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Nanotechnologies - Vocabulary - Part 12: Quantum phenomena in nanotechnology (ISO/TS 80004-12:2016)

Táto norma obsahuje anglickú verziu európskej normy.
This standard includes the English version of the European Standard.

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# Nanotechnologies - Vocabulary - Part 12: Quantum phenomena in nanotechnology (ISO/TS 80004-12:2016)

Nanotechnologies - Vocabulaire - Partie 12: Phénomènes quantiques dans les nanotechnologies (ISO/TS 80004-12:2016)

Nanotechnologien - Fachwörterverzeichnis - Teil 12: Quantenphänomene in der Nanotechnologie (ISO/TS 80004-12:2016)

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# Contents

Page

**European foreword..... 3**

# European foreword

The text of ISO/TS 80004-12:2016 has been prepared by Technical Committee ISO/TC 229 “Nanotechnologies” of the International Organization for Standardization (ISO) and has been taken over as CEN ISO/TS 80004-12:2017 by Technical Committee CEN/TC 352 “Nanotechnologies” the secretariat of which is held by AFNOR.

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## Endorsement notice

The text of ISO/TS 80004-12:2016 has been approved by CEN as CEN ISO/TS 80004-12:2017 without any modification.

TECHNICAL SPECIFICATION

**ISO/TS 80004-12**

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# Nanotechnologies — Vocabulary —

## Part 12: Quantum phenomena in nanotechnology

*Nanotechnologies — Vocabulaire —*

*Partie 12: Phénomènes quantiques dans les nanotechnologies*

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# Contents

Page

**Foreword** ..... **iv**

**Introduction** ..... **v**

**1 Scope** ..... **1**

**2 Terms describing (or related to) general quantum concepts** ..... **1**

**3 Terms related to basic quantum effects** ..... **3**

**4 Terms describing size-dependent quantum effects** ..... **4**

**5 Terms related to structural organization** ..... **5**

**6 Terms associated with quantum effects** ..... **6**

**Annex A** (informative) **Some current terms in classical and quantum physics** ..... **8**

**Annex B** (informative) **Mapping between terms and some applications and products in nanotechnologies** ..... **9**

**Annex C** (informative) **Index** ..... **11**

**Bibliography** ..... **12**

# Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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ISO/TS 80004-12 was prepared jointly by Technical Committee ISO/TC 229, *Nanotechnologies*, and Technical Committee IEC/TC 113, *Nanotechnology standardization for electrical and electronic products and systems*. The draft was circulated for voting to the national bodies of both ISO and IEC.

ISO/TS 80004 consists of the following parts, under the general title *Nanotechnologies — Vocabulary*:

— *Part 1: Core terms*

— *Part 2: Nano-objects*

— *Part 3: Carbon nano-objects*

— *Part 4: Nanostructured materials*

— *Part 5: Nano/bio interface*

— *Part 6: Nano-object characterization*

— *Part 7: Diagnostics and therapeutics for healthcare*

— *Part 8: Nanomanufacturing processes*

— *Part 12: Quantum phenomena in nanotechnology*

The following parts are under preparation:

— *Part 9: Nano-enabled electrotechnical products and systems*

— *Part 10: Nano-enabled photonic components and systems*

— *Part 11: Nanolayer, nanocoating, nanofilm and related terms*

— *Part 13: Graphene and other two dimensional materials*

# Introduction

The unique properties of nano-objects and nanoscale-dependent quantum effects are important aspects of nanotechnology.

As the size of materials decreases to the nanometre range, quantization effects (quantization of energy, quantization of angular momentum, etc.) appear mainly due to the confinement of particles in one, two or three space dimensions (quantum confinement). This leads to the emergence of new size-dependent properties and functionalities which are completely described by quantum mechanics.

It is to be noted that the term “particle” used in this part of ISO/TS 80004 encompasses both the classical and quantum standpoints. In its classical sense, a particle is a discrete portion of matter and is therefore close to the term “particle” as defined in ISO/TS 80004-2 as a “minute piece of matter with defined physical boundaries”. From the perspective of quantum, particles are objects obeying the laws of quantum mechanics. The quantum description includes electrons, atoms, molecules, etc., referred to as particles, and quasi-particles (excitons, phonons, plasmons, magnons, etc.) which are elementary excitations or quanta of collective excitations in strongly interacting systems of particles.

Although quantum effects do not occur exclusively at the nanoscale, the relationship of nanotechnology and quantum effects, or combinations thereof, is important for the identification of nano-enabled products and for the development of nanotechnology.

With regard to the origin of terms, quantum effects terms are often associated with the names of those who discovered them. As such, they are often the subject of controversy about precedence. In addition, quantum phenomena and effects might have different names in different countries.

Nanotechnologies are rapidly evolving fields of technologies and advances in these fields are closely linked to the understanding of quantum effects and phenomena. It is expected that more quantum phenomena-related terms will be added in future revisions of the present document.

This part of ISO/TS 80004 promotes a common language for use by the nanotechnology industry and interdisciplinary research in these areas, organizes features of nanotechnology and contributes to cooperation in the field of nanotechnology and trade in the global market of nano-enabled products.

Some established terms and definitions of quantum mechanics have been gathered in Annex A in order to facilitate the reading of this part of ISO/TS 80004.

# Nanotechnologies — Vocabulary —

# Part 12: Quantum phenomena in nanotechnology

## 1 Scope

This part of ISO/TS 80004 lists terms and definitions relevant to quantum phenomena in nanotechnologies.

All of these terms are important for nanotechnologies, but it is to be noted that many of them are not exclusively relevant to the nanoscale and can also be used to some extent to refer to larger scales.

The list of terms presented does not claim to provide exhaustive coverage of the whole spectrum of quantum concepts and phenomena in nanotechnology. It covers important phenomena as acknowledged by many stakeholders from academia, industry, etc.

This part of ISO/TS 80004 is intended to facilitate communication between organizations and individuals in industry and those who interact with them.

## 2 Terms describing (or related to) general quantum concepts

**2.1**
**de Broglie wavelength**
wavelength of the wave associated with any particle which reflects its wave nature according to de Broglie's formula

Note 1 to entry: de Broglie's formula is $\lambda = h/p$, where $\lambda$ is the wavelength, $h$ is the Planck's constant and $p$ is the particle momentum.

**2.2**
**quantization**
process resulting in quantized physical quantities

**2.3**
**quantized**
having discrete values which are multiples of an elementary quantity

Note 1 to entry: The elementary quantity mentioned above is usually called a quantum of the physical quantity in consideration.

**2.4**
**quantum coherence**
correlated evolution of wave function phase of a system in a *quantum superposition* (2.9)

Note 1 to entry: Quantum decoherence is the loss of quantum coherence.

**2.5**
**quantum confinement**
restriction of a particle's motion in one, two or three space dimensions when the size of a physical system is of the same order of magnitude as the particle's *de Broglie's wavelength* (2.1)

Note 1 to entry: The main characteristic lengths leading to quantum confinement may be their de Broglie wavelength, their Fermi wavelength, their mean free path, their Bohr radius (for excitons) or their coherence length.

Note 2 to entry: See Reference [2].

**2.6**
**quantum entanglement**
quantum mechanics phenomenon in which the quantum states of two or more particles are interdependent

Note 1 to entry: Quantum states of entangled particles may be described as a whole and not in terms of individual particles' states.

Note 2 to entry: See References [3] and [5].

**2.7**
**quantum interference**
coherent superposition of *wave functions* (2.14) (quantum states) of a physical system

**2.8**
**quantum number**
number specifying one of the possible discrete values of physical quantities that characterize quantum systems

Note 1 to entry: Some of the quantum numbers may characterize the spatial distribution of the particle wave function.

Note 2 to entry: Some quantum numbers characterize only the "internal" state of the particle. For example, the magnitude and direction of the spin, etc.

Note 3 to entry: A quantum state of an electron in an atom is usually described by the following four quantum numbers: the principal quantum number, the azimuthal quantum number, the magnetic quantum number and the spin quantum number.

Note 4 to entry: See References [3], [5], [6] and [7].

**2.9**
**quantum superposition**
linear superposition (or linear combination) of *wave functions* (2.14)

Note 1 to entry: The superposition principle states that any linear superposition (or linear combination) of wave functions is also a possible wave function of a physical system.

Note 2 to entry: The state of a physical system is defined (or described) at any time by a wave function.

**2.10**
**quantum tunnelling**
phenomenon of a particle passing through a potential barrier when its total energy is less than the height of the barrier

Note 1 to entry: Quantum tunnelling is a purely *quantum phenomenon* (3.8) because a classical particle with energy, E, cannot pass through a potential barrier of height, V, if $E < V$, since in such case, the kinetic energy of the particle would be negative.

Note 2 to entry: Due to quantum uncertainty principle, any subatomic particle has some probability to pass through a potential energy barrier.

Note 3 to entry: See References [1], [3] and [4].

**2.11**
**quasi-particle**
elementary excitation (a quantum of collective oscillations) in strongly interacting systems of particles

Note 1 to entry: Quasi-particles may include excitons, phonons, plasmons, magnons, polaritons, etc.

Note 2 to entry: See References [1], [2], [3] and [5].

**2.12**
**qubit**
**quantum bit**
basic unit of *quantum information* (6.8) based on two-state quantum system which can be in one of its states or in a superposition of both

Note 1 to entry: See References [1], [2], [3], [5] and [8].

**2.13**
**surface plasmon**
*quasi-particle* (2.11) corresponding to the *quantization* (2.2) of surface plasma oscillations

**2.14**
**wave function**
**wavefunction**
mathematical function that completely describes the state of a quantum system and which contains all the information regarding the measurable physical quantities of the system

Note 1 to entry: The wave function, also called “the state vector”, has the significance of a probability amplitude and is not directly measurable.

Note 2 to entry: The state of a quantum system is also referred to as a quantum state.