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Atomic Orbitals Visualization by Picoscopy

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ABSTRACT: *The paper shows that the orbital is a real material object that forms the body of an atom, and has shape and dimensions. This makes it possible to experimentally measure the spatial dimensions of the orbitals. In contrast to the theoretically calculated wave function, the experimentally obtained orbital is proposed to be called the* ***Ξ****-orbital, and the method of obtaining it is picoscopy. The unit of measurement is the picometer.*
Visualization using picoscopy of many atomic orbitals clearly showed the presence of an atomic core and external valence electrons. The atomic cores consist of internal chemically inert electrons corresponding to the noble gases and have various distorted spherical shapes. The filling of each period with valence electrons begins with a new atomic core and is successively covered with s, f, d, p-blocks. This sequence corresponds to the principle of minimum potential energy and is confirmed by quantum mechanical calculations.
KEYWORDS: electron configuration, periodic table of elements, atomic structure, picoscopy, visual chemistry, atomic orbital, atomic core, periodic-block table.

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I. INTRODUCTION

According to the classical theory, the interaction between particles of matter is carried out through the mediation of physical fields created by these particles in the surrounding environment. Fields are as real as their sources – particles and bodies.

In electrodynamics, an electron has mass, charge, and trajectory. The field, on the contrary, has wave properties and energy content. Richard Feynman said: «The fact that the electromagnetic field can possess momentum and energy makes it very real, and [...] a particle makes a field, and a field acts on another particle, and the field has such familiar properties as energy content and momentum, just as particles can have [1]».

The theory defines the field as the properties of a physical vacuum (ether), that is, an environment in which there are no particles, that is, atoms and molecules. In the relativistic quantum field theory of electrodynamics vacuum (ether), the electric and magnetic fields have zero mean values, but their polarizations are not equal to zero [2], that is, the environment has dielectric properties.

In a speech at Leiden University on May 5, 1920, Albert Einstein said: «Recapitulating, we may say that according to the general theory of relativity space is endowed with physical qualities; in this sense, therefore, there exists ether. According to the general theory of relativity space without ether is unthinkable; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense [3].»

The first experimental discovery of ether belongs to the academician of the International Academy of Informatics S.E. Lavrovsky [4]. He had shown that orbitals are cavities in the dense ether that fills the entire world.

However, contrary to the just-mentioned fundamental statements of physics, quantum mechanics attributes the property of a field to particles and calls this property corpuscular-wave dualism. It is as if the electron has the properties of both a particle and a wave at the same time [5]. Corpuscular-wave dualism is the main contradiction of quantum mechanics. The paradox of corpuscular-wave dualism arose due to the fact that until now physicists have not had the opportunity to directly consider the peculiarities of the structure and behavior of an individual atom and its constituents. Picoscopy of the orbitals of atoms, molecules, and chemical bonds eventually changes this controversial paradigm to a physically reasonable particle-field interaction.

II. WAVE BODY OF THE ORBITAL

We do not see the probability, but we see the body.

Quantum mechanics teaches that electrons revolving around the nucleus of an atom create orbitals that are described by wave functions

$$\psi(x,y,z,t) = C(x,y,z)\exp\{i(kx-\omega t)\}, \quad (1)$$

where the orbital frequency $\omega = E/\hbar$, E is the energy of the electron that creates the wave, and the wave vector $k = p/\hbar$, C is the amplitude of wave oscillations. Schrödinger called the wave an orbital [5].

As O. Kucherov [6] showed, the atomic orbital ψ and the plane wave of the electron beam ψ interact with each other according to the principle of quantum superposition. Consider two objects of quantum mechanics: a) an atom with internal and valence electrons and b) an external electron beam. The wave function $\varphi(x,y,z)$ with coordinates x, y, z describes the state of the atom system. The wave function of the electron beam $\sqrt{j(x,y,z)} =$ ***constant*** is a plane wave; it is determined by the current density and does not depend on the coordinates.

Based on the principle of quantum superposition, the wave function of the atom + electron beam system is equal to the product of their function; therefore, the intensity of the electron beam $J(x,y)$, that passed through the orbital, is equal to the integral along the line z of the wave function of the system:

$$J(x,y)=\int |\sqrt{j}|^2 \times |\varphi(x,y,z)|^2\, dz. \quad (6)$$

The integral is taken from z_{min} to z_{max} determines the intensity $J(x,y)$ of the electron beam at the point x, y of the picoscope screen. The constant value is derived from the integral:

$$J(x,y)= j\int |\varphi(x,y,z)|^2\, dz. \quad (7)$$

In this way, the integral intensity of the orbital at the point x, y along the line z of the passage of the electron beam was found. The above theory is accurate and not approximated in any way. It is the law of electron-orbital interaction discovered by O. Kucherov [6]: the orbital changes the electron beam intensity in proportion to its thickness.

We can find the thickness of the Ξ-orbital similarly with the thickness of the spectral band:

$$J(x,y)= j\, \Xi(x,y)\varphi_{max}. \quad (8)$$

Equation (8) for the maximum point has the form:

$$J_{max}= j\, \Xi_{max}\varphi_{max}. \quad (9)$$

We divide equation (8) by equation (9) and get:

$$J(x,y)/J_{max}= \Xi_{max}/\Xi(x,y). \quad (10)$$

Taking into account that the diameter of the atom is approximately equal to 100 pm, equation (10) for the thickness of the orbital finally takes the form:

$$\Xi(x,y) = 100\, J(x,y)/J_{max}\ (\text{нм}). \quad (11)$$

So the orbital thickness $\Xi(x,y)$ is directly dependent on the redistributed intensity of the electron beam passing through the orbital. The picoscope is an orbital thickness gauge and allows measuring both the spatial dimensions of the orbital and its thickness in metric units of picometers. To record the fact that the orbital was obtained experimentally according to formula (11), let's call it a Ξ-orbital (ksi is the letter of the Greek alphabet).

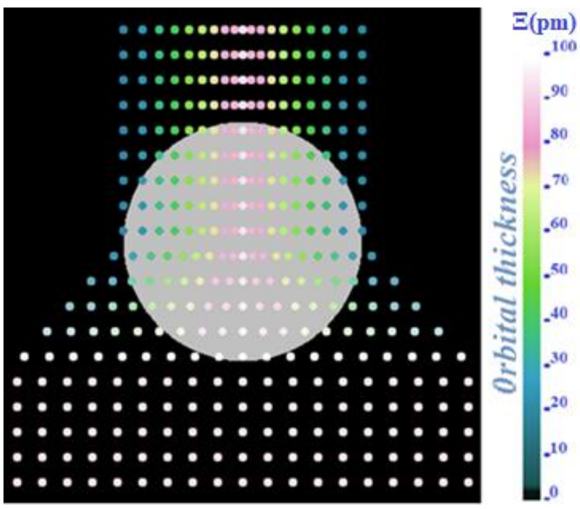

Fig. 1. Scheme of measuring the Ξ-orbital thickness. The orbital changes the electron beam intensity in proportion to its thickness. The scale of Ξ-orbital thicknesses in picometers (pm) is shown on the right.

Figure 1 shows the scheme of redistribution of the intensity of the electron beam passing through the orbital. This is the world's first method of visualizing wave functions, which actually exist in nature. A device that produces an image of the Ξ-orbital was created by O.P. Kucherov and S.E. Lavrovsky [7, 8]. That device got the name picoscope, because it allows measuring pico-sized objects. The picoscopy method transmits the total thickness of the *Ξ*-orbitals, which together form all the electrons. This is a direct proof of the absence of particle-wave dualism in quantum mechanics and the presence of a dielectric medium that is the carrier of de Broglie waves.

III. EXPERIMENT

The picoscopy is defined as the visual study of an atom`s orbitals. A massively diverse set of picoscopic images [8] shows the fundamental difference between internal (neutral) and external (chemically active) electrons. Amorphous carbon and silicon were chosen in the experiments to effectively see both the atomic core and each valence electron at the same time. The picoscopic image of a carbon atom in the amorphous state without hybrids was obtained according to the method in [9]. The picoscopic image of a silicon atom in the amorphous state without hybrids was obtained according to the method proposed in [10].

The shape of the orbitals of multi-electron atoms is not determined by the orbital quantum number **ℓ**, as it follows from the solution of the Schrödinger equation for the one-electron hydrogen atom [5]. The atom's orbital has a binary structure. The inner orbitals are closed and have a spherical shape. It is the atomic core. The outer orbitals are elongated and chemically active. They are valence electrons. The article [11] presents a discovery of the binary atomic structure. Through picoscopy experiments, it was revealed that electronic structure is divided into atomic core and outer functional electron orbitals. The atomic cores have various distorted spherical shapes in pink. The diameter of the atomic core is approximately equal to 100 picometers. The outer functional electron orbitals are elongated in green being chemically active. The diameter of the outer electron orbitals is approximately equal to 40 picometers (green color). The *Ξ*-orbital of the active valence electron has an elongated salad-colored shape, creates a dipole moment, and weakly attracts positive charges. The yellow sphere delimits the atomic core from the outer valence electrons.

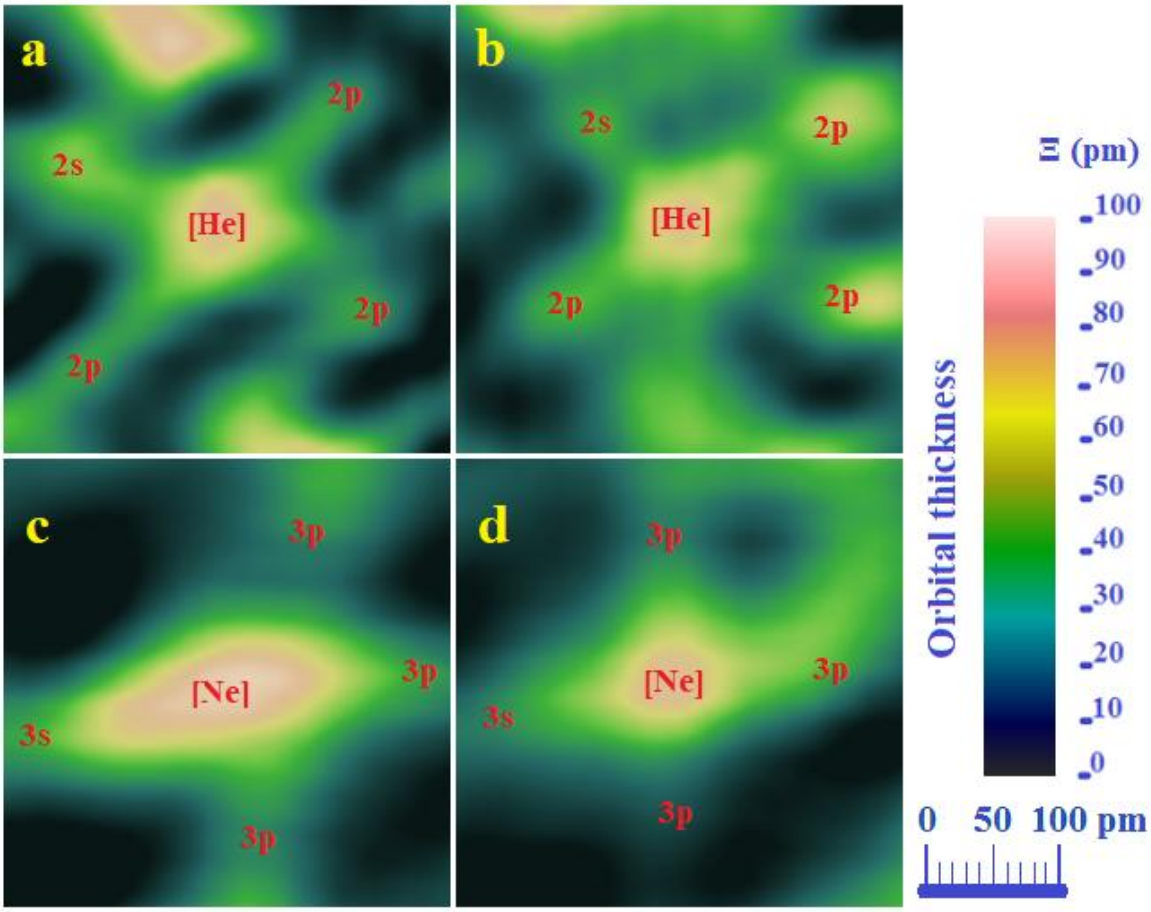

Fig. 2. *Ξ*-orbitals of the atomic cores and outer electrons by the picoscopy method. Images (**a, b**) show carbon atoms in amorphous state with helium atomic core and four outer valence electrons [He] *2s* $2p^3$. Images (**c, d**) show silicon atoms in an amorphous state with neon atomic core and four outer valence electrons [Ne] 3*s* $3p^3$. An orbital thickness scale is shown on the right.

Figure 2 shows the binary atomic structure consisting of the atomic cores and functional electrons. The atomic cores have the same spherical shapes of pink color and consist of chemically inert electrons. The outer functional electrons are chemically active and have an elongated green shape. Carbon atoms (Figures 2a, b) are divided into a nucleus with the electronic configuration of helium and the outer four functional electrons [He] 2s $2p^3$. Silicon atoms (Figures 2c, d) are divided into a nucleus with the electronic configuration of neon and the outer four functional electrons [Ne] 3s $3p^3$. Space without orbitals has zero intensity and black color. With the help of picoscopy, we obtained images of multi-electron atoms to understand the atomic structure. Picoscopy made it possible to view real subatomic objects, namely the orbitals of atoms, molecules, and chemical bonds. The results of these studies convincingly showed that both in quantum mechanics and in classical electrodynamics, the electron has only corpuscular properties, and the physical field has wave properties.

The binary atomic structure is important for understanding quantum theory and the structure of the periodic table.

IV. PERIODIC TABLE WITH THE CORE BLOCK

Electrons occupy different electronic orbitals according to the fundamental Aufbau principle, which consists in the fact that in the ground state of an atom or ion, the electron first occupies the energy level with the lowest available energy [12], which is determined by the whole quantum number $\boldsymbol{w} = \boldsymbol{n} + ¾\,\boldsymbol{\ell}$, where $\boldsymbol{n}$ is the principal quantum number, $\boldsymbol{\ell}$ is the orbital quantum number that defines a block in the structure of the periodic system [11].

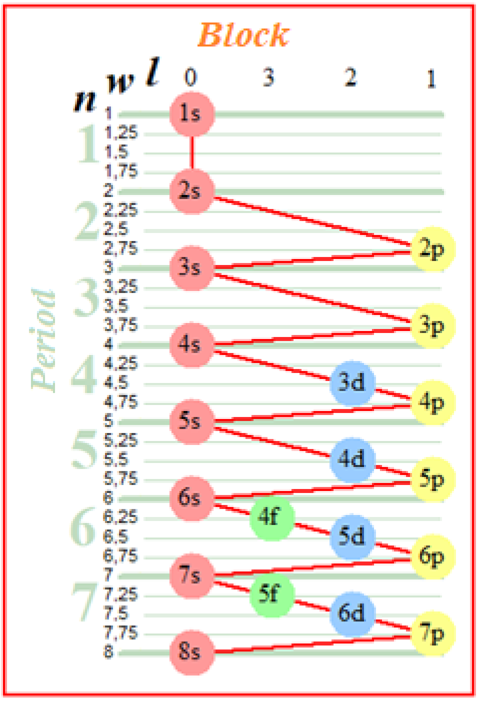

Fig. 3. The periodic-block system of chemical elements is built according to the Aufbau principle and the whole quantum number $\boldsymbol{w} = \boldsymbol{n} + ¾\,\boldsymbol{\ell}$ [11].

Electronic configuration [5] is the sequence of arrangements of electrons on different electron shells of an atom of a chemical element:

Block	$1s^2$	$2s^2$	$2p^6$	$3s^2$	$3p^6$	$4s^2$	$3d^{10}$	$4p^6$	$5s^2$	$4d^{10}$	$5p^6$	$6s^2$	$4f^{14}$	$5d^{10}$	$6p^6$	$7s^2$	$5f^{14}$	$6d^{10}$	$7p^6$
w	1	2	2.75	3	3.75	4	4.5	4.75	5	5.5	5.75	6	6.25	6.50	6.75	7	7.25	7.50	7.75
Core	[Ua]	[He]		[Ne]		[Ar]			[Kr]			[Xe]				[Rn]			

The experimental physics (Figure 2) shows the binary atomic structure: atomic core and outer valence electrons. Therefore, the periodic table should be compiled similarly. The logic of the arrangement of chemical elements in the periodic table is as follows.

The whole part of the quantum number $\boldsymbol{w}$ determines the period. The orbital quantum number $\boldsymbol{\ell}$ defines a block in the structure of the periodic table. The simple names core-block, s-block, p-block, d-block, and f-block refer to blocks with orbital quantum number $\boldsymbol{\ell}$ = 0, 1, 2, and 3 respectively. The number of groups in each block is determined by the laws of quantum mechanics and is denoted as a degree, namely: core^1, s^2, p^6, d^{10}, f^{14}. Therefore, groups should be numbered in order of increasing orbital quantum number ℓ: core – 0, s – 1-2, p – 3-7, d – 8-17, f – 18-31. It should be noted that in the periodic-block table, the groups are not numbered in the order of their location in the table, but in accordance with the growth of the orbital quantum number ℓ, which is natural.

Block		c(n)	s(n)		f	Block-d (n+1)										Block-p (n)				
Group		0	1	2	18-31	8	9	10	11	12	13	14	15	16	17	3	4	5	6	7
Period w	1	0 [Ua]	1 H																	
	2	2 [He]	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F
	3	10 [Ne]	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl
	4	18 [Ar]	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br
	5	36 [Kr]	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I
	6	54 [Xe]	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At
	7	86 [Rn]	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts
	8	118 [Og]																		
		Core-block																		

Block		Block-f (n+2)													
Group		18	19	20	21	22	23	24	25	26	27	28	29	30	31
Period w	6 *	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb
	7 **	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No

Fig. 4. Periodic-block table of chemical elements. Periodic table has five blocks: core, s, f, d, and p.

Figure 4 shows the periodic-block table of chemical elements, which consists of 118 elements arranged in five vertical blocks and seven horizontal periods. The quantum numbers ***n*** and ℓ together define the period of an element. Only blocks s^2 and p^6 appear in their period, while block d^{10} appears one period later and block f^{14} – two. The chemical properties of elements are determined by the orbital quantum number ℓ. The orbital movement creates a magnetic field. Therefore, the magnetic field itself is responsible for the chemical properties of the elements.

The atomic cores are found at atomic numbers Z = 0 [Ua], 2 [He], 10 [Ne], 18 [Ar], 36 [Kr], 54 [Xe], 86 [Rn], and 118 [Og] corresponding to helium and the other noble gases. In noble gases, all electrons are located on the atomic core. Atomic core have a zero number of valence electrons and belong to core-block of the zero group. Inert gases occupy the column on the left under the zero number of the periodic table. D.I. Mendeleev did that in his table [13]. They are grouped because of their similar chemical properties, i.e., the difficulty in removing an electron from closed shells means that they do not readily undergo chemical reactions. As they are reluctant to share electrons from their filled core electron shells, inert gases are generally considered unreactive.

The chemical element numbered zero (preliminarily named ukrainium Ua [14]) begins the electron configuration. Ua is the chemical element of the periodic table. D.I. Mendeleev gave its number zero. It occupies a cell in the first period and the atomic core-block of a zero group. It has the number zero, precedes hydrogen, and makes the periodic table complete. Ua is stable and widely found on Earth, in comets, and in astrophysical masers [13].

V. BASIS OF THE THEORY OF ORBITALS

Next, we will list the main rules of the structure of the periodic-block table, that follow from the theory of orbitals.

V.I. The order of filling orbitals in an atom.

Electrons occupy different electronic orbitals according to the fundamental Aufbau principle, which consists in the fact that in the ground state of an atom or ion, the electron first occupies the energy level with the lowest available energy, which is determined by the whole quantum number $w = n + ¾ ℓ$, where n is the principal quantum number, $ℓ$ is the orbital quantum number that defines a block in the structure of the periodic system.

V.II. Two shapes of the orbitals.

The shape of the orbitals of multi-electron atoms is not determined by the orbital quantum number $ℓ$, as it follows from the solution of the Schrödinger equation for the one-electron hydrogen atom.

The atom's orbital has a binary structure. The inner orbitals are closed and have a spherical shape. It is the atomic core. The outer orbitals are elongated and chemically active. They are valence electrons.

V.III. Group numbering rule.

The number of groups in each block is determined by the laws of quantum mechanics and is denoted as a degree, namely: core, s^2, p^6, d^{10}, f^{14}. Therefore, the numbering of groups should be appropriate: core – 0, s – 1-2, p – 3-7, d – 8-17, f – 18-31.

V.IV. The order of the blocks.

In the periodic table, the blocks are arranged in the following order: $core^1$, s^2, f^{14}, d^{10}, p^6.

V.V. Octet rule.

The electronic levels are arranged in such an order that the p-block is filled last in each period. The addition of the eighth electron to the element of the seventh group zeros out all valence electrons, makes them internal, and creates a chemically passive atomic core.

V.VI. Periodic law.

The chemical properties of elements do not depend periodically either on the mass of the atom because there are isotopes or on the charge of the nucleus, because there are ions.

The chemical properties of the elements are directly dependent on the orbital quantum number $ℓ$, which is periodically dependent on the number of electrons in the atom.

VI. CONCLUSIONS

Picoscopy made it possible to view real subatomic objects, namely the orbitals of atoms, molecules, and chemical bonds. The results of these studies convincingly showed that both in quantum mechanics and in classical electrodynamics, the electron has only corpuscular properties, and the physical field has wave properties.

The article presents the measurement theory of Ξ-orbitals. It was concluded that the electron forms an orbital in the dielectric medium around the atomic nucleus. According to this paradigm, the orbital is a real material object created. In this way, a basis has been found that unites quantum and classical mechanics and makes it possible to create the picoscope for measuring the Ξ-orbital. The importance of the device is difficult to overestimate because the orbital itself is the basis of quantum mechanics and determines the structure and properties of materials.

The experiment showed that the internal chemically neutral electrons create spherical Ξ-orbitals of the atomic cores. Ξ-orbitals of outer valence electrons are active. The Ξ-orbital of the active valence electron has an elongated, salad-colored shape, creates a dipole moment, and weakly attracts positive charges.

Each period of chemical elements begins with a new atomic core, each of which is successively covered by s, g, f, and p-block. Periods end when the p-block fills the last eighth electron. The electron first occupies the energy level with the lowest available energy. This conclusion is confirmed by quantum mechanical calculations.

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