SMALL INFRARED SOURCES:
POWERFUL AND ENERGY EFFICIENT

WHY SMALLER CAN BE BETTER

The Non-Dispersive-Infrared (NDIR) and Photo-Acoustic-Spectroscopy (PAS) sensor application segments are experiencing fast, world-wide growth. The growth is due to the increasing demand for monitoring and control, as well as the ability to switch from classical methods to infrared based applications when gas selectivity, long life-span and high-accuracy are needed. One of the industry leading trends is to continuously minimize size and optimize the sensor units to serve new market segments. Miniaturization increases the requirements for component manufacturers and demands innovative and customized solutions.

A typical NDIR or PAS setup consists of an infrared light emitter, a gas-specific, selective band pass filter and a pyroelectric, or thermopile detector respectively for PAS a piezo microphone. In various applications, multi channel detectors are built in, either as a reference or to measure several gases. Detectors vary in price and performance, e.g. special detectivity, but are similarly responsive across the whole infrared range.

The sensor units are typically in use for years, and thus a significant amount of time and effort is spent on qualifying and conducting lifetime tests. A clear advantage is to choose a light source suitable for multiple sensor applications. IR Source characteristics for universal usage are high emissivity throughout the wavelength range, high optical power, large modulation depth with higher frequencies, long life-span and compact size (Figure 1 & 2). If these requirements are met, only the band pass filter and the optical path need to be fine-tuned to adapt the sensor design to other gases and applications. Thus, months or years of lifetime tests can be saved.

Sometimes Smaller is Better

Minimizing the size of a MEMS IR emitter comes with benefits and drawbacks. A clear drawback is the smaller, active surface: following the Stefan–Boltzmann law, the emitting power is linearly proportional to the area, and thus reducing the chip size while keeping the temperature profile the same, reduces optical power. The benefits on the other hand, include reduced physical size, increased electrical efficiency and high-modulation depth with higher frequencies.

A clear advantage gained by the smaller chip is the relation of the chip size to reflector outer diameter: the light from a point source can be guided forward with much greater efficiency, especially when considering typical gas cuvette diameters range from two to four millimeters and typical high integrated IR multichannel detector with a small Field-of-View.

Figure 3: Different reflector possibilities for smaller IR Emitters. The left side shows Axetris' EMIRS50 source with Reflector 6 and the right one with Reflector 7.

Lower Power Consumption with Smaller Sensors

The total power consumption from a smaller sensor is becoming crucial when sensors are portable or battery driven. As the IR emitter influences the energy consumption significantly, efficient emitters with a small active area are required. The Axetris EMIRS technology enables to operate it with a short duty cycle, reducing the power consumption below 10 mW. Additionally, a high time resolution can be achieved by driving the EMIRS50 sources up to 100 Hz. The loss of modulation depth caused by the high frequency can be compensated by increasing the input power respectively voltage (Figure 5). Furthermore, an increase in the signal-to-noise ratio can be achieved by operating the IR Source with a duty cycle below 15% at a very high frequency combined with compensated input power.

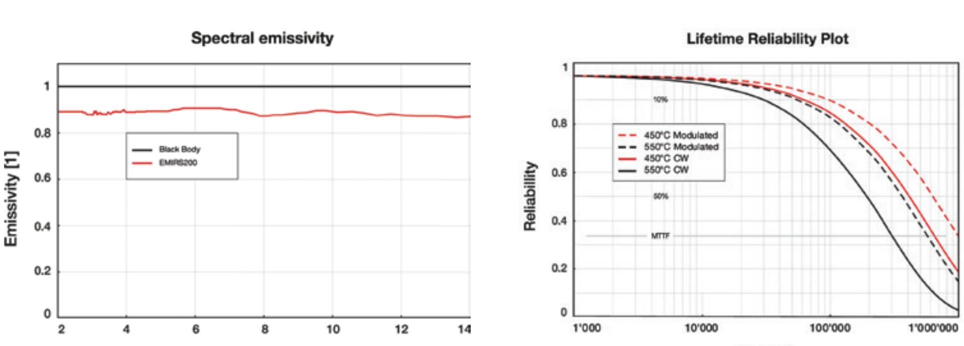

Figure 1 & 2: High emissivity and long life-span provide a great platform for NDIR gas sensing devices.

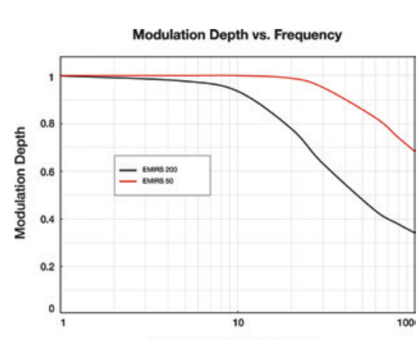

Figure 4: Significantly higher modulation depth of the EMIRS50 compared to larger EMIRS200

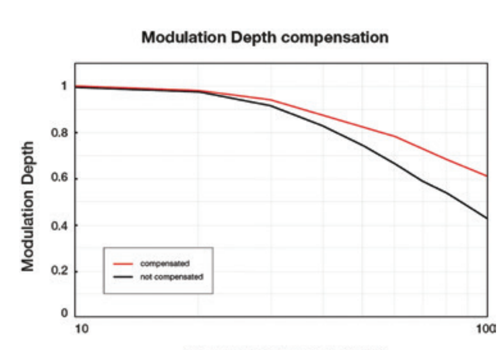

Figure 5: By compensating the input power or voltage while maintaining the membrane peak temperature, the depth of modulation can be increased significantly.

High Volume, Small Sensors

Many new, high-volume market segments are only accessible with certain end-user pricing. This sets clear boundary conditions for each supplier. At Axetris, multiple steps have been taken to meet specific needs, and as presented in Figure 6, significant cost-reduction activities have been carried out. Lastly, fully tested SMD packaged and chip level tested products are available to meet future needs.

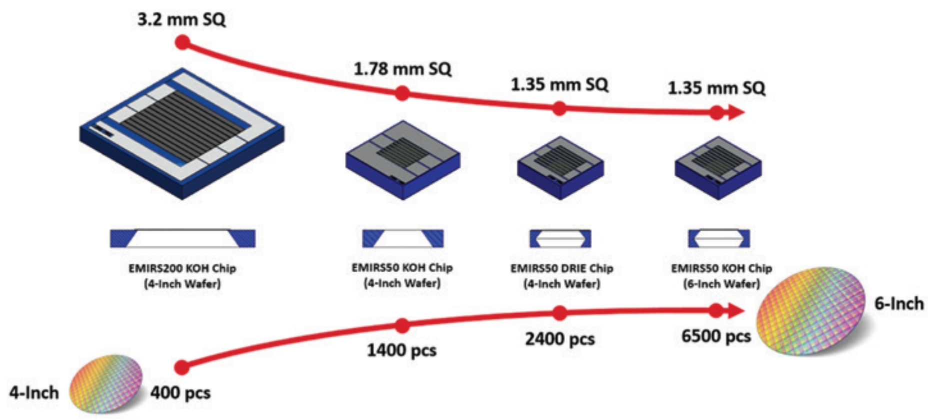

Figure 6: Chip scaling to meet the cost target for high volume application

Small, Thus Fast

Scaling down the size of the emitters means reducing the thermal mass. Cooling and heating is faster, allowing the IR Source to operate with higher frequencies. The modulation depth, i.e. the actual signal from the detector, is then higher above a certain frequency, compared to a source with larger thermal mass.

The requirements for frequency are application-dependent: In capnography for example, the requirements are high. In order to draw useful data for a capnogram, it is vital to acquire 30 to 100 measurement points per second. For this reason, an emitter operating reliably at a high sample rate is necessary. With the EMIRS50, Axetris provides an IR Source capable of emitting remarkably fast: modulation depth exceeds 60% at 100 Hz (Figure 4).

A comparison measurement shown in Figure 7, was completed with the larger Axetris EMIRS200 with Reflector 1 source and smaller EMIRS50 with Reflector 6 to study their performances: Frequency scans were conducted with a 20 mm distance from the end of the reflector to the detector. The larger EMIRS200 has clear advantages in frequency range below 17 Hz. However, when frequency is above 17 Hz, the much smaller EMIRS50 shows clear benefits and more intensity.

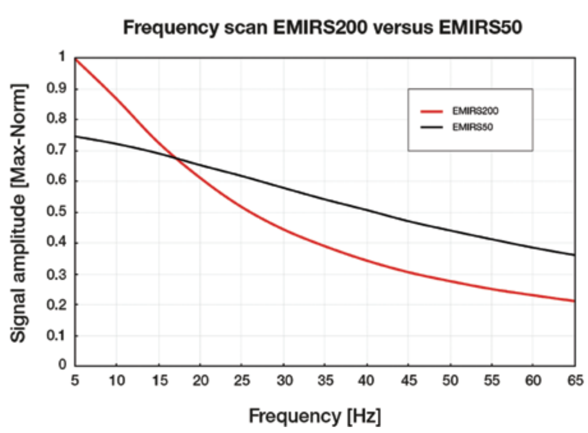

Figure 7: Above 17 Hz the EMIRS50 Refl. 6 offers more intensity in reference to the EMIRS200 Refl. 1 on the IR detector (valid for a open path setup)

Small and Efficient

For a measurement system to provide fast response times, the gas exchange must also be rapid and the space to be filled should be as small as possible. To obtain forced flow through sensors, closed reflective cuvette geometry is often used (Figure 9). The measuring range and lowest detection limit (in function of the gas absorption coefficient), together with the used detector and IR emitter define the length of the cuvette. The diameter of the cuvette should be as small as possible, but it depends on the coupling of the IR emitter and detector.

With Axetris' customized reflectors, all of the light from a small emitter can be guided to a cuvette with a diameter of 3 mm (Figure 8). The angle distribution is optimized with the shape of the reflector. Since the properties of the band pass filter are dependent on the incoming angle of the light, it is beneficial to either measure the actual performance of the band pass filter with spectrometer or simulate the expected performance.

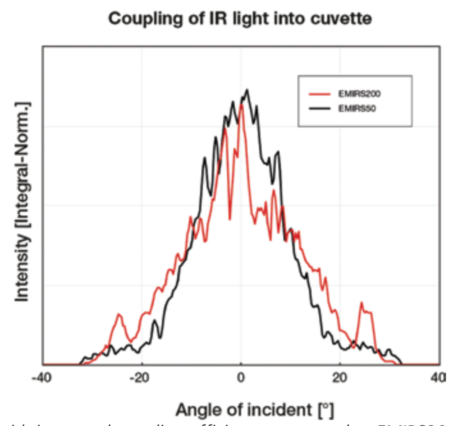

Figure 8: EMIRS50 Refl. 7 with increased coupling efficiency compared to EMIRS200 with Refl. 2

For compact diffusive sensor designs, multi-pass arrangements (Figure 10) are often used to keep the air volume low and to achieve sufficient gas absorption length. For these kinds of setups, well collimated and focused IR emitters are required to guide most of the IR light through the optical system. The smaller, highly efficient EMIRS50 reflectors offer a significant performance increase to such an advanced and high performing sensor design.

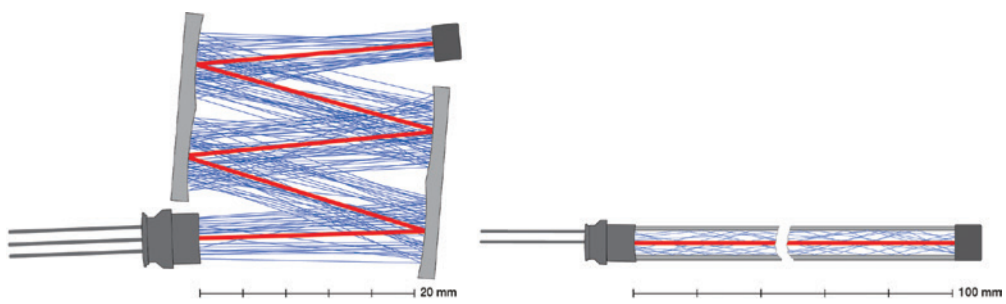

Figure 9 & 10: Classical cuvette design for flow-trough and multipath cells offering very compact diffusive sensor solutions

When comparing the performance of the smaller EMIRS50 IR Source with the larger "standard" EMIRS200 IR Source, both with optimized reflector designs, the efficiency increase with the EMIRS50 Source is clear: in gas cuvette simulation (2x2 mm detector with 1 mm distance) with < 8° angle of incident, 38% of the total optical power with the EMIRS50 Source fall in the detector, compared to 8.3 % of the total optical power of the larger EMIRS200 Source (Figure 8). The result is an optical efficiency being practically five times higher with the smaller EMIRS50 IR Source.

A Qualified and Long-Term Tested Product

Each IR Source undergoes a qualification program which focuses on quality and reliability for its main target markets. The structure of the program is set up based on AEC-Q101, while most of the stress tests are taken from IEC 60601-1. Specific features of the IR sources (e.g. lifetime) are tested according to Axetris' standards based on internal risk assessments and Failure Mode and Effects Analysis (FMEA).

Conclusion:

Increasing demand for monitoring, process control and miniaturization of sensors requires new, customized solutions, such as IR Sources, from component manufacturers. Smaller is often faster, more cost effective and less power consuming which is crucial for portable sensors. However, the requirements for an IR emitter depend on the application, on the sensor principle, the optical geometry and many more specific characteristics.

The Axetris team collaborates with its customers to find the right product design that best suits their needs regarding performance and costs. Furthermore, our application team supports our valued customers by carrying out optical analysis and optimization of specific parameters.

About Axetris

Axetris serves OEM customers with micro-optical components, micro technology-based (MEMS) infrared light sources, mass flow meters and controllers, and laser gas detection modules used in industrial, telecom, environmental, medical, analytical and automotive applications.

Axetris infrared sources are micro-machined, electrically modulated thermal infrared emitters. The unique design is based on a resistive heating element integrated onto a thin dielectric membrane, which is suspended on a micro-machined silicon structure. Infrared sources from Axetris are used in a number of gas detection applications in medical, industrial, environmental and automotive industries.

Author Contact Details

Pekka Luoma, Axetris AG • Tel: +41 41 662 79 94 • Email: pekka.luoma@axetris.com • **Web: www.axetris.com/irs**

axetris®
Company of the Leister Group