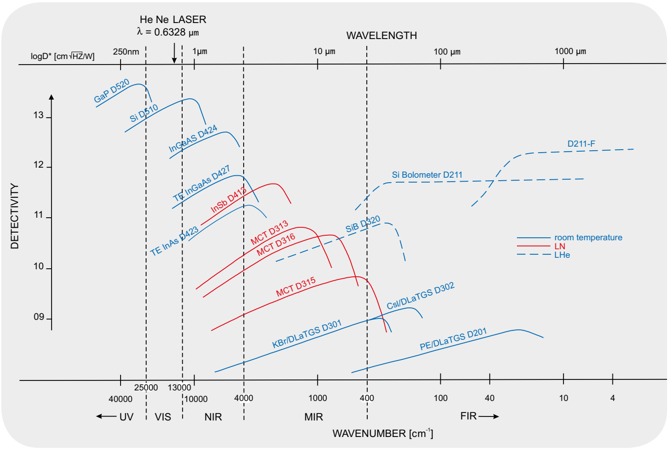

Application Note AN M161

Detector characterization using FTIR spectrometer

Introduction

The VERTEX Fourier Transform Infrared (FTIR) spectrometer series are applied for the accurate Transmittance, Absorbance and Reflectance measurements of solid samples at room and low temperatures. Therefore such FTIR spectrometers are used in the area of solid state physics as a research measurement tool for the development of detector material commonly [1, 2 and 3]. Beside the analysis of detector material as well there is the need to characterize the finally designed detector devices. Bruker provides the necessary optical, electronics and software adaptations to apply the VERTEX high-end R&D FTIR for general principles of detector characterization.

General principles of detector characterization

Detectors can be characterized by three basic parameters: the spectral range over which they respond, the speed with which they respond, and the small radiant power they can detect. Information about these basic parameters is required for all detector applications.

Sensitivity is tested by comparison with a detector of known sensitivity. Detector speed is defined by the response to the light modulated at various frequencies. Spectral range is measured using monochromators, tunable sources, or FTIR spectrometers. FTIR has a definite advantage in the detector characterization because of high optical throughput (Jacquinot’s advantage) and the capability to measure spectral information from all wavelengths simultaneously (multiplex or Fellgett advantage). All three basic detector parameters can be obtained using an FTIR instrument.

Keywords	Instrumentation and Software
Detector characterization	VERTEX 80V/80/70V INVENIO-R
Relative/absolute detector response	VERTEX 80V/80/70V INVENIO-R
Modulation dependent detector response	VERTEX 80V/80/70V INVENIO-R
Amplitude-modualted step-scan	S510/8 S510/Z S510/IR

Standard detector characterization with FTIR spectrometers

An FTIR spectrometer is a single channel instrument. Light from the source is modulated by the interferometer and focused onto the detector. The spectrometer single beam spectrum (Sb) can be defined as:

Sb= E1 x E2 x E3 [Eq.1]

Where:
E1: Emittance of the source
E2: Characteristics of the beamsplitter including the reflectivity of the mirrors and the modulation efficiency of the interferometer (instrument function).
E3: Detector response

The standard configuration of a FTIR spectrometer includes a room temperature DLaTGS detector. This detector produces a signal in response to temperature change due to absorption of light. The response of this detector versus wavelength is flat over a wide spectral range. The relative detector sensitivity of an unknown detector can be obtained by the division of the single channel spectrum measured with the unknown detector to the single channel spectrum measured with the DLaTGS. The unknown detector can be mounted in the spectrometer sample compartment or outside the spectrometer at any of the IR beam exit ports. Bruker INVENIO and VERTEX 80/80v spectrometers have three and five optional exit ports, respectively. External focusing optics are required for focusing the IR beam onto the external detector (Figure 1). The analog-to-digital

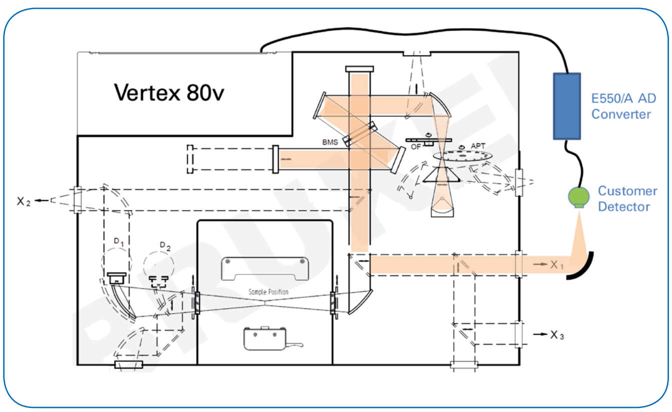

Fig.1: External detectors mount. Collimated beam from FTIR spectrometer is focused to the detector using parabolic mirror. Detector analog signal is digitized with E550/A analog-to-digital converter.

converter (part number E550/A) digitizes analog detector signal. E550/A can record two signals simultaneously with 24 bit precision. The recommended input range is ± 8.3 V. It includes a software selectable 2,4,8,16 or 32x amplifier and can provide +12 V to the detector. A special adaptation for the characterization of single element and focal plane array detectors is also available (Figure 2)

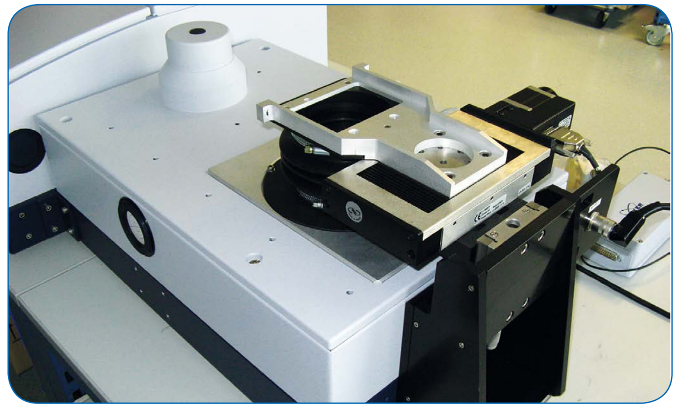

Fig. 2: External adaption for analysis of single element detectors and/or focal plane array detectors.

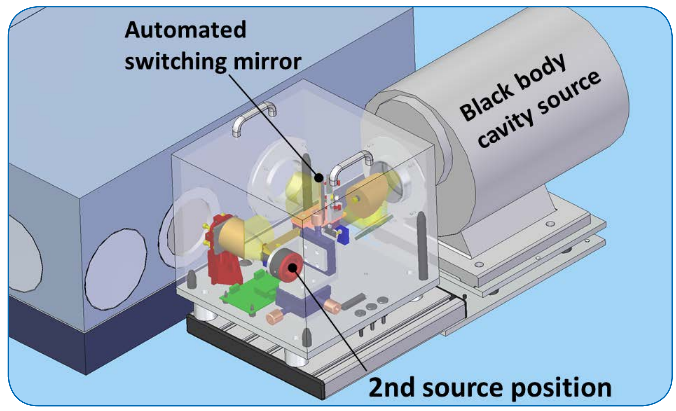

Fig.3: External platform for emission measurements, where the tunable cavity source serves as reference. Depending on the application, either the emission adapter A540 or the high temperature cell can be adapted as a second source.

The module offers the possibility to adapt a Bruker DigiTect detector, an external single element detector and a focal plane array detector. Versions for side looking and down looking arrays exist. For FPAs providing their data in commonly used CameraLink format (base or medium), an integration of the data read out of the FPA inside the OPUS software is possible.

Measurement of the absolute detector response

Measurement of the absolute detector response requires a calibrated detector and source with a known emissivity. A calibrated detector can be obtained from the detector manufacturer or calibration can be performed by the National Physics Laboratory (UK). An ideal emission source for detector characterization is a black body emitter. Bruker offers an adaptation for an external black-body cavity source tunable from 50 to 1050° C (Figure 3). The Planck Energy distribution for such source can be calculated using the standard functionality of OPUS software. An internal NIR source (tungsten lamp) can also be used if no black body source is available. The emissivity of the tungsten lamp is comparable with the emissivity of black body at 2600 K.

If the calibrated response characteristic of the detector E3 and emissivity E1 are known, the instrument function E2 can be calculated as:
E2 = Sb with calibrated detector / (E3 x E1) [Eq. 2]

Spectral range and sensitivity of unknown detector can be obtained as:

E3 (unknown) = Sb with unknown detector /(E2 x E1)[Eq. 3]

Measurement of the modulation dependent detector response

The detector response to modulated light can be acquired using single channel spectra measured in the continuous or step-scan mode. In the continuous scan mode, the scanning mirror of interferometer moves at a constant speed and modulates light at frequency f (often known as Fourier frequency):

$f(kHz)=V\,\nu/L$ [Eq.4]
where:
V is the mirror velocity in kHz
ν is the wavenumber in cm^{-1}
L is the frequency of the laser that controls the data collection. L=15,823 cm^{-1} for the VERTEX 70v and 80/80v series and INVENIO-R. L=11,670 cm^{-1} for the INVENIO-S.

As can be seen from this equation, the modulation frequency in continuous scan mode is wavelength dependent. Detector response at the particular modulation frequency can be calculated from measurements at several velocities (dotted line in Figure 4). The INVENIO-R has 8 standard and 4 optional velocities with the highest optional velocity of 160 kHz. The number of preset velocities for the VERTEX 80 and 80v are 12 (plus 4 optional). The highest optional scanner velocity for these systems is 320 kHz. Moreover, the variable velocity option allows setting the scanner velocity to any value from a few tens of Hz to hundreds of kHz. This option can be valuable for the analysis of FPAs as well because the max. read out frequency of the array (or a suitable sub-array) determines the maximum scanner velocity.

Direct measurement of detector response versus modulation frequency can be performed in the step-scan mode with the chopper and a lock-in amplifier. The IR beam is modulated by the chopper in the beam path. The scanning mirror moves in discrete steps and stops at the positions where the interferogram is digitized. The detector signal is demodulated by the lock-in amplifier

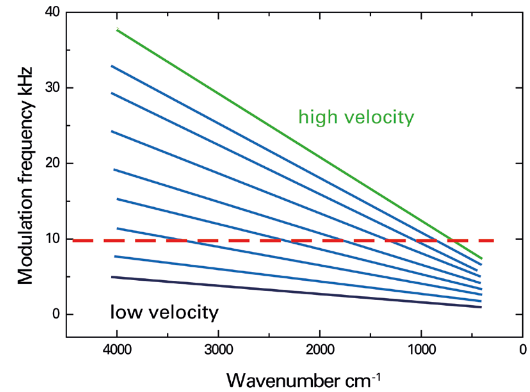

Fig.4: Light modulation frequencies for different mirror velocities. Detector response at the specific modulation frequency (red dotted line) can be calculated by measuring a series of single channel spectra at different mirror velocities.

at each sampling position. The single beam spectrum is calculated after the completion of data collection for all positions, which are required to achieve spectral resolution. Two measurements need to be performed: one with the calibrated detector and another with the unknown detector. The detector response at the chopper frequency is calculated using equations [2] and [3].

Conclusion

Bruker Optics offers several ways for the fast characterization of the spectral range, speed, and sensitivity of detectors.

References

[1] Bruker Application Note AN28 Photo Thermal Ionization Spectroscopy (PTIS)
[2] Bruker Application Note AN55 Quantification of shallow impurities in Silicon
[3] Bruker Application Note AN134 Infrared Photoluminescence (PL) Spectroscopy

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