FPI Detectors
Pyroelectric Detectors with Spectrometer Functionality
A High-tech Detector as a Low-Cost Spectrometer

Among the group of thermal detectors available, pyroelectric detectors have for years proven to be highly useful for numerous applications in gas analysis and flame sensing due to their spectral properties and robustness. Without a doubt, the simplest application for these devices is to use them as a motion detector. But pyroelectric detectors can even be used for the most demanding tasks – even those essential to protect human lives. For this reason, our detectors are now used in underground mines, on drilling platforms, in operating rooms, chemical plants or in a range of hand-held devices. For classical gas analysis, these detectors can be outfitted with narrow-band filters (NBP = narrow-band pass). These filters must each be tailored to the specific gas absorption band in order to meet the measurement requirements. For the measurement of gases, with very closely spaced absorption bands such as hydrocarbons, a high demand is placed on the specification of the narrow-band filter. The measurement of unknown gases is not possible with this method.

The installation of a tunable filter instead of a narrow-band filter removes these restrictions. Furthermore, this also adds the option of being able to measure several gases at one time with a single detector. In order to make this possible, a Fabry-Pérot interferometer (FPI) can be used in the pyroelectric detector (FPI detector). This combination with the pyroelectric detector is particularly advantageous because it can be used for almost all wavelength ranges and also does not require cooling. The entire assembly is so small that it can be put together with a signal preamplifier in a TO8 housing.

FPI Detectors offer
- High flexibility in terms of the measurement substances
- Application chemometric methods for multi-component analysis
- Measurement of known compositions with overlapping bands
- Identification of unknown substances
- Cost-effective, robust and miniaturized solution

Fig. 1: FPI detector in comparison to NDIR Detector and laboratory spectrometer
Areas of Application

The method of infrared spectroscopy, based on a physical sensor principle, is an established method in the field to determine concentrations and compositions very selectively and with long-term stability. The applications are so diverse that only a few important examples can be listed. While it plays a particularly important role in gas analysis, this method is also used for liquid and solid analysis.

**Process Measurement – Analysis of Liquids in Chemical Processes**
Fluid analysis in chemical manufacturing processes is an essential component for the optimization of product quality and safety. FPI detectors have the advantage, besides their high flexibility in terms of substances to be measured, that in their design, they are significantly cheaper, more robust and more compact than other large and very expensive process spectrometers or other complex measuring techniques such as ATR probes in combination with NDIR sensors.

**Energy Technology – Determination of the Energy Content of Natural Gas or Biogas**
The determination of the energy content, for billing purposes or for improving the energy efficiency of combustion processes, is very time-consuming and costly with previous instruments such as gas chromatography. These processes were also hardly economical when used in smaller plants. The resulting increase in demand for cheaper, faster and more precise sensors has been met with the FPI detector due to its design and measurement properties.

**Medical Technology – Monitoring/Dosage of Anesthetic Gases**
In order to monitor and ensure the safe dosage of anesthetics, up to five gases, mainly in the wavelength range (8 ... 11) ㎛, in addition to nitrous oxide and carbon dioxide must be measured simultaneously. Due to the number of gas components to be measured, spectrometric measurement and evaluation is the best method. Due to the very compact design, there is a significant miniaturization advantage when compared to conventional methods based on fixed filters.

**Further Applications for the Use of FPI Detectors**

- In **safety technology** for the detection of toxic or hazardous material or explosive gases
- In **environmental and climate research**, for the measurement of emissions, for the identification of plastics in waste sorting, leak detection in pipes, the composition of the atmosphere, etc.
- For the **measurement on surfaces** to detect contaminants, to ensure the complete coating of reflective material, to test the thickness of coatings or ensure the complete wetting of lubricants
Operation Principle of FPI Detectors

InfraTec’s tunable filter technology is based on a micromachined Fabry-Pérot interferometer, which is comprised of two flat and parallel reflector plates (Fig. 2). In simple terms, it acts as a half wave resonator, producing a series of transmittance peaks of successive interference orders (Fig. 3). By changing the plate separation the peak positions and thus the center wavelength (CWL) can be tuned. An additional order sorting filter placed in series with the Fabry-Pérot interferometer enables unambiguous narrowband filtering.

The basic functional parameters of spectrometers are wavelength range, spectral resolution and throughput (signal-to-noise-ratio). In any case, the miniaturization of a spectrometer requires a certain compromise between these parameters that has to be found. In the infrared range this is especially true for resolution and throughput. Compared to grating spectrometers, linear variable filters or miniaturized Fourier-transform spectrometers, tunable Fabry-Pérot filters offer a very attractive solution in this regard:

- No entrance slit is limiting the throughput
- The scanning principle with a large single point detector has a throughput advantage over array detectors
- Infrared array detectors are very expensive
- No additional precision optics is needed
- The parallel plate arrangement of the FPI is ideally suited for miniaturization

Despite the big advantage of the spectrometric sensing principle many applications first of all require a high signal-to-noise-ratio rather than a high spectral resolution. InfraTec’s tunable filters are designed for these specific needs:

- First order operation (widest tuning range)
- Large aperture of about 2 mm (high throughput)
- Moderate resolution (high throughput)

InfraTec’s Fabry-Pérot filters are comprised of two bonded silicon substrates, which are structured by means of bulk micromachining technology. They form the two plates of the interferometer as well as the electrodes for electrostatic actuation (Fig. 4). This approach has some great advantages over competitive solutions:

- Thick reflector plates, thereby no static or dynamic deformations
- Reflector and electrode plates separated, thereby tuning range is not limited by electrostatic instability
- Thin film material system for reflectors and AR coatings from NIR to LWIR
Setup of FPI Detectors

The Fabry-Pérot filters are integrated into TO8 housings together with a LiTaO₃-based pyroelectric detector. The latter is a state of the art thermally compensated current-mode type with an integrated op-amp. The element size of 2 × 2 mm² matches the size of the filter aperture. The order sorting filter is integrated in the cap.

Calibration data are stored in an EEPROM. An integrated ASIC offers feedback on the position of the moving mirror plates. The closed loop control greatly improves center wavelength (CWL) stability under the influence of changing gravity, e.g. by rotating the detectors inside a portable device.

Fig. 5: Set-up of FPI detectors
Product Range

Different types with first order filters and wide tuning ranges are currently available. They span nearly the whole mid and long wave infrared range of about (3 ... 11) µm. Other ranges or customized designs may be possible on request.

The letter “C” in the description of the detector stands for the integrated ASIC. This component offers detector operation in a control loop. Position feedback of the reflector plates is given by capacitance measurement. This means the filter can be stabilized against external acceleration forces. Temperature drifts are automatically compensated by closed loop operation as well.

<table>
<thead>
<tr>
<th>Type</th>
<th>LFP-3144C-337</th>
<th>LFP-3850C-337</th>
<th>LFP-5580C-337</th>
<th>LFP-80105C-337</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuning CWL</td>
<td>(3.1 ... 4.4) µm</td>
<td>(3.8 ... 5.0) µm</td>
<td>(5.5 ... 8.0) µm</td>
<td>(8.0 ... 10.5) µm</td>
</tr>
<tr>
<td>Spectral resolution HWPB</td>
<td>(55 ... 70) nm</td>
<td>(60 ... 75) nm</td>
<td>(100 ... 130) nm</td>
<td>(130 ... 220) nm</td>
</tr>
<tr>
<td>Filter time constant</td>
<td>(3 ... 15) ms</td>
<td>(2 ... 12) ms</td>
<td>(1 ... 10) ms</td>
<td>(1 ... 8) ms</td>
</tr>
<tr>
<td>Application examples</td>
<td>Environmental, climate, building and safety technology</td>
<td>Process measurement technology, liquid analysis</td>
<td>Medical technology, breath analysis</td>
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</tbody>
</table>

Several design improvements of the Fabry-Pérot filters and spectrometer modules are currently under development. The primary aims of our developments are:

**Fabry-Pérot filter with improved Spectral Resolution:**
- Higher order configuration
- For hydrocarbons in the range (3.1 ... 3.7) µm
- Other ranges possible on request

**Dualband Designs:**
- Extend tuning ranges by simultaneous use of two interference orders
- Dual-channel detector with integrated beam splitter

**Microspectrometers for fast Measurements:**
- Improved dynamic filter response, high scanning speeds
- Combination with fast photodetectors
Evaluation Kit

The kit supports customer needs for an initial test of FPI detectors without having to develop test circuitry or software themselves. It allows easy control of detector and IR source with customized software to analyze the detector signals. With the help of this kit a quick and easy configuration of a simple Fabry-Pérot spectrometer is possible.

The following features are integrated:

- Activation of FPI detector and analysis of signals
- Activation of IR source
- Extensive configuration options including mappings of complete spectra by use of the "Fabry-Pérot evaluation workbench" software

The Evaluation kit includes a basic board and a detector board with USB interface, USB cable, ribbon cable, CD-ROM with test and measurement software, USB driver, and a manual. The basic board is compatible to all FPI detectors and FPI detectors with ASIC control. A version of this kit with an IR source is also available upon request.

Technical Data

Specifications

- Power supply 12 V
- Current consumption 150 mA (without IR source)
- Integrated detector supply ± 5 V
- Integrated Fabry-Pérot control (e.g. max. 35 V for LFP-3144C-337)
- Control of IR source up to 800 mA, DC to 500 Hz (square, (0 ... 100) % duty cycle)
- Signal acquisition with 12 Bit, 2 kHz, analysis with FFT-technique

Requirements

- PC with Windows 2000, XP, Vista, 7 or higher with USB 2.0 interface
- Power supply 12 V DC (300 mA minimum)