APPLICATION NOTE

MEASURING THZ RADIATION: CHOOSE A PYROELECTRIC DETECTOR OR GOLAY CELL?

Before we start to describe the particular attributes of one detector versus the other, it makes sense to spend a little time reviewing some technical information about what each is and how they work.

What is a Golay Cell and how does it function?

A Golay Cell is a "photo-acoustic" device that is sensitive, works at ambient temperatures and has a broad spectral response. The basic elements that make up a Golay Cell are: a 6 mm HDPE or diamond window, a small fragile gas chamber that includes a thin, partially absorbing metallic film and what is called an "optical microphone section". When THz radiation is transmitted through the window and absorbed by the thin metallic film in the gas cell, the gas is heated, causing it to expand and distort the mirrored back wall of the cell. This distortion (or movement) is monitored and measured by the combination of an LED, some optics, a grating and a photodiode. The output of the photodiode is proportional to the displacement of the mirrored wall of the gas cell. Its output is calibrated against a source of known power output in Volts/Watt.

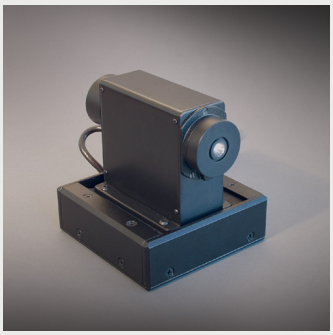

Figure 1: Golay Cell (without the power supply)

Figure 2: Hybrid THz Pyroelectric Detectors

What is a $LiTaO_3$ Pyroelectric Detector and how does it function?

A Pyroelectric Detector is an AC Thermal sensor that is sensitive, typically used at room temperature and has broad spectral response covering most of the electromagnetic spectrum, including the THz region. The Pyroelectric is based on a thin, permanently poled, ferroelectric crystal (i.e. $LiTaO_3$) that exhibits a pronounced thermal effect (the pyroelectric effect) where its instantaneous polarization is a function of the rate of temperature change of the crystal. By applying conductive electrodes to the top and bottom surfaces of the crystal, the resulting charge can be coupled out of the device and calibrated in terms of its current responsivity in μA/W. The Pyroelectric Detector normally includes a voltage or current mode circuit for optimum performance and is ultimately calibrated in Volts/Watt or Volts/Joule.

How does the performance of a Golay Cell compare to that of a $LiTaO_3$ Pyroelectric Detector?

Now lets take a look at the performance specifications that are typical for the Golay Cell versus that of a Pyroelectric Detector. Note that there is only one type of Golay Cell at present, whereas a Pyroelectric device can take many forms, for example a Hybrid Detector/Amp and Power or Energy Detector (i.e. detector, discrete electronics and microprocessor). We'll choose the Pyroelectric Hybrid Detector for this comparison.

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SPECIFICATION	GOLAY CELL	PYROELECTRIC	COMMENTS
Detector Size	6 mm Ø	1.5 to 9 mm Ø	Pyros can be made larger
Window Material	HDPE or Diamond	Windowless	In option: single crystal, wedged quartz, sapphire, TPX and more
Wavelength Range	7 to 8000 µm	0.1 to 3000 µm	
Maximum Power	10 µW	>50 mW/cm^2	Pyros can be obtained with
Optimum Chopping Frequency	20 Hz	5 to 10 Hz	metallic or black absorbers
Noise Equivalent Power (NEP)	1.2 x 10^{-10} W/(Hz)^{½}	4 x 10^{-10} W/(Hz)^{½}	
Responsivitiy	150 K @ 20 Hz	150 K @ 5 Hz	Using a 1000 °K black body source
Detectivity	7 x 10^{9} cm(Hz)^{½}/W	4 x 10^{8} cm(Hz)^{½}/W	@ optimum chopping frequency
Power Requirement	VAC	Battery or VAC	Golay Cells require power supply
Operating Temperature Range	5 to 40°C	-5 to 120°C	
Package Size	126 x 45 x 87 mm	8 Ø x 19 mm	Hybrid pyros are mounted in TO5/TO8 cans
Response Time	25 msec	µsec to msec	Pyro devices are inherently fast thermal detectors

What conclusions can we draw from the comparison?

The Golay Cell is slightly more sensitive, it has a larger sensing area (which may be important when measuring a point or extended source), a fixed window (which will affect its spectral response), it has a slow response time, is physically large and requires AC voltage for operation. The Golay Cell is "one of a kind" at present. The Pyroelectric Detector on the other hand is almost as sensitive, can be used with or without a window, may include a black absorber to enhance flat spectral response, is inherently fast, has a large operating temperature, is small and can be operated off batteries or an AC supply. Gentec-EO THz Pyroelectric products are available as Hybrid Detectors (QS-THZ), Integrated Analog instruments (THZ-I-BNC), and Digital Lock-In Radiometers (THZ-B).

Below you can compare the typical spectral response of a $LiTaO_3$ Pyroelectric Detector, like our QS2-THZ-BL hybrid detector, to that of a typical Golay Cell. Note that the spectral response is very similar. This is because both devices rely on a the absorption and thermal response of a thin metallic film.

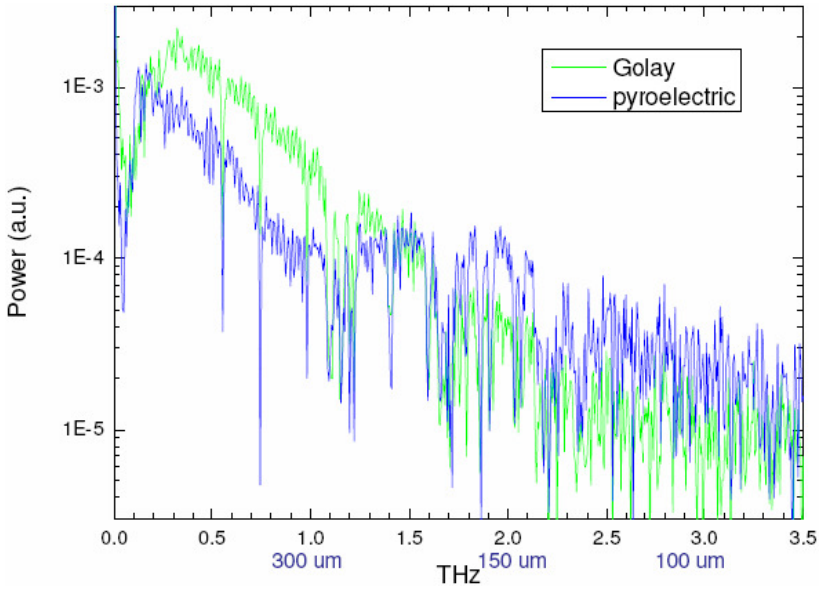

Figure 3: Typical THz spectral responses of a pyroelectric detector and a Golay cell. (Courtesy of University of Leeds)

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In summary, let's take a look at the relative advantages and disadvantages of both types of sensors.

GOLAY CELL

ADVANTAGES	DISADVANTAGES
Very sensitive (sub nW)	Very fragile (thin membrane)
Broad spectral response	Slow response
Well characterized THz spectral response (Though not calibrated)	Large, cumbersome two piece housing
Has been used as a standard in Astronomy	Very sensitive to mechanical vibration
and Extreme IR for years	Limited dynamic range (10 µW max.)
Relatively large area (6 mm Ø)	Must Inlude a HDPE or Diamond window for operation
	One model only (one configuration)
	Expensive (~$12K to $15K)

PYROELECTRIC DETECTOR

ADVANTAGES	DISADVANTAGES
Sensitive (nW)	Slightly Lower Detectivity (Can be increased with use of reflective optics)
Broad spectral response	THz Spectral response is not well established (NIST is in the process of developing THz standards)
Small, compact housing	Microphonic response requires attention when setting up the system
Large operating temperature range	
Fast response time	
Can operate without a window	
Can handle relatively high power (50 mW)	
Multiple models and detector sizes available	
Relatively inexpensive	
Quite rugged (not fragile)	
Readily available	

What is the final Conclusion?

Though the Golay Cell has been used in the THz field for many years (more than 30 years), it has some significant disadvantages compared to the $LiTaO_3$ Pyroelectric Detector. The Pyroelectric Detector, on the other hand, has not been used until recently (in the last 5 years) in the THz field, though the thermal detector technology is mature, and has several advantages (most importantly, its small size, multi-element configurations, low noise equivalent power, broad spectral response and low cost). For relative measurement of THz sources, the $LiTaO_3$ Pyroelectric Detector is a great choice today and, as the sensor science further develops, the choice will only look better.