VIGO SYSTEM

WHITEPAPER

PLASTIC SORTING USING MID-IR LINEAR DETECTOR ARRAY

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In the period of increased product supply, the quality of products delivered and the way they are presented become more and more important. Intelligent sorting is a mechanized solution that enables accurate sorting of products. The automation of the sorting process increases production capacity. This has a direct impact on profit, and, thus, on the quality and capacity of the products delivered.

Today, it is difficult to imagine a **world without plastics** - plastic objects are used in every area of our lives. The production of plastic products is much cheaper than the use of natural materials, moreover it is much faster thanks to advanced production methods. Plastics are materials that have been made by man from non-naturally occurring synthetic polymers or natural polymers (modified using appropriate additives). Colloquially, these types of materials are referred to as the collective name “plastic”, but you have to remember that this is a big simplification, which does not take into account the differences between individual types of polymer materials. The need of transparent, completely water resistant and with many other chemical factors raw materials turned out to be a turning point for the industry. This translated into a much greater availability and lower price of a single item.

Development of effective methods for the mass production of plastic objects has revolutionized many industries, but what about mass recycling methods?

Symbol	Polymer	Common products		Recycled products	Spectral range [µm]
1 PETE	**Polyethylene Terephthalate**	Soda & water bottles, cups, jars, trays, clamshells		Clothing, carpet, clamshells, soda & water bottles	**5 - 14**
2 HDPE	**High-Density Polyethylene**	Milk jugs, detergent & shampoo bottles, flower pots , grocery bags		Detergent bottles, flower pots, crates, pipe, decking	**3.3 - 14**
3 PVC	**Polyvinyl Chloride**	Cleaning supply jugs, pool liners, twine, sheeting, automotive product bottles		Pipe, wall siding, binders, carpet backing, flooring	**7 - 16**
4 LDPE	**Low-Density Polyethylene**	Bread bags, paper towels & tissue overwrap, squeeze bottles, trash bags, six-pack rings		Trash bags, plastic tumber, furniture, shipping envelopes, compost bins	**3.3 - 14**
5 PP	**Polypropylene**	Yogurt tubs, cups, juice bottles, straws, hangers, sand & shipping bags		Paint cans, speed bumps, auto parts, food containers, hangers, plant pots, razor handles	**3 - 13**
6 PS	**Polystyrene**	To-go containers & flatware, hot cups, razors, CD cases, shipping cushion, cartons, trays		Picture frames, crown molding, rulers, flower pots, hangers, toys, tape dispenses	**3 - 18**
7 OTHER	**Other**	Polycarbonate, nylon, ABS, acrylic, PLA: bottles, safety glasses, CDs, headlight lenses		Electronic housings, auto parts	**--**

There are many possibilities how to use recycled materials.

A recycled plastic can be used to make: water bottles, pipes, furniture, auto parts and much more. Having said that, the need for proper detection of plastic is growing every day. **Traditional plastic sorting deals with problem how to distinguish specific plastic types.** Even small portions of the plastic element can reduce the effectiveness of recycling. Additionally, the problem of plastic sorting is not only affecting land trash but also marine debris.

One way of plastic sorting is to do it on a sorting lane [Figure 1]. Firstly, we need to cut plastic into small fragments. Secondly, the small plastic parts are measured. Lastly, correctly identified plastic parts are put in the separate hole with air jets. Later on, this process can be repeated to deviate on different plastic types like: PETE, HDPE, PP, etc.

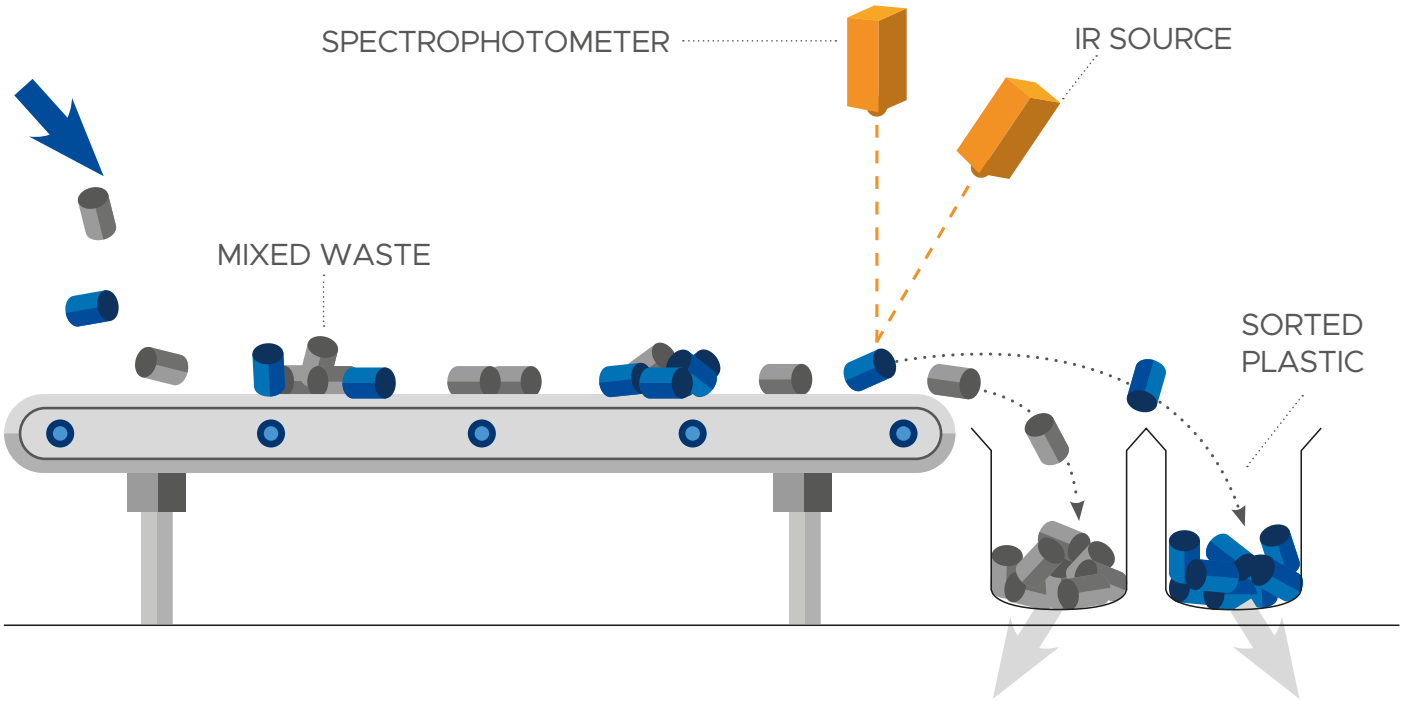


Figure 1
Example of sorting plastic by using VIGO detectors.

The simplest yet very accurate method for identification and classification can be made with spectrophotometer methods such as FT-IR. In FT-IR method IR light is illuminating the previously fragmented plastic parts. Reflected light is collected by the spectrophotometer system where thanks to detection by the VIGO detector we obtain a signal. Later this signal is transformed with Fourier Transform in order to obtain specific information about scanned material [Figure 2]. The analysis is quick and precise.

Each type of plastic has its own absorption bands which can be used for material identification. VIGO's linear detector array can differentiate all types of plastic through a detection of these characteristic absorption bands [Figure 2]. The principle is visible below.

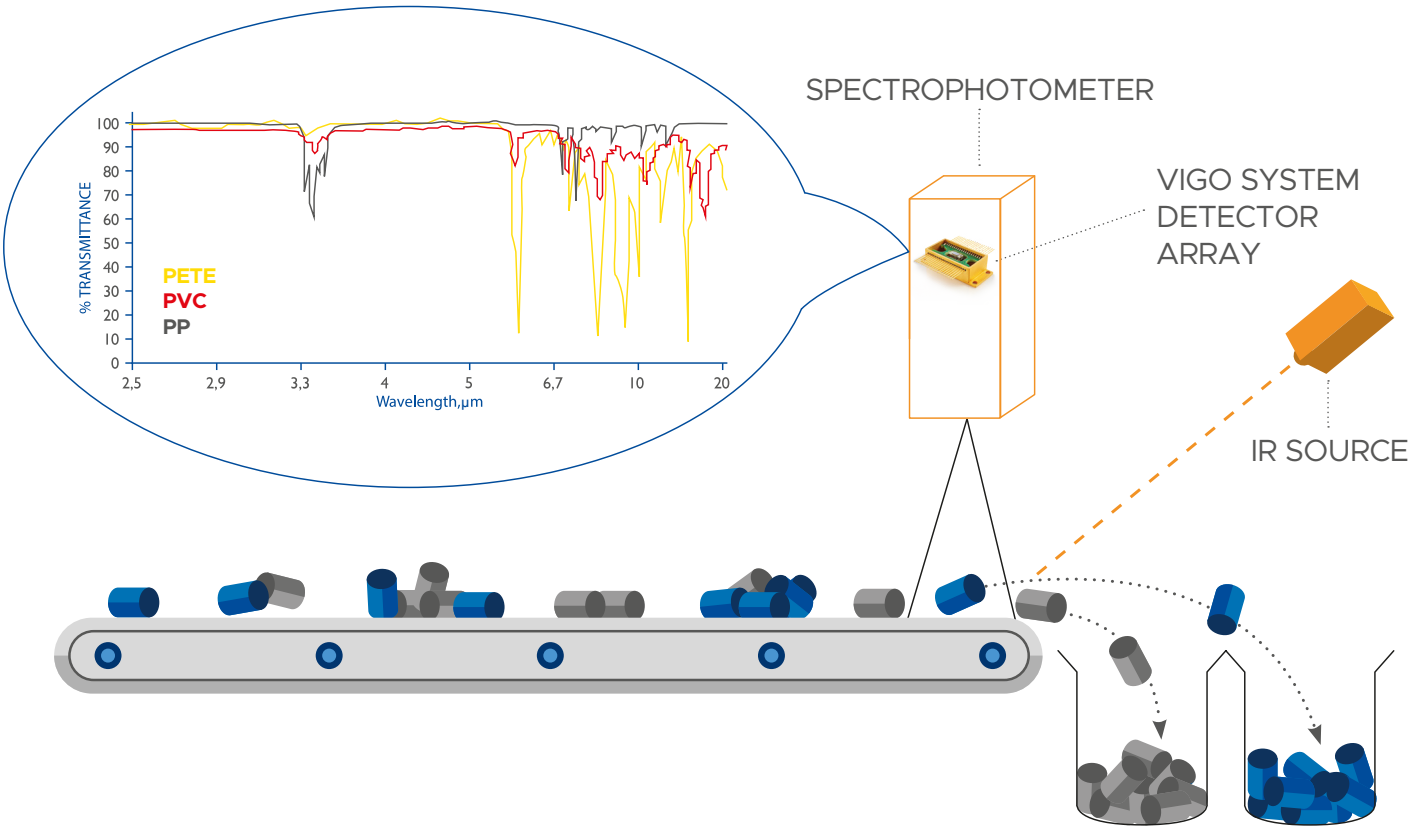
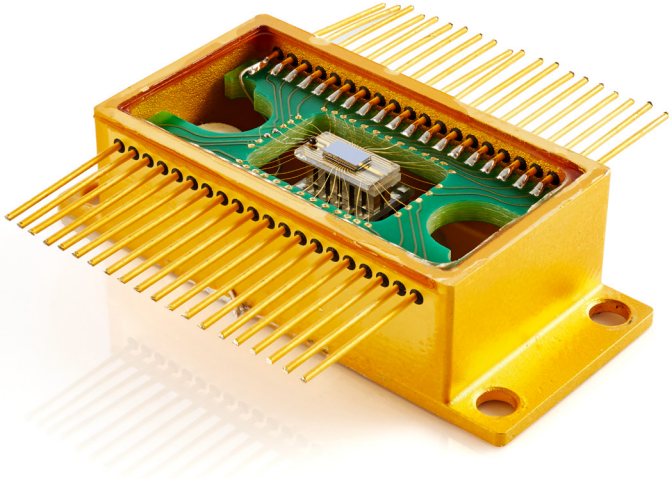


Figure 2

The method of measuring plastic by FT-IR.
The chart shows examples of absorption bands of various plastics.

By detection of each marked absorption band the VIGO detector can "see" a type of the measured plastic. **Organic compounds like polymers can be observed more precisely in the MWIR range in comparison to the NIR range.** The use of multielement detectors in spectrophotometry allows to eliminate moving parts or filters. This simplifies the spectrophotometer and increases system reliability.

A 32-element linear array detector is recommended for OEM spectrophotometer for each polymer absorption band. Key benefits from using linear array detector include:



- **Elimination of moving parts and/or filters**
- **High separation accuracy due to high SNR ratio**
- **High speed measurement**
- **Low power – uncooled detector**

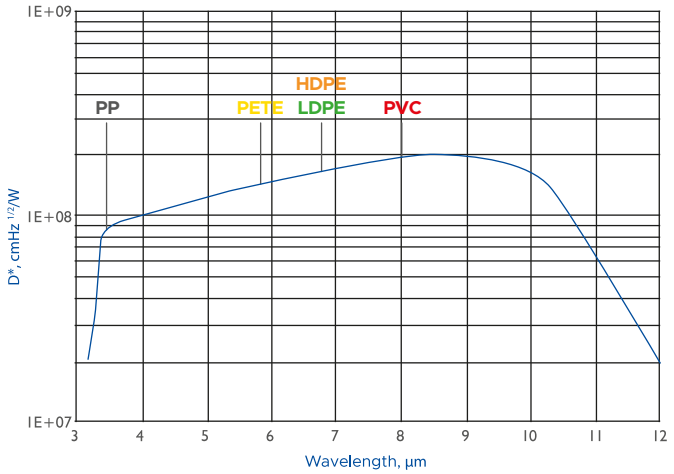


Figure 3

VIGO's detector detectivity and some examples of absorption bands which can be used for plastic identification.

MID-IR Multielement HgCdTe / InAsSb detector features

- 3-14 µm wavelength band
- High S/N ratio
- Low drift of output signals
- High frequency operation

Module configuration options

- USB digital interface
- Customized mechanical layout
- Microprocessor inside

VIGO specializes in customized detectors and modules dedicated to the client's application. 32-element arrays are now available in production with dedicated preamplifiers.

The detectors line is a set of individual active elements and the signal of each of them is output independently. A multielement detector, unlike a single-element detector, allows to record radiation of different wavelengths at the same time. Most of the multielement detectors produced in the VIGO System are based on HgCdTe (epitaxial HgCdTe heterostructure) photovoltaic detectors, thermoelectrically cooled.

Chart 1 presents examples of spectral characteristics and Table 1 - parameters of detectors optimized for different wavelengths.

Chart 1

Exemplary spectral detectivity.

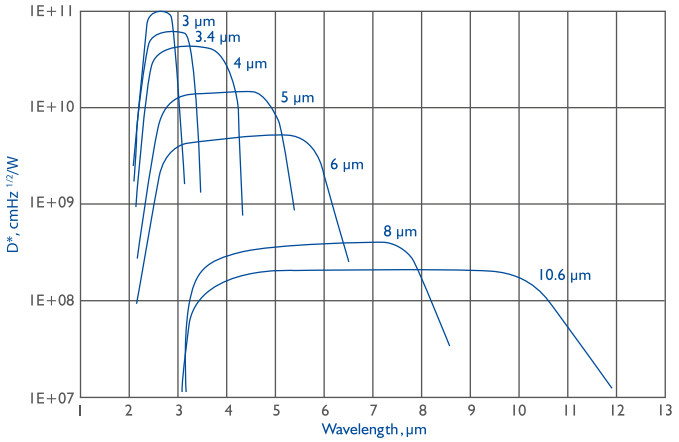


Table 1

Detectivity and time constant of HgCdTe detectors.

Optimum wavelength λ_{opt} µm	Detectivity D* (λ_{opt}), cm·Hz$^{1/2}$/W	Time constant τ, ns
3.0	≥ 7.0×10^{10}	≤ 280
3.4	≥ 4.0×10^{10}	≤ 200
4.0	≥ 3.0×10^{10}	≤ 100
5.0	≥ 9.0×10^{9}	≤ 80
6.0	≥ 2.0×10^{9}	≤ 50
8.0	≥ 7.0×10^{8}	≤ 45
10.6	≥ 7.0×10^{8}	≤ 10

Our technological capabilities also allow the production of multielement detectors with InAsSb (*indium arsenide antimonide*) using the MBE (*Molecular Beam Epitaxy*) method.

These devices are complying with the RoHS Directive. They are designed for applications where higher resistance to difficult operating conditions should be ensured.

The great advantage of VIGO System multielement detectors is that there is no need for cryogenic cooling. This results in a reduction in the size and weight of the device, and hence a reduction in power consumption.

Figure 4 shows the dimensions (unit: mm) of TO8 16pin **(a)** and flatpack 40pin **(b)** housings in which VIGO System multielement detectors are mounted.

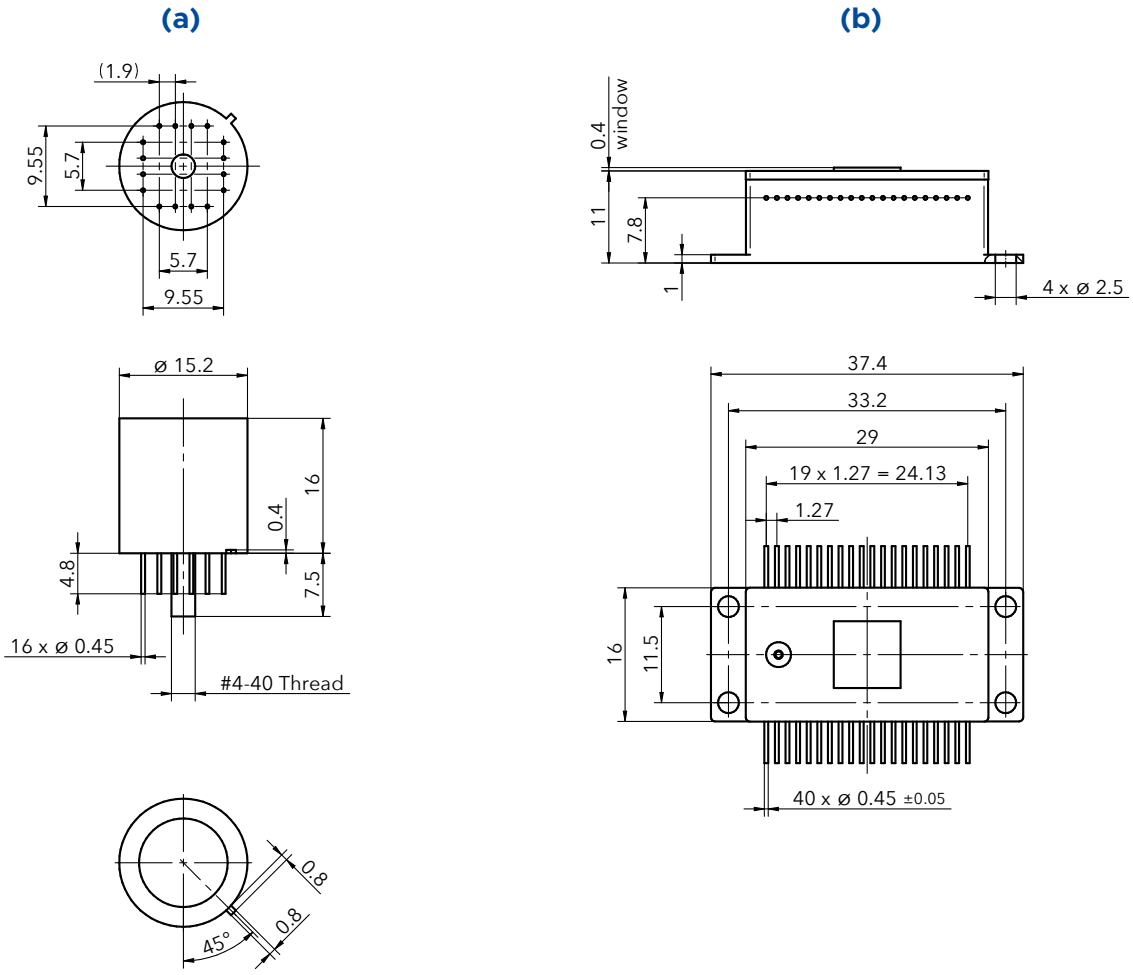


Figure 4
Mechanical layout.

KEY FEATURES OF THE PRODUCT

Advantages:

- **High sensitivity**
- **High-speed response**
- **Convenient cryogenic-free operation**

The key advantages of VIGO System multielement detectors are very high accuracy and measurement speed. In temperature measurements, accuracy of a single millikelvin is achieved, even when measuring an object present in the field of view for only a few microseconds.

In spectrophotometry, these advantages allow obtaining high-quality measurements in a short time. Measuring the entire spectral range at the same time shortens the measurement time (compared to the time needed for scanning and full spectrum analysis in one-piece detectors).

Table 2 presents the parameters of VIGO System multielement detectors, selected for the needs of individual applications.

Table 2
Parameters.

Parameter	Value
Array format	linear or bilinear, up to 32 elements
Active elements material	HgCdTe or InAsSb
Detector type	PV (phtovoltaic) or PC (photoconductor)
Operating wavelength	MWIR ($\lambda_{cut\text{-}off}$: 3.0 to 8.0µm), LWIR ($\lambda_{cut\text{-}off}$: 8.0 to 14.0µm), $\lambda_{cut\text{-}on}$ can be optimized upon request
Pixel size	minimum 25×25µm
Cooling	2- or 3-stage TEC
Active elements temperature	210 – 270 K
Temperature sensor	thermistor or diode (accuracy up to ±1 K)
Time constant	1 – 500 ns
Package	TO8 16pin or flatpack 40pin
Window	Si/Al_2O_3/Ge with or without anti-reflection coating, planar or wedged
Ambient temperature	0 to 70 °C
Storage temperature	-20 to 50 °C

VIGO System multielement detectors are offered with a wide range of accessories. Accessories can be tailored to the needs of application and integration with the user's system. Table 3 shows the examples.

Table 3
Accessories.

Accessory	Description
TEC controller	onboard analog controller
Lens mount	C-mount 1" or SM1 THORLABS
Preamplifier	ultra-low noise, selectable bandwidth
DAQ	SPI or USB HS

APPLICATIONS

Multielement detectors are used in point, non-contact temperature measurements of fast moving elements. Real-time monitoring of temperature of external and internal wheel bearings and high-speed train brakes can serve as an example. Other applications include: temperature measurements on production lines, anomalies detection, monitoring of cooling or combustion profiles etc.

Currently available spectrophotometers usually use the near infrared range of 0.8-2.5 µm. Organic compounds, greenhouse gases, hydrocarbons can be more precisely observed in the MWIR (3.0 - 8.0 µm) and LWIR (8.0 - 14.0 µm) ranges. The use of multielement detectors allows to eliminate the need for filters or use moving mechanical elements for scanning the spectra or space, and, consequently, eliminates errors related to their work. VIGO System multielement detectors allow for high quality spectrophotometric measurements in a short time and very low noise also allows for operation with low-power sources: thermal or IR diodes.

High performance optical sorting systems are another application of multielement detectors. The detector line scans elements moving on the tape and allows their specific chemical composition to be identified. Optical sorting can be used in the mining, food, chemical and pharmacological industries.

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