CRS#: **SS201**

Session Title: **Advancements in Mail Screening**

Day/Date: **Monday, October 2, 2023**

Round/Time: **Round One, 2:00-3:00pm**

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CEO, Research International, Inc.

Please be courteous to others and turn all communication devices to silent mode

Traditional Postal Screening Methods

In the past, the screening of mail has primarily been done on a periodic basis. For example:

- **Hourly or daily PCR tests;**
- **Immunoassay tests on a mail batch basis; or**
- **Canary™ tests on a daily basis.**

Traditional Postal Screening Methods

These approaches can result in at least three problems:

High cost of consumables

Slow processing rates / delayed mail

Widespread contamination during periods between tests

Event-Driven Postal Screening

An attractive alternative is "event-driven" screening, where postal articles are examined in real-time or near real-time.

A diagnostic threat-identifying assay is performed *only* if a suspicious event occurs.

This approach eliminates most testing.

Event-Driven Postal Screening

This approach has multiple benefits:

Sharply lower costs due to decreased testing

Mail is released immediately if no threat is found

Threat identification is "on" all the time

Event-Driven Methods

Shortly after 9/11 and the anthrax letters, there was a flurry of activity to develop contactless methods for detecting biological threats.

Some of the most studied approaches have been optical in nature.

A major emphasis has been the use of optical fluorescence to catch threat aerosols released during mail handling.

Some progress has been made in the use of Raman methods to identify threat aerosols, but to date the systems developed have been very expensive and have not shown significantly better performance than the fluorescence methods.

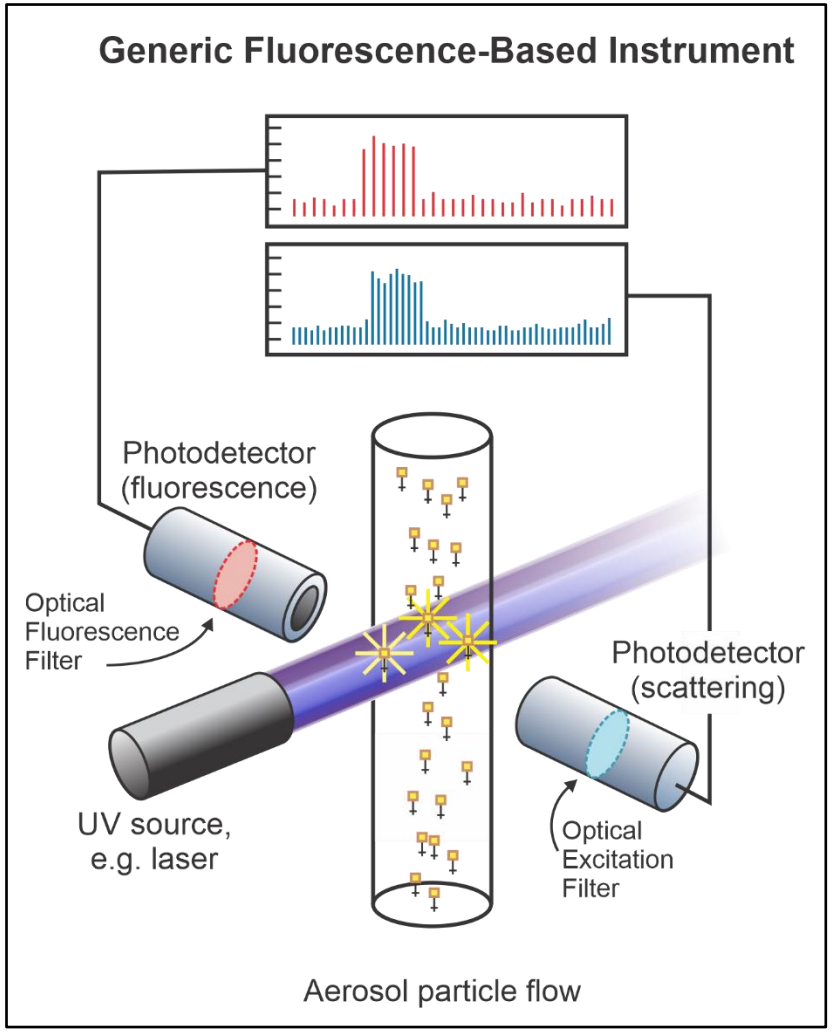
Fluorescence-Based Aerosol Detection

Certain biological molecules emit fluorescent light when excited at shorter wavelengths.

Spores, in particular, have flavins as a shell component. They can be made to emit visible fluorescence when excited by deep blue light such as from a blue CD laser.

By employing UV excitation in the "UV-A" band from about 320nm to 400nm, additional biomolecules such as NADH can be excited.

However, it is difficult to analyze emitted fluorescence in enough detail to definitively identify beyond a class-level, and its main use is as a broadband biotrigger.



Fluorescence Detector Issues

A difficulty with the UV-A and blue LED fluorescence detectors is that there are several non-biological materials that fluoresce when excited at these wavelengths:

- **Man-made paper and detergent whiteners;**
- **'Fluorescent' minerals; and**
- **Organic compounds called Polycyclic Aromatic Hydrocarbons or PAHs, frequently formed during incomplete combustion.**

This results in some level of false positives that can be difficult to eliminate.

In addition, some threats of interest such as ricin do not strongly fluoresce with UV-A or blue LED excitation.

Emerging Fluorescence Detector Technologies

In the early 2000s, Edgewood Chemical and Biological (Formerly ECBC) increased the sensitivity of fluorescence detection by using photon counting instead of analog pulse electro-optic methods:

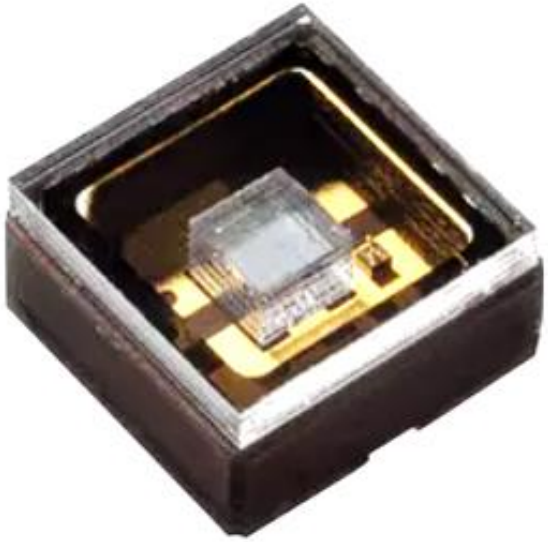
- **Smaller particles can be accessed since the detectable "packet" of photons associated with an individual particle can be quite small.**
- **Increased resistance to electro-optic drift is possible since a photon's electronically amplified pulse height can drop considerably before it falls to noise levels.**
- **Research International licensed the technology in 2010 and has been improving its capabilities since that time.**

New UV-C Light Sources I

In recent years there has been a push to develop powerful LEDs in the UV-C waveband (less than 300nm).

The primary driving applications have been the sterilization of drinking water and air.

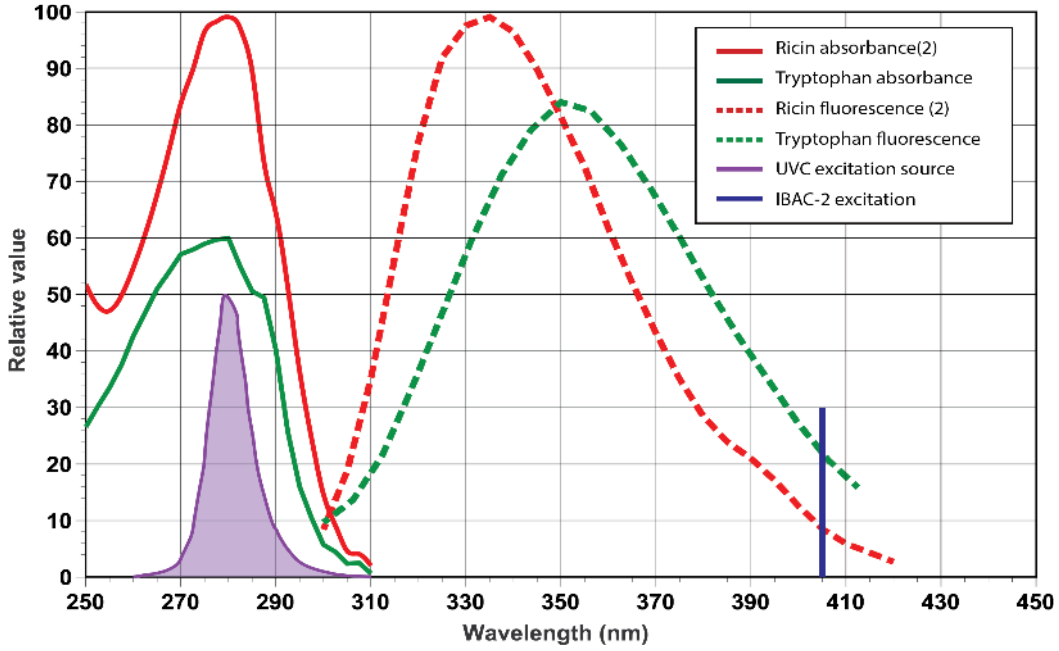
These new light sources also offer powerful new capabilities for fluorescent biodetectors.



New UV-C Light Sources II

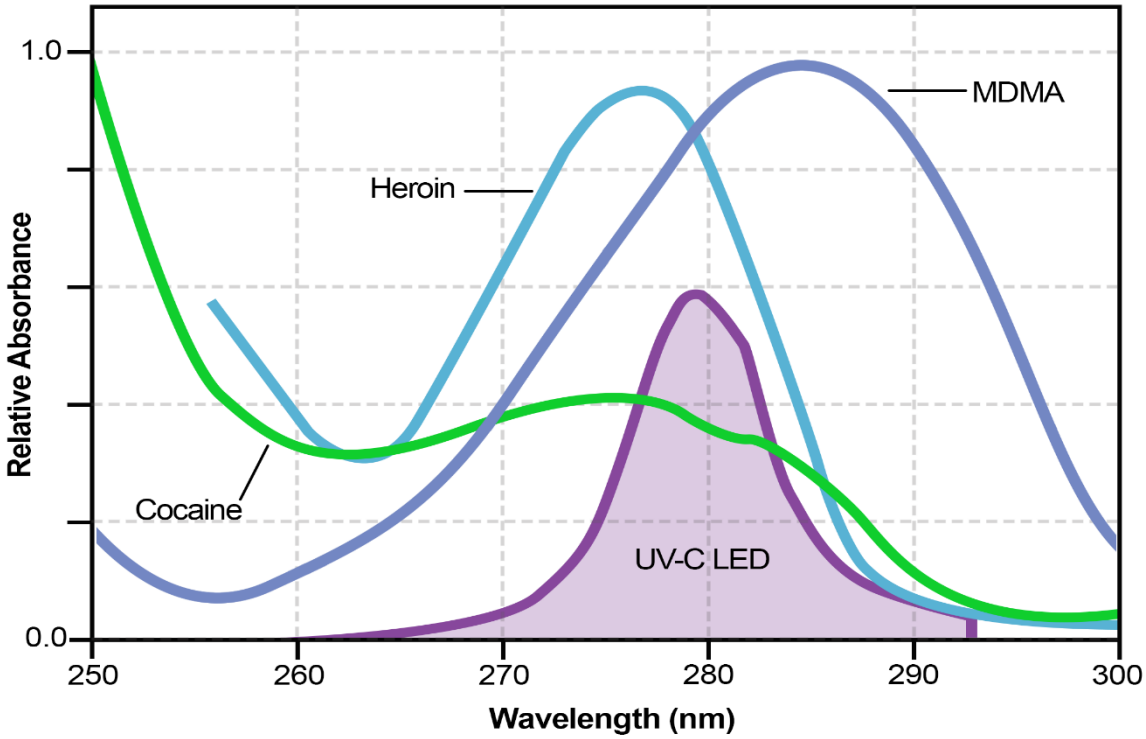
LEDs in the UV-C wavelength range are now available with up to 5% electrical-to-optical conversion efficiency and a 10,000 to 20,000 hour lifetime to 50% output.

As shown here for a typical 280nm source, the excitation power is well matched to the optical absorption of bio-proteins such as tryptophan and bio-threats such as ricin.



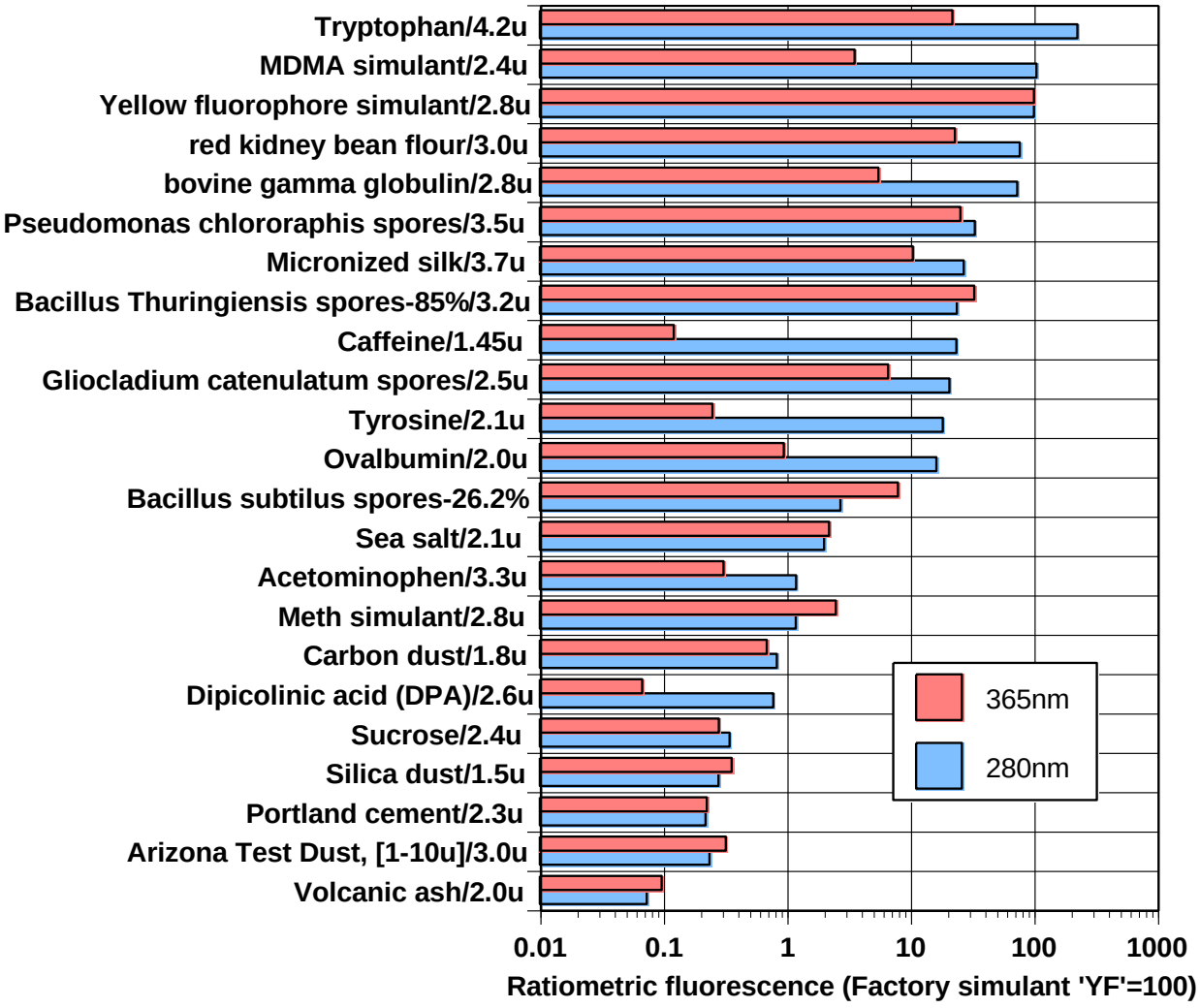
New UV-C Light Sources III

As shown here for the same 280nm source, the excitation spectrum is well matched to the optical absorption of many illicit drugs such as heroin, cocaine and MDMA. All are expected to fluoresce, although such data on solid aerosol particles has not been found.



Relative response with 365nm and 280nm excitation:

- 23 different aerosols
- MMD in microns also measured
- Spores and proteins show strong response
- Interferents such as soot and cement dust have low fluorescence



Application to High-speed Mail Screening

Past attempts to apply fluorescence detection to mail screening have been abandoned due to several issues:

- **Obscuring dust generated during mail processing;**
- **Small fluorescent signals compared to noise baselines;**
- **Slow detector reporting rates of 15s or more.**

In 2022, Research International and Tritek Technologies, Inc. collaborated to develop a purpose-built UV-C based system for biological and drug detection that would be capable of real-time operation on a high-speed mail sorter.

Early U.S. Patents for Mail Bio-Aerosol Detection/Identification

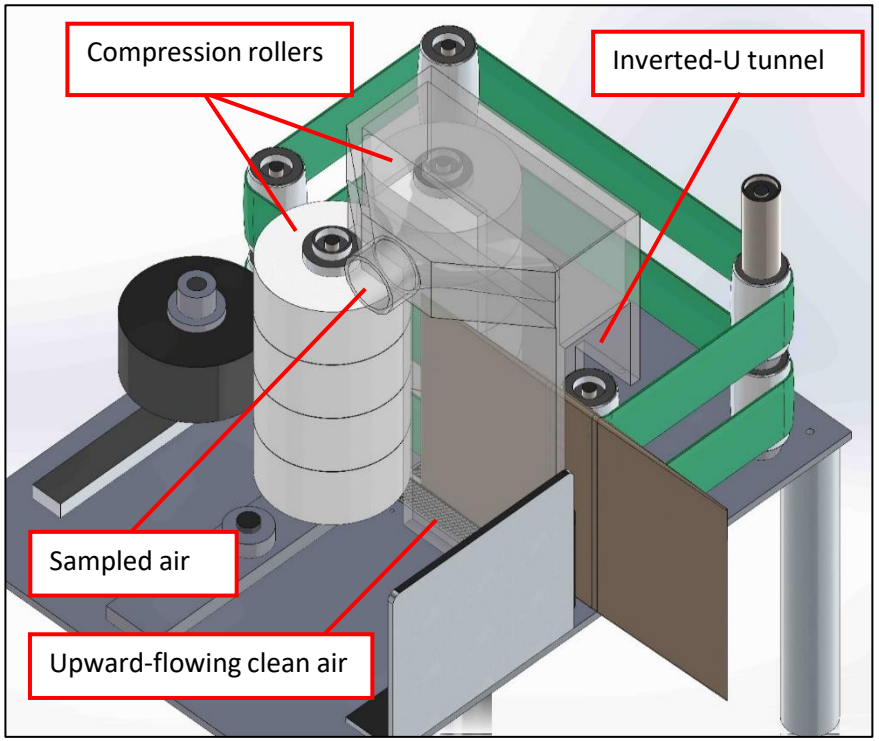
Patent Date	Lead Inventor	Patent number	Patent Focus
10-23-2003 05-03-2005	David Spencer	2003/0196937 (appl.) 6,888,085	A probe is inserted into the mail piece and a sample extracted
02-05-2004 12-28-2004	Clifford Megerle	2004/0020264 (appl.) 6,834,533	Mail is compressed in various ways during transport and aerosols are recovered by a hood or plenum adjacent to the mail flow
02-12-2004	David Daugherty	2004/0028561 (appl.)	Particulates generated during mail transport are collected and monitored by a trigger system. A sampling subsystem prepares a liquid sample.
04-01-2004 07-29-2008	David Tilles	2004/0063197-98 (appl.) 7,405,073	A PCR system that uses a collection hood and dry cyclone to collect aerosols generated by high speed mail processing systems
08-24-2004	Pradeep Das	6,781,078	Mailpiece metrics are used to flag suspicious articles
09-04-2004	Allen Jones	6,792,795, RE41,591 E (2010 Reissue)	Sampling air flows through a chamber containing a rotating drum of mail
10-30-2004	Clifford Megerle	6,823,714	A porous floor plate is used to distribute and sample air in a postal trailer
02-14-2006	Eugene Stradley	6,997,374	An enclosure with apparatus for squeezing flat postal articles and analyzing aerosols created. Example application is in an automated teller machine.
02-27-2007	Clifford Megerle	7,183,104	A separator is used to discard unwanted aerosols such as iron particles
02-27-2007	Joseph Zanovitch	7,183,906	Dynamically configureable detection systems under central computer control
03-27-2007	Michael Wisniewski	7,194,924	A pinching apparatus in a closed chamber is used to create aerosol samples
04-08-2008	John Beckert	7,356,163	Particulate matter collected from mail sorting equipment is examined in combination with images to determine suspect postal articles
06-24-2008	John Swider	7,390,465	A sealed container is supplied with coarse-filtered air and air drawn from the chamber is analyzed.
10-16-2008 06-09-2009	Eric Burroughs	2008/0250845 (appl.) 7,543,478	Air nozzles/knives are directed laterally at both sides of mail flats as they pass through a high speed mail processing system. Exhausted air is analyzed.
02-17-2009	Douglas Quine	7,491,548	Air is extracted from a mail bag and aerosols therein are captured on a dry filter
07-07-2009	Christian Beck	7,556,250	Suspect postal flats are incised for introduction of a test strip
04-17-2023	Elric Saaski	18/135,659 (appl. allowed)	High speed bioaerosol/drug aerosol trigger system

2023 Conceptual Approach

This system uses the air pumping effect of a single set of sorter rollers operating nominally at a feed rate of up to 2 m/sec or more to expel powders from within flats passing through.

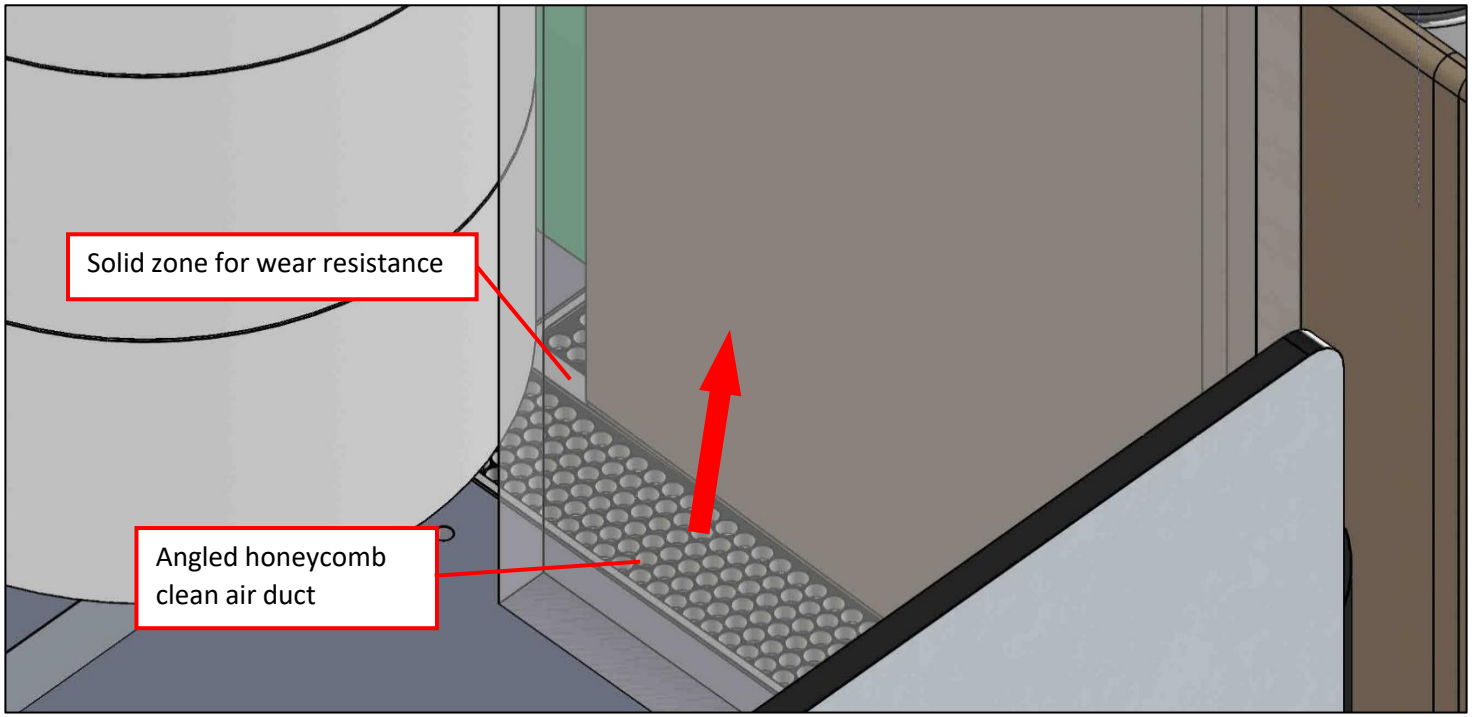
A baseplate honeycomb grid injects HEPA-cleaned air that entrains particles released by the compressed flat. An aerosol collector head above the flat delivers particulates to a biodetector.

Fluorescence detecting electro-optics and firmware optimized for this application analyze the aerosol stream at a 10 Hz rate.



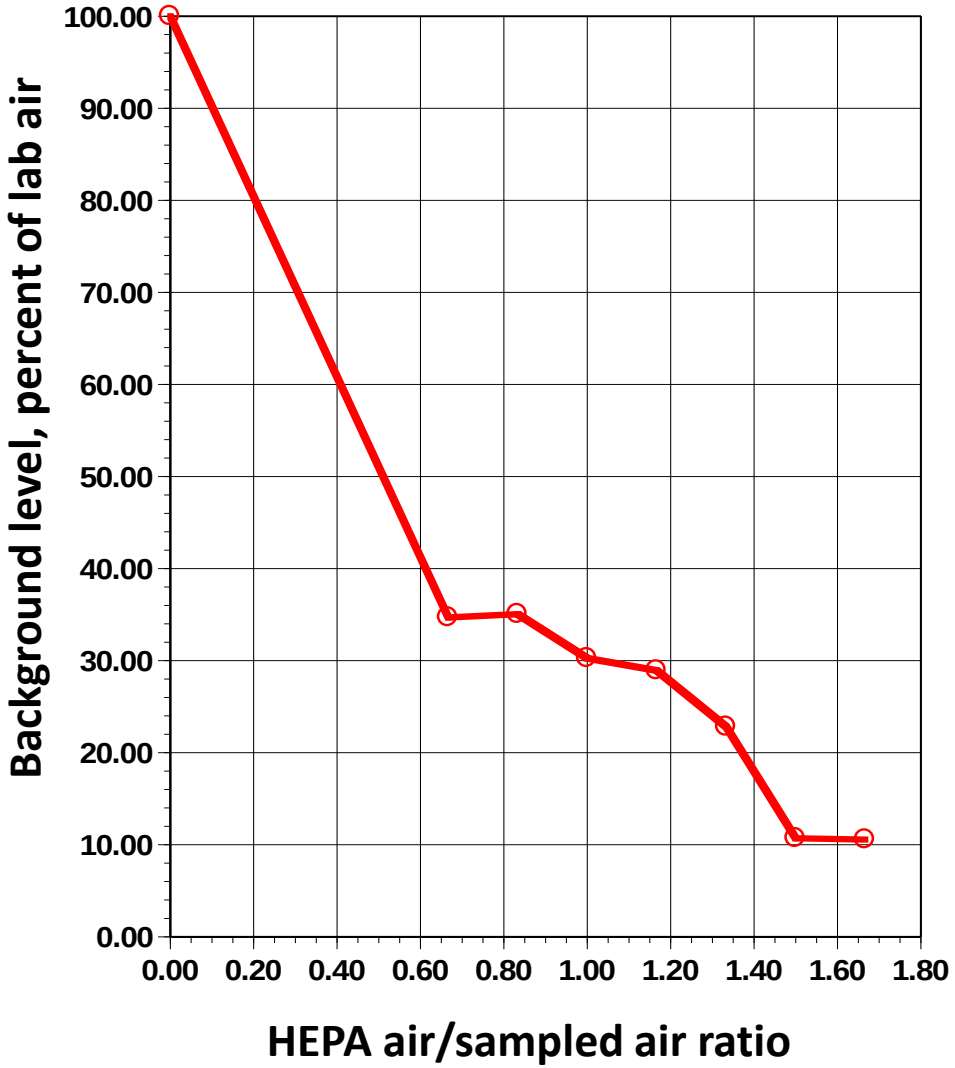
Improving Signal-to-Noise

Particulates are collected with HEPA-cleaned air injected on both sides of the flat from a honeycomb structure that provides jets of air angled to collect particles from the flat's surfaces as well as corners.



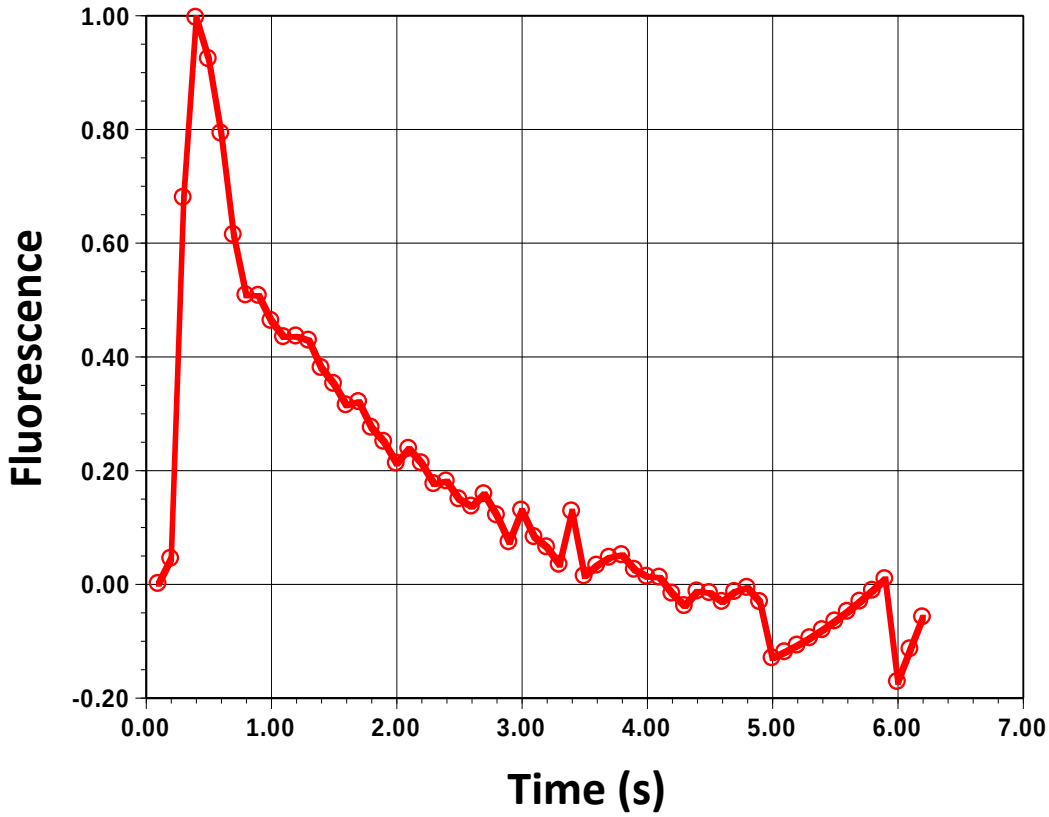
Effect of Clean Air

Injection of clean air at the baseplate significantly reduces the background particulate level even though the sampling chamber is open at each end.



Typical Fluorescence Signal

The graph shown here is biodetector fluorescence data from a 10x12-inch envelope loaded with less than 1 gram of simulant. It was run through the detection rollers at a linear rate of 2m/sec.



Alarm Protocol

A level-1 alarm is sent to monitoring software within 0.5 sec of a suspicious flat being detected, and a level-2 alarm is issued within 3 seconds of the initial warning if the electro-optic signal is confirmed as suspicious.

The suspect flat is then identified and optionally diverted along with several leading and following flats for specific analysis.

The following video shows such a sorting system in operation.

MAILCOM '23

Resorts Hotel - Atlantic City, NJ

October 2-4, 2023

Summary

In conclusion, new electro-optic systems are emerging that can monitor postal articles for harmful biologicals and drugs in real-time.

These systems are made possible by the development of new UV-C light sources, customized electro-optics and firmware, and high-speed postal processing equipment that can provide a non-invasive look inside postal flats.

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