



ADSA09 Conference Presentation
A Major Advance in the State-of-the-Art in Optical Remote Sensing of Trace Compounds

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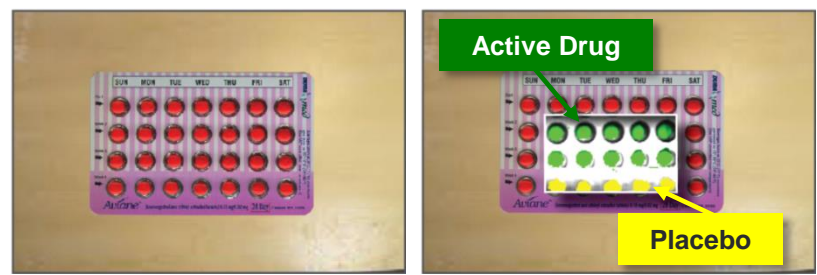
Introduction to Tornado

Business	Develop optical spectroscopy products, leveraging technical experience in Remote Sensing and Sales experience in Medical Devices and Industrial Process Control
Product Platforms	HyperFlux: High performance spectrometer for real time monitoring spectroscopy OCTANE: On-chip spectrometer for optical coherent tomography
Founded	2010 (both founders are US citizens)
Employees	22 (including contractors)
Capabilities	In-house: optical and mechanical design, freespace and nanophotonic prototype fabrication With Partners: freespace and nanophotonic product manufacturing (ISO 9001, MIL-STD-810)



▶ **Tornado has developed the next generation of spectral imaging systems for real-time monitoring:**

Example: Pharma manufacturing quality control



Traditional image

Tornado spectral image

Example: Prohibited liquid at security checkpoint



Traditional image

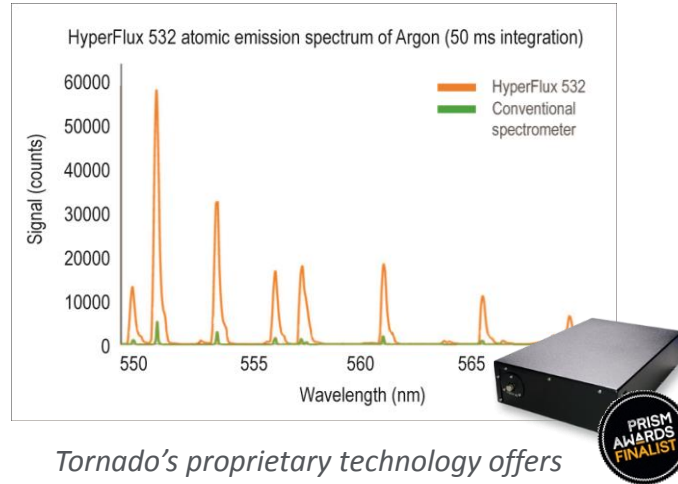
Tornado spectral image

HyperFlux: Tornado's fundamental improvement to spectrometer design dramatically outperforms conventional systems for Real-time Spectral Monitoring (RTM)

Current: Quality control relies on complex and bulky systems to approach required performance



Price: \$250,000
Weight: 200 lbs



Tornado's proprietary technology offers dramatically higher signal strength than conventional spectrometers

Future: Tornado will produce high sensitivity devices with reduced size and cost, facilitating wide spread adoption of easy-to-use non-destructive testing



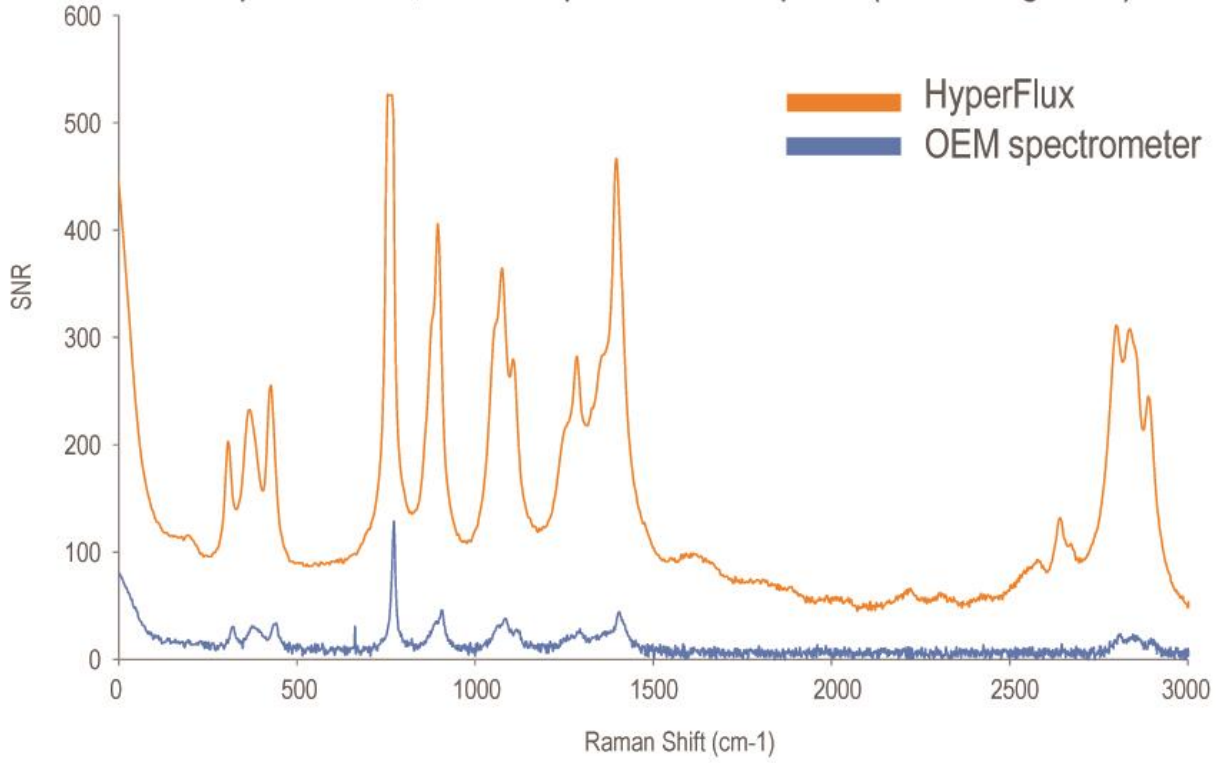
HyperFlux spectrometer system
High Throughput Virtual Slit (HTVS) is inside

Price: \$70,000
Weight: 20 lbs

- Tornado's patented technology eliminates the greatest source of reduced signal inherent in conventional designs
- The HyperFlux enables industry-leading **higher sensitivity with smaller size and lower cost** than can be achieved with conventional devices

Tornado's HyperFlux Spectrometer

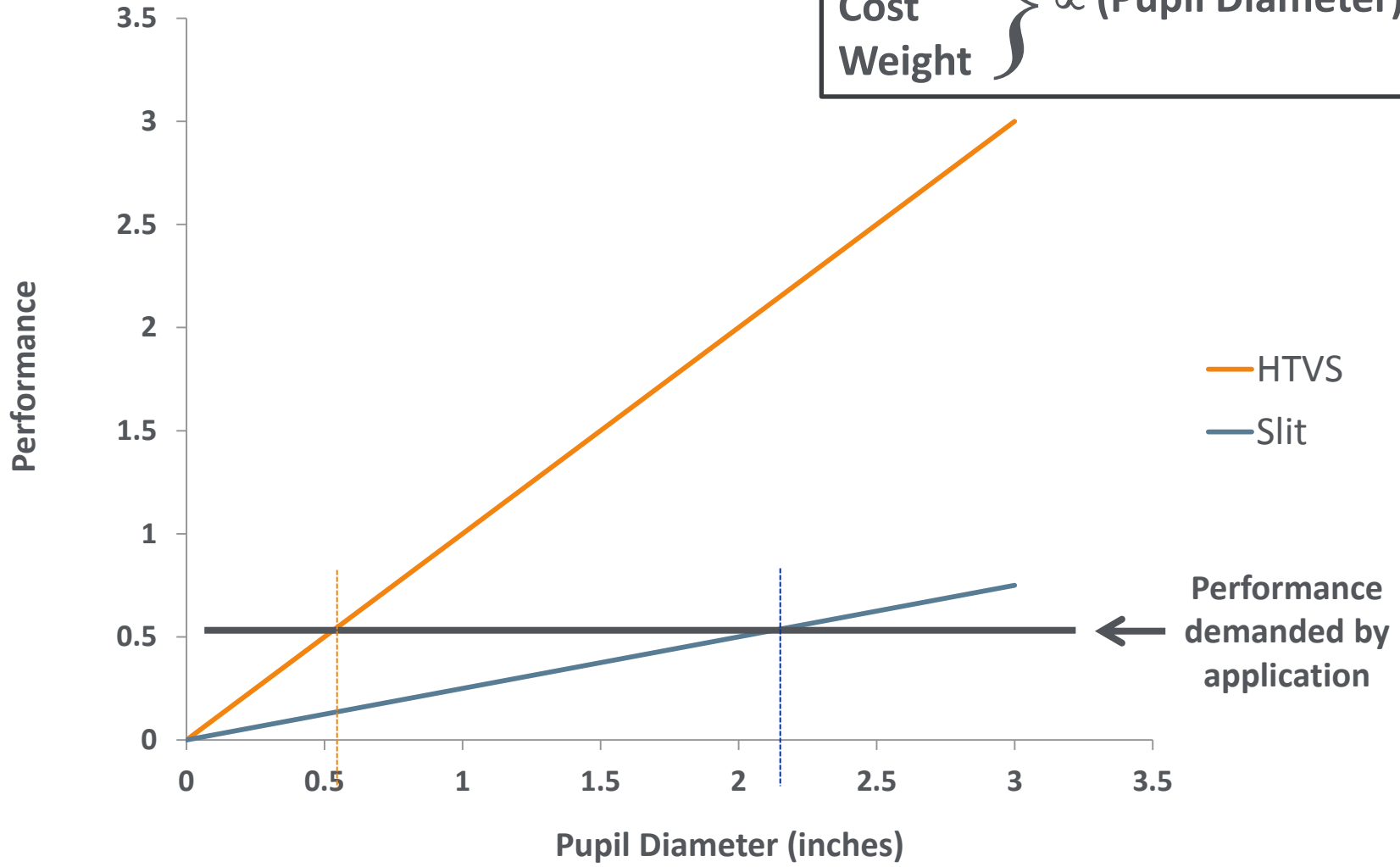
Comparison of HyperFlux 785 with conventional OEM spectrometer, Raman spectrum of Propanol (2 sec integration)



Big Spectrometers Perform Well

But only HTVS delivers high performance with a small pupil

Volume } $\propto (\text{Pupil Diameter})^{2-3}$
Cost }
Weight }



Tornado's HTVS technology has disruptive performance

Tornado has rebuilt the concept of the optical dispersive spectrometer by integrating the high throughput virtual slit

Technical impact

- Can efficiently change f-ratio and spot size independently
- Greatly mitigated/solved resolution vs throughput trade for spectroscopy
 - No need to trade detection time with specificity (have both!)
- Delivers 3-200x photons to the detector than is otherwise possible
- Can extract more information/sec than is otherwise possible
- Solution is robust, scalable, in-production
- Purely reflective, achromatic designs

Logistical impact

- Literally “do more with less” (sorry, it’s an LED vs. a filament)
- 3-200x performance in same volume/weight package
- 1x performance in much smaller volume/weight package
- Can remove cost from auxiliary components
 - Photon-counting camera to 1-stage cooled (or uncooled!) camera
 - 1m aperture to 0.3m aperture

Mission impact

- **HSI:** Can trade slit length with width
- **Baggage:** more sensitivity, fast processing, higher confidence
- **CBRNE:** better limits, larger standoff range, handheld device capability



For more information please contact:

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Summary: Tornado's Products and Current (Public) OEM Partnerships

Tornado Core Products

HyperFlux 532

Fixed-Configuration 532 nm
Raman Spectrometer



Launch date: Jan 2012

HyperFlux 785

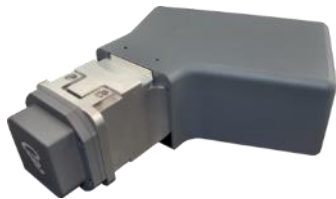
Fixed-Configuration 785 nm
Raman Spectrometer



Launch date: Jan 2012

HyperFlux U1

High Resolution Spectrometer
Platform



Launch date: Jan 2013

OCTANE-860

OCT Nanophotonic
Spectrometer-on-Chip



Launch date: Jan 2013

Tornado 'Labs' Partnerships



APEX 785



Launch date: Jan 2013



AvaRaman XHS



Target launch date: Jan 2014

Tornado has developed an advanced “spectral imaging” system using the HTVS technology

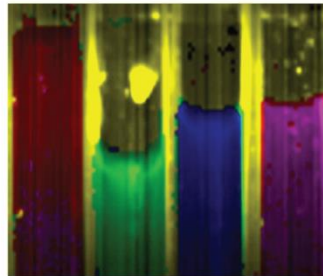
New product under development:



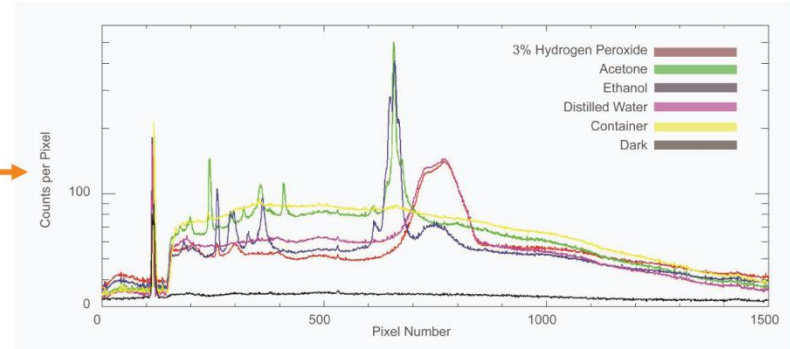
HTVS-enabled
HSI system

Example 1: Identifying multiple liquids simultaneously

1. Process scanned image



2. Corresponding spectra identification

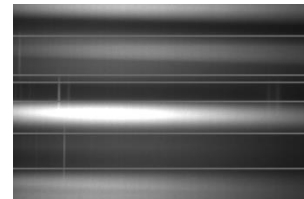


Example 2: identifying different minerals that 'look' similar

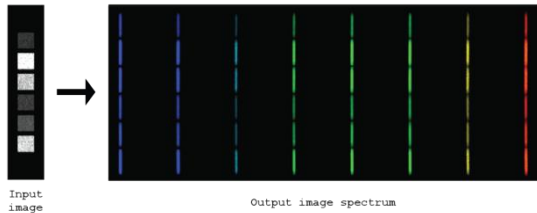
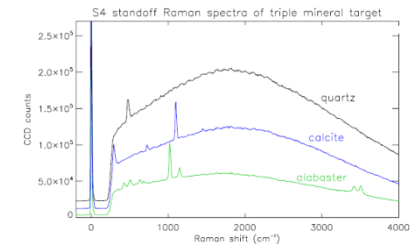
1. Slice image



2. Collect Spectra



3. Confirmed identification



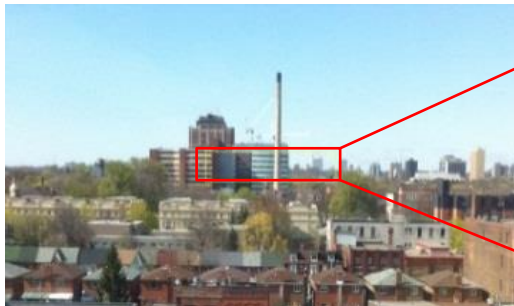
ZEMAX simulation of reformatting
along a slit input

Tornado's S4 Hyperspectral Imager

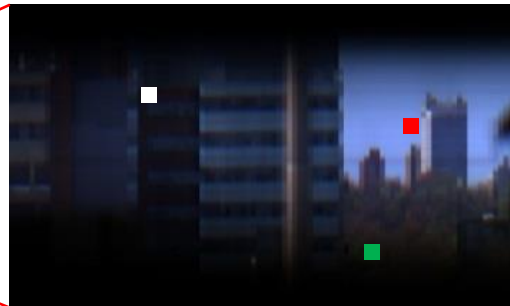
A demonstration of an HTVS-equipped hyperspectral imager

HyperSpectral Imaging

- The high spectral resolution of can identify fine spectral features that otherwise are lost
- Operates well in high-background scenarios



Original scene



HSI of scene using S4



Filtered HSI

