiophene	C_4H_4S	84,14								s											m				
Toluene	C_7H_8	92,14	0,05												0,5									0,4	0,2
2,4-Toluenediamine	$C_7H_{10}N_2$	122,17	w									m										m			
2,4-Toluene diisocyanate (TDI)	$C_9H_6N_2O_2$	174,16					s								m						m				
o-Toluidine / o-Methylanilin	C_7H_9N	107,15	0,05							0,1														0,1	
Total Organic Carbon ref. Methane (TOC).			0,1																						
Total Organic Carbon ref. Propane (TOC).			0,02																						
Total Organic Carbon ref. Toluene (TOC).			0,05																						
1,2,4-Trichloro benzene	$C_6H_3Cl_3$	181,45												s		0,4							s		
1,1,1-Trichloroethane	$C_2H_3Cl_3$	133,40	0,3											0,04										0,08	
1,1,2-Trichloroethane	$C_2H_3Cl_3$	133,40	0,7								0,4								0,3					0,07	
Trichloroethene	C_2HCl_3	131,39		0,3						0,4					4				0,07		0,08				
Trichloronitromethane / Chloropicrine	CCl_3NO_2	164,38	w							0,3								0,4		0,03					
1,2,3-Trichloropropane	$C_3H_5Cl_3$	147,43	w								m								m					s	
Triethylamine (TEA)	$C_6H_{15}N$	101,19	0,02								0,1				0,1										
Trifluoromethyliodid	CF_3I	195,91									s			0,01										m	
Trimethylamine (TMA)	C_3H_9N	59,11	0,03	0,02								0,2			0,1										
1,2,4-Trimethylbenzene	C_9H_{12}	120,19	0,02														m						s		
3,5,5-Trimethyl-2-cyclohexen-1-one / Isophorone	$C_9H_{14}O$	138,21	0,03	0,06						0,1			0,5							0,5					
1,3,5-Trioxane	$C_3H_6O_3$	90,08	w	0,09											0,08				0,09						
Undecane	$C_{11}H_{24}$	156,31	0,005	0,07																					
Vinyl acetate	$C_4H_6O_2$	86,09	0,4								0,007		0,03								0,1				
Vinyl chloride	C_2H_3Cl	62,50														0,4				0,2				0,4	
m-Xylene	C_8H_{10}	106,17	0,03		vw										0,9								0,3		

Notification used in the chart:

(yellow) = **Measured detection limit – verified by LumaSense laboratory in Denmark**

Normal = Calculated detection limit

Relative strenght of absorption band: vw=very week w=weak m=medium s=strong vs=very strong

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Converting concentration units

The detection limits listed on this wall chart are given in "parts per million" by volume (ppm) at 20°C and 1 atmosphere of pressure. These values can be converted into the concentration unit "mg/m³" by using equation (1) given in the box below.

For a gas at 20°C and at 1 atmosphere of pressure: (1)

$$\text{Concentration (mg/m}^3\text{)} = \frac{\text{Concentration (ppm) x Molec. Weight (g/mol)}}{\text{24.04 l/mol}}$$

To Convert ppm to mg/m³ (at 20°C and 1 atm.):

Reading from the chart, the detection limit at 20°C and 1 atmosphere pressure of Toluene is 0.5 ppm using the UA0974. The molecular weight of Toluene is 92.14 g/mol. Using equation (1) shown in the box above, the detection limit can be calculated in mg/m³:

$$\text{Detection Limit} = \frac{0.5 \times 92.14}{24.04} = 1.92 \text{ mg/m}^3$$

To convert measured gas concentrations from mg/m³ to ppm (at T °C and P atm.):

Equation (1) can only be used to convert concentration units of a gas measured at a pressure of 1 atmosphere and at a temperature of 20°C. If the gas is at a pressure of P atmospheres and its temperature is T Kelvin, then the conversion equation becomes:

$$\text{Concentration (ppm)} = \frac{\text{Concentration (mg/m}^3\text{) x Molar Volume (l/mol)}}{\text{Molec. Weight (g/mol)}}$$

Where: Molec. Weight = molecular weight of the substance (in g/mol). This can be found in the Detection Limit Chart.

Molar Volume = is the volume occupied by one mole of an ideal gas at a specified temperature and pressure. Table 2 lists the molar volume of a gas at various temperatures and 1 atmosphere of pressure. Its value at a temperature of T K and a pressure of P atmosphere can be calculated from the following equation:

$$\text{Molar Volume} = \frac{RT}{P}$$

Where: T = temperature of the gas in K

R = Gas Constant = 8.2054×10^{-2} liter atm. K^{-1} $mole^{-1}$

P = pressure of the gas in atmospheres

Table 2. Molar Volume of an ideal gas at 1 atmosphere of pressure at different temperatures

Temperature (°C)	-20	-15	-10	-5	0	5	10	15	20	25	30	35	40	45	50
Molar Volume (l/mol)	20.76	21.17	21.58	21.99	22.40	22.81	23.22	23.63	24.04	24.45	24.86	25.27	25.68	26.07	26.50

Calculation of detection limits for different SIT settings

To calculate the detection limit at Sample Integration Times (SIT) other than 5 seconds, the following equation must be used:

Detection limit = Detection limit in chart x DLF

The factor DLF can be read in Table 1.

Example: Reading from the chart – the detection limit for Sulphur hexafluoride (SF_6) using the optical filter UA0988 is 0.006 ppm. Calculating the detection limit using SIT of 0.5 second and 50 seconds gives the following result:

Detection limit SF_6 (SIT of 0.5) = 0.006 ppm x 3.2 = 0.019 ppm

Detection limit SF_6 (SIT of 50) = 0.006 ppm x 0.3 = 0.002 ppm