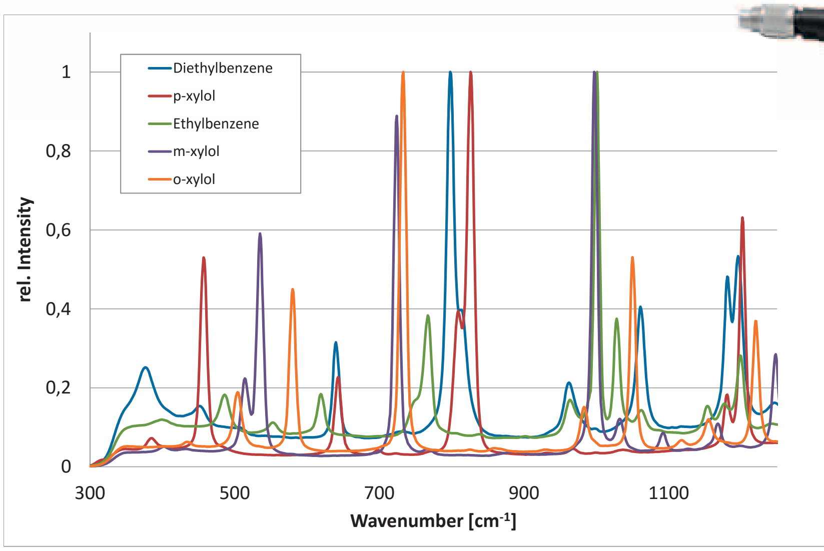
Technology for Spectroscopy

White Paper

tec5 Raman Spectrometer Systems – Laser Safety Concept



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Safety aspects play a major role when considering instrumentation for installation in industrial plants or processes. In the evaluation of Raman spectrometers, the performance of the spectrometer system is the focus. When the system is transferred from a laboratory environment into a process, some additional safety considerations have to be taken into account. Typically, the personnel in industrial plants are not trained in the operation of laser equipment. Therefore, a safety concept, which also envisions a distributed installation of components, is required.

[Background]

The optical power output and wavelength of the integrated laser contribute to the performance of the measurement system. These two factors also contribute to the classification of the laser according to the laser safety classes. Using a 785 nm laser, the emission is beyond the sensitivity of the human eye and therefore has a high potential to permanently damage the retina and may cause a total loss of vision.

During normal operation, the laser light is coupled into a fiber-optic cable which guides the light to the Raman probe. The light output from the probe interacts with the medium, which then produces a signal measured by the system. Experienced operators of Raman spectrometers are usually also trained safety experts for the operation of lasers. Under process control conditions, the laser is operated continuously 24/7, but not all of the staff on a plant may be trained in laser safety. Therefore, a carefully designed concept for safe laser operation has to be established.

[General Laser Safety]

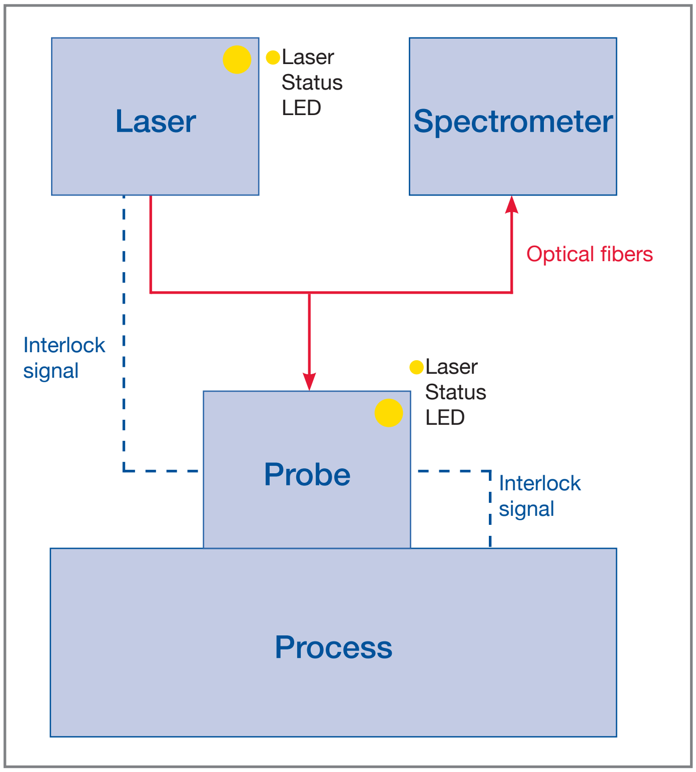
In laser safety, there are different classes which rate the potential hazards to human health. The MultiSpec® Raman spectrometer contains a class 3B laser. The system is compliant with DIN EN60825-1. For safe laser operation, please refer to the local occupational regulations for laser safety [e.g. Germany – BGV B2 " Laserstrahlung" - safety regulations].

The lowest laser class with respect to a potential threat to humans is laser class 1. Examples of devices containing class 1 lasers are CD, DVD and Blu-Ray players and recorders. The housing and operation concept of these devices ensures the operation of the laser is entirely contained within the device. The laser operation is interrupted when the housing is opened, and then after the housing is closed again, operation may commence by activation from the user. For all higher classes of lasers, the safest way to adapt this concept and to design a system, where during operation laser radiation is safely guided to the measurement and cannot leak from the housing of the device. Furthermore, laser radiation cannot be accessed at any point of the set-up by any untrained personnel without causing the system to switch-off the laser.

[Interlock Concept]

The safety concept using a distributed Raman system is schematically drawn in Figure 1. A safe operation mode, covering laser safety issues, is ensured using an elaborated interlock system. The employed interlock-loop prevents access to laser radiation by untrained personnel. Furthermore, this interlock-loop ensures deactivation of laser if theoptical path is interrupted, or if the Raman probe head is unmounted from the protective aluminum probe chamber. This interlock-loop covers the complete pathway of the laser radiation, from the source to the specimen, which may be up to several meters away.

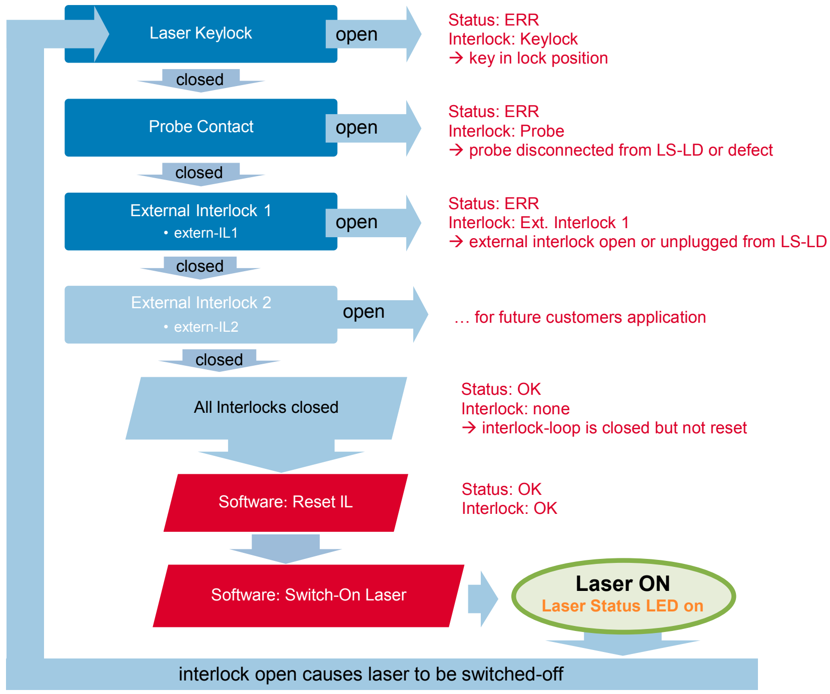
The operator is fully responsible for ensuring a proper connection of the laser fiber to the instrument as well as for ensuring a safe connection of the Raman probehead to the process.



[Figure 1: Safety concept. An interlock-loop is provided to ensure a permanent connection of the probe head to the process while the laser is emitting optical radiation [signalized by the Laser Status LEDs.]

[Realization]

[Figure 2: tec5 MultiSpec® Raman System – from left to right: main switch, LS-LD cassette, spectrometer.]



[Figure 3: Flow diagram of the electronically monitored interlock-loop [blue shapes], software-based controls [red shapes] and notifications.]

The current tec5 MultiSpec® Raman System [see Figure 2] supports an interlock-loop consisting of four interlock-interfaces. Besides the Laser-Keylock, a Probe Contact Interlock and two external interlocks [external-IL1 and external-IL2] are provided. On the front side of the light source cassette, LS-LD, is a Laser-Keylock, a key switch for trained personnel. The Probe Contact Interlock ensures protection against laser irradiation from the aperture on the front side of the LS-LD.

In the Raman probe head two optical fibers and an interlock cable are included. The fibers and interlock are sealed within the probe-head and can be connected to the MultiSpec® Raman System. The laser-guiding fiber from the LS-LD to the Raman probe head comprises the Probe Contact Interlock in its plug [type: FC-APC]. By plugging this fiber to the LS-LD, the interlock will be closed and an optical path is enabled from the laser aperture to the probe head. The other fiber is delivered with a standard SMA-plug that can be connected to the spectrometer.

The intensity of the measured Raman radiation from a specimen, which is transmitted to the spectrometer, is not critical to damaging the human eye. The fundamental radiation of the original laser beam is reduced significantly as an OD-filter is placed inside the Raman probe head in addition.

A third interlock [external-IL1] ensures a permanent connection of the Raman probe head to the measurement volume. In order to conform to laser class 1 criteria, the probe head has to be inserted into a non-transparent housing or pipe. Once the probe head is mounted, a short interlock cable connects the Raman probe head with the outside of the probe chamber or pipe installation. The length of the cable between probe head interlock socket and probe chamber is chosen such that the probe head cannot be unmounted from the probe chamber without disconnecting this cable and thus interrupting the interlock circuit.

To ensure that laser radiation, which is emitted in front of the probe head and focused inside the specimen, will be interrupted upon opening the probe chamber, the external-IL1 is serially extended with an interlock switch at the door of the probe chamber [see Figure 4].

The fourth interlock [external-IL2] is intended for additional customer applications, e.g. a second Raman probe head. This interlock is provided by two pins in the interlock socket on the front-side of the LS-LD cassette. For a standard applications including one Raman probe head and one probe chamber, this interlock is usually not needed and therefore short-circuited by the used interlock-plug.

If all interlocks are connected, the laser can be switched on using the MultiSpec® Pro II Software. Two LEDs, one at the front side of the LS-LD cassette and one at the Raman probe head, indicate that laser radiation is emitted inside the probe chamber. Since the interlocks are continuously checked via electronics, an interruption of one interlock causes the electronics to switch-off the laser.

[Measurement in a pipe / industrial plant]

Piping in industrial plants is usually constructed from non-transparent materials, such as steel or metal alloys. By using an immersion probe, the probe directs light into the sample volume. A retraction of the probe has to be prevented such that the operation of the laser stops before a manual retraction.

The interlock concept anticipates these situations. As the interlock is opened, for example, the cable is removed which features the connection between the probe and the process [see Figure 1], the laser light is extinguished.

[Measurement in a probe chamber]

In laboratory use, a flexible measurement of samples may be necessary. A measurement chamber has been developed which contains the laser irradiation during the measurement The door of the probe chamber contains an interlock, ensuring the laser emission is only active while the chamber is closed [see Figure 4].

[Figure 4: Example of a Raman installation for a measurement in a probe chamber. The Raman probe head is connected with a measurement box. During measurement the external interlock [external-IL1] ensures a permanent connection of the probe head. The probe head cannot be unmounted from the box without disconnecting the interlock-cable. An interlock-switch at the door of the box [blue] which is connected in serial to the external-IL1 further ensures the laser can be switched-on only when the door is closed. If the interlock-loop is opened, the laser will be switched-off automatically.]

[IL-concept in MultiSpec® Pro II Software]

The interlocks are electronically checked in their serial, hierarchical addressing and the first interrupted interlock connection in this addressing is displayed. This serial addressing is schematically shown in Figure 3. By default, the laser is switched-off. After all interlocks are electronically connected and the interlock-loop is closed, a check via software is needed to finally switch on the laser [see Figure 3]. This last step can be accessed by authorized personnel in the MultiSpec® Pro II software or remotely controlled from a process communication interface.

Even in the case of an uninterrupted interlock-loop, the user has to confirm the proper installation of all interlocks before the laser can be switched-on.

[Summary]

Depending on the installation layout of the measurement setup and the probe chamber or process interface used, the installation according to laser class 1 considerations, implementing an elaborated interlock-loop is essential to ensure safety for the on-site personnel.

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