Raman Process Analyzer System Design

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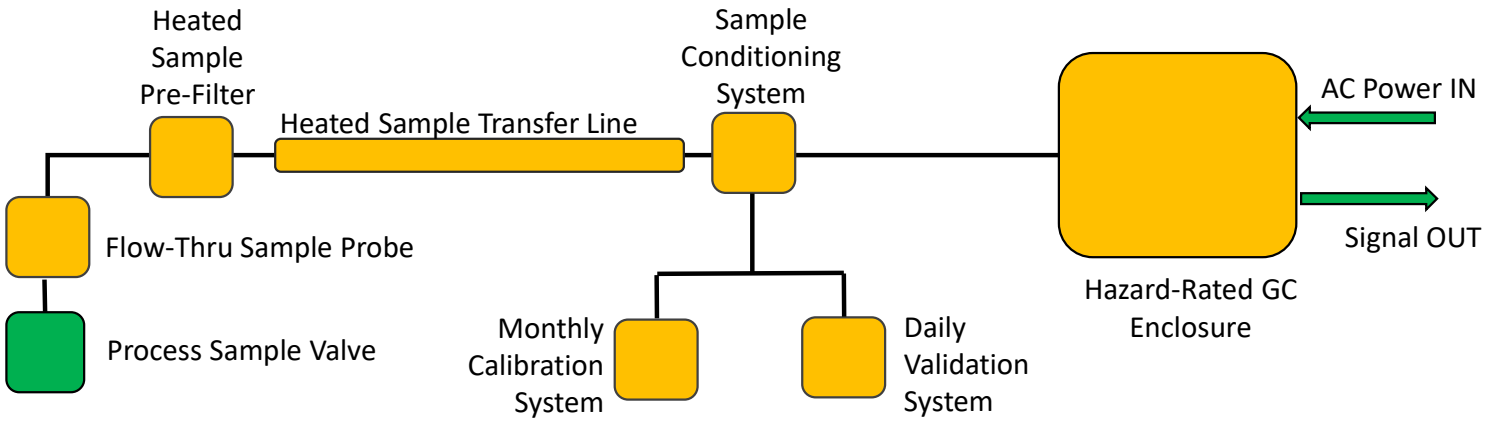
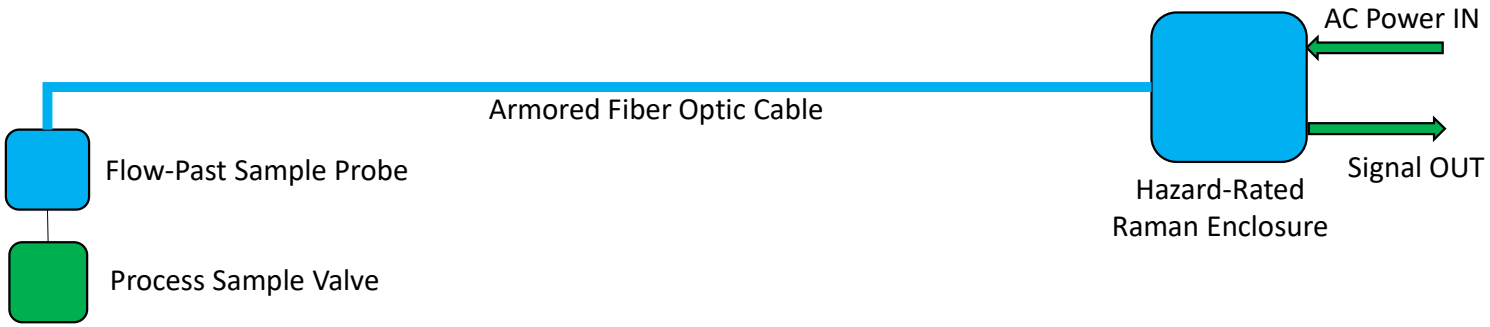
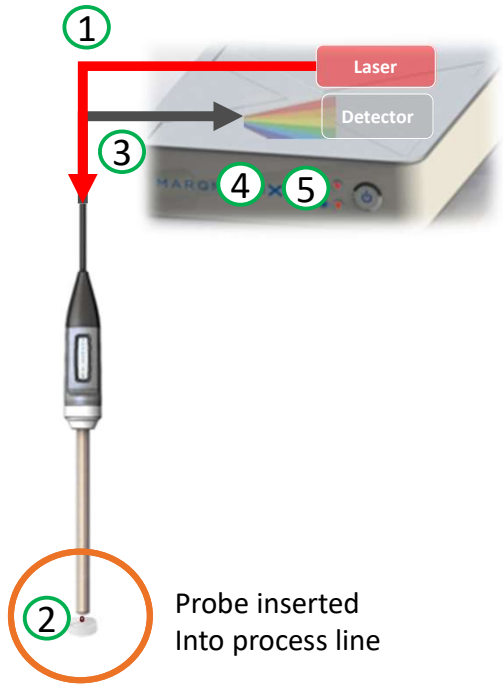
Typical Process GC System



Simplified Process Raman System

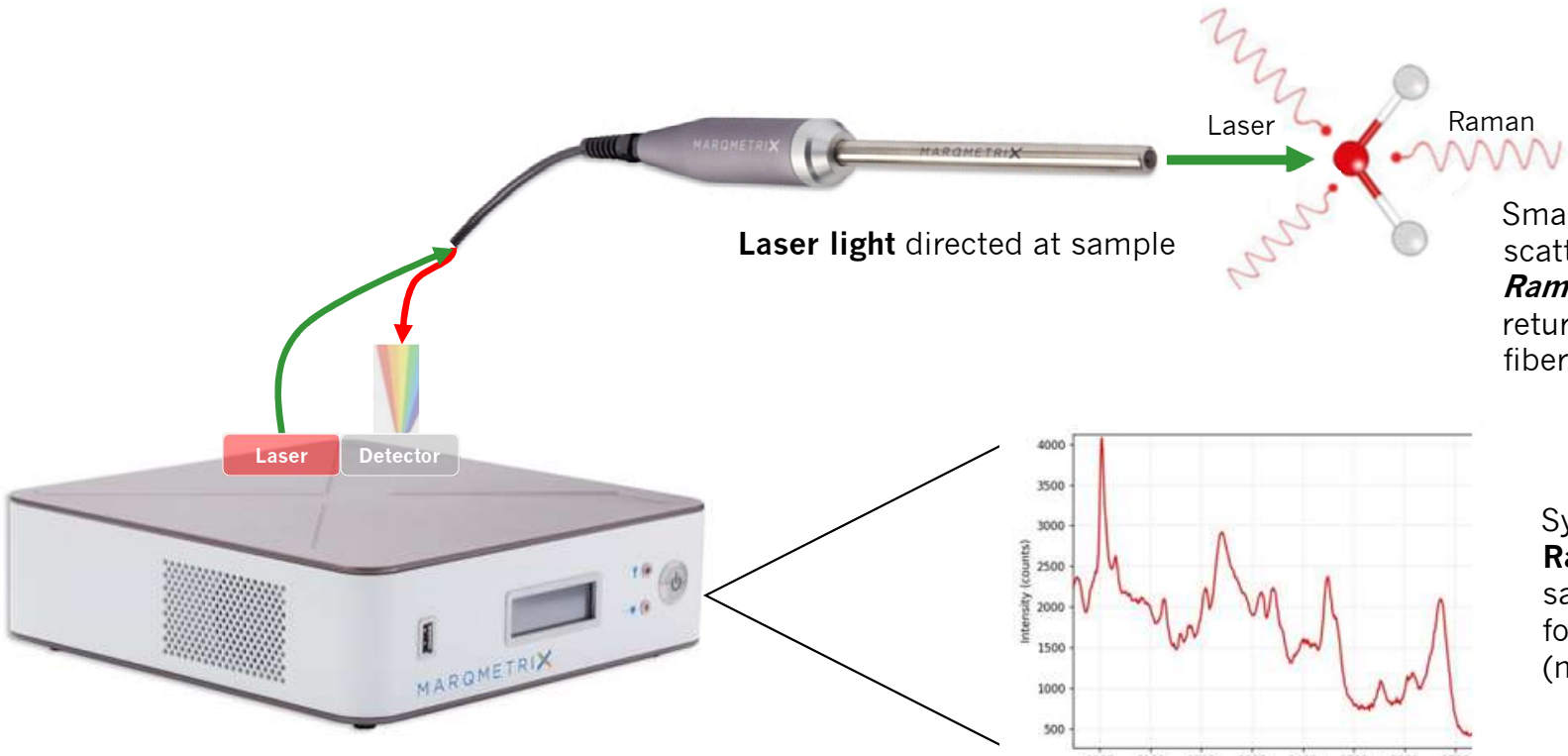


Raman is possible because of massive improvements in plant computing power



1. Laser beam excites molecules at (2)
2. Chemical bonds in molecule absorb energy and then radiate it at their unique frequency.
3. Fiber optic cable carries reflected waves from probe to a detector in the spectrometer.
4. Computer analyzes complex reflected wave and measures photons from target bonds.
5. Raman software determines concentration of molecules that radiate at the unique frequency for that compound. Other techniques measure physical properties and infer composition (e.g. chromatographs actually measure adsorption of compounds).

How Does Raman Work ?



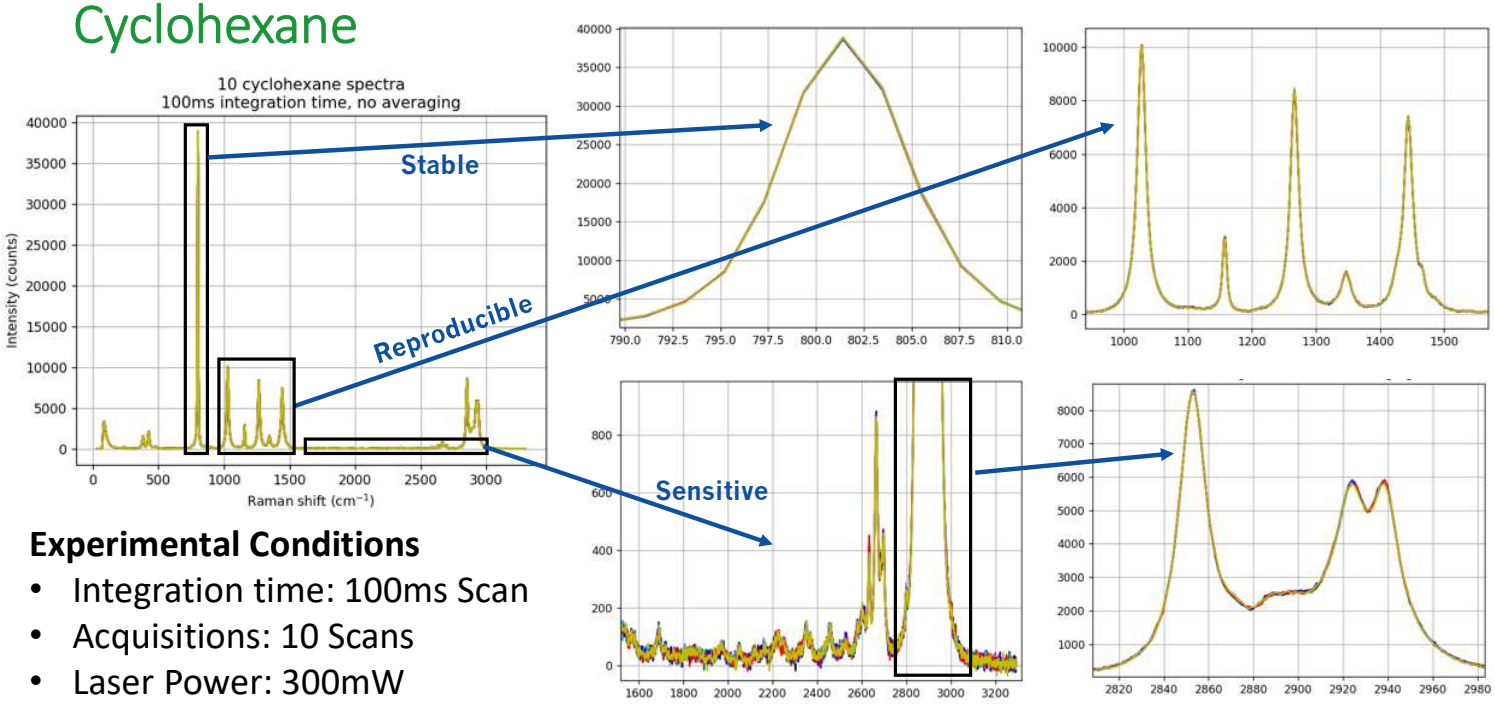
Laser light directed at sample

Small portion of scattered light, ***Raman scatter***, returns through collection fiber to the detector.

System displays the **Raman Spectrum** of the sample which is unique for every molecule (molecular fingerprint)

Raman Provides Rapid “Data Rich” Measurements

Cyclohexane



Experimental Conditions

- Integration time: 100ms Scan
- Acquisitions: 10 Scans
- Laser Power: 300mW

Raman vs. Chromatograph Comparison

Typical Plant Analyzer Comparison

	Chromatographic Analysis System	Raman Analysis System
Installed Capital Cost	$100 to 200K	$80 to 150K
Analysis Response Time	15 minutes	6 seconds (continuous)
Estimated Maintenance Cost	> $ 50,000 /yr.	< $ 5,000 /yr.
MTBF of Sensor	1 to 2 years	10 years

Comparison of 2nd and 3d Generation Raman

	Third Generation Raman	Second Generation Raman
Raman System	Raman for engineers Easy to use and accessible for technicians	First use in Process Industry Highly complex, required on-site expert support
Hardware Cost	$90 - 100K	$120 - 250K
Optical Resolution	6.5 cm^{-1}	4-5 cm^{-1}
Fiber Probe	Infinite focal distance	Critical focal distance
Immersion Probes	Pressure to 1700 bar Cryogenic to over 500°C	Pressure to 210 bar Ambient up to 400°C
Capability	Measure liquids, solids, gases and mixed phase samples	
Size	Breadbox	Refrigerator

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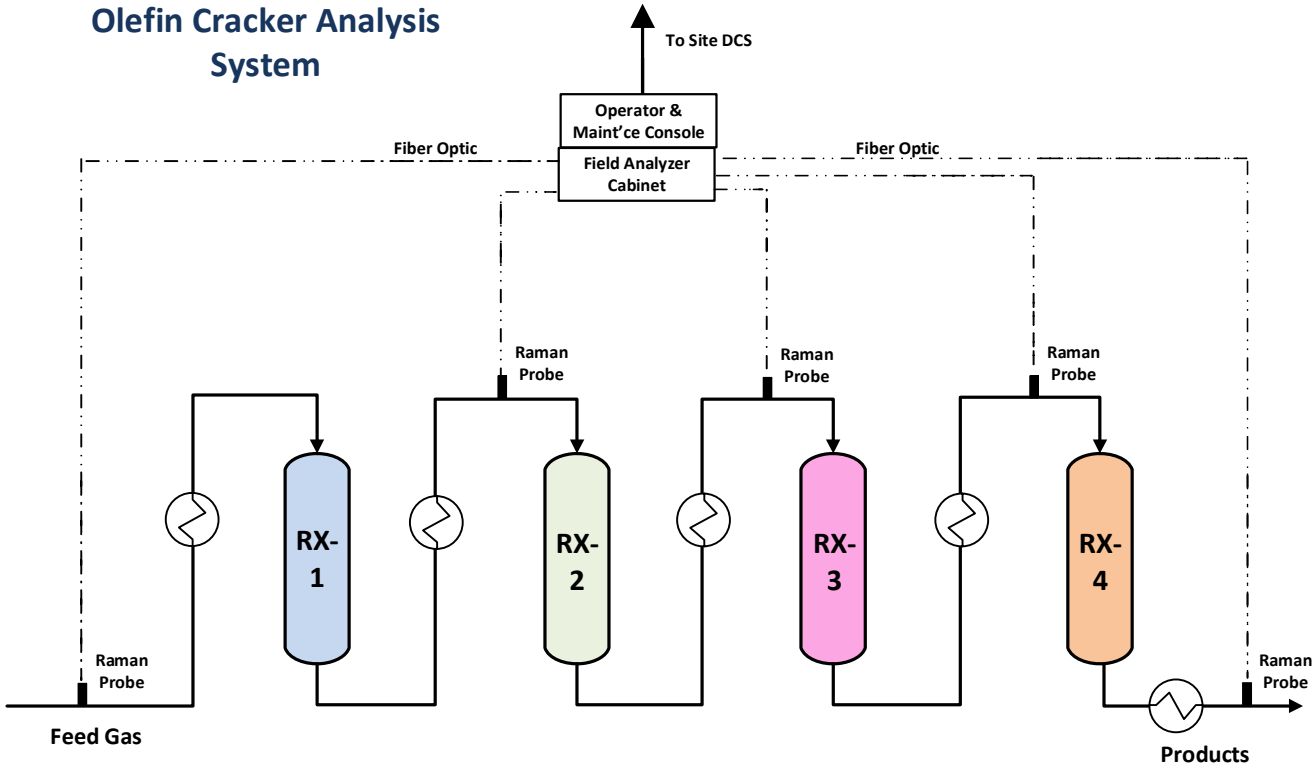
Example Raman Process Analysis Opportunities

- More economical alternative to GCs for:
  - Replacement of “End of Life” Gas Chromatographs
  - Difficult multiphase and high temperature sampling
- Alternative to GC + Laser Analyzers for Pipeline Gas Analyses
  - AGA custody transfer composition measurement
  - LNG composition (cryogenic)
- Landfill Gas Analysis
- Wastewater Treatment Effluent Analysis
- Polymerization Reaction Measurement

Replacing “End of Life” Gas Chromatographs

- Economics
  - Replace sample extraction probe with insertion probe
  - Replace heat-traced sample lines with fiber optic cable
  - Eliminate sample system and calibration system
  - Eliminate GC controller and oven assembly
  - Raman system utilizes existing power and signal conduits / wires
- Complete dataset in < 6 seconds instead of every 6 minutes
- Repeatability (10x better)
  - Raman: 0.09 – 0.11
  - GC: 0.90 – 1.1
- **10YR** MTBF: Source & detector

Difficult Multiphase and High Temperature Sampling



New Insertion and flow-through probes simplify sampling.

Eliminates traditional sample extraction and conditioning.

Typically 50% the installed cost of GC-based systems.

Dramatic reduction in maintenance & calibration cost.

Alternative to GC + Laser for Pipeline Analyses

AGA8 natural gas analysis for custody transfer

- One compact Raman analyzer eliminates separate analyzers for:
  - CO_2
  - H_2S
  - H_2O

- **NO** Sample Conditioning or Calibration Systems needed.
- Single, compact field enclosure
  - 24 x 24 x 16-inches Stainless Steel 4X Enclosure (Class I Division 2)
  - Sealed heating and cooling for any Climatic Zone
- 10YR MBTF on Source (Laser) and Detector (CCD) reduces service visits.

Process Raman for LNG Processes

- Economics
  - Eliminate cryogenic sampling problems with insertion probe
  - Eliminate cryogenic sample lines
  - Eliminate GC shelter
- Complete analysis in < 6 seconds instead of every 10 minutes
- Repeatability (10x better than GC)
  - Raman: 0.09 – 0.11
  - GC: 0.90 – 1.1
- **10YR** MTBF: Source & Detector

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Landfill Gas Analysis

- **Simplify future Landfill Gas Analysis packages**
  - AGA8 Analysis
    - **Complete** Analysis with one (1) Analyzer
    - **NO** Sample Conditioning or Calibration Systems
    - Single compact Field Enclosure (Class I, Division 2)
    - 10YR MBTF on Source (Laser) and Detector (CCD)
  - Non-Methane Organic Compounds (NMOC) Analysis
    - Acrylonitrile
    - Benzene
    - Carbonyl Sulfide (CS_2)
    - Methyl Ethyl Ketone (MEK)
    - Vinyl Chlorides (VCs)
    - ONE Probe measures ALL the above plus many more

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Wastewater Treatment Effluent Analysis

- ONE Sample Probe
  - Flow-past, instead of Flow-thru type that may clog.
- ONE Analyzer
  - Does not need different Analyzers for
    - TOC
    - Specific Ion
    - NIR
  - One Process Raman Instrument can measure:
    - CO_2 for TOC
    - Ammonium Sulfide, Carbonyl Sulfide, Carbon Disulfide
    - Hydrogen Sulfide
    - Total Sulfides
    - Oil-in-Water
  - Multiple Streams?
    - Same program on several MarqMetrix Process Raman Instruments

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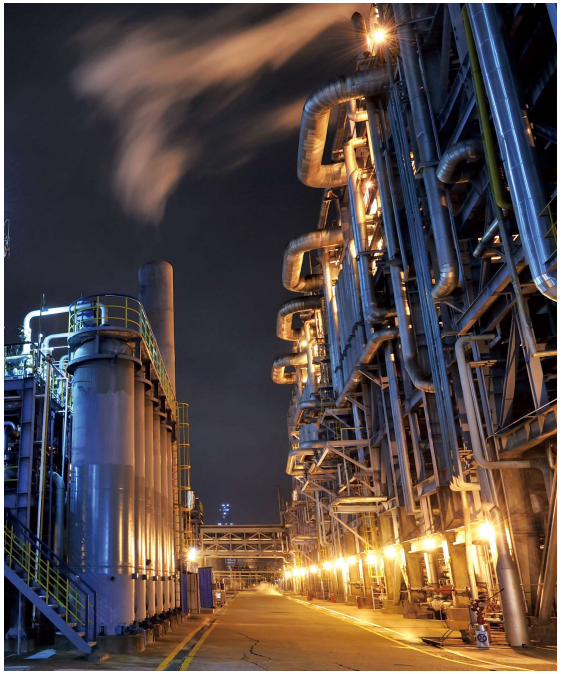
Polymerization Reaction Control & Product Quality

- High Density Polymers
- Low Density Polymers
- Linear Low-Density Polymers
- SBR (Styrene Butadiene Rubber)
- EPDM (Ethylene Propylene Diene Monomer)
- DADMAC (Diallyl Dimethyl Ammonium Chloride)
- Compatible with Industry-standard “Dynisco” probes
  - Melt Flow Rate
  - Melt Density
  - Shear Stress
  - Shear Rate
  - Apparent Viscosity
  - Instinsic Viscosity (IV – Textiles, Tire Cord manufacturing)



Developed and Supported in USA

MARQMETRIX

- ✓ Process Raman Platform
- ✓ Analytical Model Development
- ✓ Remote Support

Enterprise Consultants Int'l.

- ✓ System Integration
- ✓ Installation Design
- ✓ Certification
- ✓ Cyber Security
- ✓ Field Support