TECHNOLOGY AND PRODUCTS

ANTI-FRINGING SOLUTIONS IN DETECTORS FROM VIGO SYSTEM

Recent years have seen a dynamic development of spectroscopic devices operating within mid infrared range, such as gas and liquid analyzers.

Progress has been made mainly thanks to wide availability of QCL and ICL sources, and decrease in the prices of subassemblies for such devices. Further progress and increase in analyzer sensitivity are limited by the effects that previously did not impact the results of less precise measurements, such as for example laser noises and dependence of systems on temperature. One of the disadvantageous effects appearing on the detector side is the fringing effect, also called the etalon effect (after the French name of an optical parallel). The VIGO System company, as the mid infrared market pioneer, has proposed the first efficient solution to this problem and has initiated a research project aimed at eliminating it completely.

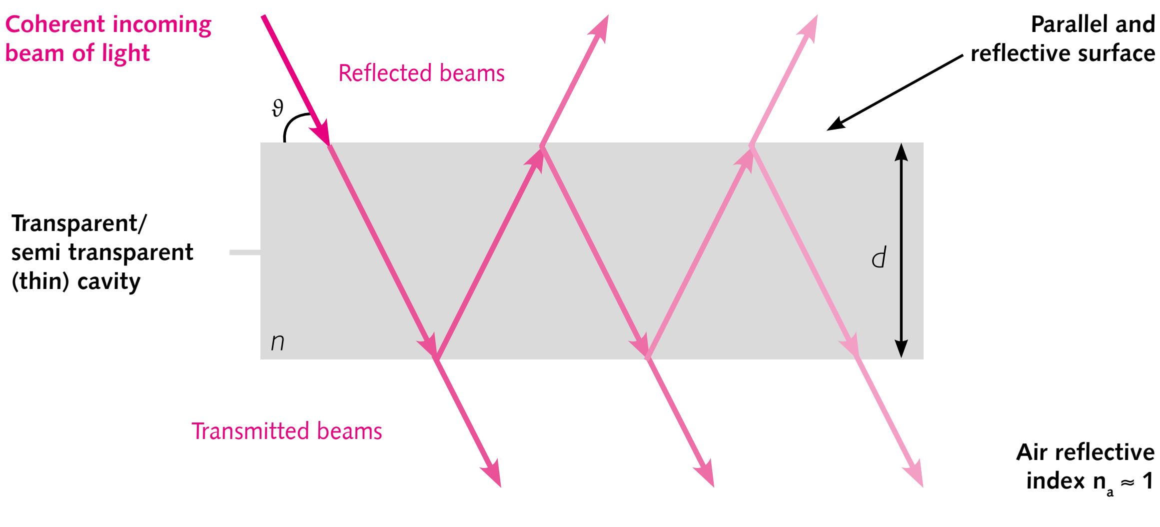
What is the etalon effect?

Photonic infrared detectors are semiconductor devices comprising multiple layers of materials with various refractive indices. Therefore, radiation may reflect from the device structure, which results in disadvantageous interaction with other portions of the signal.

Let us consider a simplified model of a monochromatic plane wave incident on an optical parallel. The wave carries a usable signal which we want to measure.

As the refractive indices of the air and the optical parallel material (n and na) are different, some of the incident radiation goes through the material, and the remaining part is reflected, with the direction of propagation changed (as shown in the picture). The percentage quantity of photons that are reflected and that go through the material depends on the difference between the refractive indices of the medium and the surroundings, and is described with Fresnel equations. The presented model does not take into account the absorption of radiation - which is the essence of detector operation - and the absorbing layer in an actual sensor is situated behind numerous other constituent layers (required for the sensor to work). It is there that the said reflections can occur. Only the part of the signal that has not been reflected reaches the absorbing layer.

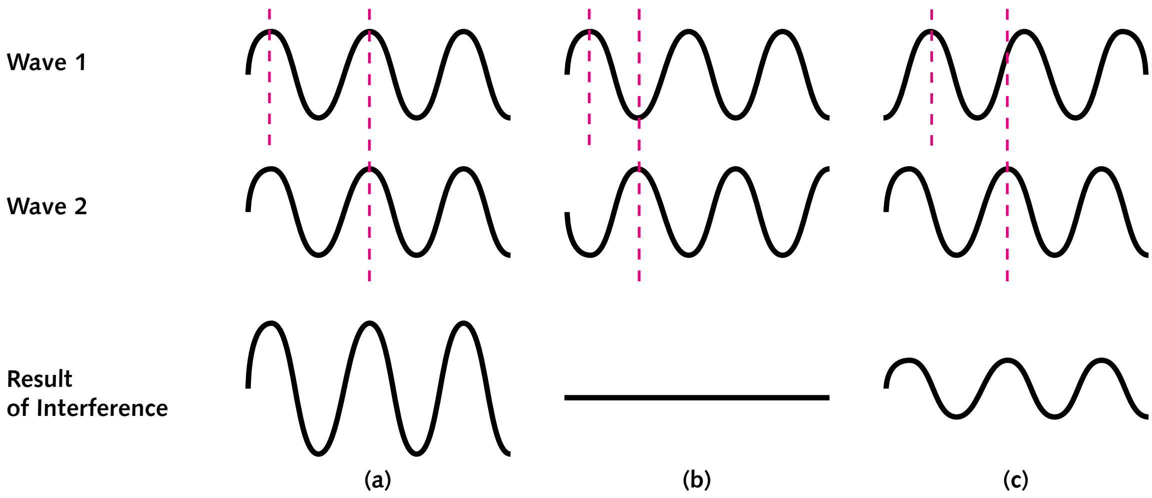
Fig. 1: The principle of etalon effect occurrence.



What are the consequences of radiation reflecting from device structures?
In the model shown above waves reach the optical parallel at a certain angle, which is a simplification needed for graphical presentation. In reality, the incident beam is most frequently perpendicular to the structure surface. In such circumstances the incident and reflected waves obviously combine, which in the language of physics is referred to as interference. Depending on the phase of the wave reaching the structure at a given moment, and depending on the relation between the wavelength λ and the optical parallel thickness *d*, the resultant superposition of beams may lead to amplification or damping of the resultant signal, as shown in Fig. 2. In the extreme cases the wave amplitude is doubled (2a) or reduced to zero (2b) – assuming that the amplitudes of both beams are equal. The intermediate cases are different variants of wave amplitudes summing (2c).

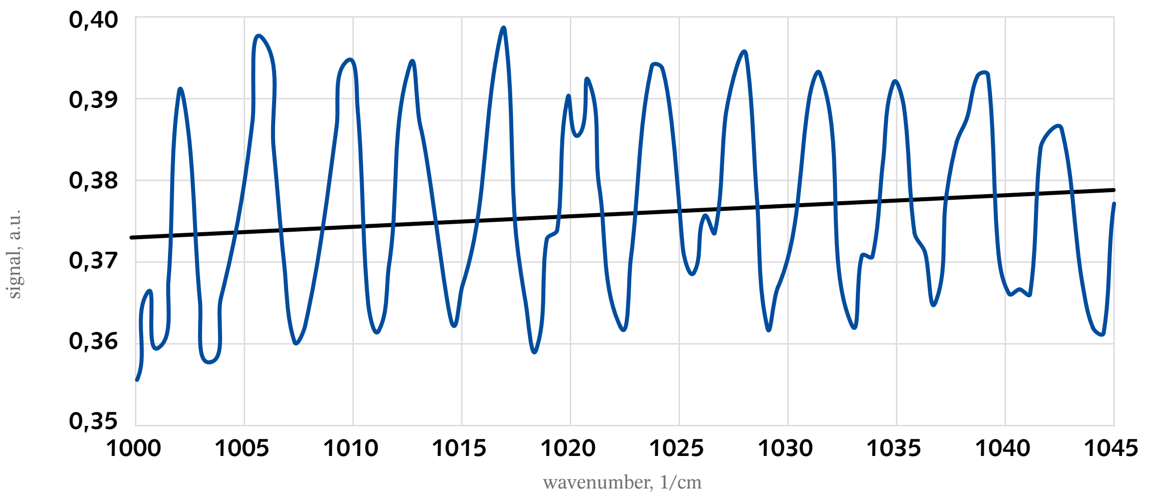
In reality, the amplitudes of incident and reflected beams are not equal, which means that the amplitude of the beam coming from a source is only slightly distorted (the amplitude of incident wave is greater). The detector is always reached by a non-zero signal with partially higher or lower intensity (the distortion depends on the scale of reflection).

Fig. 2: Superposing light waves: (a) constructive interference, (b) destructive interference, (c) intermediate cases.



How is the etalon effect observed by the user of the detector?
The phenomena described above concerned a case where the waves had a single, selected length. When the said length changes or when the radiation is not monochromatic (but is composed of many frequencies), the conditions for occurrence of constructive and destructive interference are transformed, as the relation between the wavelength and the optical parallel thickness changes, and other phase relationships also occur. That results in fluctuations of the intensity of the beam reaching the absorber layer, depending on the wavelength. As a consequence, instead of a smooth waveform on the detector's output, signal with distorted wavelength is observed (Fig. 3). That is referred to as the fringing effect.

Fig. 3: An example of fringing effect observed in signal from an infrared detector. The smooth line (dark blue) represents a theoretical spectral curve of response from the detector when illuminated with a signal from a black body, and the line with visible fluctuations (light blue) represents measurement data. The oscillatory shape of the curve is a result of the etalon effect occurred on instrument components.



Types of anti-fringing technologies applied in detectors from VIGO System

The VIGO System company has developed multiple methods of reducing fringing in its detectors. They utilize angular separation of the incident and reflected beams, anti-reflection coatings, or modifications of the internal structure of the detector. The specific method of reducing the fringing effect depends on the type of detector, the type of the observed source, and the measurement conditions. The diagram below (Fig. 4) shows all the anti-fringing solutions currently available from VIGO System.
The described methods have been developed in consultation with the customers of VIGO Systems, and have been selected with the requirements of specific applications taken into account. Each new request for information is also considered on an individual basis in order to propose the most efficient method of operation.

Fig. 4: Anti-fringing solutions offered by VIGO System.

ANTIFIRINGING SOLUTIONS

Decoherence of the radiation

- wedged window
- wedged cap
- wedged structure

Reduction of the reflection coefficient of the surface

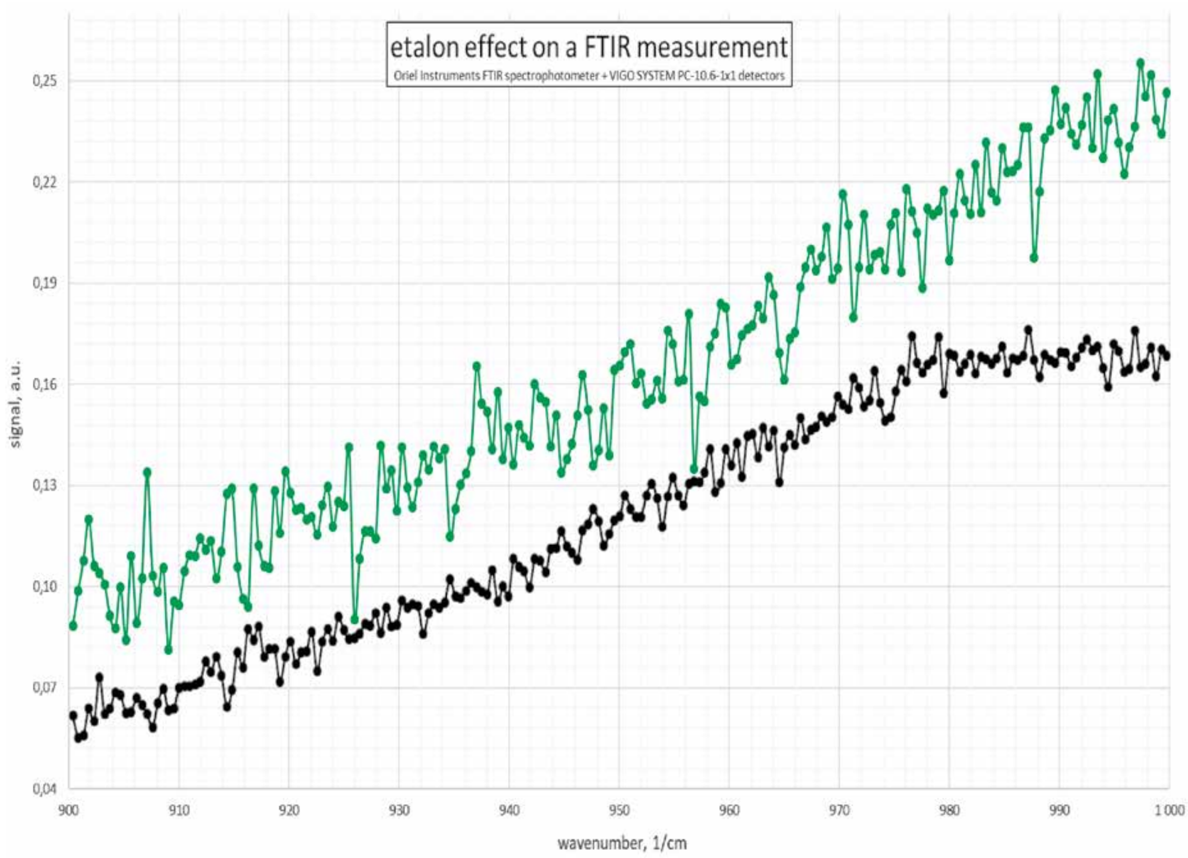
- application of the anti-reflection coating at the window
- application of the anti-reflection coating at the active structure (3-5 um)

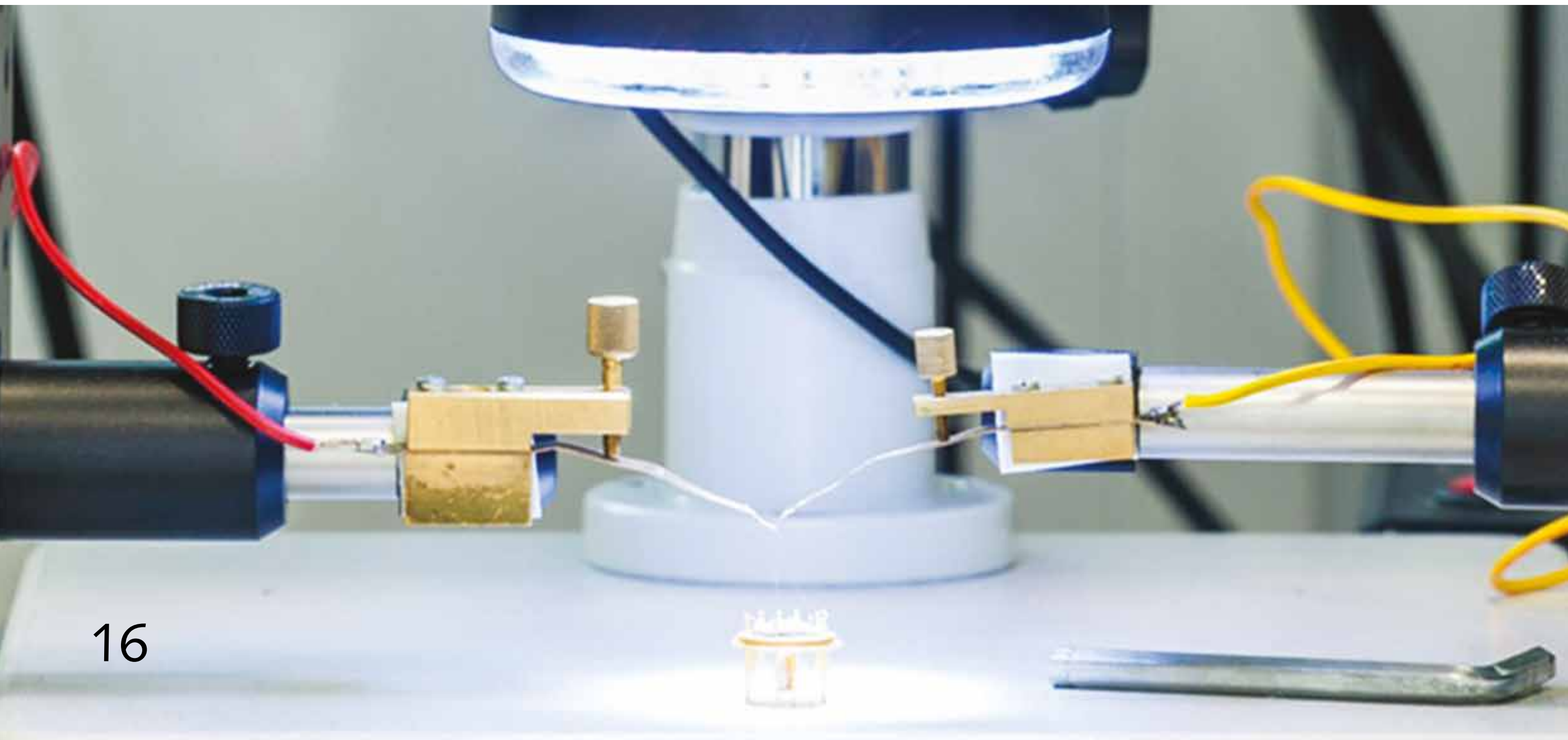
Modification of the internal design

- no metallization on the back
- roughened surface
- reducing the NA of the upcoming radiation

What are the effects of using anti-fringing technologies?
The chart below (Fig. 5) shows a sample result of using one of the anti-fringing solutions, as a part of modification of the internal structure of a detector.
As can be seen, a significant reduction in oscillations caused by interference on device components has been achieved at the cost of an insignificant decrease in detector sensitivity.

Fig. 5: Results of application of one of the anti-fringing solutions.





Are there any solutions which do not have side effects impacting detector operation, such as sensitivity decrease?
As a part of its new strategy, VIGO System has been preparing a project aimed at total elimination of the fringing problem through a single comprehensive approach. Such a solution will be useful in any type of application and, which is equally important, will not require giving up high parameters of the instrument.

For which applications is the use of anti-fringing technologies recommended?
Detectors utilizing anti-fringing technologies are best suited for operation with retunable laser sources, where there is the greatest probability of observing the etalon effect. That results from several basic reasons: the laser radiation meets the directionality condition and is coherent both in space and in time, which increases the probability of the phase-matching of photons. In addition, laser beams are characterized by very high optical power, which means that differences between radiation intensity for various wavelengths (obtained through retuning) are clearly distinguishable.
In the case of operation with bodies that emit thermal radiation, two types of measurements done with their use must be distinguished, on which the scale of observable fringing depends: tests based on collection of total signal from a heated source that are not disturbed by the phenomenon under discussion, and spectral measurements utilizing relations between detector's response to thermal radiation of various wavelengths (e.g. FTIR), which may be distorted by fringing.
The impact of the disturbances under discussion on sample applications of IR detectors has been shown schematically in Fig. 6.
Presently, the anti-fringing solutions are not included in the VIGO System products catalogue. Should you want to submit a request for proposal or be interested in technical details concerning the offered technologies, please contact local distributors or sales representatives of VIGO System.

E-mail: sales@vigo.com.pl

Fig. 6: Influence of fringing on IR detection.