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ABSORPTION SPECTROSCOPY OF XYLENE WITH A PDMS GAS CONCENTRATING LAYER ON SOI WAVEGUIDES

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Abstract

The presence of chemical substances on the environment, such Xylene, has harmful effects on human health. Exposure to Xylene to humans causes symptoms in a range from dizziness to death, being crucial to monitor it.

Silicon-On-Insulator (SOI) waveguides and absorption spectroscopic technique for gas sensing presents an interesting alternative due to its high potential of provide miniaturized, compact and high sensitivity devices. Moreover, the use of gas pre-concentrating chemical films is presented as an alternative approach for enhanced gas detection using optical waveguides.

In this work, we investigate gaseous xylene absorption in the near-infra-red region (NIR), exploiting evanescent field absorption (EFA) on SOI waveguides covered by a preconcentrating polydimethylsiloxane (PDMS) film. Estimations of absorption cross section and the PDMS enhancement factor have been made. It has been experimentally observed that 5000 times gas density enhancement is achievable with the PDMS films.

The potential benefit of gluing fibers on the grating couplers has been studied and 5 times improvement in the measurement stability with glued fibers has been observed. However, in order to maintain a better overlap between the grating transmission spectrum and the absorption band of xylene, most experiments were run without gluing the fibers.

By using a 350nm PDMS film on a 1.2 cm long SOI waveguide, an expected absorption behavior has been observed at a concentration of ∼4000ppm gaseous xylene; which is in a close agreement with an estimate taken with approximately 5000 times PDMS enhancement factor. A rising absorption trend has been observed in the region beyond 1665nm agreeing with the theoretical xylene absorption band. An absorption measurement for a drop of liquid xylene on a PDMS coated waveguide has been also carried out which gave a further confirmation on the absorption trend observed at ∼4000ppm xylene vapor. It is, however, observed that ensuring measurement and environmental stability can be critical in absorption experiments. For instance, in one experiment, the measured absorption appeared to extend outside the expected region likely due various factors such as mechanical stability and temperature contributing to the system noise. Future studies may focus on minimizing the measurement noise and lowering the gas detection limits.

Keywords: Xylene, gas sensing, absorption spectroscopy, near-infra-red (NIR), silicon-on-insulator (SOI), waveguide, polydimethylsiloxane (PDMS), evanescent field absorption (EFA).

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1. Optical sensing: State of the art

1.1 Introduction

The detection and measurement of a gas concentration using different methods is important for a variety of environmental, industrial and medical application. For example a gas may be hazardous to human health or an atmospheric pollutant so it is important to control the concentration levels. Apart from detection systems which provide an alarm signal when a determinate gas concentration is reached, is frequently required to obtain accurate real time measurements of the concentration of a particular target gas, often in a mixture of other gases.

Gas detection can be separated into two groups: direct methods, which monitor a physical parameter of the target gas, and indirect methods, which use chemical transducers or other to monitor the concentration of the gas being detected. These direct and indirect methods may be further divided into optical and non-optical sensing techniques [1.].

Table 1.1 and 1.2 show a list of direct and indirect methods in gas sensing and their principal advantages and disadvantages:

Direct Methods		
Method	Advantages	Disadvantages
Optical spectroscopy: Measurement of optical absorption, emission or scattering	Rapid and selective measure of gas concentration with good sensitivity	Gas must have a significant absorption, emission or scattering in the optical spectrum
Mass spectrometry	High selectivity and accurate measurements	Slowly acting, expensive, very bulky.
Gas chromatography	High selectivity and accurate measurements and capability to detect a wide range of compounds	Very expensive and very large size.

Interferometric/refractrometric optical sensors	Good sensitivity. Different configurations: Fabry Perot, Machzhender ,ring resonators. Implemented in free space or guide wave schemes	Limiting factors inherited to existing methodology of device desing and fabrication

Table 1.1

Indirect Methods		
Method	Advantages	Disadvantages
Interaction with a chemical indicator	Can be highly specific if suitable indicator. Can allow operation in a convenient wavelength when gas has no convenient absorption in that spectral range.	Poisoning can occur. Sensitive to groups of chemicals (eg. Acid gases) rather than to a specific gas. May exhibit non-reversible behavior and may need water vapor to act as a catalyst.
Sensors involving interaction with the surface of a semiconductor, or ceramic layer	Low cost. Can measure total exposure over time, if a non-reversible reaction is used.	Poisoning can occur, may exhibit non-reversible behavior and may consume analyte.
Catalytically induced combustion and measurement of the heat change.	Low cost and practical to detect flammable gases.	Poisoning can occur. Sensitive to a group of gases rather than to a specific gas. If other flammable gas is present, may give reading which is not predictably related to the lower explosive limit.

Table 1.2

Optical sensing techniques have some inherent advantages over other non-optical sensing techniques. Among these advantages are: immunity to electromagnetic interference, insensitivity to environmental variations such as temperature and pressure for certain optical sensor designs, and the capability of sensing without having the electronic components located at the measurement environment. Furthermore, the availability and continuous development of optical components and instrumentation from the optical communication industry provides an economic advantage to optical sensors.

1.2 Spectroscopic detection:

The spectroscopic techniques, with their numerous variations, are likely to remain the most common optical gas-sensing method, but other measuring methods are emerging due to the progress in laser sources and optical components such as ellipsometry, surface plasmon resonance (SPR) or hyperspectral imaging. Surface plasmon resonance (SPR) is a physical process that can take place when plane-polarized light hits a metal film under total internal reflection conditions and ellipsometry is an optical, reflection-based, technique used since many years for thin film and surface characterization. On the instrumentation side, optical fibers and optical circuits, provide the possibility of efficient and compact devices [2.].

In spectroscopic methods, the optical absorption/emission/scattering of a gas species is monitoriced at defined optical wavelength. The wavelength distribution of the chosen optical characteristic constitutes the feature that allows identifying the presence of specific gas species, while the intensity of the absorption/emission/scattering gives information of the concentration. Thus, spectroscopic optical methods provide a fast, accurate and stable measurement of a gas species, provided that it has significant absorption or emission of optical radiation in a suitable wavelength band.

1.3 Review of different optical techniques of gas sensing

In this section, a review of different optical gas sensing techniques is presented. Most used gas sensing techniques can be easily classified in three main groups: Free space spectroscopic, fiber optic and integrated waveguide gas sensors.

Optical fiber sensors:

Since the appearance of optical fibers in the telecommunication field, research groups have developed various types of optical fiber based sensors. These sensors can be categorized based on light modulation into interferometric and spectroscopic sensors. Fiber Bragg Gratings (FBG's) sensors are the most common type of interferometric sensors, on the other hand, Evanescent Field Absorption (EFA) sensors, which fall under the spectroscopic sensors category, are considered to be the most published type of optical fiber sensor [3.] and finally, sample cell (SC) sensors with hollow core optical waveguides are considered to be another type of spectroscopic sensors.

Besides, optical fiber sensors can be classified in two main groups depending on the parameter measured, namely, sensors based on refractive index change and those related to optical absorption.

In absorption spectroscopic sensors, spectral absorption features of a gas can be measured due to the direct interaction between the light travelling through the fibers and the gas. Photonic crystal fiber (PCF) or holey fiber that incorporates air holes within the silica cladding region opens new opportunities for exploiting the interaction of light with gases through the evanescent field in the holes. However, on the other hand, sensors with hollow core fibers are limited by poor gas diffusion into the hollow region [4.]. Noise and high sensitivity to temperature are other limiting factors in these kind of sensors.

Another type of optical fiber sensor is the one carried out by hollow core photonic bandgap fibers (PBGFs). The demand of high sensitivity in measurements requires gas cell with long interaction path length and PBGFs provide the benefit of combine long interaction length with compactness since the fiber can be coiled [5.]. As much as 95% of the optical power can be confined in the hollow core allowing filling it with the gas mixture. PBGFs provide a platform for highly localized interaction between the guided mode and the gas. The use of PBGFs cells to contain gas concentration samples allows the fabrication of compact and low-loss fiber sensors [5.].

On the other hand, variations in the complex refractive index at the fibers surface when target gas is detected are the other type of optical fiber sensors. Typically, a gas sensitive transducer film is deposited on an exposed area of the fiber core and when the gas is applied, optical characteristics of the chemical film leads to a change in the effective index of the fiber through evanescent wave interaction. This type of sensor is able to measure refractive index and intensity variations. Sensors based on fiber Bragg gratings, nanotapers and uncladded region are part of this optical fiber sensors [6.]. Different types of fibers like inverted graded index (IGI) fiber, more sensitive to environmental refractive index change have been used to detect toluene in water [7.].

Free space spectroscopic sensors:

Spectroscopic methods is one of the matures optical techniques that have been used for a wide variety of applications, however, most practical spectroscopic sensors are implemented on free space bulk configurations having as a result very large sizes. Besides, complex sources and read-out instrument such a quantum cascade lasers [8.] or distributed feedback diode lasers among others, are usually employed limiting the portability and increasing the cost of those sensors.

Techniques such Faraday rotation spectroscopy [9.] or Raman spectroscopy have also been demonstrated for molecular detection [10.] [6.]. In Raman spectroscopy, an incident photon gains or donate energy from a vibrational or rotational energy level of a molecule scattering the incident light at wavelengths shifted from the excitation wavelength and providing unique information about the molecule. This technique can be used as a complement to measure some gases having insignificant IR absorption, but as was mentioned previously, large size and expensive instrumentation has increasingly raised the interest for compact and low cost alternatives.

1.4 Integrated gas sensing on Silicon photonic chips:

In previous sections the importance of optical sensing has been mentioned and some types of fiber based optical sensors have been discussed. However, despite of the possibility of multiplexed and remote sensing optic fiber sensors do not lend themselves for an easy integration [12.]. Photonic integrated gas sensors have gathered an important success due to their high potential in miniaturized, compact and high sensitive devices. In addition, advances on existing CMOS fabrication processes have allowed develop silicon photonic sensors with significant advantages such as the integration of thousand sensors on a single millimeter scale-chip. The possibility of chip-scale fabrication provides the opportunity of mass production reducing as well, the cost of the sensors.

For all these advantages, the research on chip-scale bio-chemical sensor is being extended to gaseous analytes as well and another spectroscopic strategy is to use guided modes that are localized to a narrow region near the surface and propagate along the surface, thereby enhancing the optical interaction cross-section with surface bound species [17.]. Surface plasmon resonance sensing and evanescent waveguide sensing are the two main examples. In these guided wave methods, the linear optical properties are measures, for example absorption or refractive index.

Plasmonic gas sensors:

Surface plasmon based optical sensors have attracted a great interest in the last 10 years mostly for biochemical or biomedical applications. This kind of sensors employs optically excitable surface charge density oscillations at the interface between two media with dielectric constants of opposite
sign, typically a metal and a dielectric. This surface wave oscillation is termed surface plasmon resonance (SPR). Refractive index variations in the probed optical medium are rapidly observed with surface-plasmon-based techniques providing a high sensitivity. Refractive index changes near the surface of the plasmonic waveguide structures is detected through a shift in the SPR wavelength or angle providing the possibility of use it for gas sensing.

CO2 and N2 gas detection have been demonstrated showing that the sensitivity of this sensor is higher in the mid-infrared range that in the visible [16.]. In this reference, the sensor uses the Kretchmann configuration using a bulky prism coupling, as in the majority of SPR sensors which makes it difficult to integrate. On the other hand, phase-matching issues between the dielectric waveguide and SPR modes impose challenges for an implementation on high index contrast platforms such as SOI.

Evanescent wave optical sensors:

Evanescent wave sensors are based on the interaction of analytes with a portion of the waveguide mode field extending outside the waveguide boundaries. In this kind of sensors, different configuration on planar waveguides have been employees, for example: interferometric techniques, resonant structures and grating based schemes.

Mach-Zehnder interferometer and ring resonator (MRR) evanescent field sensors fabricated on the silicon-on-insulator material platform have been demonstrated. MRR are interesting for sensing applications because of its possibility of be very small and sensitive [12.] [13.].

Another class of sensing technology is photonic crystal waveguides which can be found in different topologies in spectroscopic gas sensing. Photonic crystal based sensors have been also proposed as gas sensors in mid infrared (mid-IR), since many gases (e.g., CO_2, CH_4, CO) exhibit absorption lines in mid-IR wavelength region [15.].

SOI in integrated photonic circuits:

Silicon on Insulator (SOI) wafers are widely used for highly integrated photonic circuits. Silicon-on-Insulator micro and nano photonic structures and devices are highly suitable for a wide range of sensing applications [14.]. SOI consists of a thin silicon layer ($n = 3.45$) on top of an oxide cladding ($n = 1.45$) layer carried on a silicon wafer. With its silicon core and its oxide cladding, it has a high vertical refractive index contrast. This high index contrast allows the fabrication of ultra-compact photonic waveguides and structures making possible the integration of large number of structures on the same chip.

The mode distribution of the guided modes in SOI structures is such that a substantial portion of the light is concentrated outside the core material, making them suitable for sensitive detection of environmental changes, called evanescent field sensing. For high effective index contrast, the confinement factor, which defines the amount of optical field available for absorption detection can be particularly high. This could be attributed to typically high group index characteristic of these waveguides. Due to its high confinement factor, high index waveguides are more sensitive to the surrounding due to the electric field enhancement at the waveguide surface [6.].

2. Optical absorption sensing

2.1 Absorption spectroscopy

In general, absorption spectroscopy refers to a measurement technique based on the interaction between matter and radiated energy. This techniques measure the absorption of radiation as a function of frequency or wavelength, due to its interaction with a sample.

When light passes through a physical medium, the interaction with the medium may lead to different phenomena, such as absorption. Particularly, optical absorption spectroscopy relies on optical interaction with the imaginary component of the dielectric permittivity which represents absorption or scattering of light by the propagation medium.

The electric field component of a light propagating through a medium with a complex refractive index, $\hat{n}$, given by :

$$\hat{n} = n + j\kappa \qquad 2.1$$

where n indicates the phase speed κ the amount of absorption loss when the electromagnetic wave propagates through the material can be expressed by equation 2.2:

$$\vec{E}(\lambda) = \exp\left(\frac{-2\pi\kappa}{\lambda}z\right).\vec{E}_0(\lambda).\exp\left(j\frac{2\pi n}{\lambda}z\right) \qquad Eq. 2.2$$

where z, k and λ are the propagation direction, the wave number and the wavelength, respectively.

Equation 2.2 shows that the optical wave traveling in a medium can undergo attenuation or amplification. Wavelength dependent absorption or attenuation by a medium is a basic principle behind optical absorption spectroscopy.

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2.1.1 Beer-Lambert Law

As it was mentioned in previous sections absorption spectroscopy is a powerful and versatile chemical analysis tool for detection and identification of gases in industrial, medical and environmental fields. Those techniques takes advantage of capacity to make in situ, real time and fast measurements with respect to conventionally used chemical measurement techniques like gas chromatography or mass spectrometry among others [19.].

The principle of linear absorption of light by sample is described by Beer- Lambert Law.

This Law states that the attenuation of the light energy of dI_Z as it passes through the thickness dz is proportional to the light energy available for absorption I_Z ,the number of absorbing molecules in a square centimeter of the infinitesimal slab, and the absorption cross section per molecule, σ. (Figure 2.1) [19.].

$$I = I_0 \exp(-\sigma CL) \qquad Eq. 2.3$$

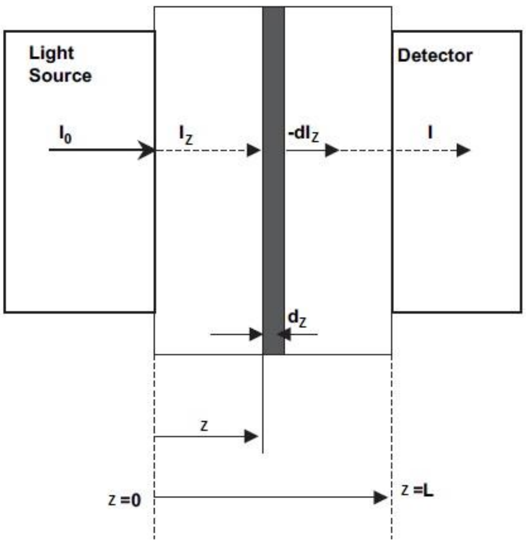


Figure 2.1. Beer-Lambert Law diagram [19.]

Where, I the output intensity, I_0, the input intensity, σ the absorption cross section in cm2/molecules, C the concentration in molecules/cm3 and L the interaction length.

From this relation, the absorbance is given by:

$$\text{Absorbance} = \ln\left(\frac{I_0}{I_T}\right) = \sigma CL \qquad Eq. 2.15$$

Hence, the concentration of molecules in an absorbing medium of a known absorption cross section, such as a gas, can be determined by measuring the transmitted light intensity in a given interaction length, L.

2.1.2 Waveguide absorption spectroscopy:

Optical sensors can be divided in two types. One of them uses open space setups and bulk optical components (mirrors, splitters...), and the other uses waveguides. Fig. 2.2 shows the main difference between both types in a simplified way.

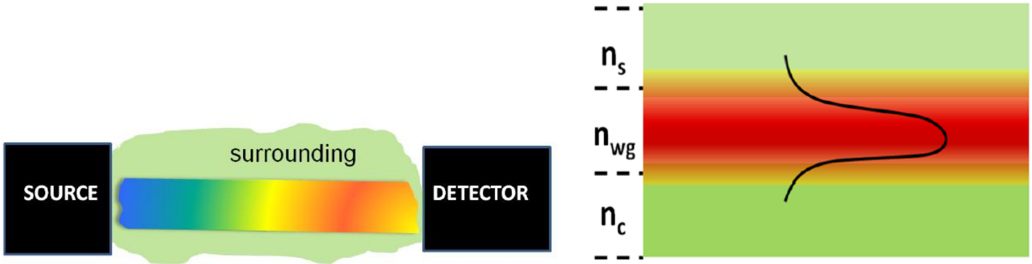


Figure 2.2 Simplified schemas of open space and waveguide sensors [6.]

Free space optical spectroscopy allows direct interaction of the beam with gas; however, such spectrometers are more sensitive to mechanical perturbations or misalignment. Moreover, these sensors are typically large in size and expensive. On the other hand, guided wave sensors have the potential benefit of low cost fabrication and high portability in addition to being less sensitive to mechanical perturbations. In guided wave sensors, different waveguide structures serve as basic building blocks.

In the second configuration presented before, a waveguide is used for the purpose of gas sensing.

The simplest model of a waveguide consists in a three layer optical waveguide (Figure 2.3) where a core layer is surrounded by upper and lower cladding layers. When the core index of refraction, n_1, is sufficiently larger than the cladding layer indices n_2 and n_3, light coupled into the end facet of the waveguide structure undergoes total internal reflection at each core-cladding interface and thereby remains confined within the waveguide core as it propagates. In a more precise description based on electromagnetic theory, light propagates in the waveguide as a superposition of modes, the eigenvalue solutions of Maxwell's equations for the electromagnetic field in the waveguide

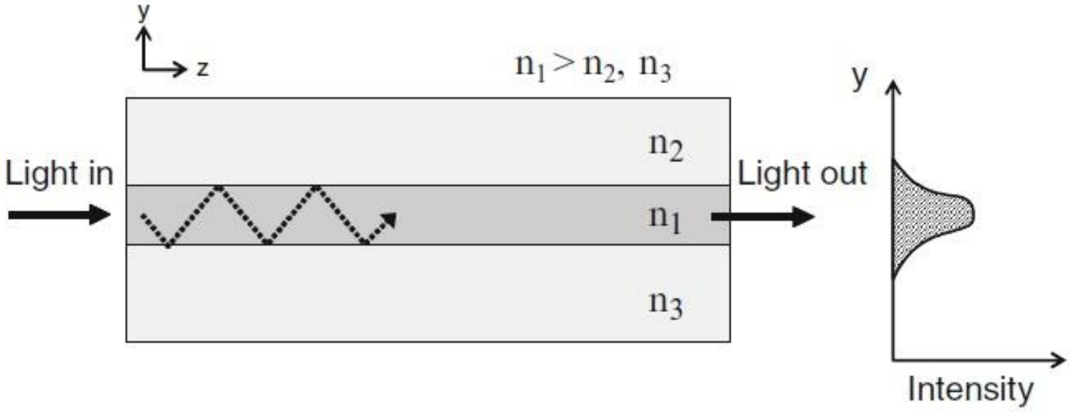


Figure 2.3 General waveguide structure [17.]

In general, a waveguide may support one or more optical modes depending on the waveguide dimensions and materials. However, for optical sensing is assumed that the waveguide design allows only one mode to propagate. In principle, the light can travel along the waveguide forever with no loss, but in practice the propagation distance is limited since losses are always present to some degree.

In semiconductor waveguides, however, losses are usually on the order of 0.1–1 dB cm^{-1}, because of microscopic roughness at the core-cladding boundary, and intrinsic optical absorption in the waveguide materials [17.]. Waveguides can take different forms and be built with many different materials.

Silicon on insulator (SOI) waveguides used in this thesis have a silicon core only a few hundred nanometers cross section with refractive index of n = 3.47 at a wavelength of λ= 1550 nm. The silicon core is bounded by an underlying SiO_2 cladding with an index of n = 1.44, and an upper cladding that may be air (n = 1.0), SiO2, or polymer (n =1.4–1.6).

With all these characteristics, the difference between the Si core and the cladding is more than a factor of two, allowing silicon waveguides to be described as high index contrast systems. Figure 2.4 shows a general SOI evanescent field sensor.

As indicated before, the evanescent field extends out of the waveguide boundaries interacting with the environment. The parameter used to measure the amount of the field which is extended outside the waveguide is termed as the confinement factor, represented by the greek letter Γ .

For high index contrast waveguides, like SOI (silicon on insulator) waveguides, used in this thesis, the confinement factor is in the range of 10-30 % [6.]. In general, confinement factor describes the amount of optical field available for absorption.

The challenges in gas absorption spectroscopy are related to the properties of the gases and the instrumentation noise. Gases are the least dense form of matter and its absorption cross section is very small. The absorption cross section is a probability of an absorption process. Is a term used to quantify the ability of a molecule to absorb a photon of a particular wavelength and for gases it is very small, in the order of 10^{-22} – 10^{-18} cm^2/molecule [6.].

Taking into account the Beer Lambert Law explained previously, those characteristics impose the condition of having enough interaction length.

One of the techniques used to compensate for these characteristics of the gas may be the use of films to increase the molecules density of gases near the evanescent field interaction region.

On the other hand, noise is another limiting factor in gas absorption spectroscopy. Noise from the light sources, the detector, mechanical vibrations, etc.. are some of the different types of noise that can affect the measurements.

2.2 Enhanced gas detection with gas preconcentrating films.

In previous sections basis of gas detection have been discussed, as well as the pros and cons of different detection techniques have been briefly mentioned. In this section, the use of gas preconcentrating chemical films is presented as an alternative approach for enhanced gas detection using optical waveguides.

The choice of these materials that compose the film is determined by factors such as the optical, chemical and morphological properties as well as the chemical nature of the gas to be detected by using an adsorption process.

The adsorption process is the adhesion of atoms, ions or molecules from a gas, liquid, or dissolved solid to a surface. This process creates a film of the *adsorbate* on the surface of the *adsorbent*. The adsorption of gaseous molecules on porous films can involve various mechanisms depending on the physical and chemical properties of the porous surface and the target molecules [18.]. In general, an adsorption process may involve a chemical interaction or physical binding on the pores.

One of the cases is that some gaseous molecules can be physically adsorbed on the pores by capillary condensation. This is usually the case for volatile organic compounds (such as Xylene) with boiling points above room temperature. In this situation, a percentage of the pore volume can be assumed to be occupied by the vapor molecules.

Based on this process, various inorganic and polymer materials have been used as gas sensitive transducer in optical sensors. Gas sensitive films with porous structures have been investigated and more concretely materials with nano dimensional pores. This material possess properties as high surface area per unit volume and it allows the enhanced adsorption for a given gas concentration. Nanoporous materials can be classified in three categories based on the pores dimensions: microporous (< 2 nm pore diameter), mesoporous (2-50 nm pore diameter) and macroporous (> 50 nm pore diameter).

For optical gas sensing applications, changes in refractive index and absorption (aim of this thesis) can be exploited. Adsorption of gas molecules in this nanoporous films alter the chemical properties, for example changes in color or refractive index changes, of these films. Besides these chemical properties, the physical binding of gas molecules within the pores can modify the overall refractive index of the porous film.

For this thesis a porous film has been chosen in order to enhance the density of gas molecules in the evanescent field interaction region [6.].

PDMS film:

In this work a polymer material, PDMS (Polydimethylsiloxane) has been used for the SOI waveguides coating. PDMS belongs to a group of polymeric organo-silicon compounds that are commonly referred to as silicones. PDMS is the most widely used silicon-based organic polymer since it has been used in conjunction with fiber optic sensors to extract and detect a variety of organic compounds, including aromatics, hydrocarbons and chlorinated compounds [20.],[21.],[22.].

This polymer is robust, hydrophobic and transparent. In addition, PDMS can reversibly absorb most non polar organic contaminants from aqueous or gaseous samples [8.].
It is a porous polymer with a good physical stability and processing properties suitable for the fabrication of ultra-thin films and membranes of high affinity for a range of volatile organic compounds such as xylene. CO_2 and SO_2 gas sensing have been demonstrated using PDMS coating by incorporating thiol functionality [24.].

A thin film is placed on the SOI waveguides surface on the chip and two coating parameters are important in the process. First of all, film homogeneity is a very important parameter due to the high sensitivity of high index contrast SOI structures to surface roughness. To make the film uniform, techniques such as spin coating are used. In this technique, a small amount of coating material is applied on the center of the substrate and then this substrate is rotated at high speed in order to spread the coating material by centrifugal force. Figure 2.6 shows the spin coating steps. With this technique the waveguides loses are minimized.

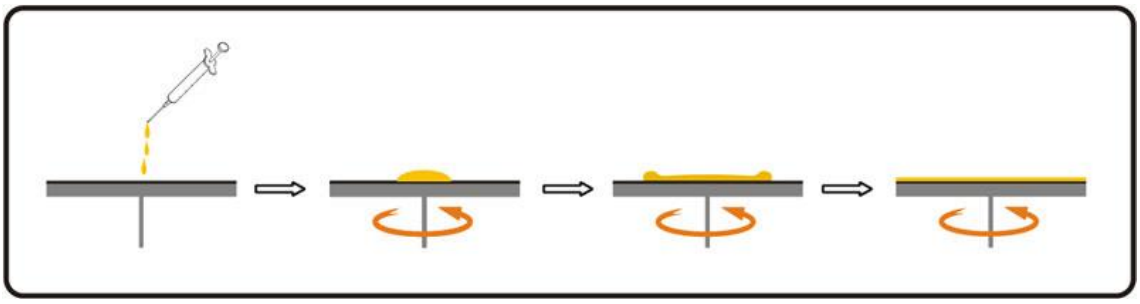


Figure 2.6 Spin coating steps [18.].

The film thickness, on the other hand, determines the extent of interaction with the evanescent field. Too thin films can limit the interaction to only some proportion of the evanescent light, hence limiting the sensitivity and dynamic range of the sensor. Excessively thick films can also raise the detection limit and, in addition, lead to slow sensor response.

3. NIR absorption spectroscopy of organic vapors: Xylene detection

3.1 Introduction

Many chemical substances have harmful effects on human health. Polluting substances can be released to the environment as a result of various industrial processes and human activities. Volatile organic compounds (VOC) are representative of such harmful pollutants and they have a potential risk to public health. Of the VOCs, benzene, toluene, and xylene are carcinogenic and pose danger to cranial nerves even at low concentrations. Thus monitoring of these substances is crucial.

Xylene is an aromatic hydrocarbon consisting of a benzene ring with two methyl substituents widely used in industry and medical technology as a solvent. Exposure to Xylene in humans can cause symptoms ranging from headaches, nausea, feelings of drunkenness or anemia up to the possibility of causing death. The current Occupational Safety and Health Administration permissible exposure limit for xylene is 100 ppm as an 8-h time-weighted average (TWA) concentration [26.]. The National Institute for Occupational Safety and Health recommended exposure limits for xylene at 100 ppm as a TWA for up to a 10-h work shift and a 40-h work week and 200 ppm for 10 min as a short-term limit [27.].

In this chapter, the absorption cross section of Xylene is estimated from absorption spectra of liquid xylene taken with a conventional spectrophotometer. Theoretical absorption spectra for different Xylene vapor concentrations are calculated based on the absorption cross section estimations. The gas pre-concentration or densification achievable with a PDMS coating is estimated using refractive index changes measured with microring resonators. These measurements have been made in an independent research which is not in the scope of this thesis. Crude estimation made with this approach provides a starting ground for gas concentration enhancement that can be achieved with PDMs films on optical waveguides.

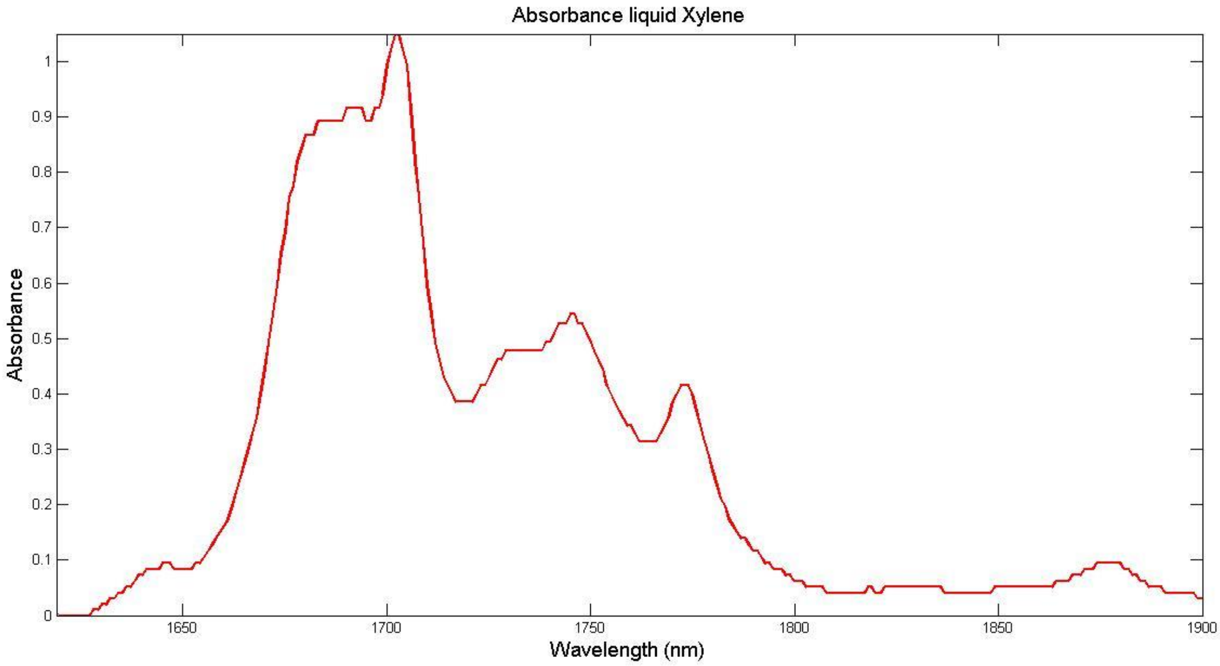


Figure 3.2.Liquid Xylene absorbance.

In order to estimate the absorption cross section, the value of C (concentration in molecules/cm3) has to be determined. The molar mass and density of liquid xylene at a determined temperature given table 1 are used in this calculation.

	Xylene
Density (25ºC (g/cm3))	0.8610
Molar mass (g/mol)	106.16
1 mol	$6.022 * 10^{23}$ molecules

Table 3.1.

With those values:

$$\text{Density}\ (\frac{\text{grams}}{\text{cm}^3})\cdot\ \frac{1\ \text{mol}}{\text{Molar mass}\left(\frac{\text{g}}{\text{mol}}\right)}\ \cdot\ \frac{6.022\cdot 10^{23}\ \text{molecules}}{\text{mol}} =$$

$$\frac{0.8610\ \text{grams}}{\text{cm}^3} * \frac{1\ \text{mol}}{106.16\ \text{grams}} * \frac{6.022 * 10^{23}\ \text{molecules}}{1\ \text{mol}}$$

$$\text{Concentration} \ = 4.8840 * 10^{21} \text{ molecules/cm3}$$

With this value and the path length (L=0.1cm) and recalling the Beer Lambert law, the value of the absorption cross section σ is determined by:

$$\sigma\ (\text{cm}^2/\text{molecule}) = \frac{\text{Absorbance}}{\text{C (molecules/cm}^3) \cdot \text{L(cm)}} \qquad Eq. 3.4$$

Figure 3. shows the absorption cross section for different wavelengths:

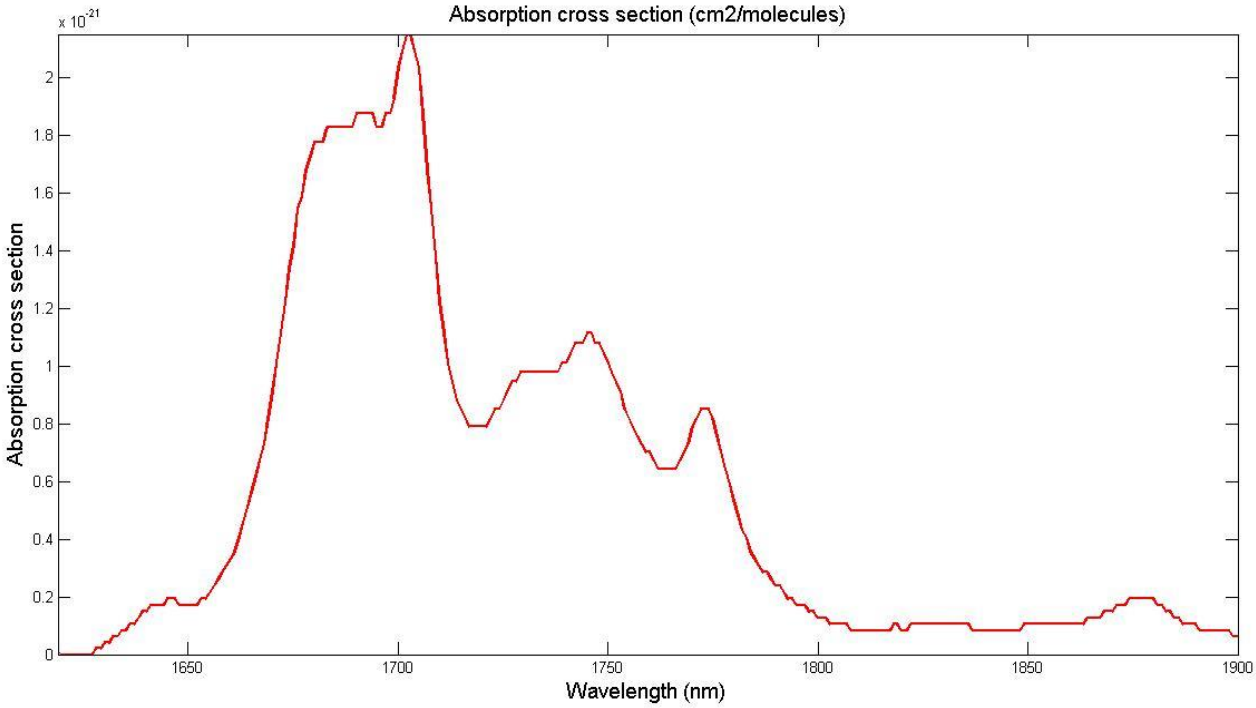


Figure 3.3 Absorption cross section estimation for different wavelengths.

It can be observed that the absorption cross section of xylene is within the expected range (10^{-22} – 10^{-18} cm2/molecule) [6.]. This value will be used in latter sections to estimate the concentration of xylene in order to prepare the experiments.

3.3 PDMS enhancement factor estimation:

In this section, a rough estimation of the PDMS densification factor have been made by using the same procedure carried out in [6.] with SOI ring resonators. In this case, for 300 nm thick PDMS coating on a TE ring resonator, 1nm resonance shift (Δλ) per % Xylene was observed around 1550 nm. Figure 4 shows the resonance shift vs. xylene concentration in%. In this plot, the data markers represent the measure shift in nm and the solid line is a linear fit to the data points. The slope can be easily calculated and is about 1nm/% xylene.

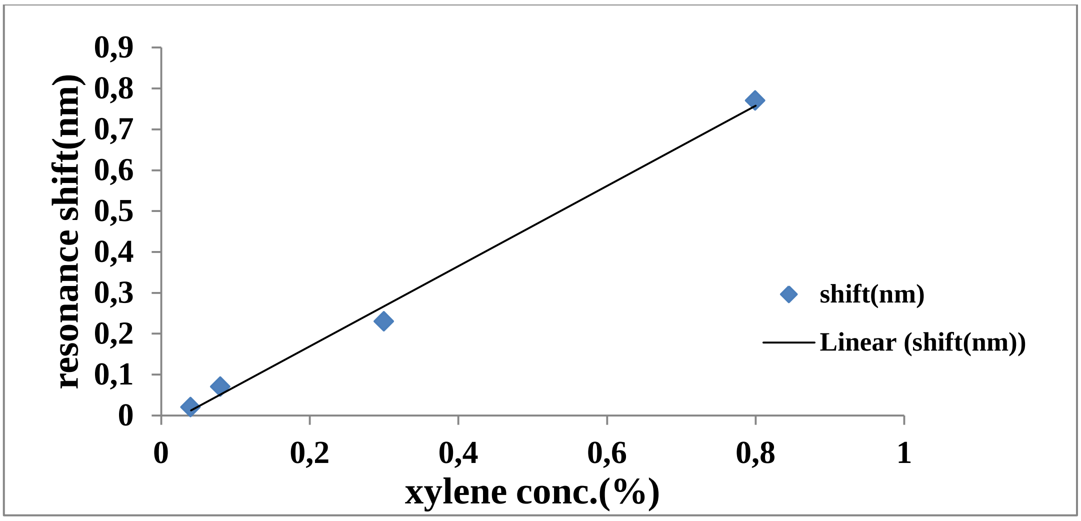


Figure 3.4 Resonance shift vs xylene concentration in %.

With these data the refractive index change can be calculated by using the following relation:

$$\frac{\Delta\lambda}{\lambda} = \Gamma \frac{\Delta n}{n_g} \qquad Eq. 3.5$$

$\Delta\lambda$	λ	Γ	n_g	Δn
1 nm	1550 nm	0.2	4.9	**1.6e-2 /%**

Table 3.2

Taking into account the refractive index of Xylene (vapor) $n = 1.0017$ [25.], the procedure to calculate the PDMS densification factor is to compare the refractive index change between air and xylene with and without PDMS. Without PDMS, the refractive index change from air to 100% Xylene is:

$$\Delta n_{100\%\ no\ PDMS} = 1.0017 - 1 = 1.7 * 10^{-3}$$

Therefore, we can assume that for 1% of xylene concentration, the refractive index change will be about:

$$\Delta n_{1\%\ no\ PDMS} = 1.7 * 10^{-5}$$

Whereas, with PDMS film on a ring, the estimation on [6.] is about:

$$\Delta n_{1\%\ PDMS} = 1.6 * 10^{-2}$$

Then, the ratio between the refractive index change with and without PDMS coating:

$$PDMS\ densification\ factor = \frac{\Delta n_{1\%\ PDMS}}{\Delta n_{1\%\ no\ PDMS}} \approx 1000$$

After doing the calculations we get a densification factor of 1000, however in practice we will observe that this factor is slightly high, which will be discussed in chapter 5.

3.4 Theoretical absorbance estimation:

In this section, we explain the procedure used to calculate the theoretical absorbance for different Xylene concentrations. As an example, the theoretical absorbance at 4000 ppm gaseous xylene will be estimated. This concentration, among others, is used in the experimental studies to be discussed in chapter 5.

In section 3.2 and 3.3 the absorption cross section and the PDMS densification factor have been calculated, respectively. These estimations will be used to calculate the theoretical absorbance. Recalling Beer-Lambert law:

$$\text{Absorbance} = \ln\left(\frac{I_0}{I}\right) = \sigma C L \Gamma \qquad Eq. 3.6$$

Where I is the output intensity after exposure to gas, I_0 is the output intensity before exposure to gas, σ is the absorption cross section in cm2/molecules, C is the concentration in molecules/cm^3, L is the interaction length and Γ is the confinement of the cladding factor in an SOI waveguide. Not to be confused with the confinement factor of the waveguide core.

With the previously estimated data σ and the PDMS enhancement factor, and knowing the length of the waveguide (L = 1.2 cm) and confinement factor (about 0.2), we can estimate the absorbance for different concentrations.

The gas concentrations are converted from ppm to molecules/cm^3 using the relation given below:

$$\frac{6.02 \cdot 10^{23}\ molecules}{22.4 \cdot 10^{3}\ cm^{3}} \cdot 10^{-6} = 2{,}68 \cdot 10^{13}\ {molecules}/{cm^{3}} = 1ppm$$

Theoretical absorbance at 4000 ppm xylene:

C=4000 ppm = $4000 * 2{,}68 \cdot 10^{13} = 1072 \cdot 10^{17} \frac{\text{molecules}}{\text{cm}^3}$

Using Eq. 3.6, the absorbance at this concentration can be estimated. Figure 3.5 shows the theoretical absorbance for 4000 ppm of gaseous xylene for a 1620-1900 nm spectral range

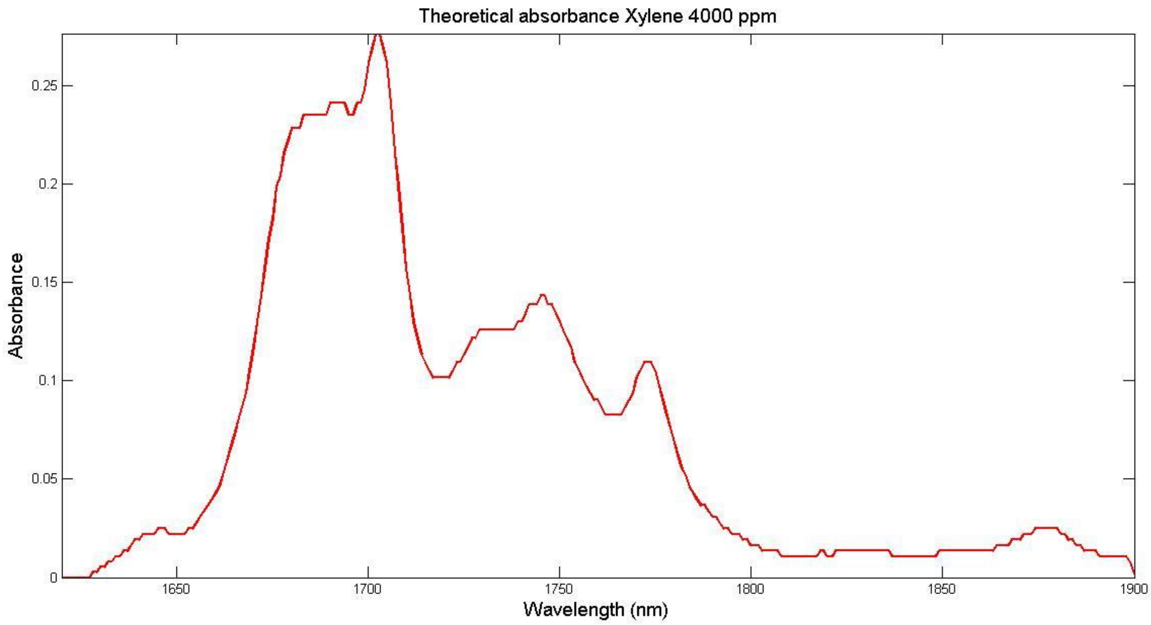


Figure 3.5. Theoretical absorbance of 4000 Xylene vapor.

Optical setup

In optical experiments conducted in this thesis, a superluminiscent light emitting diode (SLED) from DenseLIght has been used as a source. The SLED has a wide spectral coverage in the L-band (1565-1675 nm) which fairly fits with xylene absorption band studied in this thesis. A single-mode fiber (SM) guides the SLED output through a polarization controller to the input grating couplers on the sensing chip. A vertical coupling approach is used to couple the input light to the SOI chips.

The gratings are optical components used for out-of-plane coupling between the single mode fiber and the waveguide. These grating couplers are designed for light with TE polarization and give a maximum coupling for an input angle of 10 degrees. The central wavelength shifts towards longer wavelength if the angle decreases as we can deduce from this formula:

$$\frac{2\pi}{\lambda_0} n_t sin\theta = \frac{2\pi}{\lambda_0} n_{eff} - \frac{2\pi}{\Lambda} \qquad Eq. 4.1$$

Where Λ is the grating period, λ_0 is the vacuum wavelength, n_{eff} is the effective index, n_t is the refractive index of the environment , θ is the angle at which the fiber is oriented from the vertical position.

In order to be able to change the angle of the fibers and therefore shift the optical spectrum range, variable angles wedges (Figure 4.3) have been used in some of the experiments. With these wedges the angle between the fibers and the chips can be modified from 10 to 0 degrees.

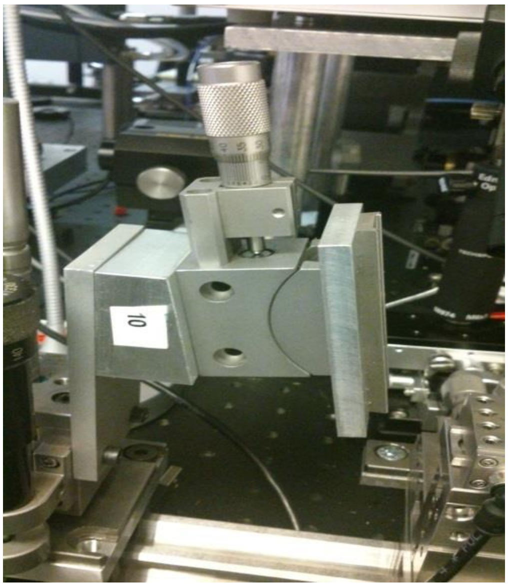


Figure 4.3. Angle wedges used to change the coupling angle between the fiber and the grating.

Xylene vapor generation setup

The diagram shown in figure 4.5 depicts the experimental configuration consisting of a vapor generation setup used in this thesis.

In the home made Teflon bubbler, the Xylene liquid is contained and it operates at a chosen temperature. To maintain this bubbler at a fixed temperature and hence a fixed vapor pressure, a refrigerated circulator water bath (Thermo Scientific DC10-K15) is used.

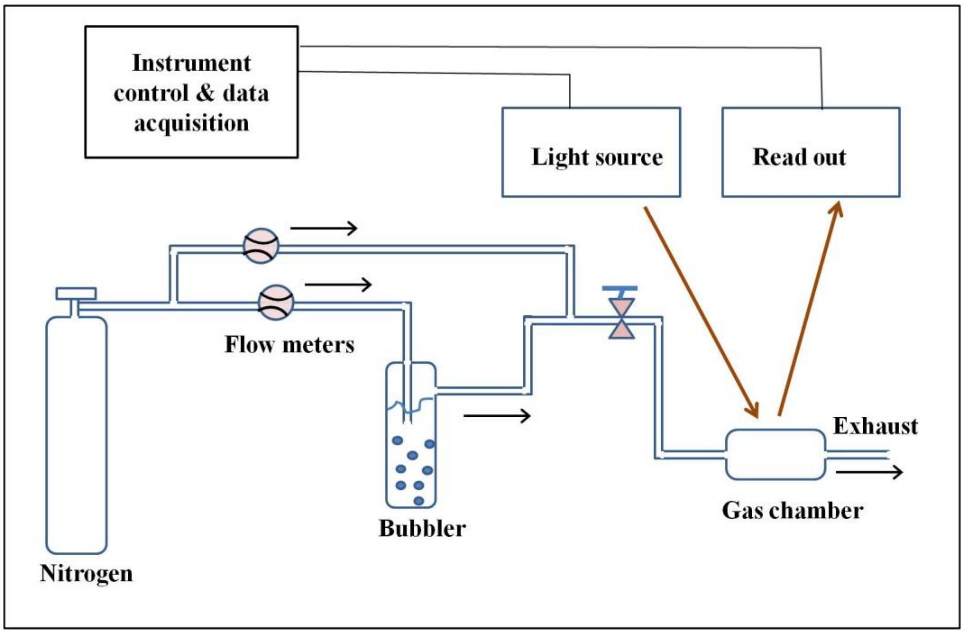


Figure 4.5 Xylene vapor generation setup

Xylene vapor is produced by bubbling the liquid with nitrogen. Nitrogen passes thought the bubbler and the vapor is carried out by means of the tubes to a gas cell glued on the chip.

The output flow rate of the vapor, $Fvapor$ is given by the bubbler equation:

$$Fvapor = \left(\frac{Pvapor}{Po - Pvapor}\right) Fc \qquad Eq. 4.2$$

where Fc is the carrier flow rate, $Pvapor$ (mmHg) is the vapor pressure of the compound, and Po is the outlet pressure in the bubbler headspace. The vapor pressure, $Pvapor$ at a given bubbler temperature is calculated with Antoine equation

$$\log Pv = A - \frac{B}{C + T} \qquad Eq. 4.3$$

where Pv is the vapor pressure, T is the temperature and A, B and C are compound specific empirical constants. For example, Xylene vapor pressure is 0.833 kPa (6.2480 mmHg) at room temperature ($\sim$20^{o}C) [28.].

Figure 4.6 shows the circulating water bath in which the bubbler is contained. The flowmeters used to control the gas flows in the experiments are also shown in the figure.

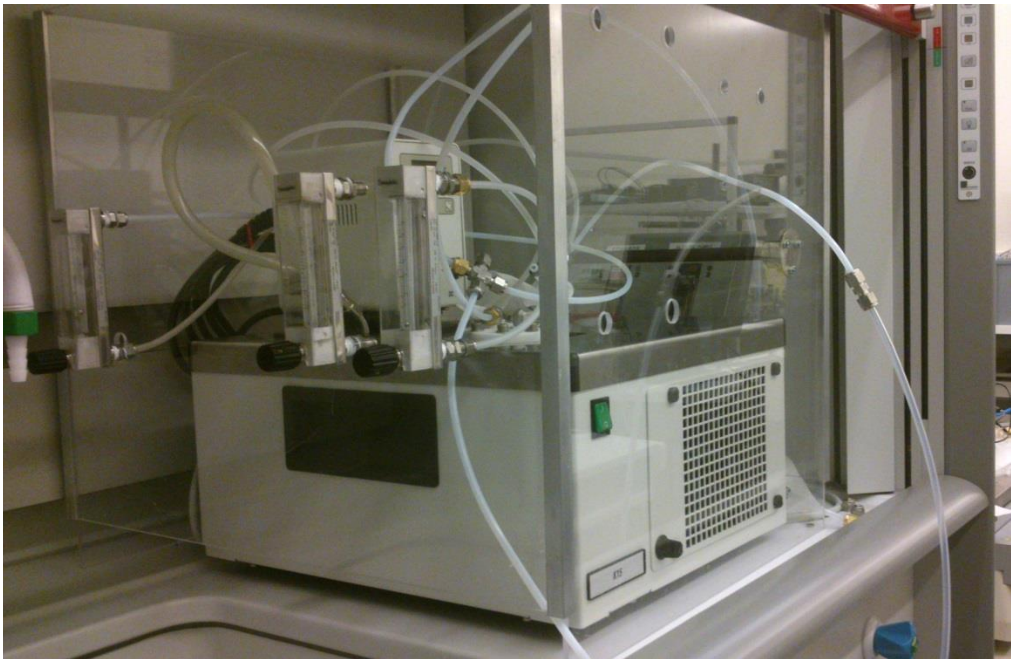


Figure 4.6 Circulating water bath and flowmeters.

The gas cell is made of glass and its dimensions are 9 mm wide, 10 mm long and 5 mm high.

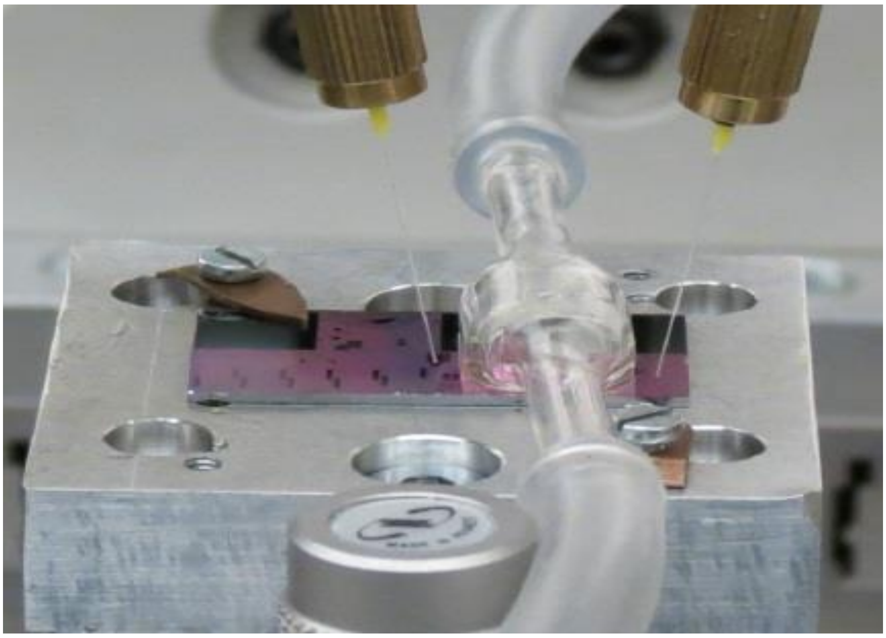


Figure 4.7 Detailed picture of the gas cell glued to the chip

This cell is glued by using UV curable glue (Norlad-NEA121) following two steps. First of all a small drop of glue is spin coated in a clean surface and finally the cell is transferred to the chip by press stamping. After that, the cell is located on top of the waveguides of interest as shown in Figure 4.8 and exposed to 100W UV Light (Ommnicure S1000) for 3 minutes (Figure 4.9) .

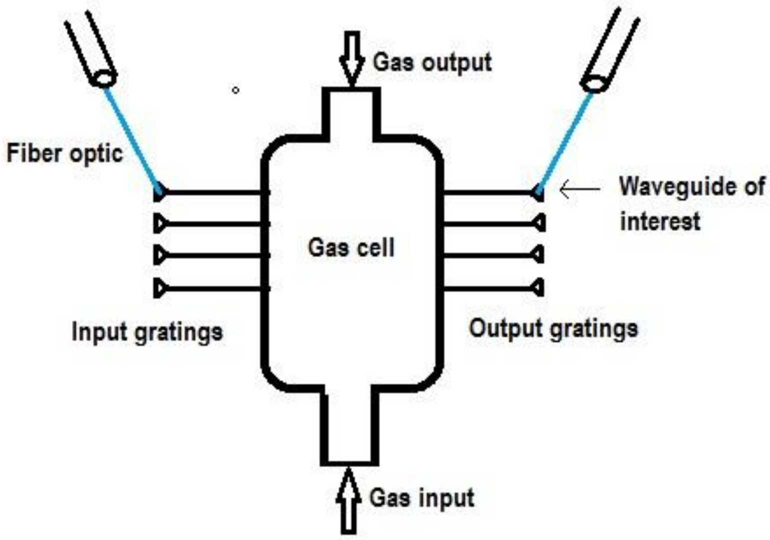


Figure 4.8. Detailed diagram of the location of

the gas cell on top of the waveguides.

As we can notice in figure 4.8 the input and output gratings are not covered by the cell allowing the light coupling between the fibers and the waveguides.

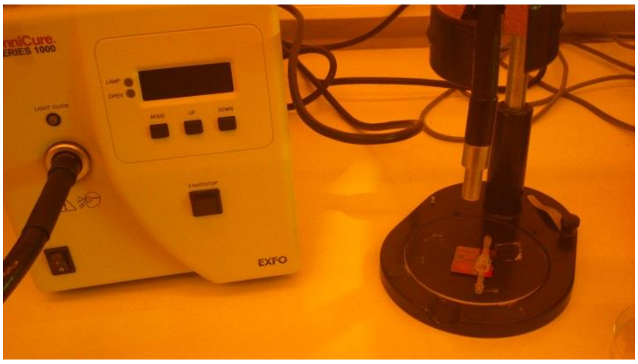


Figure 4.9 100W UV Light Ommnicure S1000

Finally, a Panasonic camera is used in order to visualize the waveguides in the chip and make easier the coupling between them and the fiber. A lamp illuminates the sample and the image from the camera is displayed on a monitor.

The mixture of PDMS and curing agent is diluted in dichloromethane (DCM). In the table (Table 4.1) below we can observe the ratios by weight of this products and the thickness of the film.

PDMS	Curing Agent	DCM	Thickness
1 gr	0.2 gr	30 ml	151 nm
2 gr	0.2 gr	30 ml	347 nm

Table 4.1

The solution with the three products is deposited with the help of a pipette on the SOI sample and spin coated at different speed, acceleration and time in order to get the suitable thickness. In Table 4.2 we can observe different values of the previous mentioned variables and the result.

Speed	Acceleration	Time	Thickness
3000 rpm	2000 rpm/s^2	40 sec	151 nm
3000 rpm	2000 rpm/s^2	50 sec	347 nm

Table 4.2

Finally, the sample is cured at 150 degrees for 10 min.

The sample, as we described in the previous section is a SOI chip with a variety of optical structures, but the waveguides of interest for this thesis are situated on the edge of the silicon chip. For that reason and because subsequently the gas cell needs to be placed, it has been necessary to add another fragment at the bottom of the chip. First, the PDMS layer is placed on both parts, to avoid the difference in thickness between both sides and afterwards they have been cleaved by the edge.

To provide stability to the two parts and prevent possible setbacks during measurements, we used an about 1 mm thick and 2cmx2cm glass. A small drop of glue (Norad -NEA121) is spin coated on the glass in order to create a thin film of glue and place the two parts of the chip on top of it. Finally, the ensemble is dried with UV Light 100W (Omnicure s1000) During 3 min. Figure 4.12 shows the whole process.

5. Experimental results:

5.1 Factors affecting absorption measurements

As mentioned in chapter two, one of the practical issues for gas absorption measurements on optical chips is achieving mechanical stability of the setup

Therefore, in this section, study of the noise and system stability has been made, and alternatives have been studied. The possibility of gluing the input and output optical fibers on the gratings is considered to minimize mechanical vibrations and reduce the intensity noise.

On the other hand, the possibility to shift the spectrum to higher wavelengths by varying the angle of coupling with the gratings to suit it to the absorption of Xylene range is discussed in the second part of the chapter.

5.1.1 Setup stability:

This section is divided into two parts. Firstly, we have studied the stability of the system using the setup described in section 4.1. As mentioned previously, the light from the SLED is carefully coupled in the waveguide of interest through the gratings. On the other hand, alternatives have been studied, considering the possibility of gluing the input and output optical fibers on the gratings to minimize mechanical vibrations and reduce the intensity noise.

Method to calculate the setup noise:

For the realization of experimental measurements, as in the case of this thesis, the experimenter has to make measurements multiple times, however, the results of each measurement will not be the same as a consequence of different variation factors such as temperature or mechanical vibrations, among others.

Because of that subsequent experiments will measure de variation of the output intensity, is necessary to make an estimation of the noise in the system.

The setup noise is estimated by calculating the standard deviation in a set of measurements taken under similar conditions. These measurements have been taken during a time period of about 3 minutes. This period has been considered optimal for subsequent measurements because for longer period, it was observed that the fibers tended to slightly decouple causing loss in the output power. The condition to perform the measurements in a period of three minutes will be carried out for the realization of all subsequent experiments.

$$Measurements\ average = \bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad Eq. 5.1$$

$$Standard\ deviation = \sigma_n = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \bar{x})^2}{N-1}} \qquad Eq. 5.2$$

being N the number of measurements, and x_i each measurement.

Noise estimation without gluing the fibers:

In this section, the standard deviation of six measures has been calculated. For these experiments, the output power was monitored by using an optical spectrum analyzer (Advantest Q8381Q) connected to a computer with a Labview program. For this experiment neither the input nor the output optical fibers were glued to the chip. Figure 5.1 shows all measured taken during 3 minutes and the average with a thicker red line.

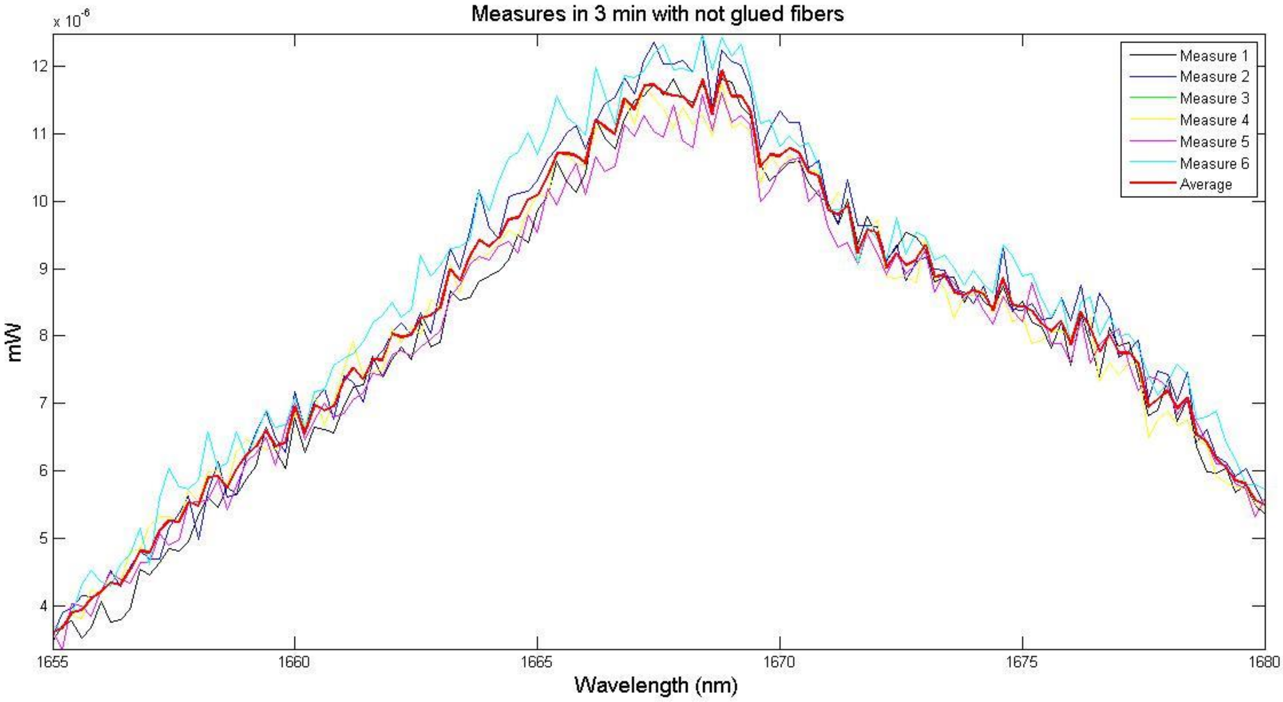


Figure 5.1 Consecutive measurements and average (red line) in 3 minutes.

If we calculate the standard deviation of these measurements by using equation 5.2, we obtain an average standard deviation of 3.85% (Figure 5.2). This value means that measurements deviate about 3.85% on average in the range of 1655 to 1680 nm.

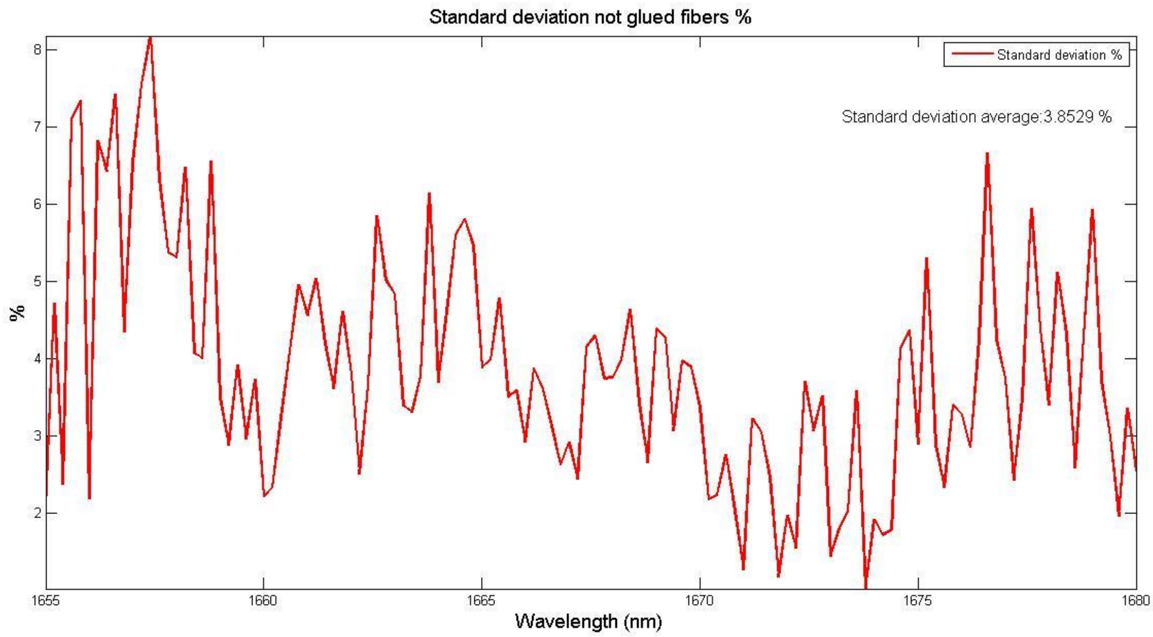


Figure 5.2 Standard deviation in percentage with not glued fibers

Both the intensity noise and the mechanical vibration can be considered to be present in these measurements. One option to reduce the noise due to mechanical vibrations is to glue input and output optical fibers on the gratings.

Noise estimations for glued fibers:

In these experiments, the input and output fibers have been glued to the gratings. In the gluing process, the fiber first dipped in a small drop of glue. The fiber is then carefully aligned to a grating by using the position controllers. After optimizing the coupling, the glue is cured by exposing it to 100W UV Light (Ommnicure S1000) for180 sec.

Figure 5.3 shows consecutive measurements taken within three minutes. The thick red curve represents the average of these measurements.

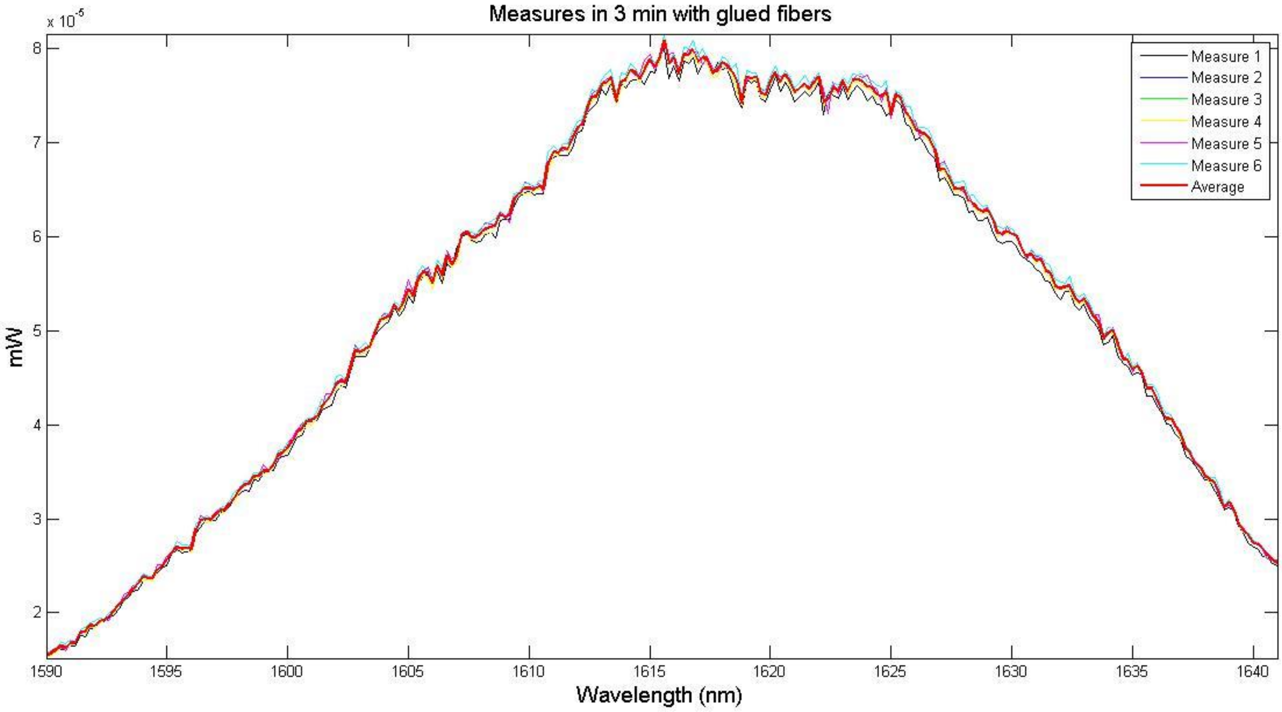


Figure 5.3 Consecutive measurements and average (red line) in 3 minutes.

An improvement in the noise is noticed after gluing the fiber. The average standard deviation with glued fibers is 0.85% in 1590-1640 nm range which is around 4.5 times lower than with not glued fibers (Figure 5.2).

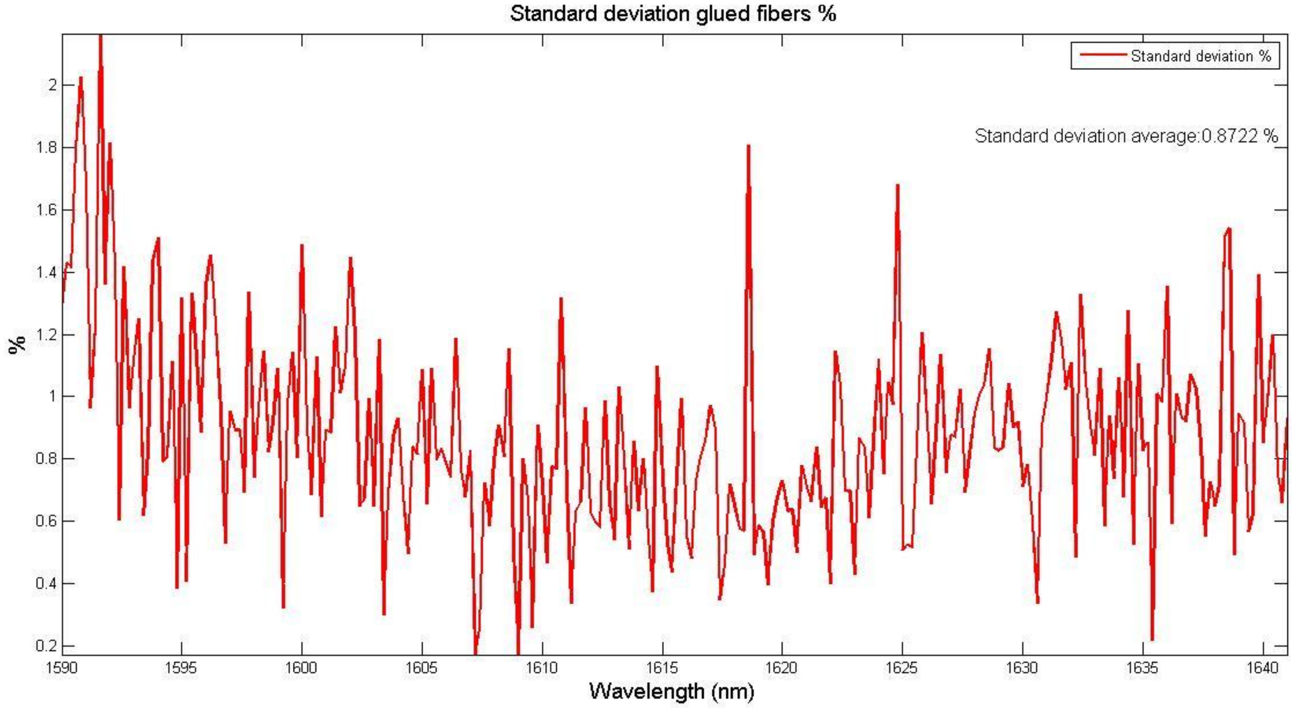


Figure 5.4 Standard deviation in percentage with not glued fibers.

Grating transmission spectrum shift upon gluing fibers:

Observing figures 5.1 and 5.3 and we can notice that when the glue is applied to the fibers the spectrum shifts towards shorter wavelengths. The transmission peak is shifted from 1650nm to around 1620nm when the fibers are glued on the chip.

This behavior can be explained by recalling gratings equation 4.2 from chapter 4:

$$\frac{2\pi}{\lambda_0} n_t sin\theta = \frac{2\pi}{\lambda_0} n_{eff} - \frac{2\pi}{\Lambda} \qquad Eq. 4.1$$

Where Λ is the grating period, λ_0 is the vacuum wavelength, n_{eff} is the effective index felt by the cylindrical wave in the grating area, n_t is the effective index of the environment and finally, θ is the fiber orientation from the vertical position.

Taking into account this formula is easy to understand that due to glue the parameter, n_t has increased because previously this refractive index was $n_{t(air)}$ = 1 and once applied the glue the new refractive index $n_{t\,(glue)}$ = 1.5 causing a shift towards lower wavelengths.

5.1.2 Shifting spectrum

In the previous section has been experimentally observed the spectrum variation to lower wavelength by adding the glue between the fibers and the gratings due to the refractive index n_t change. After observing this behavior, the possibility of shifting the spectrum towards longer wavelengths by changing the angle between the input and output fibers and the gratings was suggested. By using the wedges described in chapter 4, we were able to shift the spectrum to the Xylene absorption region. These wedges allow to change the angle between the fibers and gratings from 10 degrees to 0 (vertical). Considering again the equation 4.1 can be easily demonstrable that by decreasing the angle θ it is possible to shift the value of the wavelength to larger values.

In this section, the estimation of the angle θ necessary that the fiber must form with the gratings (Figure 5.6) will be calculated by using equation 4.1 previously mentioned [2.].

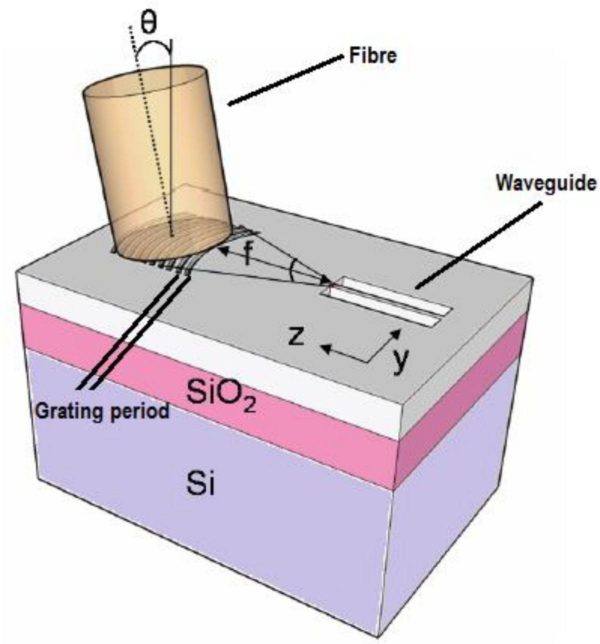


Figure 5.6 Diagram of the coupling between fibers and gratings.

First of all, one can use the relation between group index and effective index to estimate an effective index at a given wavelength.

$$n_g = n - \lambda_o \frac{dn}{d\lambda_o} \qquad Eq. 5.3$$

which can be written as:

$$n_g = n_{eff}(\lambda_o) - \lambda_o \frac{dn_{eff}}{d\lambda_o}$$

By using this relation, we can use this relation to find an expression for the effective index at a given wavelength, λ

$$n_{eff}(\lambda) = n_{eff}(\lambda_o) - \left(n_g - n_{eff}(\lambda_o)\right)\left(\frac{\lambda - \lambda_o}{\lambda_o}\right) \qquad Eq. 5.4$$

The effective refractive index can be deduced from this relation with the known data showed in Table 5.1. Clearing the n_{eff} up from equation 4.1 [30.]:

$$n_{eff}\,(\lambda_0) = \frac{\lambda_0}{\Lambda} + n_t sin\theta \qquad Eq. 5.5$$

Data:

Gratings period: Λ	n_t **(air)**	θ	λ_0	n_{eff}	n_g
690 nm	1	10º	1650 nm	**2.5649**	4.9

Table 5.1

Taking into account Eq. 5.4 and the data from table 5.1 we can calculate a different n_{eff} for each different wavelength (λ).

Once obtained the grating effective index, an estimate of the angle needed to shift the spectrum to larger wavelengths has been made. Results are shown on Table 5.2.

Wavelength (nm)	Angle (θ)
1660	8,334
1665	7,505
1670	6,678
1675	5,853
1680	5,029
1685	4,205
1690	3,383
1695	2,561

Table 5.2

Considering the previous table, and taking into account Figure 5.5 which shows the absorption spectrum of Xylene, we are able to estimate that the best angle to shift the transmission spectrum to the region of absorption of Xylene is around 2 degrees. However, experimentally this angle was very difficult to achieve due to the size of the waveguides and the wedges. 6 degrees of coupling angle was the angle chosen for the experiments because with lower angles the output power was very low since the gratings are designed for a 10 degrees coupling angle. Figure 5.7 shows the spectrum shift by using a coupling angle of 10 degrees (blue line) to 6 degrees (red line).

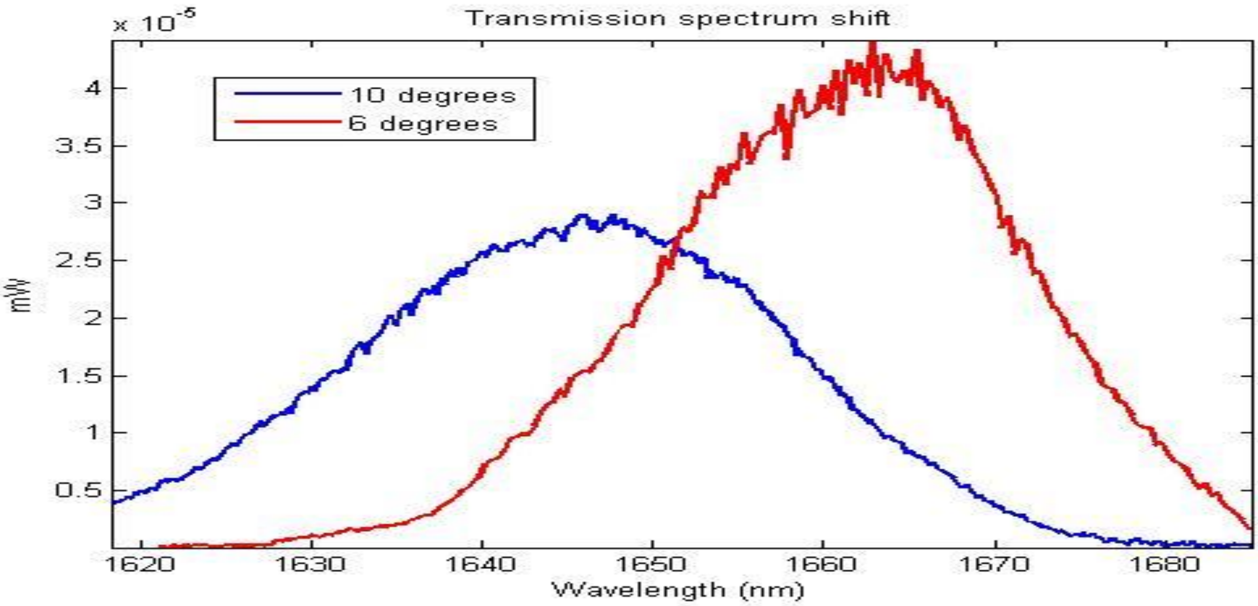


Figure 5.7 Spectral shift with 10^{o} and 6^{o} coupling angle

It is worth noting that the power difference in Figure 5.7 between the red and blue curves is due to the fact that the results are taken from two different experiments where the output power was not the same.

5.2 Xylene absorption results

In this section, experimental results on Xylene absorption with PDMS gas concentrating layer on SOI waveguides are presented. The experimental procedures are discussed and, whenever possible, comparisons between experimental and theoretical results are provided.

The section is divided in two main parts depending on the thickness of the PDMS film and the coupling angle. In the first section, the experiments have been carried out with a 151 nm PDMS film and a coupling angle of 10 degrees, and in the second part of the section with a 350 nm film and a coupling angle of 6 degrees. We note here that all the experiments presented in this section have been made without gluing the fibers to the gratings in order to avoid the spectrum shift to lower wavelengths explained in section 5.1.

5.2.1 150 nm PDMS film 10 degrees coupling angle:

In this section, we present different experiments have been performed with a PDMS film thickness of 151 nm by varying the concentration of Xylene. The thickness of the PDMS has been chosen based on the positive results of previous experiments carried out with micro rings resonators for gaseous Xylene detection [6.].

To obtain different concentrations of xylene, the temperature of the bubbler has been varied using a circulated water bath (Thermo Scientific DC10-K15) previously mentioned in Chapter 4. Experiments were performed at room temperature (RT) and at 30 degrees. The following figures show the results obtained with the different concentrations (from lower to higher concentration) that will be discussed at the end of this section.

As can be observed in the above shown figures, the absorption of xylene in this spectral range could not be clearly quantified. This could be due to weak xylene absorption in this spectral range. As shown in figure 3.1 (chapter 3), the absorption becomes stronger beyond 1660nm and the peak is around 1700nm. Both in Figure 5.13 and Figure 5.15 it is observed that around 1670 there is a trend to increase the absorption in the theoretical curve, indicating that at higher wavelengths we could expect higher absorption, as it was demonstrated in the theoretical absorption estimation in Chapter 3. After this observation, we decided to shift the spectrum to higher wavelengths by using the variable angle wedges previously mentioned in Chapter 4.

Furthermore, after performing multiple experiments we were able to notice that a possible source of noise, apart from the mechanical vibrations intrinsic on the setup, was the temperature regulator. An error of around ± 4º degrees was observed causing instability in the results. As a consequence, subsequent experiments were performed at room temperature whereby eliminating unwanted thermal effects. In addition, a constant nitrogen flow was maintained through the gas cell in order to ensure thermal stability.

Moreover, the sensor chips are purged with nitrogen flow of 200 l/h for 10minafter the completion of each experiment to regenerate the PDMS films for next experiments.

5.2.3 Liquid Xylene:

In this part, we compare experimental and theoretical absorbance for liquid xylene. In this experiment, a small amount of liquid Xylene has been dropped on PDMS coated about 1cm long waveguide after removing the gas cell from the SOI chip. The output power has been measured before and after exposure to the liquid in order to calculate the absorbance. Comparison between the experimental and theoretical absorbance is shown in figure 5.23. In the theoretical estimate, an interaction length of 7mm and a confinement factor of 0.3 are taken, and the PDMS film is assumed to be of 40% porosity. This estimate is based on the absorption cross section data of xylene calculated from a photo-spectrometer measurement discussed in chapter 3 (section 3.20).

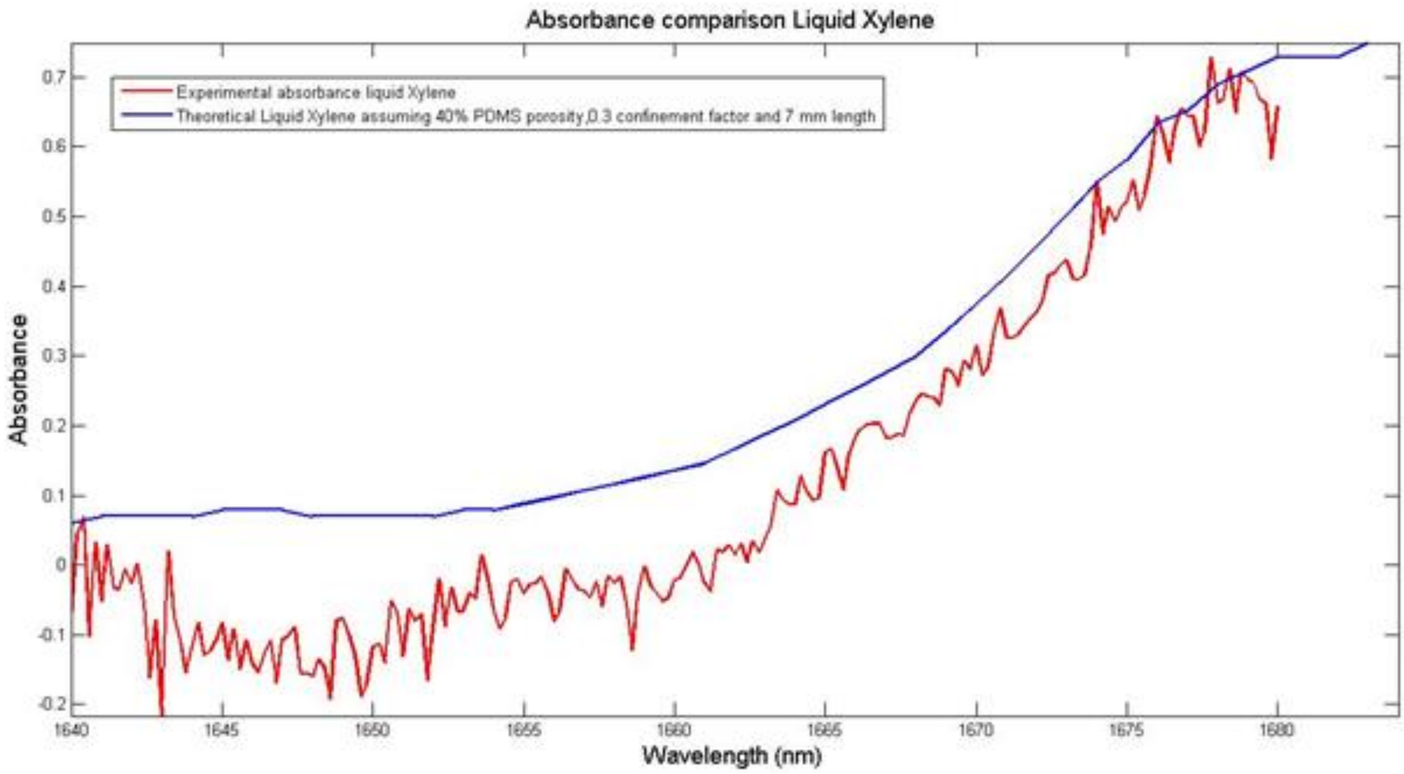


Figure 5.25 Comparison of experimental and theoretical absorbance of a drop of liquid xylene on PDMS coated waveguide assuming 7mm interaction length, a confinement factor of 0.3, and 40% porosity.

The experimental absorbance follows a similar trend as the one measured with a photospectrometer showing a good agreement between the experimental and theoretical graphs. Moreover, this same trend was observed for ~4000 ppm xylene vapor as previously shown in figure 5.19.

Considering the 40% porosity approximated with the above experiment, the percentage of pores occupied can be estimated at 4000ppm from the data presented earlier in figure 5.19. Comparing the liquid xylene absorbance with the absorbance at 4000ppm for ~1cm long waveguide, 40% porous film and a confinement factor of 0.3, it can be shown that about 30% of the pores are occupied at 4000ppm.

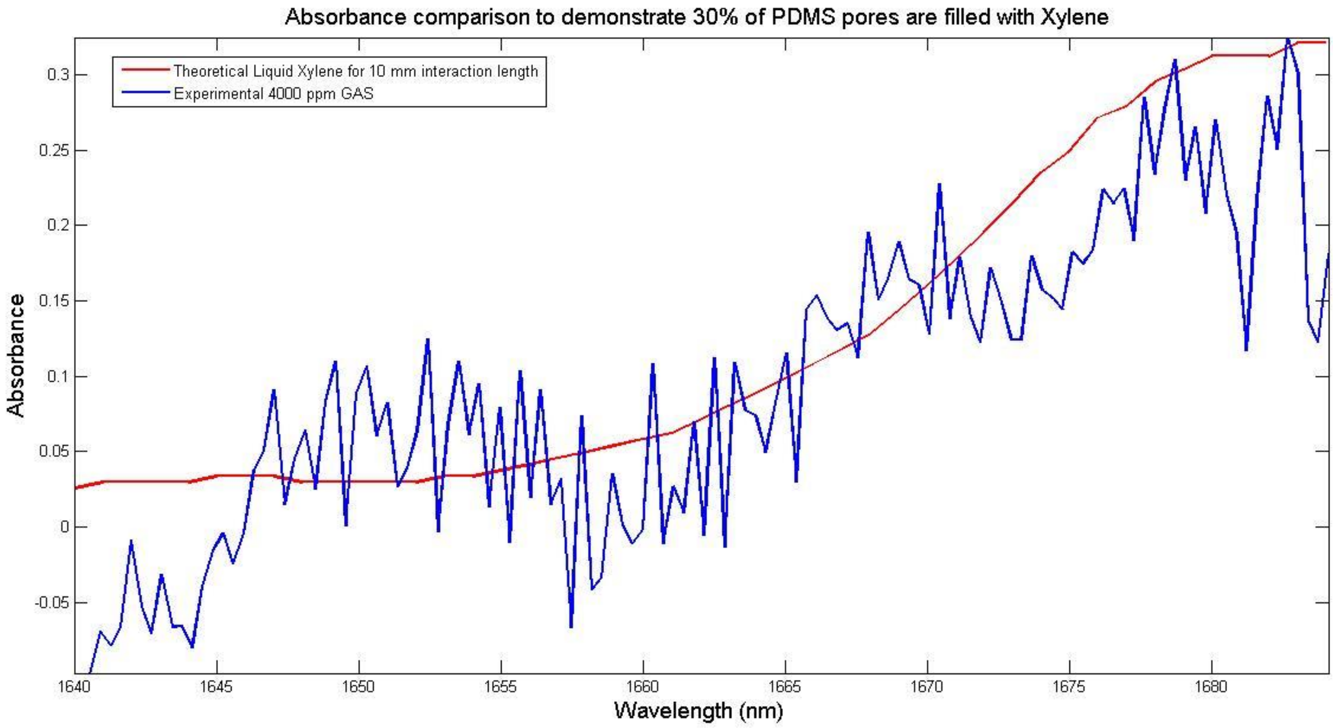


Figure 5.26: Theoretical and experimental absorbance at 4000ppm xylene assuming that 30% of the PDMS pores are filled at the concentration of 4000ppm

6. Conclusions and future perspectives

In this chapter we summarize the work done in the thesis, draw the final conclusions, and suggest directions for further research.

In this thesis, absorption spectroscopy of xylene with a PDMS gas concentrating layer on SOI waveguides has been studied. In this regard, we have studied the absorption response for two different thicknesses of PDMS film and we have observed the dependence of absorption on factors such as mechanical instability, temperature, and the transmission bandwidth of grating couplers.

In chapter 3, estimations of xylene absorption cross section has been made using an absorption data taken for liquid xylene. A rough estimation of gas densification factor with a PDMS film has also been made based on the results obtained with SOI rings resonators. A densification factor of about 1000 has been estimated. Later, it has been experimentally observed that 5000 times gas density enhancement is achievable with the PDMS films; which is 5 times higher than predicted with our simple and preliminary estimate. Finally, in this chapter, we have made an estimate of the absorbance for 4000 ppm xylene concentration.

Experimental results have been discussed in Chapter 5. The potential benefit of gluing fibers on the grating couplers was also presented in this chapter. About 5 times improvement in the measurement stability has been demonstrated with glued fibers. However, due to the transmission spectrum shift of the grating couplers away from the xylene absorption band upon gluing the fibers, the absorption experiments have only been carried out without gluing the fibers. The transmission spectrum shift to the lower wavelengths is attributable mainly to the refractive index change in the region between the fiber and the grating coupler. Furthermore, the coupling angles have been changed from 10 to 6 degrees in order to bring the waveguide (grating) transmission spectrum closer to xylene absorption band. This could lead to improvements in our absorption measurements. Successful absorption measurements have been done using a 350nm thick PDMS film and a coupling angle of 6 degrees. These experiments were performed at room temperature with a constant flow of nitrogen to maintain stable sample temperature. An expected absorption behavior is observed on two repeated measurements taken at a concentration of ~4000ppm xylene. This result is in a close agreement with a theoretical estimate for a PDMS densification factor of ~5000. An absorption measurement for a drop of liquid xylene on a PDMS coated waveguide gave a further confirmation on the absorption trend observed at ~4000ppm xylene vapor. A rising absorption trend is observed in the region beyond 1665nm, which is in agreement with the theoretical xylene absorption band. Using this result, the porosity of the PDMS is estimated to be about 40%. Moreover, it is roughly shown that about 30% of the pores are filled at the concentration of 4000ppm xylene which is experimentally measured in this thesis.

However, in another experiment carried out by varying the concentration from 1379 to 4500ppm, the absorption appeared to extend outside the expected region. This may be a noise artifact likely due to some instability in the measurement setup or in the environment. Future experimental studies would be required to further understand this observation.

Future studies may focus on the use optimal SOI structures such as grating couplers designed to match a targeted absorption band, TM waveguides to enhance interaction with the gas molecules, and experiments with glued fibers. In addition, an in depth study on thermal and other environmental effects on the absorption measurements would be crucial. Studies on other type of materials for gas pre-concentration would also be beneficial to be able to detect different gases.

Utilized equipment and resources

3. Spectrum analyzer:

Brand: Advantest

Model: Q8381Q

4. Home made Teflon Bubbler

5. Refrigerated circulator water bath

Brand: Thermo Scientific

Model: DC10-K15

Specifications: ANEXE1

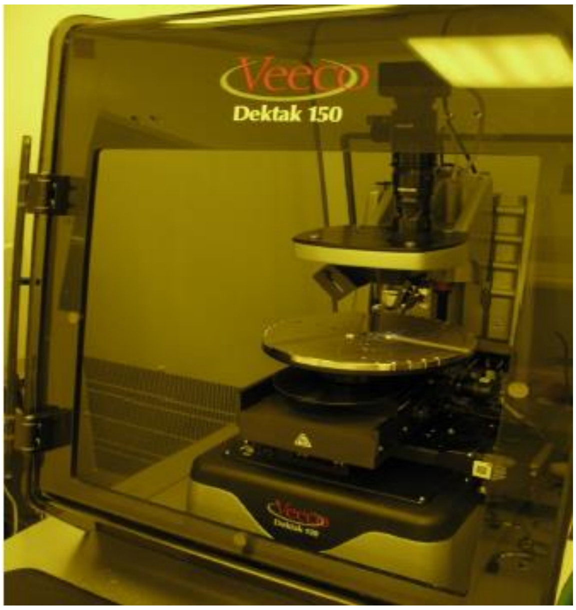
6. UV curable glue

Brand: Norlad

Model: NEA121

Specifications: ANEXE1

7. Surface profilometer



Brand: Veeco

Model: DEKTAK 150

Specifications: ANEXE1

Economic study:

In this section, an economic study is presented. This study estimates the overall budget of the personnel involved in the execution of this research project.

Staff costs:

In order to calculate the personnel budget, we assume that the project is done by a future telecommunication engineer, advised by a qualified responsible, which dedicates 30% of his working time to the advice and review.

	Salary (€/month)	Months	Total (€)
Telecommunication engineer	1500	10.5	15750
Doctor supervisor	800	10.5	8400
			24150

To the basic salary is necessary to add different bonuses and responsibilities in both of the cases:

Social charges	Percentage (%)
Accident insurance	5
Pension	3
Holidays	10
Severance pay	3
Old age pension	5
Familiar charges	3
Extraordinary grant	10
Others	12
TOTAL	**51**

Now, we need to add the social charges and the basic salary, like that, we obtain the total staff costs.

	Basic salary	Social Charges	TOTAL
Telecommunication engineer	15750 €	8032.5€	23780.5€
Doctor supervisor	8400 €	4284€	12684€
TOTAL			**36464.5€**

*The part of the budget for the material used has not been possible to determine because all material owned by the Clean Room of the University of Gent.

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ANEXE 1: DATA SHEETS

DENSELIGHT SEMICONDUCTORS PTE. LTD.
6 Changi North St. 2, S498831 SINGAPORE
Tel: (65) 64154488
Fax: (65) 64157988
www.denselight.com

SPECIFICATIONS

Low DOP ASE Broadband Source

DL-ASE-CW-CSC183A

A. PRODUCT DESCRIPTION

The DenseLight DL-ASE-CW-CSXXXXA is a series Low DOP ASE broadband source for fiber optic gyroscope, fiber optic sensor, optical test instrument and optical coherence tomography. This DL-ASE-CW-CSXXXXA consists of a DenseLight standard ASE broadband source, a temperature controller and a built-in current driver capable for CW driving, which can be customized with various options to meet your specific needs. The broadband source covers over a wide wavelength range include O, E, S, C and L bands.

B. FEATURES

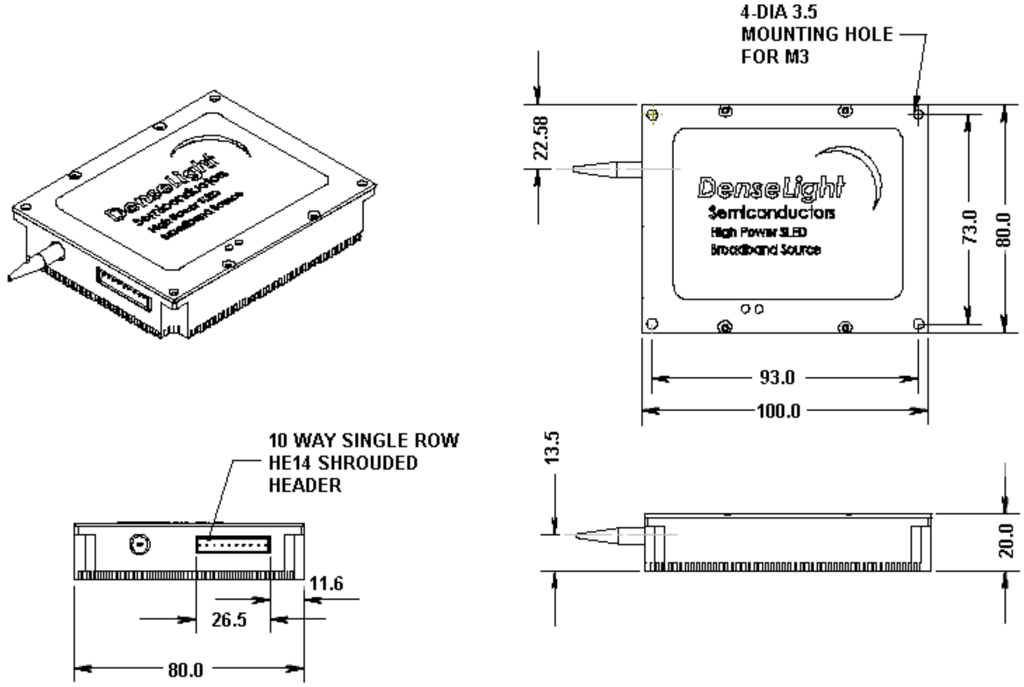
- Ex-fiber output power of >18dBm
- Spectral power density >-3.5dBm/nm over 1525 to 1565nm
- Low Degree of Polarization
- Single mode fiber output
- Integrated optical isolator
- Highly stable power output with active power control
- Built-in current driver and temperature controller
- Over temperature protection and internal PCB temperature monitor
- Single +5V power supply (optional power adapter)
- High wall-plug efficiency
- Compact size
- RoHS Compliance
- Telcordia Qualified broadband source (GR-468-CORE)

C. APPLICATIONS

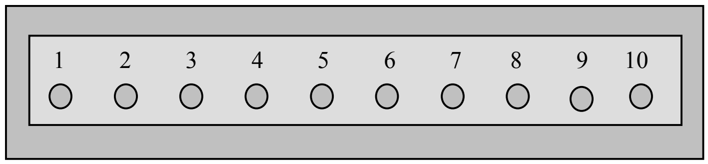
- Optical Test Instrument
- Fiber Optic Sensors
- Fiber Optic Communications
- Optical Coherence Tomography
- Biomedical Imaging Device
- Clinical Healing Equipment

D. PHYSICAL DIMENSIONS AND MECHANICAL SPECIFICATION

Dimension:	L100 x W80 x H20 mm
Enclosure:	Metal Case
Optical output:	1 m SMF-28 fiber, 900um loose tube with FC/APC
Cooling:	Air-cooled or fan cooled. (Mounting holes for fan are provided)
Electronic interface:	10-way single row HE14 shrouded header



E. PIN ASSIGMENT AND FUNCTION



HE14 Shrouded Header Pin Layout (Pin 1 near to SMF output)

Pin Assignment

Pin No.	Symbol	Power/Control /Monitor	Analog /Digital	Input /Output	Description
1	P_{GND}	P			Power Supply Ground
2	P_{GND}	P			Power Supply Ground
3	V_S	P			+5V d.c.
4	V_S	P			+5V d.c.
5	OVRT	M	D	O	To report PCB over temperature and internal self-protection shutdown in operation (Active high)
6	T_{MON}	M	A	O	To monitor the temperature of PCB
7	P_{MON1}	M	A	O	To monitor the PD current in ASE1
8	P_{MON2}	M	A	O	To monitor the PD current in ASE2
9	LO_EN	C	D	I	To enable Light output (active low or no connection to enable light driver)
10	A_{GND}				Signal ground for control and monitor signals

F. ABSOLUTE MAXIMUM RATINGS

Parameter	Symbol	Condition	Min	Max	Unit
Operating temperature (Chassis) [1]	T_{op}	I_{op}	0	60	°C
Operating Relative Humidity [2]	RH	I_{op}		85	%
Storage temperature	T_{stg}	Unbiased	-40	85	°C
Input current	I_s			6	A

1) <0°C or >60°C extended range available
2) Non condensing

G. ELECTRICAL SPECIFICATIONS [3]

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input Power Supply	V_S		4.75	5	5.5	V
Input Current	I_S				3	A
Total Power Consumption	P_S				15	W
Over Temperature	OVRT	Open-drain digital output with internal 1K pull-up to 3V for VH and 8mA current sink for VL				
	V_{OL}	Normal	0		0.45	V
	V_{OH}	Over-temp	2.0		3.0	V
Internal PCB Temperature Monitor	T_{MON}	Analog voltage: T_{MON} = 395mV + (6.2mV/°C x T), T = PCB temperature in °C				mV
Voltage	V_{OUT}	R_X = infinite	0		2.5	V
Output Impedance	R_{OUT}			150		Ω
Source Current	$\lvert I_{OUT} \rvert$	V_{OUT} = 2.5V			4	mA
Power Output Monitor	P_{MON1} P_{MON2}	Analog output: P_{MONx} ~ 1.5V x (P_o / P_{rated}), P_o and P_{rated} in mW				V
Voltage	V_{OUT}	R_X = infinite	0		3.0	V
Output Impedance	R_{OUT}			150		Ω
Source Current	$\lvert I_{OUT} \rvert$	V_{OUT} = 3.0V			4	mA
Light Output Enable	LO-EN	Digital input with internal 10K pull-down for light output enable at logic low or no connection				
	V_{IL}	Normal	0		1	Normal
	V_{IH}	Disable light output	2.5		3.3	Disable light output

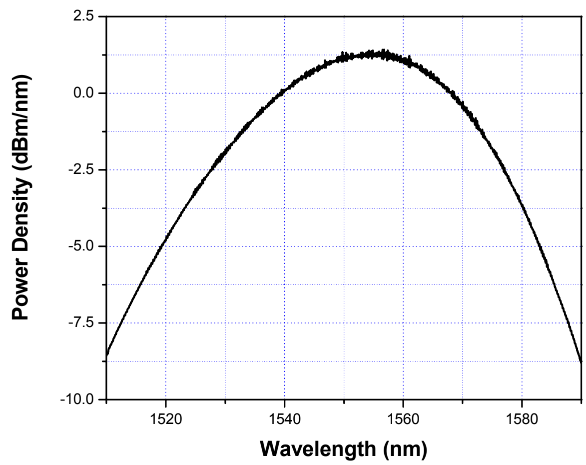
3) Unless otherwise specified, tests are performed at T_{op} = 25°C.

H. OPTICAL SPECIFICATIONS

Parameter	Symbol	Min	Typ	Max	Unit
Power output	P_o	18			dBm
Power density @ 1525 to 1565nm	$P_{density}$	-3.5			dBm/nm
Bandwidth @ 3dB	B_{FWHM}	35			nm
Degree of polarization	DOP			5	%
Output stability [4] 1 hour 8 hour	Stb			± 0.05 ± 0.1	dB dB

4) After 1 hour warm-up

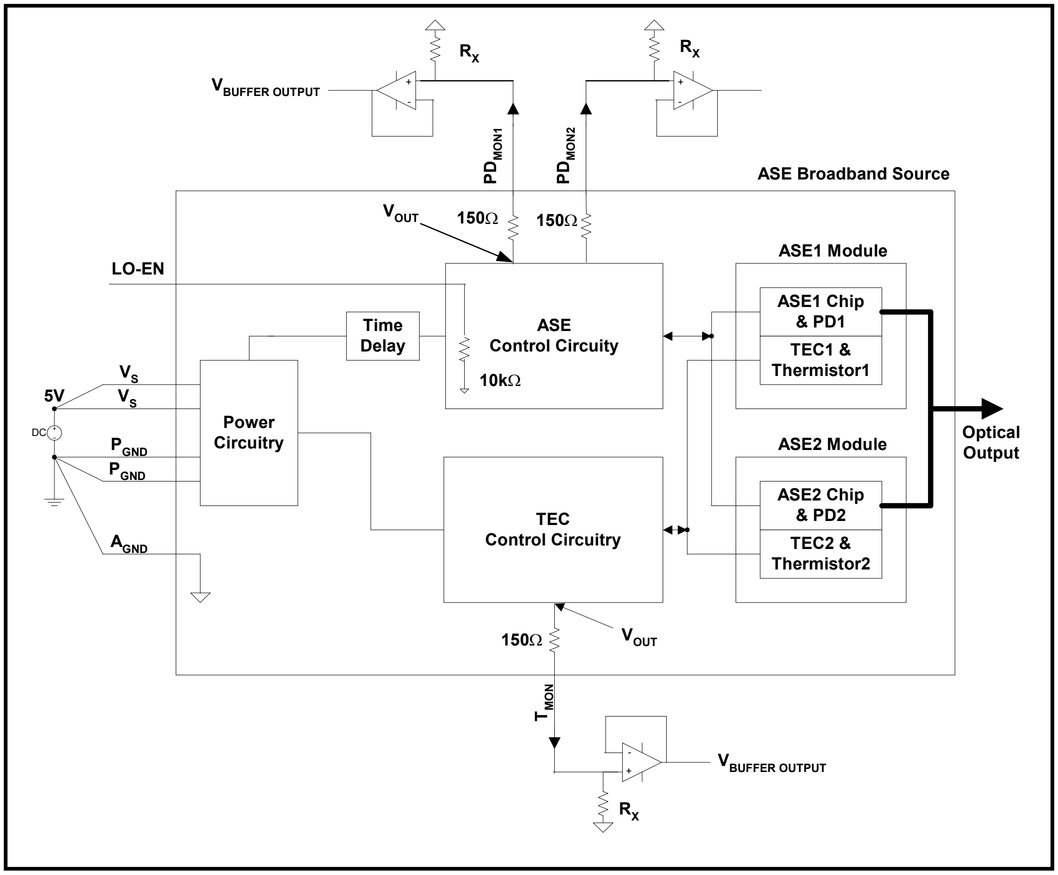
I. TYPICAL OPTICAL PERFORMANCE



Spontaneous Emission Spectrum

J. APPLICATION INFORMATION

J.1 Typical Application Circuit



J.2 Power Supply Requirement and Connections

The power supply must be capable of supplying the maximum input current (I_S) as given in the electrical specification table at all times during operation. This is because during transients (eg. switching on the light source or with a sudden change in operating ambient temperature), the ASE broadband Source will require a momentary higher current from the power supply compared to its steady-state operation.

The two cables to the two V_s pins (Pin 3 and Pin 4) should be shorted at the positive terminal of the power supply as shown in the Typical Application Circuit. This is to divide the total current load to the broadband source between the two cables. Similarly, the two cables to the P_{GND} pins (Pin 1 and Pin 2), as well as the cable to the A_{GND} pin (Pin 10) should be shorted at the ground of the power supply terminal.

J.3 Selection of Resistance R_X for Analog Monitor Signals

In the Typical Application Circuit given, the function of R_X is to increase the current in the signal cables so as to reduce the effect of environmental noise on the analog monitor signals. In a noisy environment, the value of R_X is recommended to be 1kΩ. By choosing R_X to be 1kΩ, the actual voltage measured at the buffer output will be reduced due to loading effect, as compared to when R_X is infinite.

$$V_{\text{BUFFER OUTPUT}} = \frac{R_X}{R_X + 150} \times V_{\text{OUT}}$$

where R_X is resistance in Ω

In a non-noisy environment, the value of R_X can be increased to reduce loading effect. It is not recommended to choose R_X less than 1kΩ.

For further technical information, please refer to DenseLight Semiconductor Low DOP ASE Broadband Source User Operation Manual.

K. REVISION CONTROL

Authorized Personnel	Rev	Description of Change	Date
OTK	A	Initial: Production Release	28 February 2007

9

- User-exchangeable plug-in modules for tailor-made measurements
- Traceable to NIST and PTB for accurate absolute power measurements
- Installed application software for standard measurements without external controller
- Dump to printer and dump to plotter for easy documentation
- Measurement of absolute power, insertion loss, and return loss
- Solutions for parallel-beam, unpackaged-chip, connectorized, and bare-fiber measurements

HP 8153A DESIGNED FOR HP-IB SYSTEMS

HP 8153A Lightwave Multimeter

High Flexibility through Modular Design

The HP 8153A lightwave multimeter mainframe offers two slots for plug-in modules. Since modules can be combined in any configuration, the instrument can be used as a 1/2-channel power meter, as a 1/2-channel light source, as a loss test set, or even as a return-loss test set.

Power Sensor Modules with High Accuracy and Sensitivity

Four different power sensor modules, with different sensitivities from −70 dBm down to −110 dBm, cover the 450 nm to 1700 nm wavelength range. Each is individually calibrated over its entire wavelength range and is traceable to NIST and PTB for precise optical power measurements. Their excellent linearity and the high stability of the sourcemodules provide the basis for precise determination of optical insertion loss for both single-mode and multimode components.

Stabilized Laser- and LED-Source Modules

The source modules offer very good short-term and long-term stability. The high output power can be internally attenuated by up to 6 dB. All sources output CW or pulse-modulated light (internal modulation at 270 Hz, 1 kHz, or 2 kHz).

Return-Loss Measurements with Unsurpassed Accuracy

By calibrating directly at the connector under test using the HP 81000BR reference reflector, an exceptional accuracy is achieved: ±0.4 dB for return-loss measurements over a dynamic range of 50 dB (±0.65 dB between 50 dB and 60 dB). The reference reflector is a gold-plated connector capable of providing a 96 percent reflection with just ±2 percent uncertainty. Unwanted reflections in front of the DUT can also be calibrated and compensated for. Both steps require just the push of a button.

Built-In Software for Advanced Applications

Without the need for an external controller, long-term power, insertion loss, or return-loss monitoring up to 100 hours can be performed. For easy documentation, the measured curves can be dumped to the HP ThinkJet or to any HP-GL plotter. Automatic loss measurements can be made simultaneously at 2 wavelengths. Procedures to maximize the amount of coupled light are supported as well.

Optical Heads Featuring Large-Area Detectors

The HP 81520A, HP 81521B, HP 81524A, and HP 81525A optical heads and their various accessories offer elegant solutions for every sophisticated measurement. They can be used for high-precision power measurements in both parallel-beam and connectorized applications. Together with the HP 81230FL attenuating lens adapter, they can easily be used to perform calibrated absolute power measurements on unpackaged laser chips or LED chips. The HP 81000BA/CA bare-fiber adapter facilitates interfacing to a fiber pigtail with a typical repeatability of less than 0.02 db. For more detailed information about accessories and specification, see the *Lightwave Test and Measurement Catalog.*

Sensor Module Specifications

	HP 81530A	HP 81536A	HP 81531A	HP 81532A	HP 81533B + 81520A	HP 81533B + 81521B	HP 81533B + 81524A	HP 81533B + 81525A
Sensor element	Si	InGaAs			Si, 5 mm	Ge, 5 mm	InGaAs, 5 mm	InGaAs, 5 mm
Wavelength range	450 to 1020 nm	800 to 1700 nm			450 to 1020 nm	900 to 1700 nm	800 to 1650 nm	800 to 1650 nm
Power range	+3 to −100 dBm	+3 to −70 dBm	+3 to −90 dBm	+3 to −110 dBm	+10 to −100 dBm	+3 to −80 dBm	+3 to −90 dBm	+27 to −70 dBm
Display resolution (dB)	0.001 dBm, 0.001 dB (0.0001 dB/dBm on printout)							
Display resolution (W)	0.01 pW	100 pW	1 pW	0.01 pW	0.1 pW	10 pW	1 pW	100 pW
Applicable fiber type	9/125 to 100/140 μm, (NA ≤0.3)				Parallel beam, 9/125 to 100/140 μm (NA ≤0.3)			
Accuracy (at ref. cond.)	±2.5% (600 to 1020 nm)	±2.5% (1000 to 1650 nm)			±2.2% (600 to 1020 nm)	±2.2% (1000 to 1650 nm)	±2.2% (1000 to 1600 nm)	±3% (900 to 1600 nm)
Total uncertainty	±5% ±0.5 pW (600 to 1020 nm)	±5% ±50 pW (1000 to 1650 nm)	±5% ±1.5 pW (1000 to 1650 nm)	±5% ±0.5 pW (1000 to 1650 nm)	±4% ±0.5 pW (600 to 1020 nm)	±4% ±50 pW (1000 to 1650 nm)	±4% ±5 pW (1000 to 1600 nm)	±5% ±500 pW (900 to 1600 nm)
Linearity 18° to 28° C, const. temp. 0° to 55° C, const. temp.	±0.015 dB ±0.3 pW ±0.05 dB ±0.5 pW	±0.015 dB ±30 pW ±0.05 dB ±50 pW	±0.015 dB ±1 pW ±0.05 dB ±1.5 pW	±0.015 dB ±0.3 pW ±0.05 dB± 0.5 pW	±0.04 dB ±0.5 pW ±0.15 dB ±0.5 pW	±0.04 dB ±50 pW ±0.15 dB ±50 pW	±0.04 dB ±5 pW ±0.15 dB ±5 pW	±0.04 dB ±500 pW ±0.15 dB ±500 pW

The display may vary by ±1 count.

Source Module Specifications

	81551MM	81552SM	81553SM	81554SM	81541MM	81542MM	81542MM Opt 001
Diode type	Laser	Laser	Laser	Laser	LED	LED	LED
Central wavelength (nm)	850 ± 10	1310 ± 20	1550 ± 20	1310/1550 ± 20	850 ± 30	1300 ± 40	1300 ± 40
Fiber type	50/125 μm	9/125 μm	9/125 μm	9/125 μm	50/125 μm	50/125 μm	62.5/125 μm
Spectral bandwidth	<1.5 nm	<2.5 nm	<4 nm	<2.5/4 nm	<90 nm	<90 nm	<90 nm
Output power	> −2 dBm	>0 dBm	>0 dBm	> −1 dBm	> −17 dBm	> −20 dBm	> −20 dBm
CW stability (15 min, T-const.)	±0.01 dB	±0.003 dB	±0.003 dB	±0.005 dB	±0.003 dB	±0.002 dB	±0.002 dB

LIGHTWAVE MULTIMETER & ACCESSORIES

Lightwave Multimeter/Accessories (cont'd)

HP 8153A, Accessories

Ordering Information	Price
HP 8153A Lightwave Multimeter Mainframe	$3,160
Power Sensor Modules[1]	
HP 81530A Si, +3 to −100 dBm, 450 to 1020 nm	$3,315
HP 81531A InGaAs, +3 to −90 dBm, 800 to 1700 nm	$3,620
HP 81532A InGaAs, +3 to −110 dBm, 800 to 1700 nm	$5,460
HP 81536A InGaAs, +3 to −70 dBm, 800 to 1700 nm	$2,960
Optical Heads[2]	
HP 81533B Optical Head Interface Module[3]	$1,375
HP 81520A Optical Head, Si, +10 to −100 dBm, 450 to 1020 nm	$2,805
HP 81521B Optical Head, Ge, +3 to −80 dBm, 900 to 1700 nm	$3,060
HP 81524A Optical Head, InGaAs, +3 to −90 dBm, 800 to 1650 nm	$5,920
HP 81525A Optical Head, InGaAs, +27 to −70 dBm, 800 to 1650 nm	$6,430
Laser-Source Modules[1]	
HP 81551MM 850 nm, Multimode	$6,530
HP 81552SM 1310 nm, Single-Mode	$6,680
HP 81553SM 1550 nm, Single-Mode	$10,100
HP 81554SM 1310/1550 nm, Single-Mode	$13,450
LED-Source Modules[1]	
HP 81541MM 850 nm, 50 µm Multimode Fiber Output	$3,620
HP 81542MM 1300 nm, 50 µm Multimode Fiber Output	$4,945
HP 81542MM Opt 001 62.5 µm Fiber instead of 50 µm fiber output	$325
Return Loss Module[4] **and Accessories**	
HP 81534A Return Loss Module	$6,120
HP 81102AC Patchcord HP/HRL, HP/HRL	$735
HP 81102BC Patchcord HP/HRL, Bare Fiber	$450
HP 81102DC Patchcord HP/HRL, Radiall VFO/DF	$735
HP 81102PC Patchcord HP/HRL, FC/APC	$735
HP 81102SC Patchcord HP/HRL, Diamond HRL-10	$735
HP 81109AC Patchcord HP/HRL, Diamond HMS-10/HP	$735
HP 81000UM Universal Through Adapter	$97
HP 81000BR Reference Reflector	$235

[1]One connector interface (HP 81000xI) required per module.
[2]For required lenses and adapters, see *Lightwave Test and Measurement Catalog*.
[3]Required to connect the optical head to the mainframe.
[4]Two connector interfaces (HP 81000xI) required per module.

Accessories

Optical Power Splitter for HP 81521B

The optical power splitter, HP 81010BS accepts single-mode fibers only and offers high return loss for physical-contact connectors. Depending on connector type, the return loss is up to 40 dB. Split ratio is approximately 10:1.

High-Performance Bare-Fiber Adapters for Optical Heads

The HP 81000BA for fibers with 125 µm cladding diameter and the HP 81000CA for fibers with 140 µm cladding diameter are capable of interfacing fiber pigtails to the 81520A/81521B/81524A/81525A optical heads with typically 0.02 dB repeatability. The sophisticated design makes them very easy to use and ensures not only high accuracy but also high throughput in serial testing.

Attenuating Lens Adapter for Direct Chip Measurements

With the HP 81230FL mounted on an HP 81521B or HP 81524A optical head, the output power of LED or laser chips up to 200 mW can be measured precisely, before the pigtail is attached. Anti-reflection coating on all optical surfaces guarantees minimum back-reflections. The maximum acceptable numerical aperture is NA=0.5 in the wavelength range from 1200 nm to 1650 nm.

Connector Interfaces for Both Easy Cleaning and Easy Adaptation

User-exchangeable connector interfaces permit easy cleaning of the instrument's front end connector, and also allow the use of different connector types with the same instrument. They are available for Diamond HMS-10, FC/PC, D4, SMA, SC, ST, DIN, and Biconic.

Depolarizing Adapters for Optical Heads

The HP 81000DF is a detachable adapter for the HP 81521B, HP 81524A, and HP 81525A. It reduces the polarization sensitivity to less than 0.006 dB p-p in parallel beam applications with bare fibers or straight output connectors.

A Variety of Other Accessories Help Solve Your Measurement Problems

Patch cords and adapters enable users to interface virtually every connector type to the instruments. Filters and filter holders extend the measurement range to higher power levels. For more detailed information about accessories, please see the *Lightwave Test and Measurement Catalog*.

Key Literature

Lightwave Test and Measurement Catalog, p/n 5962-6832E.

Ordering Information	Price
Connector Interfaces	
HP 81000AI Diamond HMS-10/HP	$173
HP 81000FI FC/PC	$173
HP 81000GI D4	$173
HP 81000JI SMA (lensed interface only)	$173
HP 81000KI SC	$173
HP 81000SI DIN 47256	$173
HP 81000VI ST	$173
HP 81000WI Biconic	$173

HAAKE Phoenix II
HAAKE C/DC
HAAKE EK
HAAKE DynaMax

Circulators, Cryostats, Coolers, Sealed Systems

Part of Thermo Fisher Scientific

Thermo SCIENTIFIC

Thermo Scientific Temperature Control Products

HAAKE Phoenix II – HAAKE C/DC – HAAKE EK – HAAKE DynaMax

Thermo Fisher Scientific is an industry leader in laboratories all over the world and continually drives new standards for circulators, cryostats, immersion coolers and water recirculators.

The Thermo Scientific HAAKE Phoenix II range of circulators results from our philosophy to develop and implement advanced technology that is also visually attractive and easy to use.

Phoenix II products incorporate innovative and design-conscious materials such as aluminum, polymers or glass. The simple operation of the HAAKE Phoenix II circulators and their large monitors with easily visible displays demonstrates our dedication to user-friendliness.

Our products are certified according to ISO 9001. All units have the CE-mark.

CFC-free refrigerants have been used for many years as proof of our commitment to the environment.

All units can be recycled easily.

Find out more about the advanced features and flexibility of the HAAKE circulator ranges from Thermo Fisher Scientific in the next few pages.

Your Guide to the Products

In this brochure we have grouped the circulator lines separately and have described them in detail including extensive technical specifications. The ExtraPlus features of the units are included on the last two pages.

Simple to Operate

The menu structure for all digital units enables intuitive operation and is supported by the simple allocation of the individual functions to the operating keys.

Innovative Control

High temperature accuracy and the ability to reach the set temperature quickly even under difficult conditions is made possible by the new Fuzzy-Star control system.

Many Additional Functions

Additional functions such as the Real Temperature Adjustment (RTA), the Fault Identification System (FIS), the External Temperature Control (ETC) and the Turbulence Reduction System (TRS) make operation easier for the user.

Flexible Communication

Connecting the units to PCs or within networks is simple due to a range of different interfaces: RS232C, RS485, I/O, multi-functional port, Profibus.

Extensive Range of Accessories

Insert racks, lift plates, hoses or software are just some of the optional accessories which can be used to adapt the units to suit a wide range of applications.

+ + ExtraPlus-Rating + +

The more functions the circulators have, the more ExtraPlus points they get. On page 35 you see which functions related to the points.

Inexpensive circulators with a high power capacity

The HAAKE C/DC circulators are inexpensive units with a high power capacity. These circulators are small, slimline units which can be used for a wide range of standard applications. A powerful pump and a heating capacity of up to 2000 watts enable the safe temperature control of applications up to 200°C. Digital displays with user-preset temperatures are available for simple operation.

There are five different models:

HAAKE C10: Analog unit up to 100°C, 1.5 kW heating capacity

HAAKE DC10: Inexpensive digital unit up to 100°C, 2 kW heating capacity

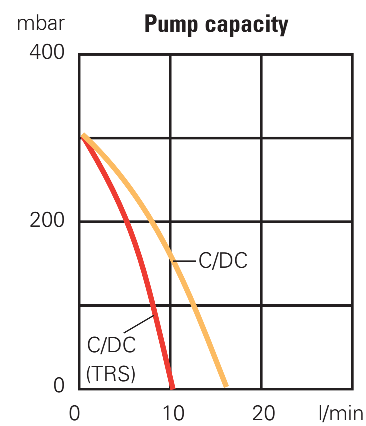
HAAKE DC30: Digital unit with RS232C up to 200°C, 2 kW heating capacity

HAAKE DL30: Same as DC30, however with 200 mm immersion depth

HAAKE DC50: Same as DC30, however with connection for Pt100 sensor and external control

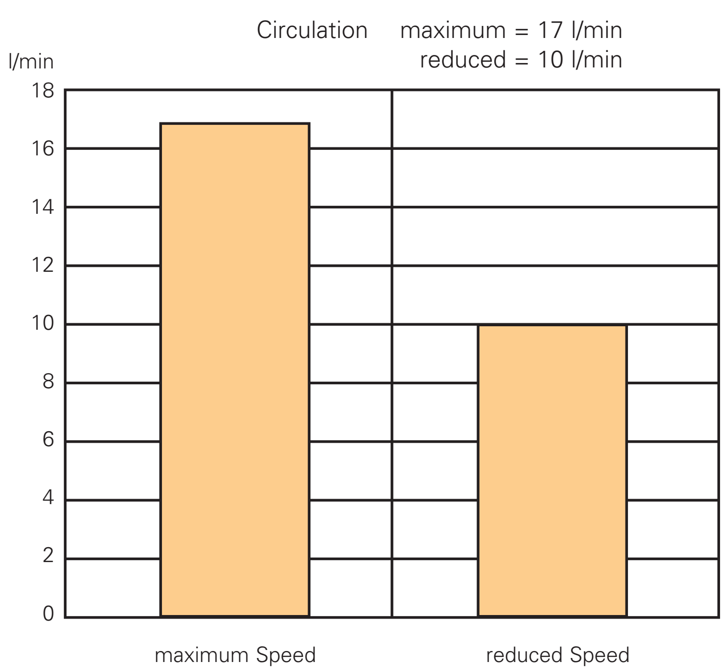
Highlights

- Powerful pumps with Turbulence Reduction System (TRS)
- Simple operation due to separate display panels for menu selection and temperature (except for C10)
- Microprocessor with PID control (except for C10)
- Resolution of the digital display for the set and actual temperature optionally 0.1 or 0.01°C
- Real Temperature Adjustment (RTA)
- Saving of 3 user-defined fixed temperatures with their respective RTA values
- The reason for a unit fault is shown on the display via the Fault Identification System (FIS)
- RS232C interface (except for C10, DC10), optional RS485 interface with the DC50
- External Temperature Control (ETC) for external systems (for DC50 only)
- Connection for an external Pt100 sensor (for DC50 only)



TRS (Turbulence Reduction System))

2-level-switching to avoid turbulence in open baths or to enable careful fi lling of external systems.



The HAAKE C/DC immersion circulators are used for the temperature control of baths up to 50 liters. They can be attached to bath walls with a thickness of up to 25 mm using a bracket clamp. A pivotal nozzle ensures even mixing and a good temperature distribution within the entire bath. The minimum depth of the bath must be 150 or 200 mm. The TRS feature can be used to avoid turbulence in the open bath.

Comes with
Screw clamp for bath wall thickness up to 25 mm and **pivotal.**
C10: plus **checking thermometer** 0 to 100°C, division 0.5°C

Optional accessories	Order-No.
Tap water cooling coil (C10, DC10, DC30 and DC50)	**333-0590**
Tap water cooling coil (DL30)	**333-0593**
Bath liquids	**(s. p. 30-31)**

Technical specifications acc. to DIN 12876		C10	DC10	DC30	DC50	DL30
Working temperature with tap water cooling with other cooling	°C °C °C	25..100 20..100 -30..100	25..100 20..100 -30..100	25..200 20..200 -50..200	25..200 20..200 -50..200	25..200 20..200 -50..200
Temperature accuracy	+/- K	0.04	0.02	0.01	0.01	0.01
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2
Pump: Pressure/Flow rate max.	mbar/l/min	300/17	300/17	300/17	300/17	300/17
Immersion depth from..to	mm	75..145	75..145	85..145	85..145	85..190
Overall dimensions: WxLxH	cm	9.5 x 15 x 32	10 x 16.5 x 32	10 x 16.5 x 32	10 x 16.5 x 32	10 x 16.5 x 37
Net weight	kg	3	3	3.2	3.2	3.6
Total wattage 230V/115V	VA	1550/1050	2050/1250	2050/1250	2050/1250	2050/1550
Order-No. for 230V/50..60Hz for 115V/60Hz		425-1001 425-1002	426-1001 426-1002	426-3001 426-3002	426-5001 426-5002	427-3001 427-3002
ExtraPlus-Rating (see page 35)		+	+ +	+ + +	+ + + +	+ + +

HAAKE Phoenix II Series

Innovative materials combined with sophisticated technology and advanced design form the basis of the HAAKE Phoenix II circulators.

The simple operation of the units is ensured by the large graphic display that incorporates plain text dialog and a simple user interface. The Phoenix II circulators come equipped with a powerful pressure and suction pump, feature a heating capacity of up to 3000 W and a maximum bath temperature of +280°C and are thus ideally suited to meet the extreme technical specifications that many applications require.

HAAKE Phoenix II circulators are available in two versions:

Basic versionHAAKE Phoenix II P1
with a 2 kW (230V) heating capacity, up to 250°C.

Full version HAAKE Phoenix II P2
with a 3 kW (230V) heating capacity, up to 280°C and with additional functional features.

Highlights

- Large monitor with plain text display and Fault Identification System (FIS)
- FuzzyStar control with neural adaptation
- Very powerful combined pressure and suction pump with automatic speed recognition and TRS
- Display resolution of 0.01°C
- Flexible interface concept
- Direct value setting at the display via numeric input
- Up to 10 ramp programs with a maximum of 30 segments (for P2)
- 4 savable fixed temperatures
- Real Temperature Adjustment (RTA) for integration in QS systems
- External Temperature Control (ETC) with connection for an external Pt100 sensor as standard
- User can choose from 6 different dialog longuages (German, English, French, Italian, Spanish, Japanese)
- Permanent display of date and time
- 3-point calibration function (for P2)
- External analog box (optional)
- Profibus interface (optional)

A more detailed explanation of the individual fetaures and the ExtraPlus-Rating system can be found on page 35.

The units are fi tted onto bath vessels with a maximum volume of 100 l.

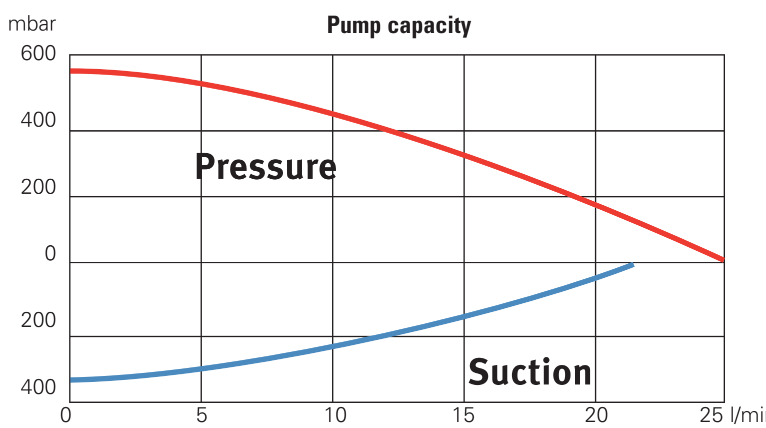
The bridge can be adjusted to fit widths between 320 and 800 mm and is thus suitable for use with a wide range of different bath sizes.

The powerful combined pressure and suction pump enables a good heat exchange in the bath and the simultaneous temperature control of an external unit.

Comes with
Connections for **tubing** with 8 and 12 mm i. Ø.

Optional accessories	Order-No.
External analog box	**333-0685**
230V Power supply for analog box	**333-0705**
Tubes and **Bath liquids**	**(s. p. 30-31)**
Immersion cooler	**(s. p. 26-27)**
Pt100-sensors	**(s. p. 33)**

Profibus-interface on request.



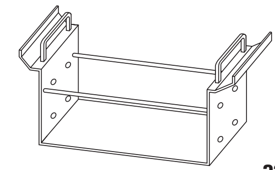
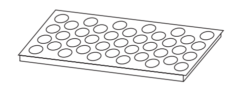
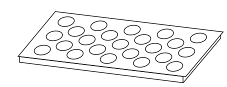
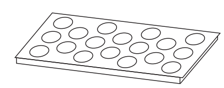
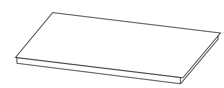
Technical specifications acc. to DIN 12876		P1-H70	P2-H70
Working temperature range with tap water cooling with other cooling	°C °C °C	30...250 20...250 -75...250	30...280 20...280 -90...280
Temperature accuracy	+/- K	0.01	0.01
Heater capacity 230V/115V	kW	2.0/1.2	3.0/1.2
Pump: Pressure max. Flow rate max. Suction max. Flow rate max.	mbar l/min mbar l/min	560 24 380 22	560 24 380 22
Width of the bath bridge from…to	mm	320...800	320...800
Immersion depth from…to	mm	70...150	70...150
Overall dimensions WxLxH	cm	32 x 17 x 36	32 x 17 x 36
Total wattage 230V/115V	VA	2100/1250	3100/1250
Net weight	kg	6.1	6.1
Order-No. for 230V/50-60Hz Order-No. for 115V/60Hz		440-0511 440-0512	441-0511 441-0512
ExtraPlus-Rating (see page 35)		**+++++**	**++++++**

HAAKE C/DC open-bath circulators very rigid baths made from modified polyphenyleneoxide (PPO) that are thermally resistant up to 100°C. Used with the temperature control units C10 and DC10, they are inexpensive open-bath circulators to be used with water as the heat transfer liquid. The baths have integrated grips and supports. They are fitted with bridge plates for locating the temperature control unit.
A range of accessories is available to adapt the units to suit specific applications.

Comes with
Directable **nozzle**
All C10-combinations include a **checking thermometer** 0 to 100°C, division 0.5°C.

Optional accessories	Order-No.
Tap water cooling coil	**333-0589**
Instead of water cooling, an **immersion cooler EK20** can be used with baths P14 and P21 (see page 26/27)	
Set for external circulation to upgrade the baths	**333-0586**
Lifting platform for C10-P14 and DC10-P14	**333-0583**

Optional accessories	Order-No.
Lifting platform for C10-P21 and DC10-P21	**333-0582**
Plastic balls as **floating bath** cover (recommended above 60°C)	**827-0310**
Bath cover for P5	**333-0618**
Bath cover for P14	**333-0619**
Bath cover for P21	**333-0620**
Racks for bath P5 (fits 2 in the bath) for: 18 tubes, 16 mm Ø	**333-0500**
26 micro centrifuge tubes, 10 mm Ø	**333-0501**
6 centrifuge tubes, 30 mm Ø	**333-0502**

Optional accessories	Order-No.
Basic rack without inserts (fits 1 x into P14; 2 x in P21) 	**333-0129**
Inserts for tubs into basic rack  for 86 of 10 mm Ø	**333-0130**
 for 46 of 16 mm Ø	**333-0131**
 for 23 of 25 mm Ø	**333-0132**
 without holes	**333-0151**
 **plastic snappers** to reduce the hole Ø in the inserts from 16 to 3..10 mm, 50 pieces	**333-0134**
25 to 6..17 mm, 25 pieces	**333-0135**
Optional accessories for C10-P5 and DC10-P5 (see page 9)	

Technical specifications acc. to DIN 12876		C10-P5	DC10-P5	C10-P14	DC10-P14	C10-P21	DC10-P21
Working temperature range	°C	25..100	25..100	22..100	22..100	22..100	22..100
with tap water cooling	°C	20..100	20..100	20..100	20..100	20..100	20..100
with other cooling	°C	0..100	0..100	0..100	0..100	0..100	0..100
Temperature accuracy	+/- K	0.04	0.02	0.04	0.02	0.04	0.02
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2
Pump: Pressure/Flow rate max.	mbar/l/min	300/17	300/17	300/17	300/17	300/17	300/17
Bath opening: WxLxD	cm	13 x 17 x 16	13 x 17 x 16	30 x 19 x 16	30 x 19 x 16	30 x 38 x 16	30 x 38 x 16
Bath volume	l	3..5	3..5	8..14	8..14	13..21	13..21
Overall dimensions: WxLxH	cm	16 x 33 x 36	16 x 33 x 36	33 x 38 x 36	33 x 38 x 36	33 x 54 x 36	33 x 54 x 36
Net weight	kg	4.8	4.8	6	6	6.3	6.3
Total wattage 230V/115V	VA	1550/1050	2050/1250	1550/1050	2050/1250	1050/1050	2050/1250
Order-No. for 230V/50..60Hz		425-1821	426-1821	425-1831	426-1831	425-1841	426-1841
for 115V/60Hz		425-1822	426-1822	425-1832	426-1832	425-1842	426-1842
ExtraPlus rating (see page 35)		+	+ +	+	+ +	+	+ +

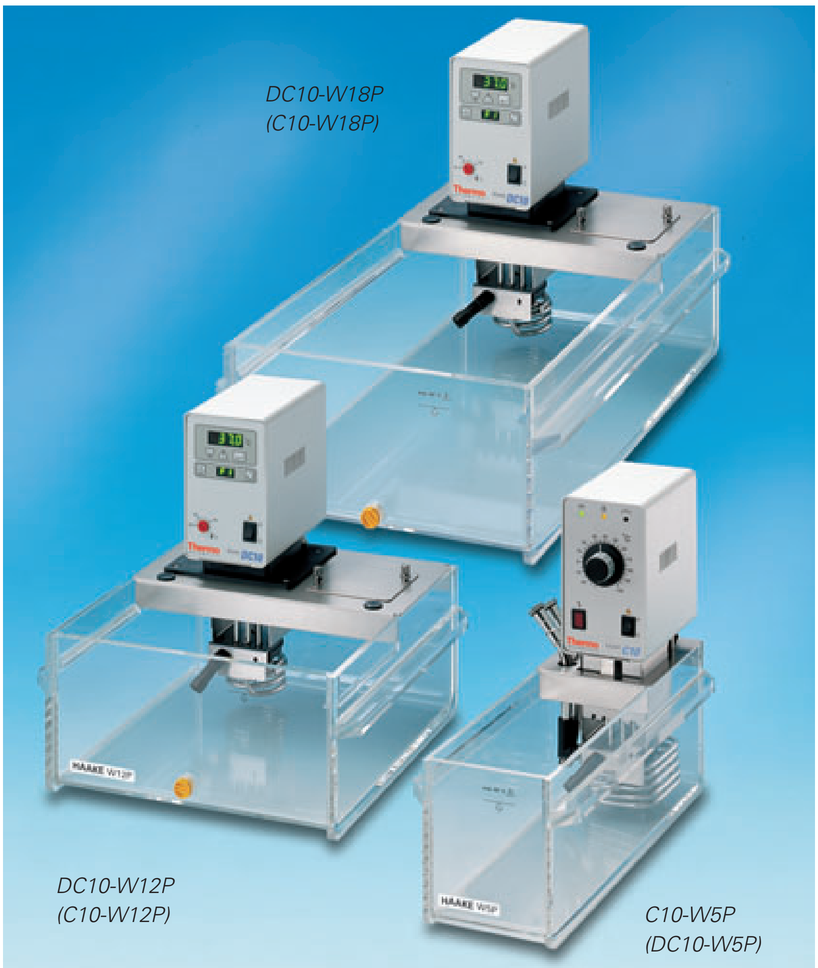
Open-Bath Circulators C10- and DC10-W12P, C10- and DC10-W18P

These transparent baths allow clear viewing during processing.

A water cooling coil is necessary for working temperatures below 25°C. These units can also be adapted for external circulation by adding a pump set.

Open-Bath Circulators with a built-in recirculation pump C10-W5P, DC10-W5P

These circulators are used for the simultaneous temperature control of external systems such as a photometer and the insertion of flasks or test tubes within the circulator's own bath. A powerful, two-stage pressure pump is available as a standard feature.

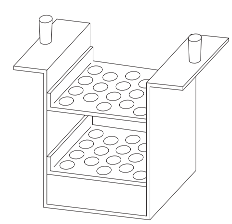


Comes with

C10-W5P and DC10-W5P:
Each 2 **nozzles** for tubing with 8 and 12 mm i. Ø, **set for externalcirculation** and **tap water cooling coil.**

C10-W5P:
plus **checking thermometer** 0 to 100°C
W12P und W18P: **Bath bridge** to fix the circulator onto the bath and a **directable nozzle.**

Optional accessories	Order-No.
Tap water cooling coil for W12P/W18P	**333-0589**
Plastic balls as floating bath cover	**827-0310**
Lifting platforms for W12P	**333-0583**
for W18P	**333-0582**
Set for external circulation for W12P/W18P	**333-0586**
Reservoir drain for W12P/W18P	**333-0499**
Racks for W5P-bath (to be used max. 3 per bath) for:	



18 tubes, 16 mm Ø	**333-0500**
26 micro centrifuge tubes, 10 mm Ø	**333-0501**
6 centrifuge tubes, 30 mm Ø	**333-0502**
Optional accessories for DC10-W12P and DC10-W18P (see page 8)	

Technical specifications acc. to DIN 12876		C10-W5P	DC10-W5P	C10-W12P	DC10-W12P	C10-W18P	DC10-W18P
Working temperature range with tap water cooling with other cooling	°C °C °C	30..60 20..60 0..60	30..60 20..60 0..60	25..60 20..60 0..60	25..60 20..60 0..60	25..60 20..60 0..60	25..60 20..60 0..60
Temperature accuracy	+/- K	0.04	0.02	0.04	0.02	0.04	0.02
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2
Pump: Pressure/Flow rate max.	mbar/l/min	300/12,5	300/12,5	300/17	300/17	300/17	300/17
Bath opening: WxLxD	cm	12 x 24 x 15	12 x 24 x 15	30 x 17 x 15	30 x 17 x 15	30 x 34 x 15	30 x 34 x 15
Bath volume	l	4..6	4..6	8..12	8..12	12..19	12..19
Overall dimensions: WxLxH	cm	17 x 40 x 34	17 x 40 x 34	31 x 34 x 34	31 x 34 x 34	31 x 51 x 34	31 x 51 x 34
Net weight	kg	6	6.2	7	7.2	8.2	8.4
Total wattage 230V/115V	VA	1550/1050	2050/1250	1550/1050	2050/1250	1550/1050	2050/1250
Order-No. for 230V/50..60Hz for 115V/60Hz		425-1051 425-1052	426-1051 426-1052	425-1121 425-1122	426-1121 426-1122	425-1181 425-1182	426-1181 426-1182
ExtraPlus-Rating (see page 35)		+	+ +	+	+ +	+	+ +

The high-quality stainless steel used on the bath interior and exterior is characteristic of these circulators. The handles and drain nozzle enable easy handling.

The temperature control units C10 and DC10 are suitable for used with water or a mixture of water and antifreeze. A large range of accessories such as an immersion cooler, a set for external circulation, test tube racks or lift plates can be used to quickly adapt the circulator for different applications.

The bath depth for all baths is 200 mm to allow both large and long objects to be placed within. The units V15/B and V26/B are fitted with a compressor cooling unit, i.e. are independent of tap water and are therefore environmentally friendly.

Comes with

Bath bridge to attached the circulator onto the bath and a directable nozzle.

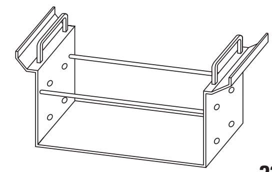
All C10-combinations include a **checking thermometer** 0 to 100°C, division 0.5°C.

Optional accessories	Order-No.
Tap water cooling coil Instead of water cooling, an immersion cooler EK20 or EK30 can be used (see page 26/27)	**333-0589**
Set for external circulation to upgrade the baths	**333-0586**
Lifting platforms for W15, V15	**333-0583**
for W26, V26	**333-0582**
for W46	**333-0584**
Bath cover out of s/s (fits 1 x onto W15, V15; 2 x onto W26, V26; 4 x onto W46)	**333-0225**
Plastic balls as floating bath cover	**827-0310**
Reservoir drain	**333-0499**

Baths with angled clamps are also available for more budget-conscious customers.

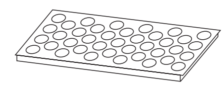
Optional accessories **Order-No.**

Basic rack without inserts (fits 1 x into W15, V15; 2 x into W26, V26; 4 x into W46)

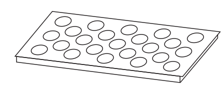


333-0129

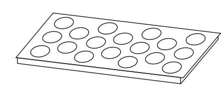
Inserts for tubes into basic rack



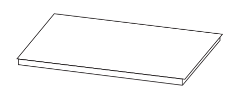
for 86 of 10 mm Ø **333-0130**



for 46 of 16 mm Ø **333-0131**



for 23 of 25 mm Ø **333-0132**



without holes **333-0151**

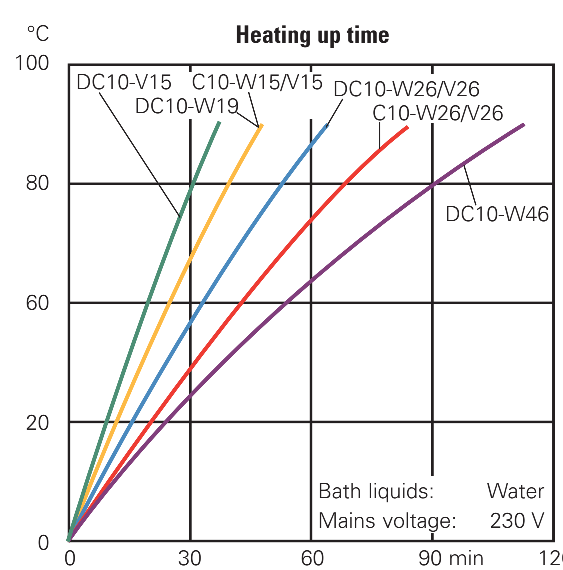
plastic snappers to reduce the hole Ø in the inserts from

16 to 3..10 mm, 50 pieces **333-0134**

25 to 6..17 mm, 25 pieces **333-0135**

Technical specifications acc. to DIN 12876		C10-V15/B	DC10-V15/B	C10-V26/B	DC10-V26/B	C10-W15/B
Working temperature range with tap water cooling with other cooling	°C °C °C	-5..100 – –	-5..100 – –	-10..100 – –	-10..100 – –	25..100 20..100 -30..100
Temperature accuracy	+/- K	0.04	0.02	0.04	0.02	0.04
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2	1.5/1.0
Cooling capacity at 20°C	W	200	200	250	250	–
Pump: Pressure/Flow rate max.	mbar/l/min	300/17	300/17	300/17	300/17	300/17
Bath opening: WxLxD	cm	30 x 17.5 x 20	30 x 17.5 x 20	30 x 35 x 20	30 x 35 x 20	30 x 17.5 x 20
Bath volume	l	11..15	11..15	19..26	19..26	11..15
Overall dimensions: WxLxH	cm	36 x 59 x 40	36 x 59 x 40	36 x 75 x 40	36 x 75 x 40	34 x 36 x 40
Net weight	kg	26.1	26.1	31	31	8.3
Total wattage 230V/115V	VA	1900/1400	2400/1600	2000/1500	2500/1700	1550/1050
Order-No. for 230V/50..60Hz for 115V/60Hz		425-1531 425-1532	426-1531 426-1532	425-1561 425-1562	426-1561 426-1562	425-1161 425-1162
ExtraPlus-Rating (see page 35)		+	+ +	+	+ +	+

	DC10-W19/B	C10-W26/B	DC10-W26/B	DC10-W46/B
	25..100 20..100 -30..100	23..100 20..100 -30..100	23..100 20..100 -30..100	22..100 20..100 -30..100
	0.02	0.04	0.02	0.02
	2.0/1.2	1.5/1.0	2.0/1.2	2.0/1.2
	–	–	–	–
	300/17	300/17	300/17	300/17
	30 x 35 x 15	30 x 35 x 20	30 x 35 x 20	30 x 70 x 20
	12..19	19..26	19..26	35..46
	34 x 54 x 35	34 x 56 x 40	34 x 56 x 40	36 x 95 x 40
	9	10.9	10.9	23.3
	2050/1250	1550/1050	2050/1250	2050/1250
	426-1191 426-1192	425-1261 425-1262	426-1261 426-1262	426-1461 426-1462
	+ +	+	+ +	+ +



The temperature control unit is attached to the bath vessel by means of a bath bridge. The bridge is equipped with openings designed for the subsequent attachment of an immersion cooler, cooling coil and circulation set for temperature controlling external systems. The units used with the DL30 have an especially large filling range. This enables the frequent exchange of objects with a large volume without triggering level alarms.

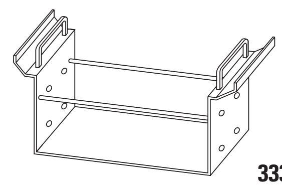
The integrated TRS (Turbulence Reduction System) avoids excessive turbulence in the bath via a reduction of the flow rate. Full capacity is available if required.

The units V15/B and V26/B are fitted with a compressor cooling unit, i.e. are independent of tap water and are therefore environmentally friendly.

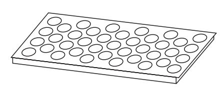
Comes with
Bath bridge to fix the circulator onto the bath and a directable nozzle

Pumpset (optional)

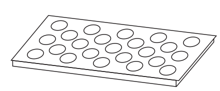
Optional accessories	Order-No.
Lifting platforms	
for W13, W15 and V15	**333-0583**
for W19, W26, V26	**333-0582**
for W46	**333-0584**
for W45	**333-0581**
Reservoir drain	**333-0499**
Set for external circulation to upgrade the baths for DC30-Combinations	**333-0586**
for DL30-Combinations	**333-0625**
Basic rack without inserts (fits 1 x into W13, W15, V15; 2 x in W19, W26, W45; 4 x in W46)	



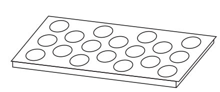
	333-0129
inserts for tubes into basic rack	



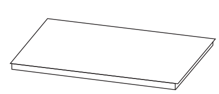
for 86 of 10 mm Ø	**333-0130**



for 46 of 16 mm Ø	**333-0131**



for 23 of 25 mm Ø	**333-0132**



without holes	**333-0151**

Optional accessories	Order-No.
plastic snappers to reduce the hole Ø in the inserts from	

16 to 3..10 mm, 50 pieces	**333-0134**
25 to 6..17 mm, 25 pieces	**333-0135**
Tap water cooling coil for DC30-Combinations	**333-0589**
Tap water cooling coil for DL30-Combinations	**333-0595**
Instead of water cooling, an immersion cooler EK20 or EK30 can be used (see page 26/27)	
Bath cover made from stainless steel (fits 1 x onto W13, W15, V15; 2 x onto W19, W26, V26; 4 x onto W46)	**333-0225**
Bath cover made from stainless steel (fits 2 x onto W45)	**333-0648**

Lifting platform (optional)

Technical specifications acc. to DIN 12876		DL30-V15/B	DL30-V26/B	DC30-W13/B	DL30-W15/B
Working temperature range with tap water cooling with other cooling	°C °C °C	-5..150 – –	-10..150 – –	25..200 20..200 -50..200	25..200 20..200 -50..200
Temperature accuracy	+/- K	0.01	0.01	0.01	0.01
Heater capacity 230V/115V	kW	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2
Cooling capacity at 20°C	W	200	250	–	–
Pump: Pressure/Flow rate max.	mbar/l /min	300/17	300/17	300/17	300/17
Bath opening: WxLxD	cm	30 x 17.5 x 20	30 x 35 x 20	30 x 17.5 x 15	30 x 17.5x 20
Bath volume	l	8..15	14..26	7..12	8..15
Overall dimensions: WxLxH	cm	36 x 59 x 40	36 x 75 x 40	34 x 36 x 35	34 x 36 x 40
Net weight	kg	27	32	8.8	9
Total wattage 230V/115V	VA	2400/1500	2500/1700	2050/1250	2050/1250
Order-No. for 230V/50..60Hz for 115V/60Hz		427-3531 427-3532	427-3561 427-3562	426-3141 426-3142	427-3161 427-3162
ExtraPlus-Rating (see page 35)		**+++**	**+++**	**+++**	**+++**

DL30-W45/B

DL30-V26/B

DL30-V15/B

DC30-W19/B
(DC30-W13/B)

DL30-W15/B

	DC30-W19/B	DL30-W26/B	DL30-W46/B	DL30-W45/B
	25..200 20..200 -50..200	23..200 20..200 -50..200	22..200 20..200 -50..200	22..200 20..200 -50..200
	0.01	0.01	0.01	0.01
	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2
	–	–	–	–
	300/17	300/17	300/17	300/17
	30 x 35 x 15	30 x 35 x 20	30 x 70 x 20	30 x 35 x 30
	12..19	14..26	27..46	30..42
	34 x 54 x 35	34 x 54 x 40	36 x 95 x 40	36 x 54 x 51
	9	11.2	24	23
	2050/1250	2050/1250	2050/1250	2050/1250
	426-3191 426-3192	427-3261 427-3262	427-3461 427-3462	427-3451 427-3452
	+++	+++	+++	+++

HAAKE DC30-W26/B
with cooler
HAAKE EK30

These space-saving heating circulators are used to control temperatures in smaller external systems such as density meters, viscometers, photometers, refractometers or similar devices. A powerful pressure pump provides a good heat exchange with closed systems and thus optimum temperature accuracy.

The available bath opening also allows samples to be inserted into the circulator's own bath. Various bath volumes and depths cover a wide application range. The interior and exterior of the bath vessels are made from stainless steel for easy cleaning and durability. The bath P5 is made from polyphenyleneoxide (PPO). A built-in water cooling coil enables temperature control down to 2°C...3°C above the cooling water temperature.

Die HAAKE DC- and DL-Class

- **Robust PID control**
- **Double display**
- **3 fixed temperatures**
- **RS232C Interface (RS485 option)**
- **RTA / FIS / ESK / TRS**

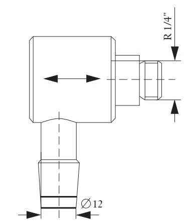
Comes with

Each 2 **nozzles** for tubins with 8 and 12 mm i. Ø, a **tap water cooling coil** and a **bath cover.**

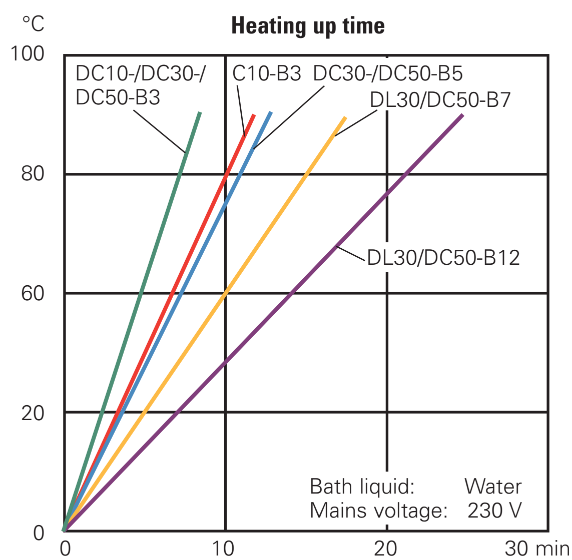
C10-P5/U, C10-B3: plus **checking thermometer** 0 to 100°C, division 0.5°C.

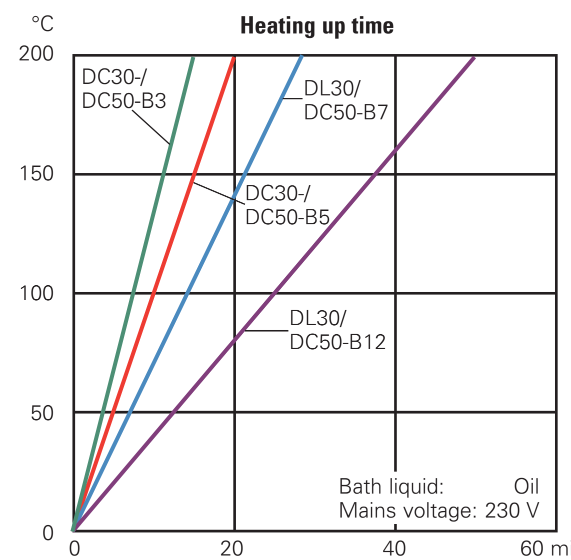
Optional accessories	Order-No.
Rack for 20 tubes/ 16 mm Ø for B3-bath	**333-0456**

Optional accessories	Order-No.
Racks for bath B5, B7 18 tubes, 16 mm Ø	**333-0500**
26 micro centrifuge tubes, 10 mm Ø	**333-0501**
6 centrifuge tubes, 30 mm Ø	**333-0502**
Universal hose nozzle for tubing of 3 to 6 mm i. Ø	**832-0275**
Reservoir drain	**333-0499**
Software for DC30, DL30, DC50	**(s. p. 32)**



Choose the **necessary tubes, bath liquids** or **Pt 100 sensors** on pages 30/31/33.





Technical specification acc. to DIN 12876		C10-P5/U	DC10-P5/U	C10-B3	DC10-B3	DC30-B3	DC50-B3
Working temperature range with tap water cooling with other cooling	°C °C °C	25..100 20..100 0..100	25..100 20..100 0..100	32..100 20..100 -30..100	32..100 20..100 -30..100	32..200 20..200 -50..200	32..200 20..200 -50..200
Temperature accuracy	+/- K	0.04	0.02	0.04	0.02	0.01	0.01
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2	2.0/1.2	2.0/1.2
Pump: Pressure/Flow rate max.	mbar/ l/min	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5
Bath opening: WxLxD	cm	13 x 17 x 16	13 x 17 x 16	13 x 10 x 15	13 x 10 x 15	13 x 10 x 15	13 x 10 x 15
Bath volume	l	5	5	3	3	3	3
Overall dimensions: WxLxH	cm	16 x 33 x 36	16 x 33 x 36	20 x 30 x 37	20 x 30 x 37	20 x 30 x 37	20 x 30 x 37
Net weight	kg	5.2	5.4	7.1	7.3	7.3	7.4
Total wattage 230V/115V	VA	1550/1050	2050/1250	1550/1050	2050/1250	2050/1250	2050/1250
Order-No. for 230V/50..60Hz for 115V/60Hz		425-1851 425-1852	426-1851 426-1852	425-1701 425-1702	426-1701 426-1702	426-3701 426-3702	426-5701 426-5702
ExtraPlus-Rating (see page 35)		+	+ +	+	+ +	+ + +	+ + + +

DC30-B5	DC50-B5	DL30-B7	DC50-B7	DL30-B12	DC50-B12
32..200 20..200 -50..200	32..200 20..200 -50..200	30..200 20..200 -50..200	30..200 20..200 -50..200	28..200 20..200 -50..200	28..200 20..200 -50..200
0.01	0.01	0.01	0.01	0.01	0.01
2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2
300/12.5	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5
14 x 15 x 15	14 x 15 x 15	13 x 10 x 20	13 x 10 x 20	22 x 14 x 20	22 x 14 x 20
4.5	4.5	7	7	12	12
21 x 36 x 38	21 x 36 x 38	23 x 36 x 44	23 x 36 x 44	32 x 38 x 44	32 x 38 x 44
8.5	8.5	9.5	9.5	13.2	13.2
2050/1250	2050/1250	2050/1550	2050/1250	2050/1550	2050/1250
426-3801 426-3802	426-5801 426-5802	427-3811 427-3812	426-5811 426-5812	427-3821 427-3822	426-5821 426-5822
+ + +	+ + + +	+ + +	+ + + +	+ + +	+ + + +

The HAAKE Phoenix II heating circulators are designed for temperature controlling external systems. The bath opening also enables the immersion of samples within the circulator bath. All units have a stainless steel bath and can be used up to 280°C. The powerful pump guarantees a good heat exchange and optimum temperature accuracy.

Innovative:
The pump automatically adapts itself to the viscosity of the bath liquid used due to the automatic speed recognition function. This guarantees constant pressure and flow rate conditions over a wide temperature range.

P1-B5/P2-B5
Compact heating circulators with a 5-liter bath, ideal for temperature controlling small open or closed systems with short heating up times and thus quick reaction times.

P1-B7/P2-B7
Slim-line heating circulators with a deep 7-liter bath for temperature controlling open and closed systems; high temperature accuracy for medium-size external systems.

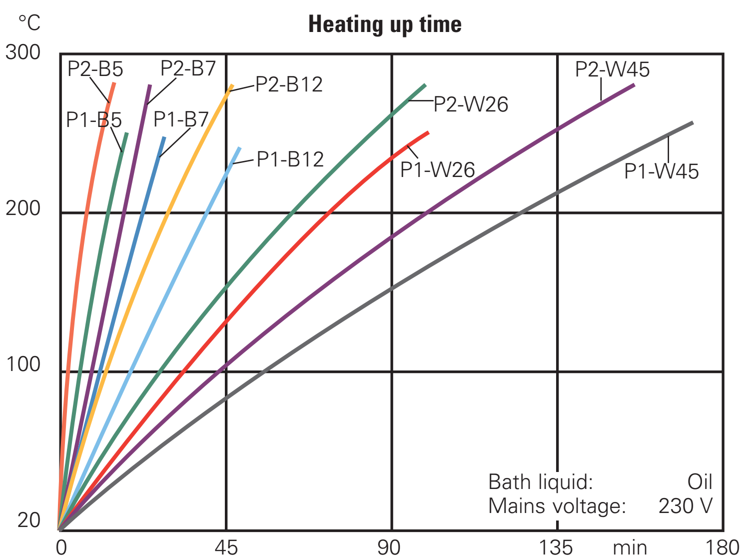
P1-B12/P2-B12
Heating circulators with a 12-liter bath suitable for external systems with high volume variations; use as open-bath circulator also possible due to the large bath opening.

Technical specification acc. to DIN 12876		**P1-B5**	**P2-B5**	**P1-B7**	**P2-B7**
Working temperature range	°C	32...250	32...280	30...250	30...280
with tap water cooling	°C	20...250	20...280	20...250	20...280
with other cooling	°C	-60...250	-60...280	-60...250	-60...280
Temperature accuracy	+/- K	0.01	0.01	0.01	0.01
Heater capacity 230V/115V	kW	2.0/1.2	3.0/1.2	2.0/1.2	3.0/1.2
Pump: Pressure max. Flow rate max. Suction max. Flow rate max.	mbar l/min mbar l/min	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22
Bath opening: WxLxD	cm	14 x 14.5 x 15	14 x 14.5 x 15	13 x 10 x 20	13 x 10 x 20
Bath volume max.	l	4.5	4.5	7	7
Overall dimensions: WxLxH	cm	24 x 38 x 44	24 x 38 x 44	25 x 38 x 50	25 x 38 x 50
Total wattage 230V/115V	VA	2100/1250	3100/1250	2100/1250	3100/1250
Net weight	kg	10.2	10.2	11.8	11.8
Order-No. for 230V/50-60Hz for 115V/60Hz		440-0051 440-0052	441-0051 441-0052	440-0071 440-0072	441-0071 441-0072
ExtraPlus-Rating (see page 35)		+ + + + +	+ + + + + +	+ + + + +	+ + + + + +

P1-W26/P2-W26
Combined open-bath and heating circulators with a 42-liter bath. Extra deep bath (300 mm) for large objects, simultaneous temperature control of external systems.

P1-W45/P2-W45
Combined open-bath and heating circulators with a 26-liter bath. Large bath opening for direct temperature control of objects, simultaneous temperature control of external systems.

Additional pump
If the capacity of the integrated circulator pump would not be high enough for temperature controlling an external system, this booster pump can provide up to 3 bar pressure.



Comes with

Each 2 **nozzles**
for tubings with 8 and 12 mm i. Ø
Bath cover for B5, B7, B12
Tap water cooling coil
for B5, B7, B12

Optional accessories	**Order-No.**
Tap water cooling coil for baths W26 and W45	**333-0677**
Universal hose nozzle for tubing of 3 to 6 mm i. Ø	**001-3718**
Reservoir drain	**333-0499**
Bath cover made from stainless steel (fits 2 x onto W45)	**333-0648**
Bath cover made from stainless steel (fits 2 x onto W26)	**333-0225**
External analog box	**333-0685**
230V Power supply for analog box	**333-0705**
Tubing and bath liquids	**(s. p. 30-31)**
Pt100 sensors	**(s. p. 33)**
Additional heater B7 bath	**333-0741**
Additional heater B12	**333-0743**
Solenoid valve control for tap water cooling	**333-0744**
Additional pump	**333-0746**
Profibus interface	on request
Optional accessories for P1/P2-W26 and P1/P2-W45 (see page 12)	

P1-B12	**P2-B12**	**P1-W26**	**P2-W26**	**P1-W45**	**P2-W45**
28...250	28...280	28...250	28...280	28...250	28...280
20...250	20...280	20...250	20...280	20...250	20...280
-60...250	-60...280	-60...250	-60...280	-60...250	-60...280
0.01	0.01	0.01	0.01	0.01	0.01
2.0/1.2	3.0/1.2	2.0/1.2	3.0/1.2	2.0/1.2	3.0/1.2
560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22
22 x 14 x 20	22 x 14 x 20	30 x 35 x 20	30 x 35 x 20	30 x 35 x 30	30 x 35 x 30
12	12	26	26	42	42
34 x 38 x 50	34 x 38 x 50	35 x 54 x 44	35 x 54 x 44	36 x 54 x 55	36 x 54 x 55
2100/1250	3100/1250	2100/1250	3100/1250	2100/1250	3100/1250
13	13	11	11	19	19
440-0121 440-0122	441-0121 441-0122	440-0261 440-0262	441-0261 441-0262	440-0451 440-0452	441-0451 441-0452
+++++	++++++	+++++	++++++	+++++	++++++

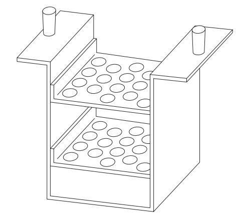
The powerful refrigerated circulators in the HAAKE C/DC class are available either in a space-saving vertical version or an ergonomic flat version. The K10 does not require more space than a sheet of DIN A4 paper at the bench. The units K10, K15 and K20 are primarily used at room temperature. The units also feature efficient heat removal even at high temperatures and enable the temperature controlling of external closed liquid circuits at temperatures well below 0°C. Unit selection depends mainly on the required cooling capacity and the desired temperature range.

Note:
The units K10, K15 and K20 can be combined with all circulator heads from C10 to DC50.

Comes with
Each 2 **nozzles** for tubings with 8 and 12 mm i. Ø and **bath cover.**
C10-K10, C10-K15 and C10-K20: plus **checking thermometer** 0 to 100°C, division 0.5°C.

Optional accessories	Order-No.
Universal hose nozzle for tubing of 3 to 6 mm i. Ø	**832-0275**
Reservoir drain	**333-0499**
Software for DC30, DC50 (see page 32)	
Trolley with castors for K35, K40, K41, K50	**333-0508**

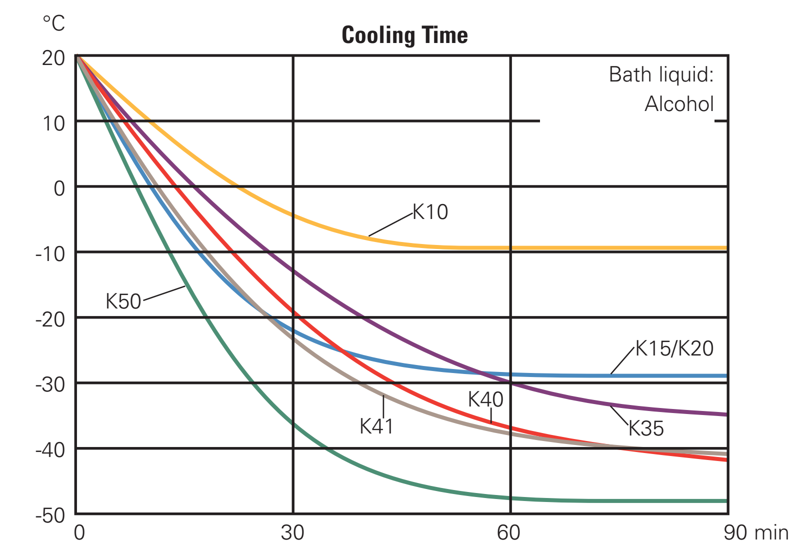
Optional accessories	Order-No.
Rack for 20 tubes, 16 mm Ø for K10	**333-0456**



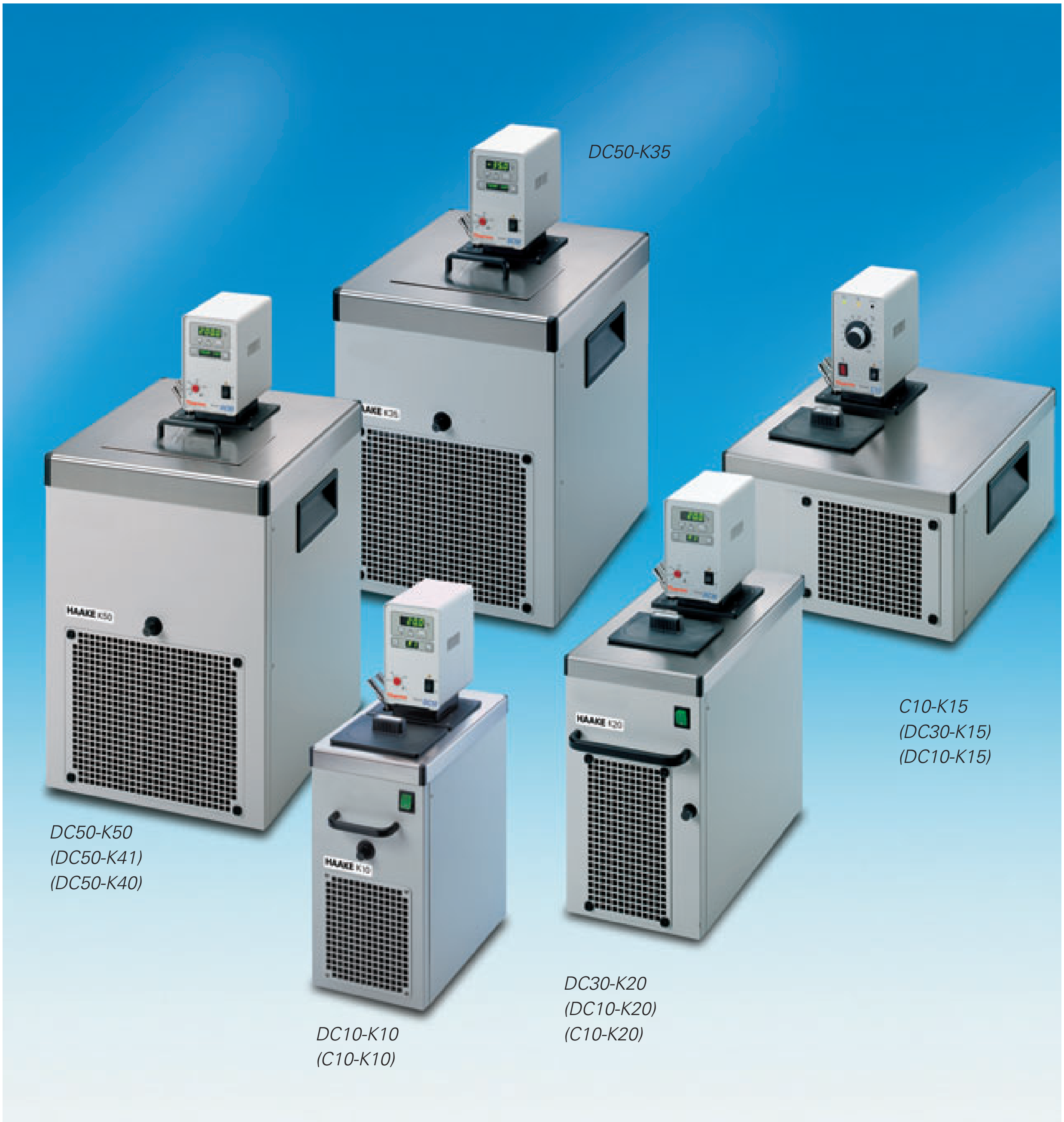
Rack for K15 and K20	
18 tubes, 16 mm Ø	**333-0500**
26 micro centrifuge tubes, 10 mm Ø	**333-0501**
6 centrifuge tubes, 30 mm Ø	**333-0502**

Choose the necessary **tubes, bath liquids** and **Pt-100 sensor** for DC50-units on pages 30/31/33.

Sealed bath cover with K10, K15 and K20



Technical specifications acc. to DIN 12876		C10-K10	DC10-K10	C10-K15	DC10-K15
Working temperature range	°C	-10..100	-10..100	-28..100	-28..100
Temperature accuracy	+/- K	0.04	0.02	0.04	0.02
Heater capacity 230V/115V	kW	1.5/1.0	2.0/1.2	1.5/1.0	2.0/1.2
Cooling capacity at 20°C at 0°C at -20°C	W W W	240 70 –	240 70 –	300 200 70	300 200 70
Pump: Pressure/Flow rate max.	mbar/l/min	300/12.5	300/12.5	300/12.5	300/12.5
Bath opening: WxLxD	cm	13 x 10 x 15	13 x 10 x 15	13 x 10 x 15	13 x 10 x 15
Bath volume max.	l	3	3	4.5	4.5
Overall dimensions: WxLxH	cm	19.5 x 36 x 57	19.5 x 36 x 57	39 x 46 x 41	39 x 46 x 41
Net weight	kg	22.7	22.7	30.8	30.8
Total wattage 230V/115V	VA	1800/1300	2300/1500	1900/1400	2400/1600
Order-No. for 230V/50Hz for 220V/60Hz for 115V/60Hz		425-1641 425-1641 425-1642	426-1641 426-1641 426-1642	425-1501 425-1501 425-1502	426-1501 426-1501 426-1502
ExtraPlus-Rating (see page 35)		+	+ +	+	+ +



DC30-K15	C10-K20	DC10-K20	DC30-K20	DC50-K35	DC50-K40	DC50-K41	DC50-K50
-28..150	-28..100	-28..100	-28..150	-35..200	-40..150	-40..150	-47..200
0.01	0.04	0.02	0.01	0.01	0.01	0.01	0.01
2.0/1.2	1.5/1.0	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2	2.0/1.2
300 200 70	320 205 75	320 205 75	320 205 75	400 300 150	700 550 300	1000 750 400	850 700 500
300/12.5	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5	300/12.5
13 x 10 x 15	13 x 10 x 15	13 x 10 x 15	13 x 10 x 15	22 x 14 x 15	29 x 15 x 15	29 x 15 x 20	22 x 14 x 15
4.5	4.5	4.5	4.5	8	12	15	8
39 x 46 x 41	23 x 46 x 58	23 x 46 x 58	23 x 46 x 58	38 x 46 x 68	38 x 46 x 74	38 x 46 x 74	38 x 46 x 74
31.1	29.8	29.8	30.1	37	43	50	46
2400/1600	1900/1400	2400/1600	2400/1600	2500/1700	2550/ –	2600/ –	2650/ –
426-3501 426-3501 426-3502	425-1601 425-1601 425-1602	426-1601 426-1601 426-1602	426-3601 426-3601 426-3602	426-5351 426-5351 426-5352	426-5401 426-5409 –	426-5411 426-5419 –	426-5491 426-5499 –
+ + +	+	+ +	+ + +	+ + + +	+ + + +	+ + + +	+ + + +

The HAAKE Phoenix II refrigerated circulators feature FuzzyStar control with neural adaptation, the tried-and-tested energy management system. External connection options greatly extend the application range.

All units are characterized by their simple operation and represent the optimum combination of design and functionality.

The refrigerated circulators are especially suited for the temperature control of open and closed temperature control circuits due to their powerful pressure and suction pump.

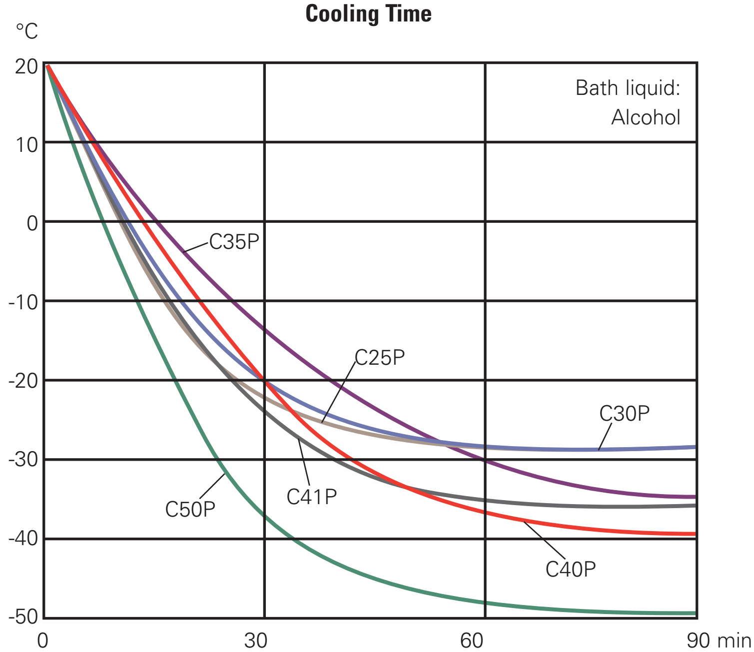
Innovative:
The pump automatically adapts itself to the viscosity of the bath liquid due to the automatic speed recognition function.

This guarantees constant pressure and flow rate conditions over a wide temperature range.

Comes with	
nozzles for tubings with 8 and 12 mm i. Ø	
Bath cover	

Optional accessories	Order-No.
Universal hose nozzle for tubing of 3 to 6 mm i. Ø	**001-3718**
Reservoir drain	**333-0499**
Trolley with castor for C30P, C35P, C40P, C41P, C50P	**333-0678**
External analog box	**333-0685**
230V Power supply for analog box	**333-0705**
Tubes and bath liquids	**(s. p. 30-31)**
Pt100 sensor	**(s. p. 33)**
Additional heater for C25P	**333-0741**
Additional heater for C30P, C35P, C50P	**333-0745**
Additional heater for C40P, C41P	**333-0742**
Additional pump	**333-0746**

Cooling Time



Optional accessory: Additional heater ZH1 to accelerate heating-up

Technical specifications acc. to DIN 12876		P1-C25P	P2-C25P	P1-C30P	P2-C30P
Working temperature range	°C	-28...150	-28...150	-30...200	-30...200
Temperature accuracy	+/- K	0.01	0.01	0.01	0.01
Heater capacity 230V/115V	kW	2.0/1.2	2.0/1.2	2.0/–	2.0/–
Cooling capacity at 20°C at 0°C at -20°C	W W W	300 200 70	300 200 70	800 620 450	800 620 450
Pumpe: Pressure max. Flow rate max. Suction max. Flow rate max.	mbar l/min mbar l/min	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22
Bath opening: WxLxD	cm	13 x 10 x 15	13 x 10 x 15	22 x 14 x 20	22 x 14 x 20
Bath volume max.	l	4.5	4.5	12	12
Overall dimensions: WxLxH	cm	26 x 48 x 63	26 x 48 x 63	40 x 51 x 77	40 x 51 x 77
Total wattage 230V/115V	VA	2450/1650	2450/1650	2600/–	2600/–
Net weight	kg	26.3	26.3	46	46
Order-No. for 230V/50Hz for 220V/60Hz for 115V/60Hz		440-0251 440-0251 440-0252	441-0251 441-0251 441-0252	440-0301 440-0309 –	441-0301 441-0309 –
ExtraPlus-Rating (see page 35)		+ + + + +	+ + + + + +	+ + + + +	+ + + + + +

P1-C25P/P2-C25P
Compact refrigerated circulators down to -28°C with a small 4.5 liter bath for rapid cooling. 300 watt cooling capacity at 20°C.

P1-C30P/P2-C30P
Refrigerated circulators for high loads down to -30°C, reliable cooling even at high ambient temperatures. 800 watt cooling capacity at 20°C.

P1-C35P/P2-C35P
Refrigerated circulators with a wide temperature range from -35°C to +200°C. 400 watt cooling capacity at 20°C.

P1-C40P/P2-C40P
Refrigerated circulators with a large bath opening, down to -40°C ideal for the simultaneous temperature control internally and externally. 700 watt cooling capacity at 20°C.

P1-C41P/P2-C41P
High power refrigerated circulators down to -40°C. High cooling capacity for applications under 0°C. 1000 watt cooling capacity at 20°C.

P1-C50P/P2-C50P
Refrigerated circulators for extreme low temperatures down to -47°C. Inexpensive cooling alternative to a cryostat. 850 watt cooling capacity at 20°C.

	P1-C35P	P2-C35P	P1-C40P	P2-C40P	P1-C41P	P2-C41P	P1-C50P	P2-C50P
	-35...200	-35...200	-40...150	-40...150	-40...150	-40...150	-47...150	-47...150
	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	2.0/1.2	2.0/1.2	2.0/–	2.0/–	2.0/-	2.0/-	2.0/-	2.0/-
	400 300 150	400 300 150	700 550 300	700 550 300	1000 750 400	1000 750 400	850 700 500	850 700 500
	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22	560 24 380 22
	22 x 14 x 15	22 x 14 x 15	29 x 15 x 15	29 x 15 x 15	29 x 15 x 20	29 x 15 x 20	22 x 14 x 15	22 x 14 x 15
	8	8	12	12	15	15	8	8
	40 x 51 x 71	40 x 51 x 71	40 x 51 x 71	40 x 51 x 71	40 x 51 x 77	40 x 51 x 77	40 x 51 x 77	40 x 51 x 77
	2500/1700	2500/1700	2550/–	2550/–	2600/–	2600/–	2650/–	2650/–
	40	40	41	41	45	45	46	46
	440-0351 440-0359 440-0352	441-0351 441-0359 441-0352	440-0401 440-0409 –	441-0401 441-0409 –	440-0411 440-0419 –	441-0411 441-0419 –	440-0501 440-0509 –	441-0501 441-0509 –
	+++++	++++++	+++++	++++++	+++++	++++++	+++++	++++++

Cryostats application and selection

Very low temperatures are best reached with both P2-CT90L and -W, the P1/P2-C75P and the DC50-K75 cryostats. The P2-CT50L and -W both deliver a high cooling capacity.

The cryostats are cooled by powerful, quiet compressors. The cooling circuits are either air-cooled (K75, C75P, CT50L, CT90L) or watercooled (CT50W, CT90W).

The powerful, water-cooled units are equipped with a water flow limiter. The water consumption is kept low, thus considerably reducing operating costs.

The cooling capacity for all HAAKE Phoenix II cryostats is controlled by a fuzzy logic-supported energy management system.

The floor-based units are fitted with stable, adjustable castors.

The cryostats HAAKE DC50-K75 and P1/P2-C75P are suitable for location either under or on the lab table.

HAAKE Phoenix II cryostats

The most user-friendly cryostat baths available to handle a wide range of applications.

The Phoenix II cryostats come equipped with a powerful pressure and suction pump, feature a cooling capacity of up to 5000 W, and are thus ideally suited to meet the extreme technical specifications that many applications require. Phoenix II circulators are available in two versions:

- Basic version Phoenix II P1 with a 1 kW heating capacity
- Full version Phoenix II P2 with 1 to 3 kW heating capacity and with additional functional features

HAAKE Phoenix II P1-C75P / P2-C75P

- Compact cryostat down to -75°C
- Unit can be placed on the lab table
- 280 W cooling capacity at 20°C

HAAKE Phoenix II P2-CT50L

- Cryostat with high capacity down to -50°C
- Air-cooled floor-based unit
- Ideal for direct temperature control in the bath
- 2500 W cooling capacity at 20°C
- Large bath volume (24 l)

HAAKE Phoenix II P2-CT50W

- Cryostat with big power down to -50°C
- Water-cooled floor-based unit
- 5000 W cooling capacity at 20°C
- Large bath volume (24 l)

HAAKE Phoenix II P2-CT90L

- Cryostat with high capacity down to -90°C
- Air-cooled floor-based unit
- Ideal for direct temperature control in the bath
- 1650 W cooling capacity at 20°C

HAAKE Phoenix II P2-CT90W

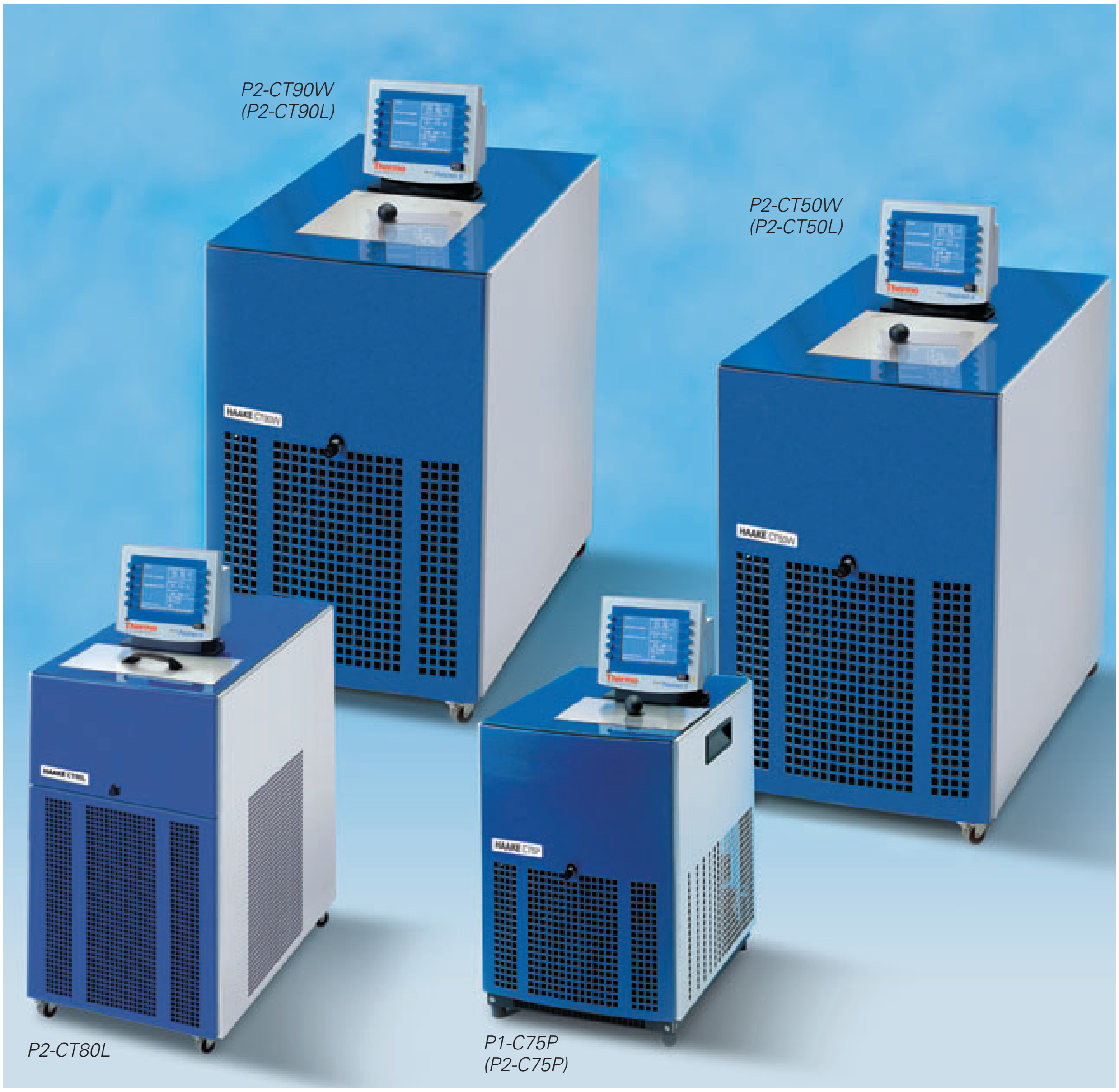
- Cryostat with big power down to -90°C
- Water-cooled floor-based unit
- 1900 W cooling capacity at 20°C
- 200 W cooling capacity at -80°C

HAAKE Phoenix II P2-CT80L

- Compact cryostat down to -80°C
- Excellent price-performance ratio
- 800 W cooling capacity at 20°C

Technical specification acc. to DIN 12876		DC50-K75	P1-C75P	P2-C75P	P2-CT80L	P2-CT50L
Working temperature range	°C	-75..100	-75..100	-75..100	-80..100	-50..100
Temperature accuracy	+/- K	0.05	0.02	0.02	0.1	0.1
Heater capacity	kW	1.5	1.0	1.0	1.0	2.0
Cooling capacity at 20°C/0°C at -20°C/-40°C at -60°C/-80°C	W W W	280/220 180/130 50/–	280/220 180/130 50/–	280/220 180/130 50/–	800/750 700/600 500/50	2500/1750 1100/300 –
Pump: Pressure/Flow rate max. Suction/Flow rate max.	mbar/l/min mbar/l/min	300/12.5 –/–	560/24 380/22	560/24 380/22	560/24 380/22	560/24 380/22
Bath opening: WxLxD	cm	13 x 10 x 20	13 x 10 x 20	13 x 10 x 20	22 x 14 x 20	22 x 27 x 20
Bath volume	l	6	6	6	12	24
Overall dimensions: WxLxH	cm	38 x 46 x 72	40 x 51 x 77	40 x 51 x 77	42 x 66 x 102	50 x 75 x 109
Net weight	kg	65	68	68	107	125
Total wattage	VA	2450	2500	2500	2500	3300
Order-No. for 230V/50Hz for 220V/60Hz for 380V/3 Ph/50Hz for 220V/3 Ph/60Hz		426-5751 – – –	440-0751 440-0759 – –	441-0751 441-0759 – –	441-0801 441-0809 – –	– – 446-0503 446-0504
ExtraPlus-Rating (see page 35)		+ + + +	+ + + + +	+ + + + + +	+ + + + + +	+ + + + + +

(see page 35)



P2-CT50W	P2-CT90L	P2-CT90W
-50..100	-90..100	-90..100
0.1	0.1	0.1
3.0	2.0	2.0
5000/3000 1900/800 –	1650/1500 1300/1150 600/170	1900/1700 1500/1300 700/200
560/24 380/22	560/24 380/22	560/24 380/22
22 x 27 x 20	22 x 15 x 20	22 x 15 x 20
24	15	15
50 x 75 x 109	50 x 90 x 109	50 x 90 x 109
180	190	185
5800	5300	5300
– – 447-0503 447-0504	– – 448-0903 448-0904	– – 449-0903 449-0904
++++++	++++++	++++++

HAAKE DC50 cryostats are used for a wide range of standard applications.

A powerful pump enables the temperature control of small, closed external systems.

The unit can be set by a push-button keypad. The read-out is shown via two separate display panels.

HAAKE DC50-K75

- Compact cryostat down to -75°C with a temperature accuracy of ± 0.05 K
- Unit can be placed on the lab table
- 280 W cooling capacity at 20°C
- 130 W cooling capacity at -40°C

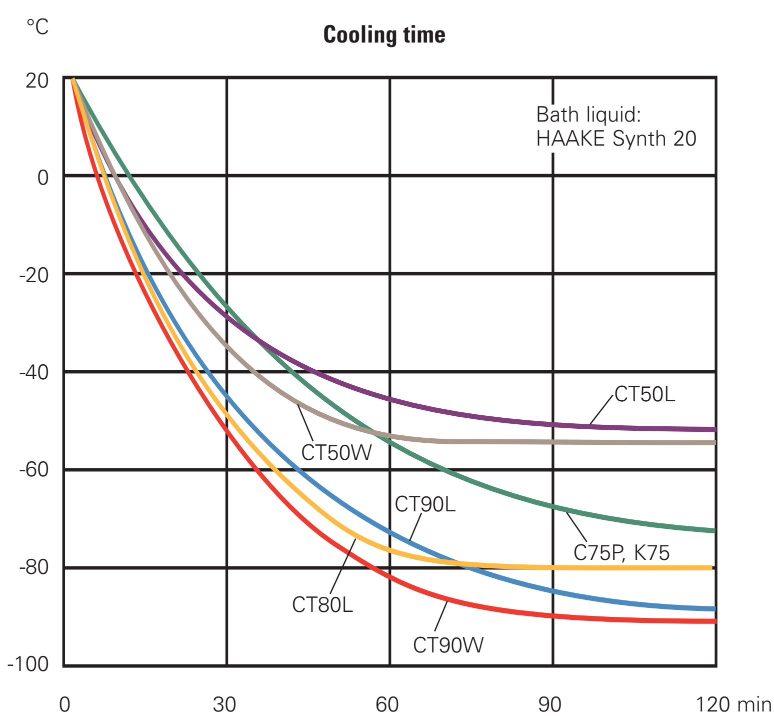
HAAKE DC50 Highlights

- Powerful pumps with Turbulence Reduction System (TRS)
- Simple operation due to separate display panels for menu selection and temperature
- Microprocessor control with PID control
- Resolution of the digital display for the set and actual temperature optionally 0.1 or 0.01°C
- Real Temperature Adjustment (RTA)
- Ability to save 3 user-defined fixed temperatures with their respective RTA values
- The reason for a unit fault is shown on the display via the Fault Identification System (FIS)
- RS232C interface, optional RS485
- External Temperature Compensation (ETC) for controlling external systems with connection for an external Pt100 sensor

HAAKE Phoenix II Highlights

- FuzzyStar control with neuronal adaptation
- Easy operation of the units due to a large monitor with plain text display and direct value setting
- Very powerful combined pressure and suction pump with automatic speed recognition for the precise temperature control of external objects
- 4 savable fixed temperatures
- Flexible interface concept: RS232C (standard), multifunctional output (standard), RS485 (for P2), Profibus (optional for P2)
- External Temperature Control (ETC) with connection for an external Pt100 sensor as standard
- User can choose from 6 different dialog languages
- Permanent display of date and time
- Up to 10 ramp programs with a maximum of 30 segments (for P2)
- 3-point calibration function (for P2)

Cooling time

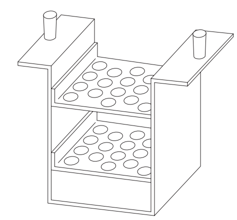


Comes with

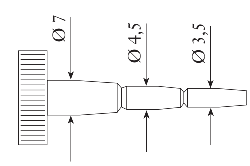
Each 2 **nozzles** for tubings with 8 and 12 mm i. Ø

Reservoir drain for CT50L, CT50W, CT80L, CT90L and CT90W

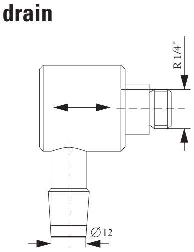
Optional accessories	Order-No.
Rack for DC50-K75, P1-C75P and P2-C75P for:	



18 tubes, 16 mm Ø	**333-0500**
26 micro centrifuge tubes, 10 mm Ø	**333-0501**
6 centrifuge tubes, 30 mm Ø	**333-0502**
Universal hose nozzle	



for for tubing of 3 to 6 mm Ø for Phoenix II-Cryostats	**001-3718**
Universal hose nozzle for tubing of 3 to 6 mm i. Ø for DC50-K75	**832-0275**
Reservoir drain	



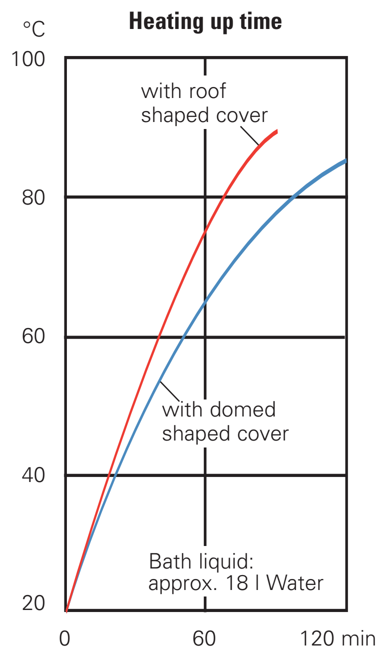
for DC50-K75, P1-C75P and P2-C75P	**333-0499**
Trolley with castors for DC50-K75	**333-0508**
Trolley with castors for P1-C75P and P2-C75P	**333-0678**

Choose the necessary tubes, bath liquids and Pt100 sensors on pages 30, 31 and 33.

The SWB25 features a high safety level for constant operation in addition to very accurate temperature control (PID control). Shaking frequency and temperature are adjusted via a keypad and digital display. The heater and control sensor are located underneath the bath, thus guaranteeing easy cleaning.

The fluid level can vary from 50 mm to 180 mm to accommodate sample vessels of differing heights.
A second shaking carriage (optional) can be inter-changed quickly and easily.

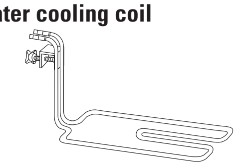
The transparent plastic gable-shaped bath cover (optional) prevents water spillage caused by turbulence. It is recommended for temperatures above 70°C.



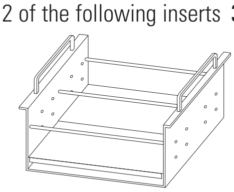
SWB25 with swivelling gabled cover

Comes with	
One **Shaking carriage plate** without clamps	

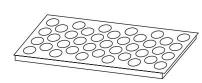
Optional accessories	Order-No.
Tap water cooling coil	**000-8581**



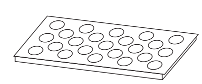
Swivelling roof-shaped **cover** (transp.)	**333-0642**
Basic rack for each 2 of the following inserts	**333-0259**



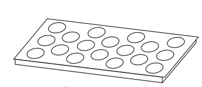
Inserts for tubes into basic rack



for 86 of 10 mm Ø	**333-0130**



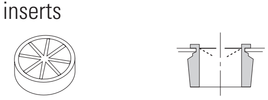
for 46 of 16 mm Ø	**333-0131**



for 23 of 25 mm Ø	**333-0132**

without holes	**333-0151**

Plastic clip for diameter reduction in the inserts



16 to 3..10 mm, 50 St.	**333-0134**
25 to 6..17 mm, 25 St.	**333-0135**

Clamps to fix beakers or flasks onto the shaking carriage plate or the basic rack

flask-cont. (ml)	glas Ø (mm)	no. per carriage plate	
25	42	40	**000-8732**
50	51	32	**000-1980**
100	64	18	**000-1982**
250	85	12	**000-1990**
500	105	8	**000-1994**
1000	131	5	**000-1995**
Spare shaking carriage plate			**000-8384**

SWB25 with test tube rack

Technical specification acc. to DIN 12876		SWB25
Working temperature range with tap water cooling	°C °C	22..90 20..90
Temperature accuracy	+/- K	0.2
Heater capacity 230V/115V	kW	1.5/1.5
Type of control		PID
Overtemperature protection		adjustable
Bath opening: WxLxD	cm	50 x 30 x 20
Bath volume	l	8..26
Shaking amplitude	mm	15
Shaking frequency (cont. adj.)	min^{-1}	20..200
Overall dimensions: WxLxH	cm	65 x 34 x 26
Net weight	kg	18
Total wattage 230V/115V	VA	1600/1600
Order-No. for 230V/50..60Hz for 115V/60Hz		375-0001 375-0002

These coolers are ideal for the following applications:

- to cool smaller volumes down to -90°C,
- to remove reaction heat or
- to replace tap water cooling

The lowest reachable temperature depends upon:

- the quantity of liquid
- the type of liquid and its viscosity
- the bath insulation

Immersion Coolers HAAKE EK20/EK30
Used together with the open-bath circulators, these coolers provide an alternative to tap water cooling. The lowest attainable temperature and the cooling down times are illustrated in the diagrams.

The EK20 is designed for baths with a 15 cm depth and the EK30 for baths with a depth of at least 20 cm.

Vessels can of othersizes also be cooled. End temperatures of -25°C resp. -30°C can be reached in a 5 l Dewar vessel.

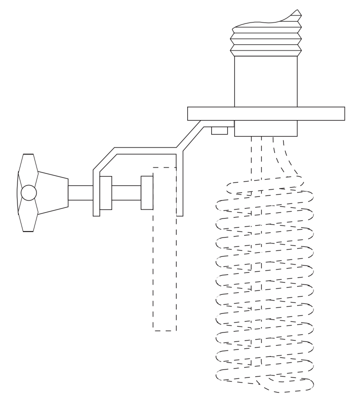
Immersion Cooler HAAKE EK45
This multi-purpose cooler has its own controller with digital temperature display, reaching temperatures down to -45°C in a 5 l Dewar vessel. The controller enables temperature accuracy of approx. 1°C to 2°C. Improvement is possible using a stirrer.

Immersion Cooler HAAKE EK90
This unit is designed for working temperatures down to -90°C. The cooling coil is flexible and can therefore be adapted to suit virtually any bath shape. The minimum diameter of the vessel to be cooled is 110 mm.

Comes with

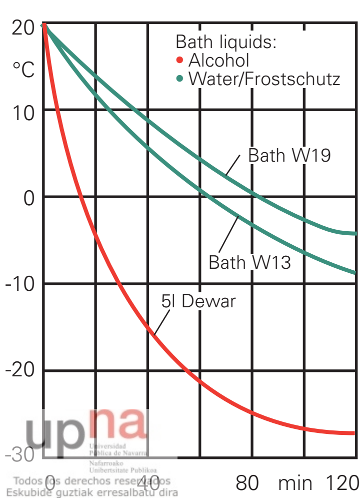
EK45 and EK90:
Electronic controller
and Pt100 sensor (Ø 6 mm, 50 mm long, cabel 2.5 m long).

Optional accessories	Order-No.
Trolley with castors for EK90	**333-0508**
Holder to fix a cooler EK20, EK30 or EK45 onto a wall with a thickness up to 25 mm	**333-0602**

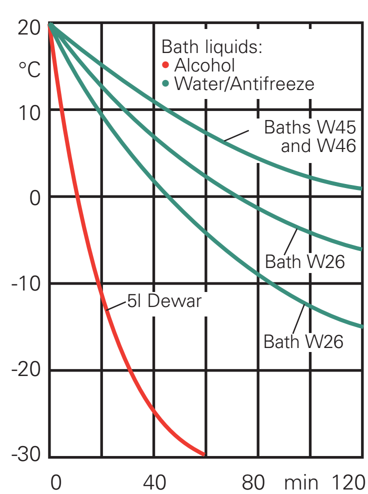


Technical specification acc. to DIN 12876		EK20	EK30	EK45	EK90
Working temperature range	°C	-25..150	-30..150	-45..40	-90..40
Cooling capacity at 20°C	W	300	400	350	300
at -10°C	W	150	250	250	280
at -40°C	W	–	–	50	170
at -60°C	W	–	–	–	100
Hose length	cm	150	150	150	150
Cooling coil dimensions (Ø x L)	mm	81 x 145	81 x 195	81 x 195	13 x 900
Smallest bending radius	mm	–	–	–	40
Overall dimensions: WxLxH	cm	23 x 46 x 38	23 x 46 x 38	23 x 46 x 38	38 x 46 x 49
Net weight	kg	22	23	30	60
Total wattage	VA	160	270	300	750
Order-No. for 230V/50..60Hz		322-1201	323-1301	328-1451	329-1901
for 115V/60Hz		322-1202	323-1302	328-1452	–

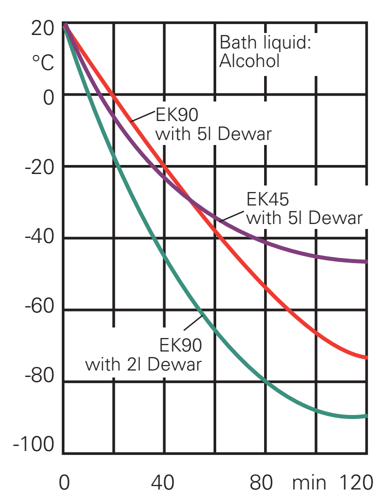
Cooling time with the EK20



Cooling time with the EK30



Cooling time with the EK45 and EK90



Tap water is still used far too often when measuring instruments, distillation equipment or rotary evaporators need to be cooled. This method is not only environmentally damaging, but it is also technically unsound. The presence of minerals and bacteria create problems with scaling and contamination.

Water recirculators are both an economical and ecologically sensible alternative to wasting tap water for cooling purposes.

Haake TC water recirculators are available in 5 different cooling capacity models up to 5 kW.

A variable pump and accessories program fits the units to your application. Ask for our special water recirculator brochure.

HAAKE TC water recirculators are flexible:
You can combine the available pumps and cooling compressors to suit your requirements. They are also available in two versions.

HAAKE TC water recirculators are economical:
They do more than save tap water. Short pay-back periods are guaranteed by their excellent cost/benefit ratio.

HAAKE TC water recirculators are safe and reliable:
The units are designed and manufactured according to EN 61010. A variety of safety elements guarantee reliable operation.

This low cost mini-cooler is specially designed to remove up to 240 watts of heat from connected analysis instruments, apparatus or any thermic processes.

The water recirculator HAAKE WKL 26 is a small-scale unit which can be situated practically anywhere. A high level of noise reduction is attained due to the quiet-running compressor.

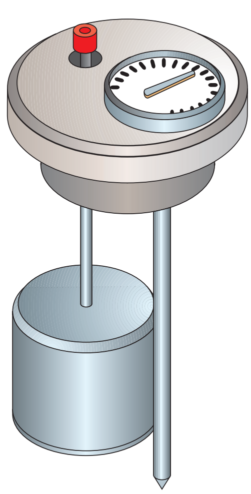
HAAKE WKL 26 Highlights

- The working temperature can be variably adjusted.
- The control accuracy is approx. ± 1.1K.
- The powerful pump is designed for hoses with an inner diameter of 8 to 12 mm.
- A long unit service life as the switching on and off of the compressor is avoided.
- Small and compact, the unit base takes up roughly the surface area of a DIN A4 sheet of paper.
- The ventilation grid can be removed for easy cleaning of the liquifier fins.
- All parts which come into contact with the bath liquid are made from stainless steel.
- The compressor circuit and circulation pump do not require maintenance.
- A drainage opening for easy water changing.
- A combined temperature and water level indicator is available as an optional accessory.
- The unit is CFC-free and has the CE-mark.

Comes with

Each 2 nozzles for tubes with 8 and 12 mm Inside-Ø

Optional accessories	Order-No.
Combined temperature and liquid level indicator	333-0567



Technical Specifications		WKL 26
Working temperature range	°C	-10 to 30
Temperature accuracy	± K	1.0
Cooling capacity at 20°C Refrigerant (CFC-free)	W	240 R 134a
Pump capacity Pressure max. Flow rate max.	 mbar l/min	 300 12
Bath volume Filling opening	l mm	3 45 Ø
Dimensions Base area Height	 mm mm	 200 x 340 490
Weight	kg	22
Total wattage max.	VA	450
Max. ambient Temperature	°C	5 to 40
Order-No. for 230 V/50 Hz for 115 V/60 Hz		 386-0001 386-0002

Hoses
All circulators and cryostats are always delivered with nozzles for tubings with an inner Ø of 8 and 12 mm. The tubings and insulation (if applicable) have to be ordered separately and should be selected according to the application.

Description	Order-No.
Insulated metal tubing made from stainless steel with M 16 x 1 unions on both ends. To be used from -50 to +300°C.	
50 cm long	**333-0292**
100 cm long	**333-0293**
150 cm long	**333-0294**
coupling to connect 2 tubings to each other	**001-2560**
coupling for circulation set C-/DC-line	**333-0302**
Insulated metal tubing made from stainless steel with M 16 x 1 unions on both ends. Especially for the low temperature range -90..105°C	
100 cm long	**333-0578**
150 cm long	**333-0579**
coupling to connect 2 tubings to each other	**001-2560**
coupling for circulation set C-/DC-line	**333-0302**
PVC tubing to be used only with water	
8 mm i. Ø; per meter	**082-0745**
12 mm i. Ø; per meter	**082-0304**
Viton tubing for a temperature range of -60 to + 200°C	
8 mm i. Ø; per meter	**082-1214**
12 mm i. Ø; per meter	**082-1215**
Silicone tubing for a temperature range of -30 to + 220°C (not to be used with any silicone oil)	
8 mm i. Ø; per meter	**082-0663**
12 mm i. Ø; per meter	**082-0664**
Perbunan tubing for a temperature range of -40 to + 100°C	
8 mm i. Ø; per meter	**082-0172**
12 mm i. Ø; per meter	**082-0173**
Foam rubber insulation for PVC, Viton, silicone and Perbunan tubings	
for tubings with 8 mm i. Ø; per meter	**806-0373**
for tubings with 12 mm i. Ø; per meter	**806-0374**

Bath Liquids
The carefully selected and proven heat transfer liquids offer the following advantages:

- Eliminates health hazards and minimizes unpleasant odors.
- High resistance against aging while retaining a low viscosity with a low corrosive tendency.

Note: Good ventilation is recommended when working at temperatures > 200°C.

1. Viscosity

For optimum temperature accuracy it is very important that the heat transfer liquid be of low viscosity.

2. Fire Point

Flammable thermal liquids can ignite when a specified temperature is surpassed. The usage of bath liquids is limited to a temperature level 25°C below the fire point as defined by the EN 61010.

3. Selection

Silicone oils (Sil):
Carry a low risk of inflammation, do not give off unpleasant odors and have a long service life.

Synthetic thermal liquids (Synth):
Are mainly produced on a hydrocarbon basis and exhibit a low viscosity within the recommended working temperature range.

4. Application Range

Working temperature range:
This is the range within which the circulator can be operated optimally over a longer period of time.
The maximum viscosity is approx. 5 mPas.

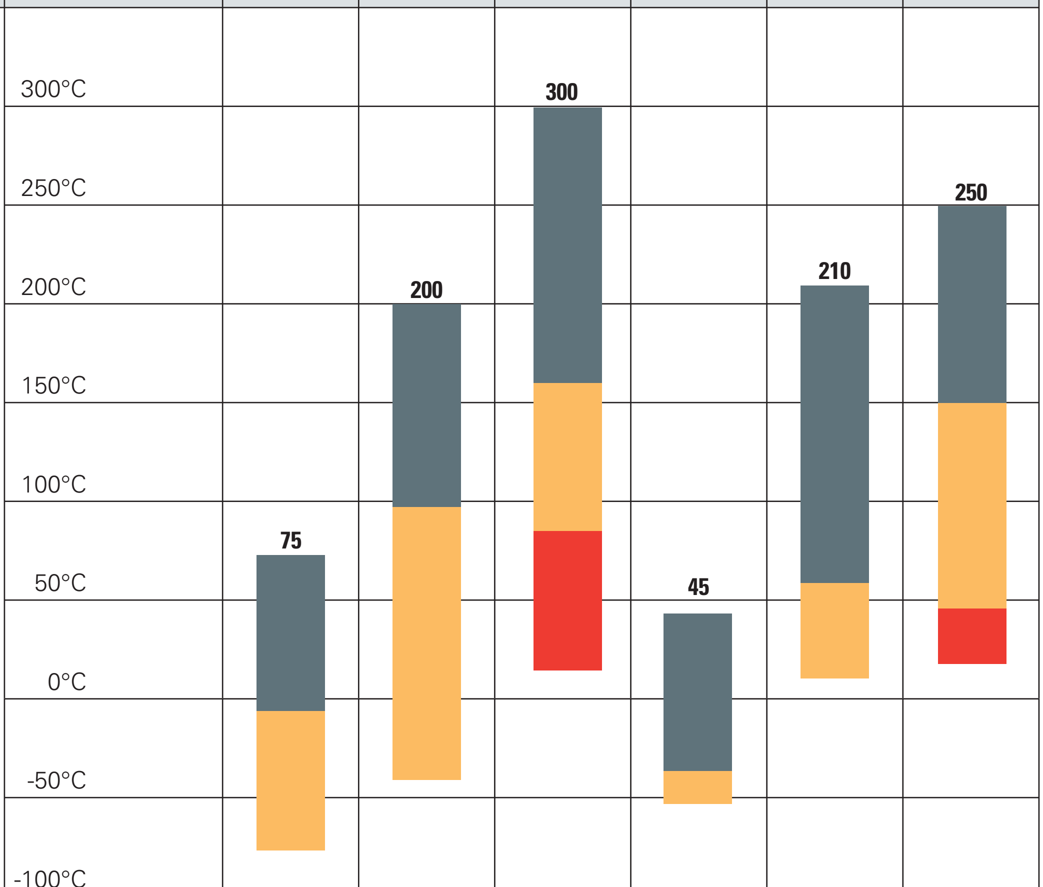
Operating temperature range:
The circulator may be operated only within this range over a longer period of time under certain conditions. Viscosity may rise to a maximum of 30 mPas. The pump capacity no longer matches the specifications made in the brochure.

Heating range:
Long-term temperature control in this range is not permissible as the pump motor's excess temperature protection may switch off the pump.

Application range		Sil 100	Sil 180	Sil 300	Synth 60	Synth 200	Synth 260
Fire point	°C	>100	> 225	>325	70	>235	275
Viscosity	at 20°C [mPas]	3	11	200	2	100	140
Density	at 20°C [kg/dm^3]	0.89	0.93	1.08	0.76	0.86	1.03
Spec. heat capacity	[kJ/kg x K]	1.67	1.51	1.56	2.1	1.96	2

Temperature ranges

- Heating-up range
- operating temperature range
- working temperature range



		Sil 100	Sil 180	Sil 300	Synth 60	Synth 200	Synth 260
Color		transparent colorless	ttransparent colorless	transparent colorless	transparent colorless	transparent light brown	transparent colorless
Reacts with		Silicone	Silicone	Silicone	Rubber Silicone	Copper Light-metal Bronze	Copper Light-metal Bronze
Order-No. for 10 l Container		**999-0202**	**999-0204**	**999-0206**	**999-0210**	**999-0226**	**999-0214**
Order-No. for 5 l Container		**999-0201**	**999-0203**	**999-0205**	**999-0209**	**999-0225**	**999-0213**

EC-Safety Data Sheets will be delivered together with each container of liquid.

n.a. not applicable

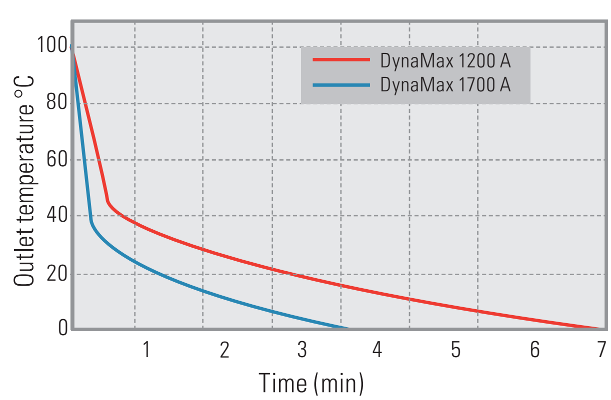
HAAKE DynaMax Sealed Systems

HAAKE DynaMax sealed temperature control systems dissipate heat from chemical reactions much faster than other products in their class. The systems incorporate new Dynamic Heat Load Suppression (DHLS) technology that offers incredibly fast reactions to temperature changes while maintaining precise temperature stability. If your application limits are exceeded during exothermic reactions, the system rapidly inject fluids from the cold storage tank to bring the system back within safety limits.

HAAKE DynaMax units are easy to use and feature intuitive menu programming in any one of seven languages. The systems are self-degassing and completely self-draining for greater ease of operation. The units' sealed system design prevents hot fluids from contact with the atmosphere, preventing fumes, and it also eliminates icing at low temperatures.

Specifications	HAAKE DynaMax 1200	HAAKE DynaMax 1700
System Performance		
Temperature Range	-40 to 150°C	-45 to 150°C
Cooling Capacity at 20 K (50Hz / 60Hz)	1.2 kW	1.7 kW
Cooling Capacity at 0 K (50Hz / 60Hz)	900 W	1.25 kW
Cooling Capacity at -20 K (50Hz / 60Hz)	250 W	550 W
Cooling Capacity at -40 K (50Hz / 60Hz)	–	150 W
Heating Capacity (230V - 50Hz / 208V - 60 Hz)	2 kW / 1.6 kW	2 kW / 1.6 kW
Temperature stability	+/- 0.01 K	+/- 0.01 K
Pump Performance (with silicon oil)		
Maximum Pump Pressure (bar)	1,2	1,2
Maximum Flow Rate	20 l/min	20 l/min
Pump Performance (with water)		
Maximum Pump Pressure (bar)	1,5	1,5
Maximum Flow Rate	25 l/min	25 l/min
Electrical Performance		
Power Requirements	230V/50Hz - 1 phase,	230V/50Hz - 1 phase
	208V/60Hz - 1 phase	208V/60Hz - 1 phase
Communication	RS232, RS485	RS232, RS485
General Information		
Footprint (HxWxD cm)	70 x 49 x 70	70 x 49 x 70
Fluid Connections	M30x1.5	M30x1.5
Compliance	CE, NRTL certified	CE, NRTL certified
	(CE, UL & CSA)	(CE, UL & CSA)
System Weight	95 kg	100 kg
Order numbers		
230V/50Hz	460-0111	461-0111
208V/60Hz	460-0119	461-0119

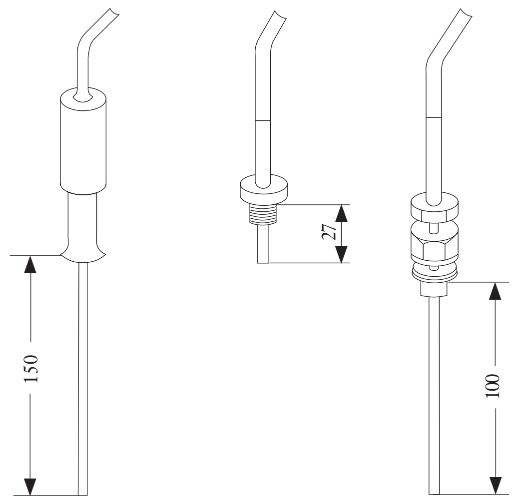
DHLS effect (Outlet to Inlet, Sil 180 oil)



Pt100 Sensor

The following sensors are available for external temperature control applications (ETC-System) with circulators and cryostats.

Description	Order-No.
Sensor TT for Phoenix II-units Pt100 sensor in closed protection tube made from stainless steel 18/8, 150 mm long, Ø 3 mm, cable length 3 m, up to 600°C	**333-0429**
Sensor DTT for DC50-units Pt100 sensor in closed protection tube made from stainless steel 18/8, 150 mm long, Ø 3 mm, cable length 3 m, up to 600°C	**333-0613**
Sensor ST for Phoenix II-units as Sensor TT, 27 mm long, Ø 3 mm, with thread M 10 x 1, cable length 3 m, up to 600°C	**333-0428**
Sensor DST for DC50-units as Sensor DTT, 27 mm long, Ø 3 mm, with thread M 10 x 1, cable length 3 m, up to 600°C	**333-0612**
Sensor HT for Phoenix II-units as Sensor TT, only to be used with the T-piece 001-1766, cable length 3 m, up to 600°C	**333-0423**
T-Piece for the sensor HT to be mounted into HAAKE metal tubing connections	**001-1766**

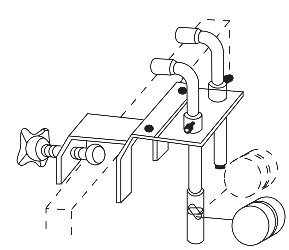


Level Control
All circulators and cryostats equipped with a combined pressure and suction pump can be used for the temperature control of external open baths. Tubing mounts with integrated level control are fitted for this purpose to make sure that the external bath will not overflow.

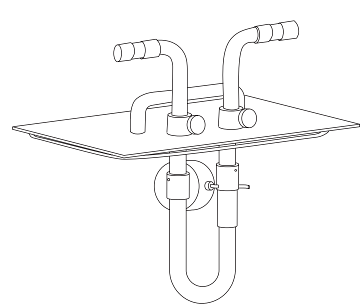
Replenishing Device
This device enables the user to transfer evaporated water into a bath circulator automatically. The water loss will be compensated in small amounts to avoid temperature shocks and drifts.

The device comprises a controller and a float switch. The float switch has to be mounted into the bath cover of the circulator.

Description	Order-No.
Automatic replenishing device AN2 for 230 V/50..60 Hz/60 VA	**333-0752**
Holder for AN2 in bath bridge H62 and H73	**333-0762**
Holder for AN2 in bath cover B3, B7, K10, K15, K20, C25P	**333-0764**
Holder for AN2 in bath cover B5	**333-0765**
Holder for AN2 in bath cover B12, K35, K50, C30P, C35P, C50P	**333-0757**
Holder for AN2 in bath cover K40, K41, C40P, C41P	**333-0759**

Description	Order-No.
Tubing mount for the level control in the external bath with screw clamp: 	**333-0587**

Description	Order-No.
Tubing mount built into bath cover for level control in the circulator bath when temperature controlling external open vessels. For units with bath:	
B7, C25P	**333-0609**
B5	**333-0610**
B12	**333-0603**
C30P, C35P, C50P	**333-0591**
C40P, C41P	**333-0608**



This glossary contains the most important terms used to describe the features of HAAKE circulators.

1 PID++-control

This robust control system is specially developed for HAAKE DC circulators and adapted to each respective unit. No customer adjustments are necessary.

2 FuzzyStar-control system with neural adaptation

This intelligent control system is included in all Phoenix II circulators designed for the special demands of temperature control. This range incorporates a Fuzzy Logic control system combined with a system identification feature via neural networks.

Advantages:
- Quick heating and cooling
- Exact control without fluctuations
- Extremely robust control compensation in case of system changes
- High level of adaptability to suit a variety of applications
- Energy saving due to integrated cooling management
- Phoenix II units sense your application needs and automaticaly adapt for optimal results

3 TRS system

The pump capacity can be reduced with the Turbulence Reduction System (TRS) to avoid heavy turbulence in open baths.

4 ESK system with external sensor connection

The External Temperature Control (ETC) handles the temperature control of external systems when an external Pt100 is connected. The inlet temperature in the circulator is adapted so that the set temperature in the external system is maintained precisely. A Pt100 sensor is used for this purpose.

5 Direct dialog via LCD graphic display

Phoenix II circulators are equipped with a large LCD graphic display that shows the necessary operating steps in plain text. The selection of menu options is carried out via the direct assignment of the functions to keys.

6 HAAKE RTA system

The Real Temperature Adjustment (RTA) enables the difference between the actual temperature displayed and the real temperature in the bath or external system to be compensated for. To do this, the temperature difference must be measured once and entered into the circulator as a correction value. The correction of the display is then carried out automatically.

7 Safety classes NFL and FL

Units with safety elements classified according to NFL (Non Flammable Liquids) can be used only with water or water and antifreeze. Units with elements classified according to FL (Flammable Liquids) can be used with the recommended bath liquids.

8 HAAKE FIS system

The Fault Identification System (FIS) ensures that the cause for an alarm is clearly shown on the display. All safety-relevant parts are switched off.

ExtraPlus Rating System

Each circulator has been given an individual ExtraPlus rating. This rating can be found at the bottom of the specification table in the product description.

Have you already chosen your circulator?
You can now cross-reference the ExtraPlus rating with the specifications in the corresponding column of the table on this page and see which features your circulator has.

Are you looking for a circulator with special features?
Select the desired features in the first column of the table on this page, and you can then determine which ExtraPlus rating your circulator should have. Phoenix II line circulators with a rating of 5 and 6 Pluses can be found on pages with HAAKE Phoenix II circulators. Circulators with a rating of 1 and 4 stars can be found on pages with HAAKE C/DC-line circulators.

Rating	+	++	+++	++++	+++++	++++++
Control and Technology						
Stable On/Off-Control	✔					
1 Advanced PID++-Control		✔	✔	✔		
2 FuzzyStar®-Control with neural adaption					✔	✔
Energy management of cooling					✔	✔
3 TRS-system/flow rate reduction	✔	✔	✔	✔	✔	✔
Self-adapting pump					✔	✔
4 External sensor connection with ETC-system				✔	✔	✔
Microprocessor and digital electronics		✔	✔	✔	✔	✔
Operation						
Analog setting and fine adjustment	✔					
Touch pad front panel with double display		✔	✔	✔		
5 Direct dialog on LCD-graphic display					✔	✔
Display selection (°C, °F, K)					✔	✔
Digital Display resolution (0.1 / 0.01 °C)		✔	✔	✔	✔	✔
Simultaneous SET/ACTUAL display				✔	✔	✔
Green 7-segment LED-display		✔	✔	✔		
Language Selection				✔	✔	✔
User-defined fixed temperatures (storable)		✔	✔	✔	✔	✔
6 RTA-system for internal temperature		✔	✔	✔	✔	✔
6 RTA-system for external temperature				✔	✔	✔
High temperature limitation		✔	✔	✔	✔	✔
Low temperature limitation		✔	✔	✔	✔	✔
Continous display of date and time					✔	✔
Time for Start/Stop						✔
Number of saveable programs					1	10
3-point calibration						✔
Safety						
7 Safety elements acc. to NFL	✔	✔				
7 Safety elements acc. to FL			✔	✔	✔	✔
Variable overtemperature protection	✔	✔	✔	✔	✔	✔
Fixed low liquid level protection			✔	✔	✔	✔
Pump and motor overload protection	✔	✔	✔	✔	✔	✔
Control sensor monitoring		✔	✔	✔	✔	✔
Measuring and external sensor monitoring				✔	✔	✔
Cooling circuit overload protection					✔	✔
Optical alarm	✔	✔	✔	✔	✔	✔
Acoustical alarm			✔	✔	✔	✔
8 FIS		✔	✔	✔	✔	✔
Communication						
RS 232C interface			✔	✔	✔	✔
RS 485 interface				optional		✔
Profibus interface						optional
LIMS-compatible				optional		✔
Remote alarm connection						✔
External Start/Stop/Alarm						✔
Rating	+	++	+++	++++	+++++	++++++

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UV/Visible Spot Curing System

OmniCure® S1000

The OmniCure® S1000 Provides Excellent Versatility in a Cost-Effective System

- 100W lamp with a broad spectral output
- Intelli-Lamp® technology to cool and monitor the lamp for extended lamp life (typically 2000 hours) and optimal performance
- Automatic lamp striking with hot strike prevention that will protect lamp life
- Adjustable light output in 1% increments for precise control
- Selectable bandpass filters to customize light wavelengths for specific applications
- Easy-to-use finger touch controls with LED display

LUMEN DYNAMICS
PUTTING YOU IN CONTROL

OmniCure®
UV Bonding • In Control

OmniCure® S1000

The OmniCure® Advantage In Spot Curing Systems

The OmniCure® S1000, the entry-level system in the OmniCure® Platform, provides excellent versatility in a cost-effective system. Ideal for manual or semi-automated processes, this system contains many features previously found only in higher-priced curing systems.

Easy to Use

Finger touch controls, a bright orange LED display, process indicators and automatic lamp striking make the OmniCure® S1000 simple to use. The snap-in lamp insertion and low noise fan improves ongoing operation.

Intelligent

The OmniCure® S1000 includes many built-in features which are normally found only in higher-priced curing systems. They include an adjustable iris, patented Intelli-Lamp® technology, bandpass filters, process alarms, and password protection.

Versatile

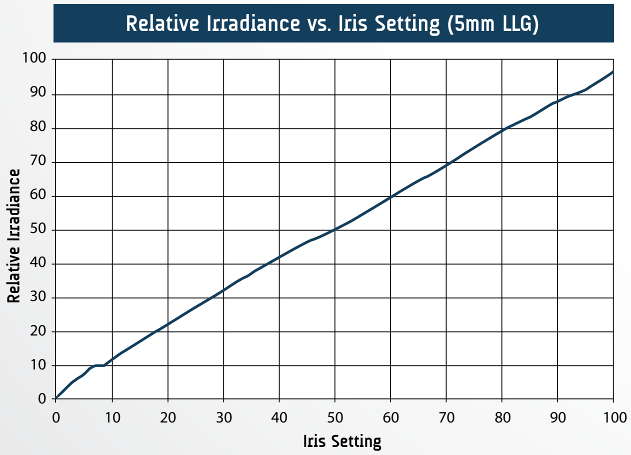
The OmniCure® S1000 includes a powerful 100W lamp providing high-intensity curing and over 2000 hours of lamp life. The broad spectral output makes it ideal for a wide range of applications, while the adjustable iris and selectable bandpass filters allow you to control the light for your specific application.

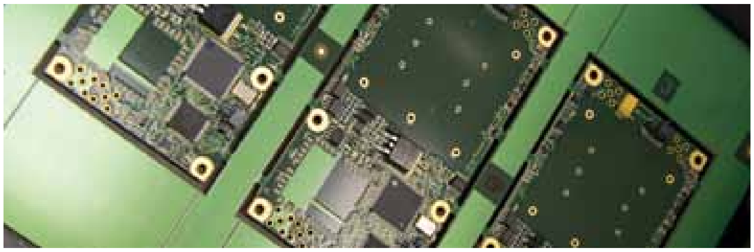
Adjustable Iris

The adjustable iris allows you to select very precise irradiance levels for your curing application. The iris setting is adjustable in 1% increments with a very linear relationship between the iris position and the output irradiance.

Radiometer Control

For even greater control, combine your OmniCure® S1000 with the OmniCure® R2000 Radiometer to adjust the output to specific irradiance values. Over time, lamp output diminishes effective curing. The OmniCure® R2000 Radiometer enables you to measure the irradiance from the OmniCure® S1000 and, when necessary, adjust the manual iris to compensate for any change in lamp output.

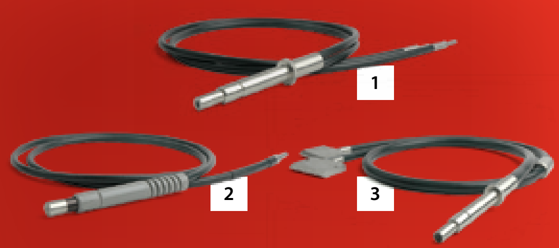




Expanding Your Options

Light Delivery

To accommodate the various needs of its customers, the OmniCure® S1000 is adaptable to four different light guide options. Ideally used with a multi-legged High Power Fiber Light Guide to cure multiple sites with a single light source, Single-Legged, Liquid-Filled and Fiber Light Guides are also available.



1. High Power Fiber Light Guide
2. Liquid Light Guide
3. High Power Fiber Light Line

Optional Accessory:
OmniCure® R2000 Radiometer

Flexible Spectral Output

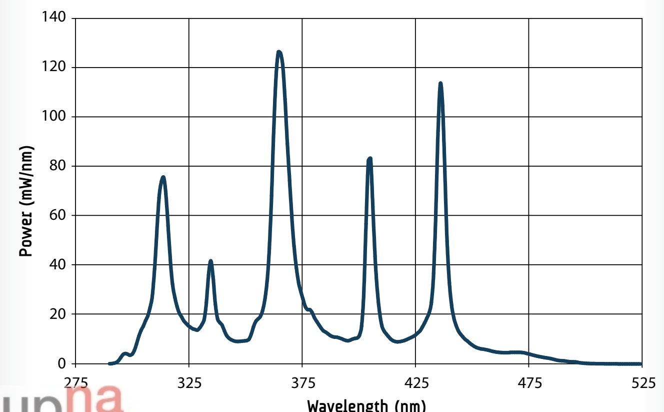
The broad spectral output makes the OmniCure® S1000 ideal for a wide range of applications. Selectable bandpass filters allow you to customize the light for your specific application.

OmniCure® S1000 Filter Options

(W/cm^2), 5mm LG & 0mm Working Distance

Filter Range (nm)	Notes on Typical Applications
320-500	General Purpose – suitable for most UV and visible light curing Epoxy and Acrylic adhesives on a broad variety of substrates.
400-500	Visible light output – used with visible curing Acrylic adhesives, particularly when UV-sensitive substrates are involved.
320-390	Narrow band filter – some Epoxy adhesives have superior response to this filter. May also be used when unwanted substrate heating results from visible light irradiation.
365	Peak filter – may be used when unwanted substrate heating results from UV and/or visible light irradiation.
250-450	Provides some UVC input that can be helpful for surface curing of Acrylic adhesives. Must be used in conjunction with an Extended Range Liquid Light Guide or a Quartz Fiber Light Guide.

Power Spectra of OmniCure® S1000 Standard Lamps



FEATURES	BENEFITS
Powerful 100W lamp with a broad spectral output	Versatility: Delivers the intensity and wavelength required for a broad range of applications; ideal for use with multi-legged Light Guides
Long lamp life - 2000 hours (typical)	Lower operating costs
Iris adjustments in 1% increments	Select the specific output intensity required
Advanced shutter/iris wheel	Tested to over 6 million activations for increased reliability
Intelli-Lamp® technology	Maintains optimum operating conditions, stable lamp output, longer lamp life, accumulated lamp hours
Finger touch control panel with LED display	Easy to use
Selectable bandpass filters	Customize the light wavelengths for your application
Shutter, lamp and Light Guide alarms	Confirms process: ensures repeatability and quality control
Hot strike prevention	Protects lamp life
Password protection	Protects settings for ensured repeatability
Foot pedal (standard)	Convenient hands-free operation
Low-noise fan	Quiet operation in the workplace
Small footprint	Ideal for bench-top use and small workstations

DESCRIPTION

Lamp	High-pressure 100W Mercury Vapor Short Arc
Lamp life	2000 hours (typical)
Available filters	Standard: 320-500nm Optional: 250-450nm*, 365nm, 320-390nm, 400-500nm, NO FILTER*
Panel controls	Power On/Off, Display Mode, Adjust Up/Down, Start/Stop, Lock/Unlock
Panel displays	Accumulated lamp usage, exposure time (0.2 - 999.9 sec), iris setting (0-100%), lamp on, shutter open, Light Guide detection, shutter/lamp error, lamp warm-up
Warm-up period	90 seconds (typical)
Power in	100-120VAC / 200-240VAC, 50/60Hz
Power supply	High efficiency, switch mode, line isolated
Certifications	CE Marked, certified to IEC, Canadian and US Standards, RoHs compliant

GENERAL SPECIFICATIONS

Dimensions (LxWxH)	13.3" x 7.1" x 7.9" (33.8cm x 18.0cm x 20.1cm)
Weight	9.9lbs (4.5kg)
Includes	Lamp module, selected filter (installed), protective eyewear, grounded and shielded power cord, foot pedal, manual
Warranty	1 year (excluding Lamp and Light Guide)

* This configuration must be used with Fiber or Extended Range Light Guide

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PLEASE NOTE: Hg-LAMP CONTAINS MERCURY, Manage in Accord with Disposal Laws, See: www.lamprecycle.org or 1-800-668-8752
For a detailed look at our application solutions visit: www.LDGI-OmniCure.com/applications.php

Lumen Dynamics Group Inc. is certified under the globally recognized ISO 9001 Quality Management System and the ISO 14001 Environmental Management System. Our global customers can trust that Lumen Dynamics strives to be the best possible supplier in all aspects of our business.

Veeco DEKTAK 150 Profilometer

The Dektak 150 from Veeco is a surface profilometer that takes surface measurements using contact profilometry techniques. The Dektak 150 uses stylus profilometry technology, which is the accepted standard for surface topography measurements, roughness and step size.

The Dektak 150 is an accurale, reliable, repeatable, inexpensive device that measures properties such as surface roughness, topography and step heights.

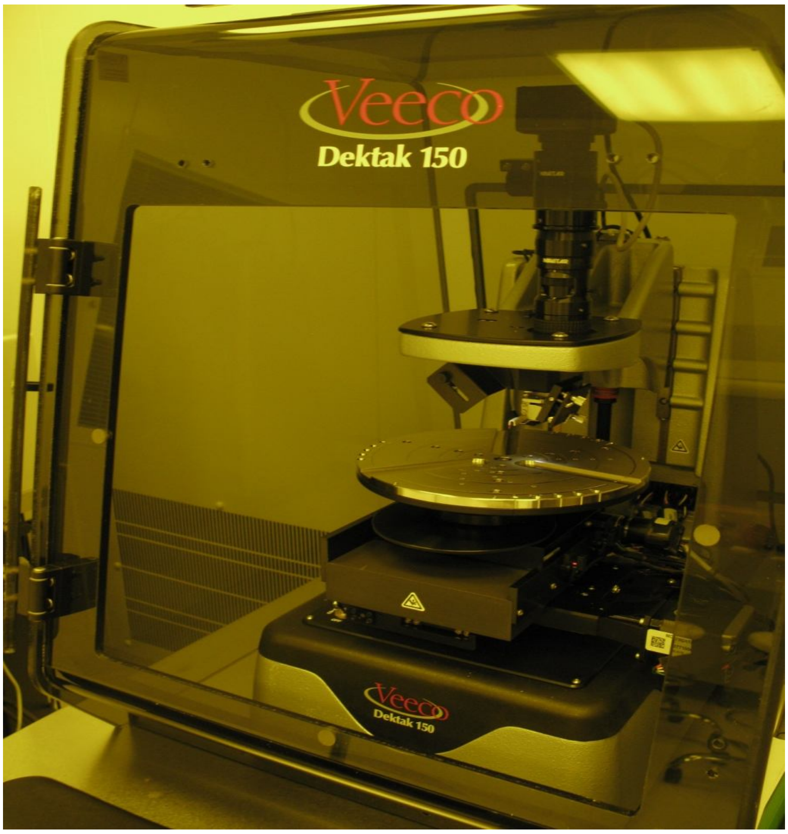

Figure 1:Dektak

Benefits:

- Cost-effective, complete solution for numerous research and industry applications
- 3D mapping capability
- sample flexibility
- 4-angstrom repeatability
- Industry's lowest noise flor

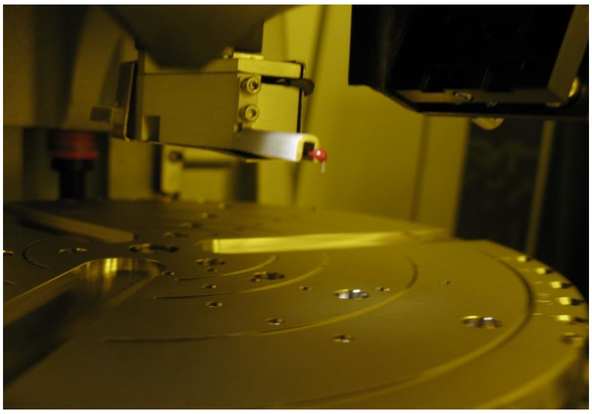

Figure 2:Dektak Stylus

Techinical Specifications and Accessories of DEKTAK

- Large standard Z range of 1 millimeter enables larger step measurements
- Optional X-Y and Y automated stage delivers programmability of over 200 locations
- Cast aluminum frame and rigid support elements
- Easy measurement setup
- 200 mm wafer support

SPECIFICATIONS	
Measurement Technique	Contact Stylus Profilometry
Measurement Capability	Two-dimensional surface profile measurements
Sample Viewing	640X480 pixel camera 100x to 644x magnification 0.67 to 4.29 mm HFOV (high field of View)
Stylus Sensor	Low Inertia Sensor (LIS3)
Stylus	1.25 □m
Stylus Force	1mg to 15 mg
Sample Stage	Manual X/Y/□ , 100X100 mm X-Y translation,360 ^{o} rotation, manual leveling, X-Y auto stage, 150 mm travel, 1 □□m repeatability
Vibration Isolation	Vibration Isolation Table
PERFORMANCE	
Scan Lenght Range	55mm to 200mm
Data Points Per Scan	Max. 120,000
Max. Sample Thickness	Up to 90 mm
Max. Wafer Size	200mm
Step Height Repeatability	$\leq$ 6A ^{o}
Vertical Range	1mm
Vertical Resolution	Max. 1A ^{o}
Lateral Accuracy	< 0.1 % (on 55mm scan)