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# TECHNICAL SPECIFICATION

# ISO/TS 17915

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# Optics and photonics — Measurement method of semiconductor lasers for sensing

*Optique et photonique — Méthode de mesure des lasers semi-conducteurs pour la sensibilité*



Reference number
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# Foreword

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# Optics and photonics — Measurement method of semiconductor lasers for sensing

## 1 Scope

This Technical Specification describes methods of measuring temperature, injected current dependence and lasing spectral line width in relation to semiconductor lasers for sensing applications. This Technical Specification is applicable to all kinds of semiconductor lasers, such as edge-emitting type and vertical cavity surface emitting type lasers, bulk-type and (strained) quantum well lasers, and quantum cascade lasers, used for optical sensing in e.g. industrial, medical and agricultural fields. This Technical Specification is an application of ISO 13695, in which the physical bases are explained.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13695, *Optics and photonics — Lasers and laser-related equipment — Test methods for the spectral characteristics of lasers*

## 3 Optical sensing using semiconductor lasers

### 3.1 General

The methods described in this Technical Specification are to be followed in accordance with ISO 13695.

Optical sensing using tunable semiconductor laser spectroscopy has been widely used in various engineering fields. For example, optical sensing is being used for bio-sensing and environmental monitoring. Semiconductor lasers are key devices for those applications and are indispensable for building sensing equipment. Semiconductor lasers and sensing techniques are described in 3.2 to 3.6.

### 3.2 Semiconductor laser

#### 3.2.1 General

A semiconductor laser is an optical semiconductor device that emits coherent optical radiation in a certain direction through stimulated emission resulting from electron transition when excited by an electric current that exceeds the threshold current of the semiconductor laser. Here, the mechanism of coherent optical radiation is divided into two categories, (1) electron-hole recombination due to interband electron transition between conduction and valence band (bulk type) or between two quantized states (quantum well type, see 3.2.5) and (2) intraband electron transition between two quantized states (quantum cascade type, see 3.2.5).

Edge-emitting types with single lasing modes, such as distributed feedback (DFB) lasers, have been conventionally used in sensing equipment because of their high power and single lasing modes. Surface-emitting types are also widely used in sensing systems because they are easy to handle. Some names are given to those lasers from various aspects. Those lasers are briefly categorized in 3.2.2 to 3.2.5.

### 3.2.2 Basic structure

a) Edge emitting type semiconductor laser: a semiconductor laser that emits coherent optical radiation in the direction parallel to junction plane.

b) Surface emitting type semiconductor laser: a semiconductor laser that emits coherent optical radiation in the direction normal to junction plane. Vertical cavity surface emitting type semiconductor laser (VCSEL) is the typical one.

### 3.2.3 Transverse mode stabilizing structure

a) Gain guiding: a semiconductor laser in which emitted light propagates along the gain region generated by carrier injection and is amplified by stimulate emission along the gain region. Planar type lasers are typical ones in gain guiding.

b) Refractive index guiding: a semiconductor laser in which a stripe-shape active layer (light emitting layer) or junction is formed to introduce effective refractive index difference between the stripe and the outer region. Buried heterostructure (BH) is typical in refractive index guiding.

### 3.2.4 Mode (wavelength) selection structure

a) Distributed feedback (DFB) semiconductor laser: a semiconductor in which stimulated emission is selected by a grating (equivalent to distributed mirror). This laser operates in single longitudinal mode.

b) Distributed Bragg reflector (DBR) semiconductor laser: a semiconductor laser in which stimulated emission is selected by a Bragg grating (equivalent to distributed mirror) jointed at a side or the both sides of light emitting layer. This laser operates in single longitudinal mode.

c) Fabry-Perot (FP) semiconductor laser: a semiconductor laser in which stimulated emission is generated between two mirror facets. This laser normally operates in multiple longitudinal modes.

d) External cavity controlled semiconductor laser: a semiconductor laser in which the optical cavity is composed of one mirror and an external mirror (ex. grating) set on the opposite side of the mirror. Stimulated emission is generated at the semiconductor part in the optical cavity. This laser normally operates in single longitudinal mode.

### 3.2.5 Active layer structure

a) Double heterostructure semiconductor laser: a semiconductor laser in which the active layer (light emitting layer) is sandwiched with two heterojunctions (pn- and iso-junction).

b) Quantum well semiconductor laser: a semiconductor laser that emits coherent optical radiation through stimulated emission resulting from the recombination of electrons and holes between two quantized states. Here, the light emitting layer is composed of a single quantum well layer or multiple quantum well layers. Quantum wire and quantum dot (box) semiconductor laser are included in this category but the light emitting area of quantum wire and dot is two-dimensional and three-dimensional structure, respectively.

c) Strained quantum well semiconductor laser: a semiconductor laser that emits coherent optical radiation through stimulated emission resulting from the recombination of free electrons and holes between two quantized states. Here, the light emitting layer is composed of strained single quantum well layer or multiple quantum well layers.

d) Quantum cascade semiconductor laser: a semiconductor laser that emits coherent optical radiation through stimulated emission resulting from electron transition between two quantized states without any electron-hole recombination. The light emitting layer is composed of quantum cascade layers.

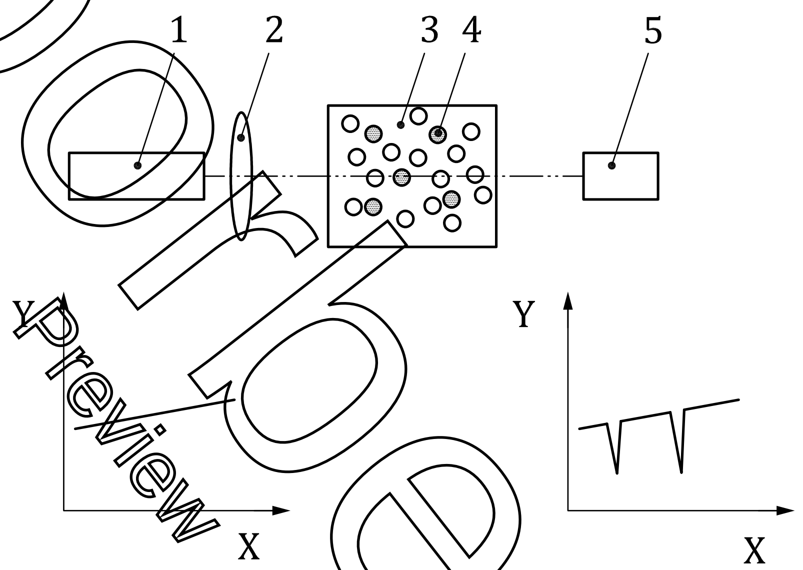
## 3.3 Common sensing technique and equipment using semiconductor laser

### 3.3.1 General

Semiconductor lasers including quantum cascade semiconductor lasers have various advantages: compact size, light weight, low power consumption, easy controlling of wavelength by pulsed or continuous wave operation, etc. Sensing techniques and equipment using such semiconductor lasers have been researched and developed in academic and industrial fields. The main sensing techniques are described in 3.3.2 to 3.3.4.

### 3.3.2 Tunable laser absorption spectroscopy (TLAS)

Absorption spectrum is monitored by scanning repeatedly the wavelength of light emitted from semiconductor laser as shown in Figure 1. The composition of material and mixture to be examined are qualitatively and quantitatively analysed based on the monitored spectrum (shape, peak wavelength and intensity). The lasing wavelength of semiconductor laser is scanned by controlling the ambient temperature or injected current in this technique.




**Key**

X wavelength

Y optical intensity

1 tunable laser diode

2 lens

3 cell

4 element to be detected

5 optical detector

**Figure 1 — Basic concept of tunable laser absorption spectroscopy (two absorption peaks are observed)**

### 3.3.3 Cavity ring down spectroscopy (CRDS)

This technique is usually used for detecting trace element and originated from tunable semiconductor laser spectroscopy. Material to be analysed is introduced into the cavity built up with two mirrors as shown in Figure 2. Light pulse (with a certain wavelength) introduced to the cavity is repeatedly reflected between the mirror and passes through the material. A part of reflecting light escapes through the mirror, and a pulse train with a time interval determined with the cavity length is monitored. The

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