



INFRARED DETECTORS
FOR MEDICAL APPLICATIONS

MEDICAL APPLICATIONS



VIGO System infrared detectors and detection modules at MWIR and LWIR spectral ranges can be used in a wide variety of biological, biotechnological and medical applications including human breath analysis, noninvasive blood tests, dentistry, pharmacy, protein composition analysis. Some of them are described below.

I. HUMAN BREATH ANALYSIS

Breath analysis has become an important field of medical research. Exhaled breath contains more than 3 000 substances. The concentration of some of them may depend on health status. Those substances are called biomarkers and may be used to diagnose some diseases or pathological processes in human body. Breath analysis is a promising screening test, because it is non-invasive, quick and painless. Due to low concentrations of breath biomarkers use of high-resolution measurement techniques and sensitive detectors is needed.

Infrared detectors are widely used in construction of breath analysis equipment. Techniques based on mid-IR laser absorption spectroscopy for trace gas sensing, compared to other techniques, are considerably faster with response times < 1 s, exhibit minimal drift, offer high gas specificity, are capable of ppm/ppb/ppt detection sensitivity, and permit real-time in situ measurements. Some breath biomarkers detected by infrared detectors are presented in the table below.

Breath biomarker	Health condition	Selected absorption line, μm	Measurement technique
CH_3COH acetaldehyde	<ul style="list-style-type: none">• after alcohol consumption• lung cancer	5.79 and 5.67	TDLAS
C_2H_6 ethane	<ul style="list-style-type: none">• oxidative stress• Alzheimer's disease	3.33	TDLAS

Breath biomarker	Health condition	Selected absorption line, μm	Measurement technique
$\text{C}_3\text{H}_6\text{O}$ acetone	<ul style="list-style-type: none"> type I diabetes 	8.2	QCL-based infrared spectrometer
CH_4 methane	<ul style="list-style-type: none"> oxidative stress cancer 	3.3916 and 3.3920	HWG-TLAS
NO nitrogen monoxide	<ul style="list-style-type: none"> asthma chronic bronchitis allergic rhinitis 	5.26296	ICOS
NH_3 ammonia	<ul style="list-style-type: none"> renal diseases asthma 	10.341	pulsed QCL-based spectrometer
CH_2O formaldehyde	<ul style="list-style-type: none"> lung and breast cancer 	3.530	ICOS
HCN hydrogen cyanide	<ul style="list-style-type: none"> cystic fibrosis 	1.538	ICOS
CH_3SH methanethiol	<ul style="list-style-type: none"> halitosis hepatic cirrhosis encephalopathy coma 	3.3565	WMS/TDLAS
C_2H_4 ethylene	<ul style="list-style-type: none"> lipid peroxidation ultraviolet radiation damage of skin 	10.309	pulsed QCL-based spectrometer
OCS carbonyl sulfide	<ul style="list-style-type: none"> hepatic failure cystic fibrosis rejected lung transplant 	4.86	TDLAS

Table 1. Breath biomarkers detected by IR detectors

TDLAS – Tunable Diode Laser Absorption Spectroscopy; HWG-TLAS – Hollow WaveGuide-Tunable Laser Absorption Spectroscopy; ICOS – Integrated Cavity Output Spectroscopy; WMS-TDLAS – Wavelength Modulation Spectroscopy-Tunable Diode Laser Absorption Spectroscopy

A. PROJECT SENSORMED

Optoelectronic sensor system, using laser absorption spectroscopy with VIGO detection module, to detect biomarkers of diseases (asthma, angina, stomach diseases and elevated bilirubin levels in the blood – including Gilbert’s syndrome, Dubin-Johnson syndrome, Rotor syndrome, Crigler-Najjar syndrome) was developed.

This sensor system consists of five functional blocks:

- sampling system – breath collection,
- conditioning system – gas sample preparation,
- CEAS (Cavity Enhanced Absorption Spectroscopy) sensor – detection,
- dual spectral MUPASS (MULTiPass Absorption Spectroscopy System) sensor – detection,
- signal processing system – data analysis.

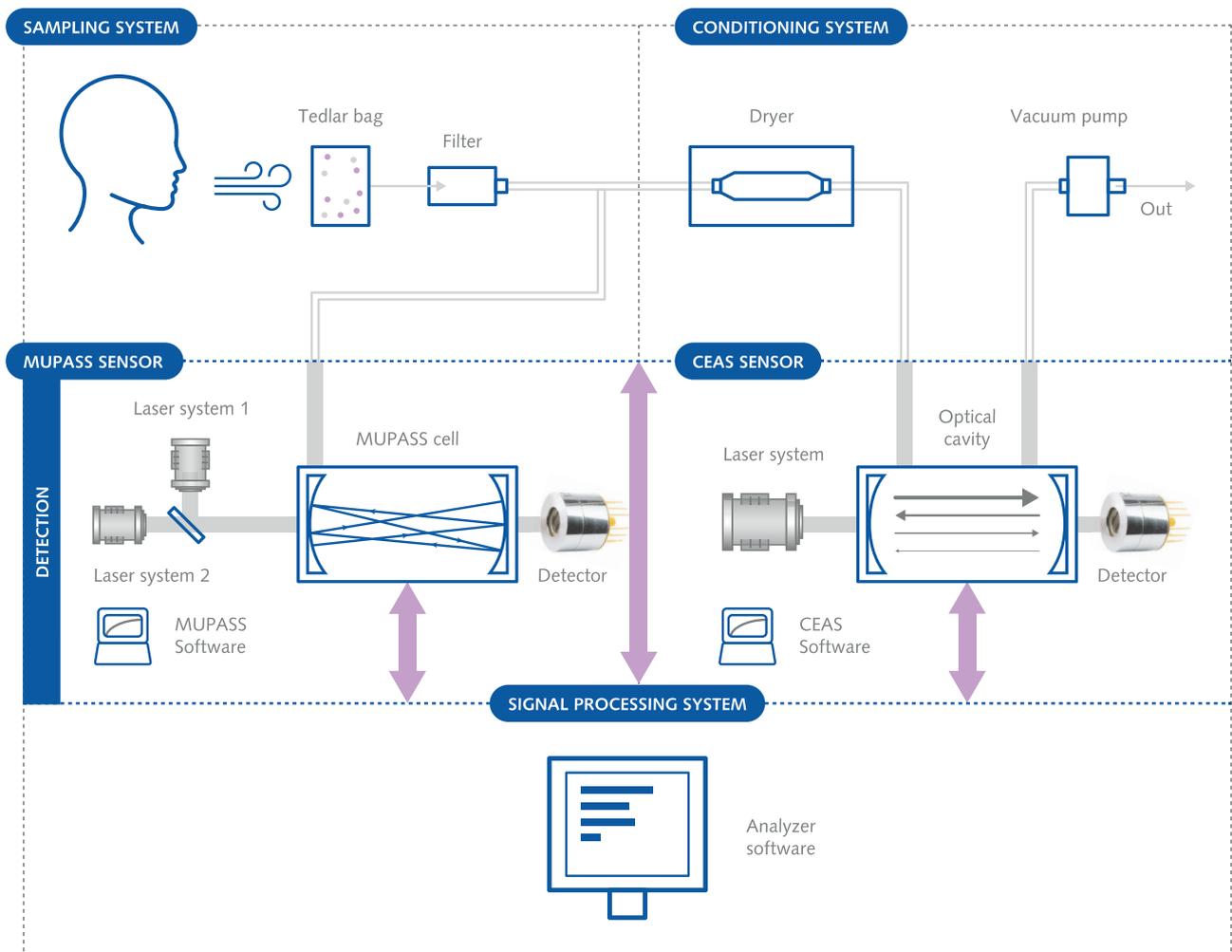


Figure 1. Sensormed optoelectronic breath analyzer

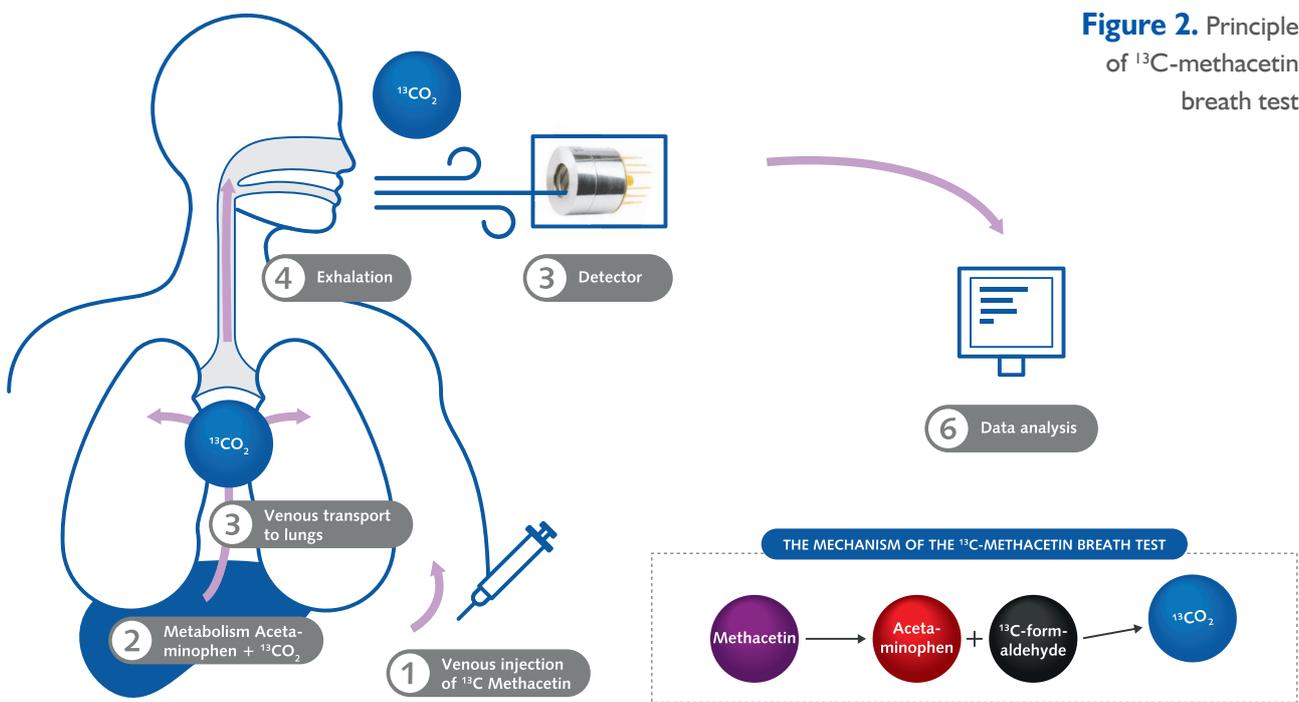
The **sampling system** collects the patient's exhaled air. In accordance with the ATS / ERS standards, it can operate in „on-line” or „off-line” mode. In the **conditioning system** gas sample is prepared for further processing: removing moisture, creating negative pressure, providing appropriate airflow velocity. **CEAS sensor** detects NO (nitric oxide). It uses QCL laser ($\lambda = 5.26 \mu\text{m}$) and VIGO highly sensitive IR detection module with detection limit of approx. 30 ppb. For the detection of CH_4 (methane) and CO (carbon monoxide), a two-spectral **MUPASS sensor** with one multi-pass cell was used. For methane ($\lambda = 2.2536 \mu\text{m}$) the limit of detection was 100 ppb, and for carbon monoxide ($\lambda = 2.336 \mu\text{m}$) it was 400 ppb. The signals from the sensors are recorded by the interface block and directed to the **signal processing system** (computer & software) where the obtained results are integrated, visualized and analyzed.

B. LIVER FUNCTION CAPACITY TESTING

Correct evaluation of liver function capacity has huge importance in liver surgery, liver transplantation, hepatology, and oncology. Methacetin breath test represents a safe and accurate diagnostic tool in the evaluation of hepatic functional mass in chronic liver disease patients.

The dynamic liver function test is based on the metabolism of ^{13}C -methacetin. Methacetin is metabolized by the liver-specific hepatic cytochrome P450 1A2 system to acetaminophen and ^{13}C -formaldehyde, which is then converted in several fast enzymatic steps to $^{13}\text{CO}_2$, which is in turn transported via the bloodstream to the lung and exhaled. Individual liver function can be assessed by continuous measurement of $^{13}\text{CO}_2/^{12}\text{CO}_2$ ratio.

Figure 2. Principle of ^{13}C -methacetin breath test



C. THE ^{13}C UREA BREATH TEST IN THE DIAGNOSIS OF HELICOBACTER PYLORI INFECTION

The urea breath test is one of the most important non-invasive methods for detecting *Helicobacter pylori* infection. It is based upon the ability of *Helicobacter pylori* to convert urea to ammonia and carbon dioxide. Patients swallow urea labelled with a non-radioactive carbon-13. In the 10 – 30 minutes, the detection of isotope-labelled carbon dioxide $^{13}\text{CO}_2$ in exhaled breath indicates that the urea was split. This indicates urease – the enzyme that *Helicobacter pylori* uses to metabolize urea is present in the stomach, and hence that *Helicobacter pylori* bacteria are present.

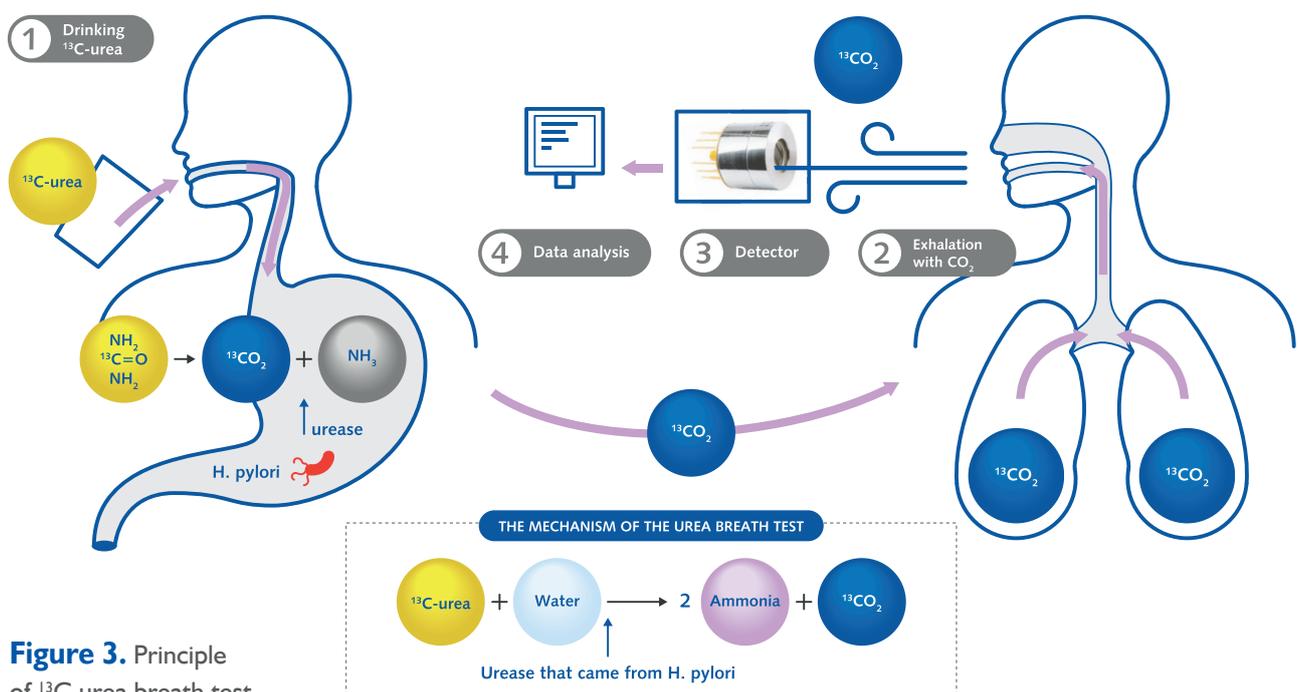


Figure 3. Principle of ^{13}C urea breath test

2. NON-INVASIVE IN-VIVO GLUCOSE SENSING

Needle-free glucose-sensing device enables people with diabetes to non-invasively measure their blood sugar level. This could significantly improve the quality of life of diabetes patients. In addition, such device helps healthy people easily monitor and manage their blood glucose levels to maintain healthy and active life.

The mid-IR region features strong vibrational resonances for many molecules, including glucose. Unlike the near-IR range, glucose absorption features in mid-IR are much more easily distinguished from other competing absorbers. The primary challenge for in vivo glucose sensing using mid-IR radiation is the limited penetration depth in skin due to high water absorption.

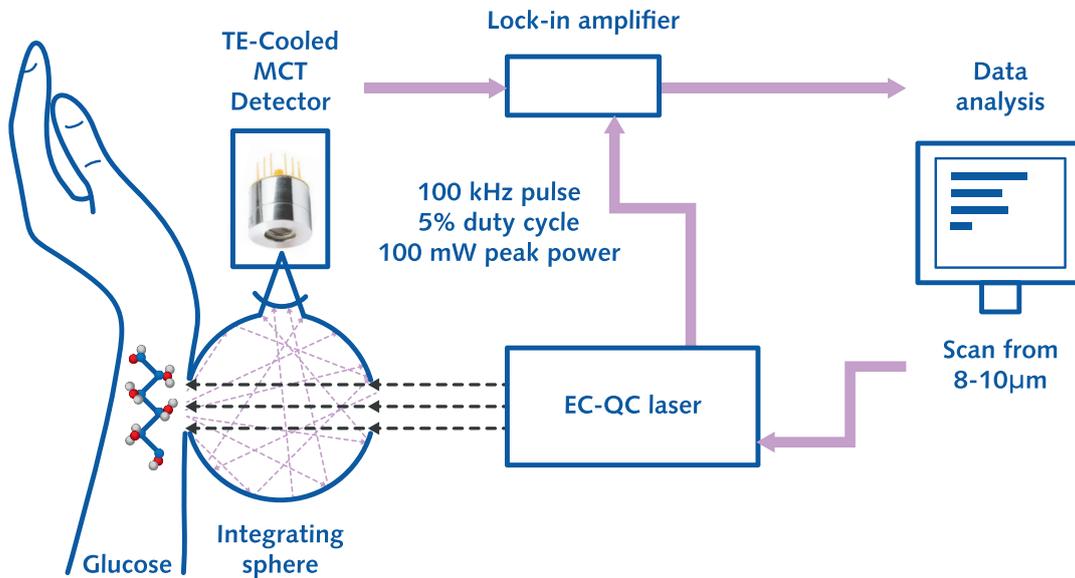


Figure 4. Principle of operation mid-IR non-invasive glucose measurements in skin using QCL spectroscopy

Radiation from a pulsed QC laser, with a tuning range between 8 – 10 μm, is focused into a human skin. The light is then absorbed by glucose molecules and back-scattered off the dermis layer of the human skin. The divergent light exiting the skin is collected by a miniaturized integrating sphere and detected by VIGO TE cooled LWIR detector.

3. DENTISTRY

A. EARLY DETECTION OF TOOTH DECAY

The traditional methods for decay A.on and radiography, are not effective enough in detecting early caries lesions. If dental caries is diagnosed early, before a substantial amount of the tooth is destroyed, remineralization therapy can prevent tooth decay and stabilize or reverse carious lesions. This can prevent invasive treatment.

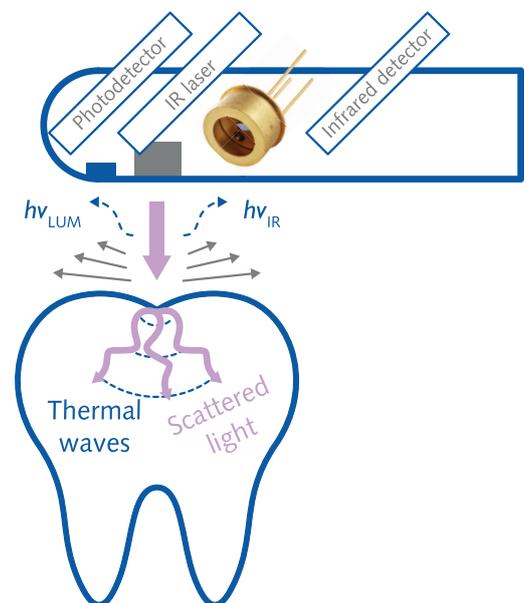


Figure 5. Infrared detector applied to early detection of tooth decay

When low-power pulsed laser light is shone onto the tooth, the system measures the level of glow (luminescence) and heat (photothermal radiometry) released from the tooth. Laser radiation interacts differently with healthy teeth than with decayed teeth. Lesions as small as 50 μm and up to 5 mm below the tooth surface can be detected.

IR laser radiation that hits the tooth enamel and dentin gets converted into heat and raises the temperature of the tooth by about 1°C. This slight increase in temperature should have no effect on the health or integrity of the dental pulp or nerve of the tooth.

By changing the cycling frequency of the laser pulse, it is possible to probe different depths inside enamel or dentin. VIGO MWIR infrared detector captures the emitted thermal radiation and measures how far the heat travels to give information about deeper regions of the tooth. Other part of laser energy is converted to the visible luminescence which can be measured by simple photodetector.

B. ANESTHESIA-FREE CO₂ LASER DENTAL SURGERY



Laser dentistry is the use of precisely focused laser light sources to treat a number of different dental conditions. It offers a more efficient, cost-effective and comfortable treatment option for dental procedures involving hard or soft tissue compared to drills and other non-laser tools. Hard tissue refers to the teeth, and soft tissue refers to the gums.

Hard tissue CO₂ laser can cut through tooth structure. The laser radiation is absorbed by the combination of water and a specific mineral found in teeth. It is used to prepare or shape teeth for composite bonding, to repair dental fillings that have worn down, and to remove some tooth structure. The laser allows to perform cavity preparations and the removal of carious tooth structure, in many cases without the use of local anesthesia.

Surgical lasers must comply with radiation safety performance standards. VIGO LWIR detectors enable high precision, control and safe of dental lasers operation.

If you need safe and RoHS compliant infrared detection systems dedicated for specific medical applications please contact us.



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