Raman spectroscopy installation in hazardous areas (ATEX, IECEx, NEC/CEC)

Learn how Raman spectroscopy systems are safely installed in hazardous areas. This article explains optical ignition risks, protection concepts, and how ATEX, IECEx, and North American standards shape compliant Raman system design and installation.

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Scope and assumptions

This learning article focuses on Raman spectroscopy systems installed in gas explosive atmospheres, including ATEX Zones 0/1/2, IECEx, and North American Class I (NEC/CEC) environments. It explains:

- Why Raman systems fall under hazardous-area requirements
- How optical ignition risks arise and are mitigated
- How regional frameworks translate the same physical safety principles into certification and installation rules

Note: Raman spectroscopy equipment is not certified for use in dust, powder, or fiber explosive atmospheres. As a result, these environments are outside the scope of this article. This article also does not address non-optical ignition mechanisms or detailed national legal compliance procedures, which require separate system design and certification approaches.

What you will learn

- When Raman spectroscopy installations require hazardous-area compliance
- How optical ignition risks are assessed and controlled
- How ATEX, IECEx, and North American frameworks affect Raman system installation
- How optical ignition risks are managed using power limitation (op is) and interlocked system (op sh) concepts, and how this impacts labeling and installation

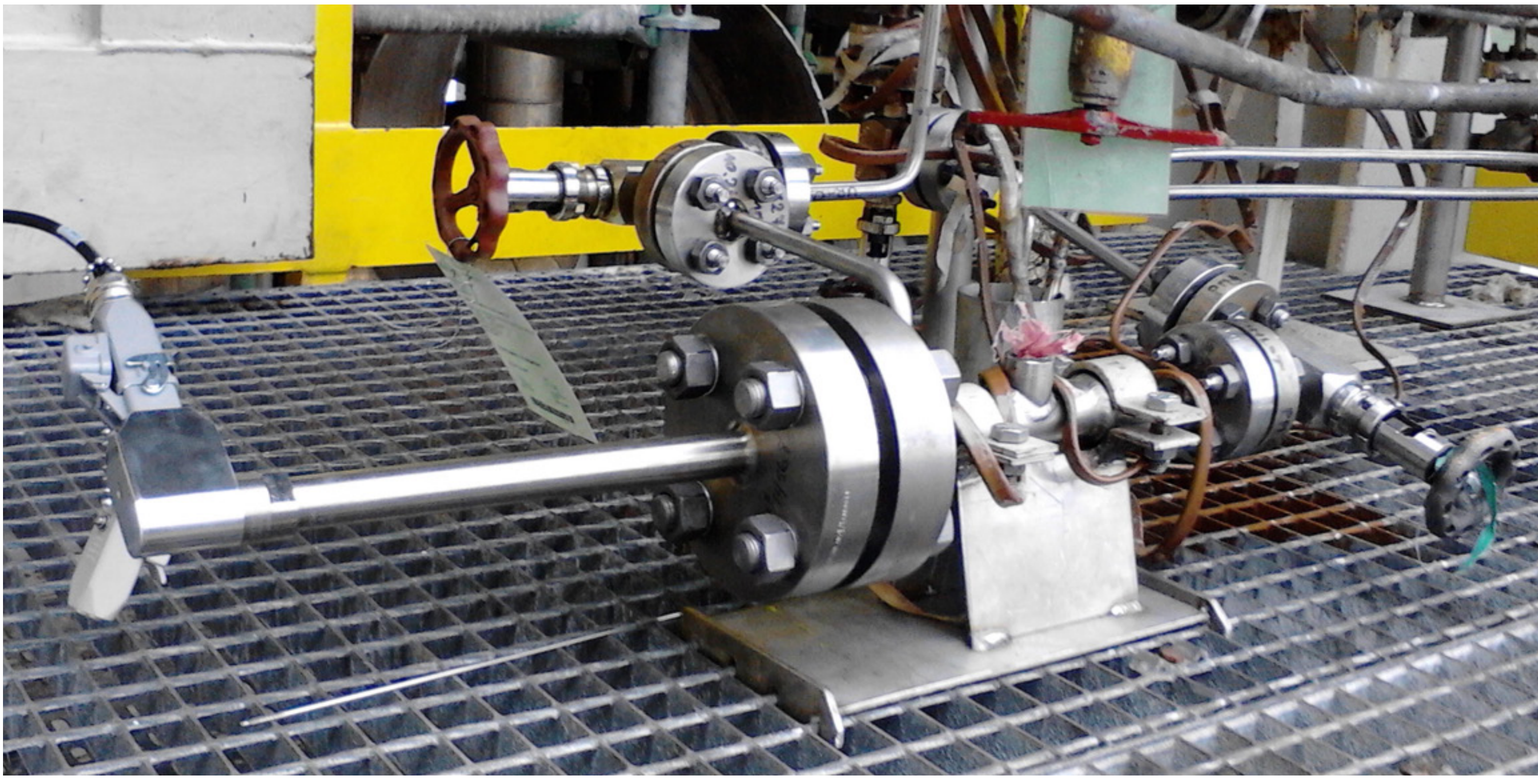
Do Raman system installations fall under hazardous-area compliance?

Raman spectroscopy systems can become a potential ignition source when optical radiation is concentrated in a flammable gas or vapor atmosphere, even though Raman probes do not generate sparks or hot electrical components at the measurement point.

The ignition risk arises from localized heating caused by focused optical energy at surfaces or particles. As soon as a Raman installation is exposed to an atmosphere that could contain a combination of oxygen and flammable gas vapors or mist, it is considered to be in a hazardous area and must comply with the relevant hazardous-area equipment requirements.

Key learning point

Hazardous-area compliance for Raman spectroscopy is driven by optical ignition physics, not by electrical sparking or regional legislation alone.



Hazardous-area frameworks: ATEX, IECEx, and North America (NEC/CEC)

Raman system hazardous-area compliance is governed by the same physical safety principles worldwide. Regional frameworks differ primarily in how hazardous areas are classified and documented, not in the underlying installation logic or ignition prevention mechanisms.

Same physics, different frameworks

ATEX (Europe) and IECEx (international) use a Zone-based classification system (Zones 0, 1, 2) to define the likelihood and duration of the presence of explosive gas atmospheres. These zones determine where Raman probes may be installed and which protection concepts must be applied.

- ATEX (EU) is a legal framework tied to CE marking.
- IECEx (international) provides a global conformity system based on IEC standards.

North America (NEC/CEC) applies Class/Division or Class/Zone concepts for gas hazardous locations (Class I), with equipment approvals typically issued by UL, FM, or CSA.

While the terminology differs, the intent is equivalent: defining hazardous locations and ensuring ignition sources are controlled.

Across all regions, the same principles apply:

- Hazardous-area classification defines where optical probes and associated components may be installed (Zones in ATEX/IECEx; Class/Division or Class/Zone in NEC/CEC).
- Beam confinement, including interlocks on optical paths and fiber connections, together with laser power limitation at the measurement point (probe end), prevents optical ignition.
- Optical protection concepts are applied at system level to ensure that laser radiation cannot ignite a flammable gas atmosphere.

Zones and classes: what they mean for probes and analyzers

Probe-driven zoning and system-level assessment

In Raman installations, the probe tip location drives the hazardous-area requirement, because this is where optical energy is intentionally emitted into the process.

- Zone 0: explosive atmosphere present continuously or for long periods
- Zone 1: likely to occur occasionally
- Zone 2: unlikely or present for short periods

The analyzer is often physically installed in a non-hazardous (general) area, while fiber-optic cables connect the analyzer to the probe in Zone 0, 1, or 2.

Important system-level nuance

Even when installed in a general area, the analyzer may still require hazardous-area (Ex) marking if it forms part of a system that transmits optical energy into a hazardous zone. In such cases, the analyzer is assessed and marked based on its functional connection to the hazardous area, not solely on its physical location.

The following list shows a simplified conceptual mapping between ATEX gas zones (left) and North American classifications (right). The terminology differs, but the ignition-risk logic is the same.

- Zone 0 → Class I, Division 1
- Zone 1 → Class I, Division 1
- Zone 2 → Class I, Division 2

Equipment marking essentials for Raman systems

Key elements of Raman system marking include:

- Equipment group: Group II (surface industries such as chemical and pharmaceutical)
- Equipment Protection Level (EPL):
  - Ga → Zone 0
  - Gb → Zone 1
  - Gc → Zone 2
- Gas groups: IIA, IIB, IIC (IIC being the most demanding)
- Temperature class: e.g., T6 (85 °C), T4 (135 °C)

Gas group and temperature class are specified by the plant owner based on process data and drive the final system labeling.

Optical ignition & protection: IEC 60079-28:2015, Ex op is, and maximum power

Optical ignition risk

Optical radiation can ignite flammable atmospheres when energy is concentrated and absorbed by small surfaces or particles. IEC 60079-28:2015 describes this mechanism and defines protection concepts to prevent ignition in explosive atmospheres.

The standard includes reference tables defining inherently safe optical radiation (Ex op is) power limits for specific wavelengths, exposure conditions, and gas groups. These tables provide baseline guidance for optical power levels that are considered non-ignitive under defined assumptions.

In practical Raman applications, the applicable safe power limit must be confirmed through a Laser Hazard Assessment (LHA). The LHA takes into account not only the standard reference values, but also application-specific parameters, including:

- Gas group and ignition sensitivity
- Wavelength and beam geometry
- Exposure duration and optical focusing
- Probe design and fault assumptions

The LHA therefore defines the maximum permissible laser power at the probe tip and the final Ex labeling of the system.

Inherently safe optical radiation (Ex op is)

Ex op is limits optical energy so that ignition is not possible under normal operation and defined fault conditions. In Raman systems, this is typically achieved by limiting laser power at the probe tip.

There is no universally safe laser-power value. While IEC 60079-28 provides reference limits, the maximum permissible power remains application-specific and must be validated by the LHA, which defines the safe operating envelope and final system labeling.

Interlocked optical systems (Ex op sh)

Ex op sh allows higher optical power but relies on engineered safety measures and interlocks to ensure that optical radiation is disabled whenever ignition-relevant conditions could occur.

This concept is commonly used when:

- Measurement performance requires laser power above Ex op is limits
- Unsafe conditions can be reliably detected and mitigated

Ex op sh may include:

- Cable-break detection
- Interlocks on fiber connections
- Process-condition monitoring (e.g., loss of liquid coverage)
- Automatic laser shutdown

Ex op sh applies at system level and may involve components located outside the hazardous area.

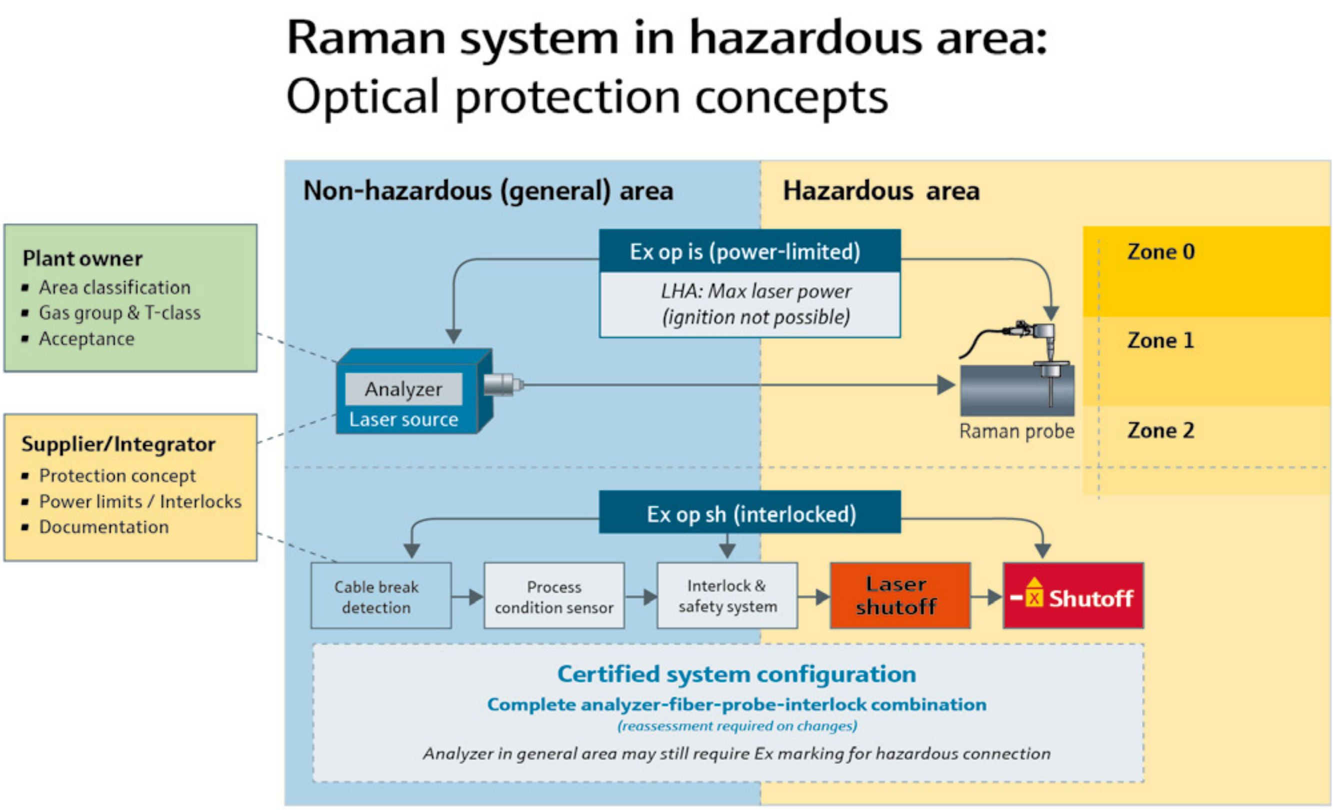


Figure 1: System-level view of a Raman system installation in hazardous areas

Why Ex op sh is relevant beyond permanently hazardous areas

In many process applications, Raman probes are installed in environments that are normally non-explosive, such as liquid-filled lines or vessels. Under normal operation, the presence of liquid prevents the formation of an ignitable gas atmosphere at the probe tip.

However, process conditions can change. Loss of liquid coverage, degassing, drying, or abnormal operation may lead to the temporary formation of a flammable gas or vapor phase at the measurement point. In such scenarios, the optical ignition risk can change dynamically, even though the installation is not classified as permanently hazardous.

Industry guidance, including NAMUR recommendations, recognizes this scenario and describes the use of interlocked optical protection concepts (Ex op sh) to manage conditionally explosive environments. In these cases, Ex op sh does not only enable higher optical power but ensures that optical radiation is automatically disabled whenever conditions transition into an ignition-relevant state (for example, when liquid coverage is lost).

This approach allows Raman spectroscopy to be applied safely in processes where explosive atmospheres are not expected during normal operation but cannot be excluded under defined abnormal or transient conditions, provided that the detection logic, interlocks, and shutdown behavior are clearly defined and validated at the system level.

Typical system architectures and installation patterns

A typical Raman system installation includes:

- An analyzer located in a non-hazardous area or, where applicable, in an enclosure certified for installation in Zone 1 / Division 2
- Fiber-optic cables routed into hazardous areas
- An Ex-certified Raman probe (ATEX, IECEx, or North American NEC/CEC as applicable) installed in Zone 0, 1, or 2

Depending on the selected optical protection concept (Ex op is or Ex op sh), the certified system relies on beam confinement, laser power limitation at the probe, and associated protective measures. Additional interlocks or monitoring functions, when implemented using separate devices, are not part of the Raman system certification and must be assessed by the end user as part of the overall installation and safety concept.

As shown in Figure 1, the probe location defines zoning (Zone 0/1/2) while the analyzer is typically in a general area. Optical ignition is controlled via Ex op is (power limited per LHA) or Ex op sh (interlocked optical system: cable break/condition monitoring → laser shutdown). The complete analyzer fiber probe interlock combination is assessed and marked as a single certified system, and the analyzer still requires Ex marking when functionally connected to a hazardous zone.

Ex op sh considerations during installation – Fibers, connectors, and interlocks

In practical installations, the application of Ex op sh is most visible during system installation and integration, rather than at the probe itself.

While the Raman probe is typically designed to meet defined optical protection requirements, system-level ignition risk control is often driven by how optical energy is transmitted from the analyzer to the hazardous area. This includes:

- Fiber-optic cable routing through hazardous and non-hazardous zones
- Optical connectors located at zone boundaries or inside enclosures
- The integrity of the optical path between analyzer and probe

For this reason, Ex op sh systems implement interlocks that monitor cable continuity and connector status, ensuring that laser radiation is automatically disabled if the optical path is interrupted or exposed. These measures are particularly relevant during:

- Installation and commissioning
- Maintenance or fiber reconnection
- Abnormal conditions, such as cable damage

From an installation perspective, Ex op sh therefore shifts the focus from component-level certification to system-level behavior: cable routing, connector handling, and interlock validation become part of the hazardous-area safety concept and must be considered during design, installation, and documentation.

Roles, responsibilities, and system integrity in Ex-certified Raman systems

Plant owner / operator

- Define area classification (zones or classes)
- Specify gas group and temperature class based on process data
- Ensure correct mechanical and electrical installation
- Perform or commission the hazardous-area and laser hazard assessments

Supplier / integrator

- Supply Ex-certified Raman equipment (analyzer, probe, or individual components as applicable), with the probe marked according to the requirements defined by the Ex responsible person at the customer site
- Communicate the available optical protection methods supported by the equipment (for example Ex op is or Ex op sh)
- Define and document the certified laser power limits, built-in protective features, and required equipment labeling
- When Ex op sh is applied, clearly define the scope of certification and the boundary between certified equipment and the customer’s overall system integration and safety assessment responsibilities

System integrity principle

Hazardous-area compliance applies to the entire Raman system, not to individual components. Analyzer, probe, fiber optics, power settings, and safety functions form a single certified configuration. Any change requires reassessment.

Steps required by Ex-responsible person at the customer site before selecting equipment for Ex area

1. Confirm and document hazardous-area classification
2. Define gas group and temperature class
3. Perform Laser Hazard Assessment (LHA)
4. Decide whether Ex op is (power limitation) or Ex op sh (interlocked system) is required
5. Select certified analyzer and/or probe, ensuring the Ex probe marking is appropriate for the gas group and temperature class defined during hazardous area classification
6. Plan installation architecture and fiber routing
7. Verify markings (EPL, gas group, temperature class, optical protection concept)
8. Complete as-built documentation and retain certificates
9. Train personnel on safe operation

Glossary

Term	Definition
ATEX	EU regulatory framework for equipment and protective systems intended for use in potentially explosive atmospheres (Directive 2014/34/EU).
IECEx	International conformity assessment system for equipment used in explosive atmospheres, based on IEC standards.
NEC/CEC	North American electrical codes (USA/Canada) governing installation of equipment in hazardous locations using Class/Division or Class/Zone concepts.
Zone/Class/Division	Area-classification models describing the likelihood and duration of the presence of explosive atmospheres (Zones in ATEX/IECEx; Classes/Divisions or Classes/Zones in North America).
Equipment Protection Level (EPL)	Classification indicating the level of protection of equipment for explosive atmospheres (Ga, Gb, Gc), corresponding to permitted use in Zones 0, 1, and 2 respectively.
Gas group (IIA/IIB/IIC)	Classification of flammable gases according to ignition sensitivity, with IIC being the most demanding.
Temperature class (T-class)	Maximum permissible surface temperature of equipment (e.g., T6 = 85 °C, T4 = 135 °C), defined to prevent ignition of surrounding atmospheres.
Optical ignition	Ignition of a flammable atmosphere caused by localized heating resulting from absorption of concentrated optical radiation.
IEC 60079-28:2015	International standard defining protection concepts for equipment and transmission systems using optical radiation in explosive atmospheres.
Ex op is	Inherently safe optical radiation per IEC 60079-28:2015, where optical energy is limited so that ignition is not possible under normal operation and defined fault conditions.
Ex op sh	Optical system with interlock per IEC 60079-28:2015, where ignition risk is controlled by engineered protective measures and interlocks that disable optical radiation when unsafe conditions occur.
Laser Hazard Assessment (LHA)	Assessment used to determine safe operating conditions for optical systems, including maximum permissible laser power and required protective measures.
Interlock	Safety function that automatically disables optical radiation when defined conditions are violated (e.g., cable break, loss of liquid coverage, open beam path).
System-level certification	Assessment of hazardous area compliance for the complete Raman system (analyzer, probe, fiber optics, configuration, and safety functions), not for individual components in isolation.

Common misconceptions about Raman systems in hazardous areas

"Laser power is fixed by the instrument."
No. Maximum permissible power is application-specific and defined by hazardous-area conditions.

"If the analyzer is certified, the system is compliant."
No. Compliance is assessed at the system level, so an Ex-certified probe is also required.

"IECEx, ATEX and North American standards (NEC/CEC) installations follow different rules."
No. Whether using Zone or Division classification, the installation logic is the same. Differences lie in how hazardous areas are classified and certified.

"Ex op sh is an exception."
No. Ex op sh is a standard, recognized protection concept intended for specific use cases, typically when the Raman probe window is submerged in a liquid sample and hazardous conditions (gas, mist, or vapor in combination with oxygen) can occur only in the absence of that liquid, and can be reliably detected and mitigated.

FAQ

What is the difference between IECEx and ATEX?
ATEX is legally required in the EU, while IECEx is an international conformity system. Both rely on the same IEC technical standards; installation physics do not change.

What changes for Raman installation under IECEx?
Nothing in the physical installation logic. Zoning, optical protection, and laser-power limitation remain the same; documentation and recognition differ.

What about North America standards?
In North America, hazardous locations are governed by the Class/Division or Class/Zone frameworks defined in the U.S. NEC and Canadian CEC. Raman installations follow the same fundamental principles (probe location based on area classification, optical protection, and maximum laser power limitation) but must comply with region-specific legal and code requirements.

In the United States, this is a legal obligation under OSHA 29 CFR § 1910.307 for electrical equipment in hazardous (classified) locations. In Canada, installations must comply with the Canadian Electrical Code (CEC), Part I—CSA C22.1, Section 18 (Hazardous Locations).

Does this guidance cover dust or powder ATEX environments?
No. Dust and powder atmospheres involve different ignition mechanisms and protection concepts and require separate system design and certification. Currently, no Raman equipment is approved for use in dust or powder hazardous atmospheres.

Does hazardous-area installation limit Raman measurement performance?
Safety requirements define a safe operating envelope. Raman systems are configured to deliver reliable measurements within that envelope, validated for the specific application.

References

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2. ATEX Directive 2014/34/EU – EU legal framework governing equipment intended for use in potentially explosive atmospheres
3. Guide to the Canadian Electrical Code, Part 1[i], 26th Edition– A Road Map: Section 18 Hazardous Locations - Electrical Industry News Week
4. Hazardous area classification (North America) – Overview of Class / Division and Zone concepts used in NEC and CEC frameworks
5. IEC 60079-28:2015 – International standard defining ignition risks and protection concepts (Ex op is, Ex op sh) for optical radiation in explosive atmospheres
6. IECEx system overview – International conformity assessment system for Ex equipment based on IEC standards
7. NAMUR (user association) guidance – Industry recommendations on practical implementation of explosion protection concepts in process automation

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