

THE ANALYSIS OF CONCEPTS IN A TERMINOLOGY: A CASE STUDY OF RUSSIAN AND ENGLISH TERMS IN THE FIELD OF PHOTONIC CRYSTALS

A ANÁLISE DE CONCEITOS EM UMA TERMINOLOGIA: UM ESTUDO DE CASO DE TERMOS EM RUSSO E INGLÊS NO CAMPO DOS CRISTAIS FOTÔNICOS

EL ANÁLISIS DE CONCEPTOS EN UNA TERMINOLOGÍA: ESTUDIO DE CASO DE TÉRMINOS RUSOS E INGLÉS EN EL ÁMBITO DE LOS CRISTALES FOTÓNICOS

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ABSTRACT: Since the 20th century, cognitive linguistics has been extremely influential. Scientists became interested not only in what is represented in the language but also in how speech occurs. The language ceased to be understood as something isolated and began to act as the primary means of expressing a person's thoughts. Through observing language forms, the process of cognition is indirectly studied. A human recognizes reality through senses, logical understanding, and practical verification. Regarding scientific knowledge, it also includes modeling, synthesis, and prediction. Language, in this case, acts not only as an intermediary between thought and its verbalization. It becomes a unique and self-acting tool. This article is devoted to the concept analysis of the photonic crystal terminology. For terms selection, the method of continuous sampling was applied. The work shows how to find the most constitutive terms for terminology and which concepts are objectified foremost. Particular attention is paid to the process of correlating main concepts with thematic groups. The correlation is necessary to determine the boundaries of the terminology and its place in modern science. The difference between Russian and English nature of term-creation is investigated. The relevance of the research is to show how mental knowledge is represented through terms.

KEYWORDS: Terminology. Concepts. Cognitive analysis.

RESUMO: Desde o século 20, a linguística cognitiva tem sido extremamente influente. Os cientistas ficaram interessados não apenas no que é representado na linguagem, mas também em como a fala ocorre. A linguagem deixou de ser entendida como algo isolado e passou a atuar como o principal meio de expressão do pensamento de uma pessoa. Por meio da observação das formas de linguagem, o processo de cognição é indiretamente estudado. Um humano conhece a realidade através dos sentidos, compreensão lógica e verificação prática. No que diz respeito ao conhecimento científico, inclui também modelagem, síntese e previsão. A linguagem, nesse caso, não atua apenas como intermediária entre o pensamento e sua verbalização. Torna-se uma ferramenta única e de ação automática. Este artigo é dedicado à análise de conceito da terminologia do cristal fotônico. Para a seleção dos termos, foi aplicado o método de amostragem contínua. O trabalho mostra como encontrar os termos mais constitutivos da terminologia e quais conceitos são mais objetivados. É dada especial atenção ao processo de correlação dos conceitos principais com os grupos temáticos. A correlação é necessária para determinar os limites da terminologia e seu lugar na ciência moderna. A

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diferença entre a natureza russa e inglesa da criação de termos é investigada. A relevância da pesquisa é mostrar como o conhecimento mental é representado por meio de termos.

PALAVRAS-CHAVE: Terminologia. Conceitos. Análise cognitiva.

RESUMEN: Desde el siglo XX, la lingüística cognitiva ha tenido una gran influencia. Los científicos se interesaron no solo en lo que está representado en el lenguaje, sino también en cómo ocurre el habla. El lenguaje dejó de entenderse como algo aislado y comenzó a actuar como el medio principal para expresar los pensamientos de una persona. Mediante la observación de las formas del lenguaje, se estudia indirectamente el proceso de cognición. Un ser humano conoce la realidad a través de los sentidos, la comprensión lógica y la verificación práctica. En cuanto al conocimiento científico, también incluye modelado, síntesis y predicción. El lenguaje, en este caso, actúa no solo como intermediario entre el pensamiento y su verbalización. Se convierte en una herramienta única y autoactiva. Este artículo está dedicado al análisis de conceptos de la terminología del cristal fotónico. Para la selección de términos se aplicó el método de muestreo continuo. El trabajo muestra cómo encontrar los términos más constitutivos de la terminología y qué conceptos se objetivan principalmente. Se presta especial atención al proceso de correlación de conceptos principales con grupos temáticos. La correlación es necesaria para determinar los límites de la terminología y su lugar en la ciencia moderna. Se investiga la diferencia entre la naturaleza rusa e inglesa de la creación de términos. La relevancia de la investigación es mostrar cómo se representa el conocimiento mental a través de términos.

PALABRAS CLAVE: Terminología. Conceptos. Análisis cognitivo.

Introduction

Categorization is one of the critical aspects of research in cognitive linguistics. Categorization is not only the ability to classify the surrounding phenomena but also about creating one's understanding and explanation of reality based on this classification (KAGEURA, 2002, p. 65). In linguistics, this process is associated more with semantic fields than with conceptual domains (as in logic). Therefore, the influence of the human factor is considered. Despite this, in scientific categorization, there is certainly a clearly defined center of the category. However, there are still elements that are located on the periphery and may fall into other categories (CABRÉ CASTELLVÍ, 2003, p. 178). Compare, for example: "Self-assembly takes place at molecular, mesoscopic, and macroscopic scale" (LACHOWICZ, 2011, p. 55). The point is not that scientific sources can represent the term as an element of different fields, but that, in a human mind, different categories interact at the common and scientific levels. This example points to the procedural nature of categorization, which is reflected in a specific communicative situation.

In addition to categorization, the central aspect of cognitive linguistics, or rather semantics, is conceptualization. Conceptualization is the cognitive processing of incoming information and cognitive creating of objects and phenomena, resulting in the formation of concepts (REY, 1998, p. 123). Thus, conceptualization includes both old and new concepts, a determination of context, and emotional and sensory experience. The concept is the reflection of conceptualization aimed to fix a specific non-rigid structure. To represent such non-rigid structures, semantics uses four types of cognitive models. Among them are figurative schemes, propositional models, and conceptual metaphor and metonymy (RIGGS, 1984, p. 234). Several features characterize the use of such cognitive models in terminology. Firstly, propositional models can only be used to analyze complex terms, while figurative schemes are successfully used for those concepts that include well-established and new meanings, emotional, motor, and sensory experience of a person. Conceptual metaphor and metonymy allow us to describe the elements of one terminological system through the prism of another professional field (TURNER; FAUCONNIER, 2000, p. 127).

To describe more complex processes in terminology, the concept of mental space should be implemented. J. Fauconnier defined mental spaces as the structure of domains in which certain information is collected (FAUCONNIER; TURNER, 2002, p. 120). A unique feature of these domains and the relationships between them is that they can represent both the professional field and the hypothetical situations or hopes of a person, because connections between domains may differ from connections in the real world. Mental spaces are conveniently represented in the form of frames. This allows one to enter reasons for regulating relations between domains, which significantly facilitates the search for the necessary element in the stream of consciousness. The introduction of the concept of mental structures into terminology allows us to observe how discourse occurs in the process of creating new concepts and using already established concepts (ANTIA, 2000, p. 140).

Not all concepts of a science field have the same specific gravity in it. In order to build a high-quality frame that describes the mental space of photonic crystals, let us first turn to the key concepts of this science. Studying various definitions of the same concept in science, it can be noted that other concepts are involved in explaining this concept because all concepts of one science are in a certain relationship. However, not all concepts must be used to describe others, and some are used more often than others. This confirms the assertion that different concepts have a distinct specific gravity in science. The importance of defining the key concepts of each science is to understand what knowledge of this science is objectified foremost (BUDIN, 2001 p. 9).

Method

To understand which concepts are constitutive for the science of photonic crystals, i.e., those concepts which help to understand the essence of science, it is necessary to analyze the database of this science.

Interest in photonic crystals arose at the end of the 20th century, and at the beginning of the 21st century, this area became very popular and promising. The unique properties of photonic crystals allow them to control light and transfer much more information many times faster than the classic silicon microcircuits. The use of photonic crystals as the substrate for solar cells is also auspicious because of the crystals' ability to retain light. The study of such terminology from linguistics perspectives is relevant because we can observe the processes occurring in the terminological system in real-time.

Terms selected by a continuous sampling method are used in this study. Three of the most famous scientific books on this subject are analyzed (K. Sakoda (2005) "Optical Properties of Photonic Crystals"; John D. Joannopoulos et al. (2008) "Photonic Crystals. Molding the Flow of Light" and "Semiconductor Nanocrystal Quantum Dots" edited by Andrey Rogach (2008)). The selected terms (124 pieces) are compiled into a glossary; each term is equipped with the Russian equivalent and an example. Thematic dictionaries (Photonics Encyclopaedia, Universalium, physical encyclopedia, etc.) and scientific articles are also used for analysis. After picking up terms, we divided them into thematic groups based on word frequency count, analysis of scientific books titles and subtitles and experts' recommendations. Then we carried on a definition analysis to build a more general concept sphere under all thematic groups and highlight the links between photonic crystals and other sciences.

Results

The analysis of concepts can be based on verbal sources: monographs, articles, references, and dictionaries (FELBER, 1979, p. 87). Considered the fact that concepts are essentially mental structures, and notions are a kind of interface between consciousness and meaning; meaning, in turn, is reflected in the definition. Therefore, the objects for analysis are precisely the definitions (ZAWADA; SWANEPOEL, 1994, p. 255).

Let us turn to various definitions of the term "photonic crystal".

Photonic crystals (PCs) are highly ordered materials that possess a periodically modulated dielectric constant, with the properties of confining and controlling the propagation

of light owing to the existence of photonic band gap, a band of frequencies in which light propagation in the photonic crystal is forbidden (SHAO; LIU; ZHOU, 2016, p. 269).

Photonic crystals are periodic composites of dielectric material that can be used for controlling propagation and emission of light (LODAHL, 2012, p. 395).

By analyzing the light transmission in photonic crystal as an eigenvalue problem of electromagnetism, we obtain the photonic band gap diagrams of photonic crystal, and the effects of dielectric constant and lattice structures on band gap of photonic crystal are discussed (LOU *et al.*, 2012, p. 164).

Photonic crystals composed of dielectric lattices form bandgaps for electromagnetic waves. These artificial crystals can totally reflect light or microwave at a wavelength comparable to the lattice spacings by Bragg deflection (FUKUI *et al.*, 2018, p. 301).

Photonic crystal is known as a periodic dielectric array with different dielectric constants which can totally reflect light or electromagnetic waves with the wavelength similar to the periodicity, due to Bragg, and form the photonic band gap like the formation of electronic band gap in semiconductors (MIYAMOTO *et al.*, 2005, p. 3).

The analysis of these definitions can identify that this science is determined through such features as structure characteristics, material properties, the conditions of electromagnetic waves propagation. All these conceptual features are interconnected and interdependent. Changing one of them will entail the destruction of the whole concept of “photonic crystal”. The conceptual attribute “structure characteristic” is represented verbally by the following expressions: highly ordered materials, periodic composites, lattice structures, lattices, periodic array. All these definitions mention that this structure is a periodic one (periodicity) and, if the wavelength is equal to the spacing between the ribs of the lattice, it is totally reflected by Bragg law (Bragg deflection). It is also emphasized that the material of this structure has the property of a dielectric, i.e., characterized by dielectric constant. For all photonic crystals, as seen from the definitions, band gap, in which electromagnetic waves do not propagate, is needed. Thus, the following concepts are key to this science: the concepts of photonic crystal, crystal lattice, dielectric constant, band gap or photonic band gap, and Bragg reflection or deflection. There is no doubt that these concepts are key for this science. Nevertheless, the constitutional nature of these concepts can be confirmed by a definitional analysis of each of these concepts, and such an analysis will help to identify which other concepts in this area can be added to the list of key ones.

Consider, for example, a few definitions of the above-mentioned key concepts - crystal lattice.

The crystal lattice is the regular arrangement of particles (atoms, their nuclei, ions, molecules, electrons) inherent in crystals, characterized by periodic repeatability in three dimensions (Physical Encyclopedia, 2021).

A crystal lattice is a periodic spatial arrangement of atoms or ions in a crystal. Points of crystal lattice, in which atoms or ions are located, are called crystal lattice nodes (Big Encyclopedic Dictionary, 2021).

Crystal lattice is a three-dimensional configuration of points connected by lines used to describe the orderly arrangement of atoms in a crystal. Each point represents one or more atoms in the actual crystal. The lattice is divided into a number of identical blocks or cells that are repeated in all directions to form a geometric pattern (Encyclopedia Britannica, 2021).

Crystal lattice - the arrangement of atoms or molecules in a crystal, represented as a repeating arrangement of points in space, each point representing the location of an atom or molecule; called also space lattice (The Collaborative International Dictionary of English, n.d.).

As can be seen from the above examples, the following minimal meanings form the content of this concept: “orderliness” and “repeatability”. Verbally they are represented by synonymous expressions and words (регулярный/orderly and повторяемость/repeating arrangement, be repeated).

The concept of being organized in the lattice form is explicated in its comprehension. Verbally, it is represented by terms that are related as a hyperonym and hyponyms (particles: molecules, atoms, ions, electrons). Thus, the conceptual system of a photonic crystal is included in the conceptual system of any structure that is organized into a crystal lattice. In order to indicate the boundaries of the frame of photonic crystals, we also analyze the definitions of other keywords of the terminological system.

Consider several definitions of the term band gap.

In the most extreme situation, light is prohibited from propagating in any direction and a photonic band gap is said to exist (SUDARSAN, 2012, p. 285).

[...] A band gap forbids propagation of a certain frequency range of light. This property enables one to control light with amazing facility and produce effects that are impossible with conventional optics (MATHUR, 2018, p. 146).

In certain situations, so-called photonic band gaps arise; here, one considers states of the light field rather than states of electrons. The analysis of those situations, occurring in certain photonic metamaterials, one also finds that there are certain regions of the photon energy for which there are no states. That implies that light with such photon energies cannot propagate over substantial distances in the medium (RP Photonics Encyclopaedia, 2021).

The most striking feature of photonic crystals is the existence of 3D photonic crystals with a sufficiently large contrast of the refractive indices of the components of certain spectral regions, which are called complete photonic band gaps: the existence of radiation with photon energies belonging to the photonic band gap in such crystals is impossible (Thesaurus Rusnano, 2021).

By analyzing the definitions of the keywords, we gradually narrow the frame of photonic crystal terminology and find its place in the conceptual landscape. Thus, photonic crystals are characterized by a periodic structure (crystal lattice) with a band gap, which implies that light in this zone cannot propagate and even penetrate it. Verbally, it is expressed by the number of hyponyms (states of the light field, photon energy) with the single hyperonym “light”. The idea of “prohibiting” the distribution of light is expressed by a number of synonyms (be prohibited, forbid, cannot, impossible). It is also worth notice the difference between the English term “band gap” and the Russian term “запрещенная зона”.

In the Russian term, the idea of “forbiddleness” is presented directly in the appearance of the term, while in English “gap” is a hole. Therefore, if one looks at the band diagram for the photon energies in the photonic crystal, it can be seen how the curves limit the banned zone in a way it creates a hole. This may indicate the different nature of term creation in these languages, figurative in English and descriptive in Russian.

It should also be noted that the word “light” and its derivatives are used in all definitions. The reason is that the phenomenon of the band gap is also attributed to electrons and holes. To avoid homonymy, authors usually clarify what kind of “band gap” they talk about. The term photonic band gap is often used to eliminate confusion in terms. However, it is the intersection of the concepts of photonic band gap and “electronic” band gap which is used to build analogues in the scientific literature. The theory of “electronic” band gap appeared much earlier and is used by scientists to explain some of the phenomena of the photon band gap. Of course, such use of some earlier concepts to explain new ones has undeniable scientific value and convenience. Yet, on the other hand, it makes it necessary to use multiword expressions or add attributes to an existing term. This example demonstrates that instead of using a multiword explanation of the phenomenon, the attribute “photonic” is added to the existing terms to adopt it.

Another key term for the terminology of photonic crystals is the term “dielectric constant”. Consider several examples of its use and definitions.

The features of the transmission spectra of a one-dimensional photonic crystal are studied, in which the dielectric constant of one of the two layers in the structural period is many times greater than the permittivity of the other (FEDOROVA; SEMENTSOV, 2019, p. 1245).

Our systematic study shows that the effective permittivity or permeability of dielectric photonic crystal is negative within a band gap region (JI-YONG *et al.* 2008, p. 25).

Photonic crystals are characterized by three parameters: the lattice topology, the spatial period, and the dielectric constants of the constituent materials (USTYANTSEV, 2007, p. 76).

In this paper, we consider a two-dimensional photonic crystal; the dielectric constant in it periodically changes in two directions (NANIY; PAVLOVA, 2004, p. 48).

Having analyzed these examples, we can see that the dielectric constant and its variance are associated with a change of the band gap in the crystal. We also observe that this quantity is variable, therefore, often the term “constant” is replaced by the term “permittivity” or “проницаемость”. Some scientist report that the term “dielectric constant” is obsolete; however, this seems unnecessary and unreasonable. The most likely and confirmed by examples are the following explanations: the content of both concepts is the idea of electric charges interaction. However, in the case of the dielectric constant, we are talking about the amount of electric current that can pass through a certain material in comparison with a vacuum medium. In contrast, the dielectric permittivity is a characteristic of the material, i.e., how much electric current a given material can let through. The content of the concept remains unchanged, but the object changes. In some contexts, the use of these terms as synonyms is allowable, but in some works, this is unacceptable, especially concerning textbooks and other teaching materials.

Verbally, we see how these two terms are used as synonyms in the first example, “dielectric constant of one of the two layers” and “greater than the permittivity of the other”.

In the third example, it is obvious that the term dielectric constant is used in the meaning of dielectric permittivity: "the dielectric constants of the constituent materials".

Analyzed key concepts of photonic crystals terminology, we, firstly, defined the boundaries of the terminological system, and secondly, wrote the terminology in the general scientific frame.

Discussion

We correlate the key concepts of the terminology with the structure of this terminology. Previously, we carried out the structural analysis, during the analysis, the following thematic groups and subgroups were identified: design, manufacturing, use (KULESHOVA, 2019, p.

219). The following subgroups are allocated in the “design” group: basic concepts, properties of materials, mathematical tools. The “manufacturing” group consists of the following subgroups: structure, materials, tools. We have also identified lexical and thematic links between all these groups and subgroups. Moreover, system-forming concepts were identified in each group and subgroup.

The correlation of the basic concepts of terminology with its thematic structure is important for the following reasons: firstly, when we talk about key concepts, it is assumed that they cover not only one part of the terminology, but also represent it entirely, respectively, key concepts should represent each thematic group or, at least, have a connection with it. Secondly, it is necessary to confirm that key concepts are that necessary and sufficient bunch of knowledge that allows you to form a sphere of meanings, which will include all groups and subgroups of the terminological system. Thirdly, key concepts should represent the relationship between the structure of the terminological system with other systems, thus, outlining the entry points of the photonic crystal system into the global system of science. Accordingly, key concepts are a kind of gateway between the terminological system of particular science and the terminological systems of other sciences. On the other hand, it is a mental frame that forms the boundaries of a particular terminological system.

Using the terminological system of photonic crystals as an example, let us consider how the thematic classification relates to the key concepts of the terminological system.

Even though the logical foundation of photonic crystal terminology is all the terms in the “design” group, the heart of the terminology is certainly triangle "structure-manufacturing-materials." Therefore, the process of applying basic concepts to thematic classification begins with these subgroups. The concept “crystal lattice” is directly connected with the subgroup “structure”, also, depending on the type of a crystal (two-dimensional, one-dimensional or etc.), it is associated with the subgroup “manufacturing” and also with the group “use”, because depending on the type of a crystal, various applications are proposed. The concept “band gap” is also associated with the subgroup “structure” and has an effect on the group “use”, however, we can also impose it on the subgroup “mathematical tools”. The concept of “dielectric constant” correlates well with the subgroup “properties of materials” and, accordingly, is associated with the subgroup “materials”. Thus, we see how five key concepts of the photonic crystal terminology create an information dome over all thematic groups and subgroups of the terminology, combining them and highlighting the connections between the structural components of the terminological system.

Moreover, through key concepts, the photonic crystals terminological system relates to the terminological systems of other sciences. It is known that young terminologies, which, of course, refers to the terminology of photonic crystals, are characterized by the fact that they include terms from other older sciences. The borrowed terms are rethought within the terminology and receive new interpretations. Through key concepts, we can outline a circle of terminologies that influenced the photonic crystal terminology.

Let us start with “crystal lattice”, this concept takes us both to the solid-state physics and crystal chemistry, also, because of the nano-sized lattice to nanotechnology. As we have already found out, photonic crystals control light quanta, i.e., photons, therefore, fall into the sphere of photonics and nanophotonics, because of their sizes. The “band gap” acquired its name and explanation due to a similar effect described in microelectronics.

Conclusion

Thus, the terminology of photonic crystals was influenced by the following sciences: various branches of classical and quantum physics, nanotechnology, and microelectronics. On the one hand, it can be argued that the terms that came from these sciences were rethought in the photonic crystal terminology and acquired their new meanings, which are realized only within the framework of this terminology. However, on the other hand, any term is a bunch of meanings, and at the moment when one uses it, one of the meanings dominates. This does not mean that, in the context, the certain meaning of the term is isolated and turns into a separate term with its meaning, which exists only in this context at a given moment. The use of the term requires the involvement of the whole bunch of meanings by a communicator and a recipient to encode and decode the message, respectively.

Analyzing the concepts of photonic crystal terminology, we have identified the following key concepts: photonic crystal, band gap, crystal lattice, dielectric constant/permittivity. They reflect the boundaries of the terminological system and determine its place in the whole scheme of things. Moreover, we followed up the evolution of certain terms, saw how the homonymy is solved in the photonic crystal terminology, and compared Russian and English terms. This conceptual, comprehensive approach allows us to understand how to define the boundaries of different terminologies, find their place in global science and detect the terms that are extremely important in particular terminology. Respectively, it helps to pick up terms for terminological dictionaries, develop courses of particular subjects more precisely and even change university programs to make them clean and clear.

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