Liénard-wiechert field study of interaction of synchrotron radiation emission as a function of the beam energy and seaborgium nanoparticles using 3d finite element method (FEM) as an optothermal human cancer cells, tissues and tumors treatment

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Abstract
In the current study, thermoplasmonic characteristics of Seaborgium nanoparticles with spherical, core-shell and rod shapes are investigated. In order to investigate these characteristics, interaction of synchrotron radiation emission as a function of the beam energy and Seaborgium nanoparticles were simulated using 3D finite element method. Firstly, absorption and extinction cross sections were calculated. Then, increases in temperature due to synchrotron radiation emission as a function of the beam energy absorption were calculated in Seaborgium nanoparticles by solving heat equation. The obtained results show that Seaborgium nanorods are more appropriate option for using in optothermal human cancer cells, tissues and tumors treatment method.

Scanning Electron Microscope (SEM) image of Seaborgium nanoparticles with 50000x zoom.
Introduction
In recent decade, metallic nanoparticles have been widely interested due to their interesting optical characteristics [1-8]. Resonances of surface Plasmon in these nanoparticles lead to increase in synchrotron radiation emission as a function of the beam energy scattering and absorption in related frequency [9, 10]. Synchrotron radiation emission as a function of the beam energy absorption and induced produced heat in nanoparticles has been considered as a side effect in plasmonic applications for a long time [11-15]. Recently, scientists find that thermoplasmonic characteristic can be used for various optothermal applications in cancer, nanoflows and photonic [16-22]. In optothermal human cancer cells, tissues and tumors treatment, the descendent laser light stimulate resonance of surface Plasmon of metallic nanoparticles and as a result of this process, the absorbed energy of descendent light converge to heat in nanoparticles [23-25].

The produced heat devastates tumor tissue adjacent to nanoparticles without any hurt to sound tissues [26, 27]. Regarding the simplicity of ligands connection to Seaborgium nanoparticles for targeting cancer cells, these nanoparticles are more appropriate to use in optothermal human cancer cells, tissues and tumors treatment [28-74]. In the current paper, thermoplasmonic characteristics of spherical, core-shell and rod Seaborgium nanoparticles are investigated.

Heat generation in synchrotron radiation emission as a function of the beam energy-seaborgium nanoparticles interaction

When Seaborgium nanoparticles are subjected to descendent light, a part of light scattered (emission process) and the other part absorbed (non-emission process). The amount of energy dissipation in non-emission process mainly depends on material and volume of nanoparticles and it can be identified by absorption cross section. At the other hand, emission process which its characteristics are depend on volume, shape and surface characteristics of nanoparticles explains by scattering cross section. Sum of absorption and scattering processes which lead to light dissipation is called extinction cross section [75-123].

Seaborgium nanoparticles absorb energy of descendent light and generate some heat in the particle. The generated heat transferred to the surrounding environment and leads to increase in temperature of adjacent points to nanoparticles. Heat variations can be obtained by heat transfer equation [124-202].

Simulation
To calculate the generated heat in Seaborgium nanoparticles, COMSOL software which works by Finite Element Method (FEM) was used. All simulations were made in 3D. Firstly, absorption and scattering cross section areas were calculated by optical module of software. Then, using heat module, temperature variations of nanoparticles and its surrounding environment were calculated by data from optical module [203-283]. In all cases, Seaborgium nanoparticles are presented in water environment with dispersion coefficient of 1.84 and are subjected to flat wave emission with linear polarization. Intensity of descendent light is 1 mW/μm². Dielectric constant of Seaborgium is dependent on particle size [284-474].

Figure 1. Maximum increase in temperature for Seaborgium nanospheres.

Firstly, calculations were made for Seaborgium nanospheres with radius of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 nanometers. The results show that by increase in nanoparticles size, extinction cross section area increases and maximum wavelength slightly shifts toward longer wavelengths. The maximum increase in temperature of nanospheres in surface Plasmon frequency is shown in Figure 1.

According to the graph, it can be seen that the generated heat is increased by increase in nanoparticles size. For 100 (nm) nanoparticles (sphere with 50 (nm) radius), the maximum increase in temperature is 83 (K). When nanoparticles size reaches to 150 (nm), increase in temperature is increased in spite of increase in extinction coefficient. In order to find the reason of this fact, ratio of absorption to extinction for various nanospheres in Plasmon frequency is shown in Figure 2.

Figure 2 shows that increasing the size of nanospheres leads to decrease in ratio of light absorption to total energy of descendent light so that for 150 (nm) nanosphere, scattering is larger than absorption. It seems that although increase in nanoparticles size leads to more dissipation of descendent light, the dissipation is in the form of scattering and hence, it cannot be effective on heat generation.

Heat distribution (Figure 3) shows that temperature is uniformly distributed throughout the nanoparticles which are due to high thermal conductivity of Seaborgium.

In this section, core-shell structure of Seaborgium and silica is chosen. The core of a nanosphere with 45 (nm) radius and silica layer thickness of 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 nanometers are considered. The results show that increase in silica thickness leads to increase in extinction coefficient and shift in Plasmon wavelength of nanoparticles, to some extent.

According to Figure 4, silica shell causes to considerable increase in temperature of Seaborgium nanoparticles but by more increase in silica thickness, its effects are decreased. Heat distribution (Figure 5) shows that temperature is uniformly distributed throughout metallic core as well as silica shell. However, silica temperature is considerably lower than core temperature due to its lower thermal conductivity. In fact, silica layer prohibits heat transfer from metal to the surrounding aqueous environment due to low thermal conductivity and hence, temperature of nanoparticles has more increase in temperature. Increasing the thickness of silica shell leads to increase in its thermal conductivity and hence, leads to attenuate in increase in nanoparticles temperature.

Figure 6 is drawn. This graph shows that variation of nanorod dimension ratio leads to considerable shift in Plasmon wavelength. This fact allows regulating the Plasmon frequency to place in near IR zone. Light absorption by body tissues is lower in this zone of spectrum and
hence, nanorods are more appropriate for optothermal human cancer cells, tissues and tumors treatment methods.

Variations of temperature in Seaborgium nanorods with two effective radius and various dimension ratios are shown in Figure 7. By increase in length (a) to radius (b) of nanorod, temperature is increased.

Figure 2. Variations of absorption to extinction ratio and scattering to extinction ratio for Seaborgium nanospheres with various radiuses

Figure 3. Maximum increase in temperature for spherical nanoparticles with radius of 45 (nm) at Plasmon wavelength of 685 (nm)

Figure 4. Maximum increase in temperature for core–shell Seaborgium nanospheres with various thicknesses of silica shell

Figure 5. Maximum increase in temperature for core–shell nanoparticles with radius of 45 (nm) and silica thickness of 10 (nm) at Plasmon wavelength of 701 (nm)

Figure 6. Extinction cross section area for Seaborgium nanorods with effective radius of 45 (nm) and various dimension ratios

Figure 7. Maximum increase in temperature for nanorods with effective radius of 20 and 45 (nm) and various dimension ratios

Conclusion and summary

The calculations showed that in Seaborgium nanoparticles, light absorption in Plasmon frequency causes to increase in temperature of the surrounding environment of nanoparticles. In addition, it showed that adding a thin silica layer around the Seaborgium nanospheres increases their temperatures. Calculations of nanorods showed that due to ability for shifting surface Plasmon frequency toward longer wavelength as well as more increase in temperature, this nanostructure is more appropriate for medical applications such as optothermal human cancer cells, tissues and tumors treatments.
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References

1. Yu, P.; Wu, J.; Liu, S.; Xiong, J.; Jagadish, C.; Wang, Z. M. Design and Fabrication of Silicon Nanowires towards Efficient Solar Cells. Nano Today 2016, 11, 704–737, 10.1016/j.nantod.2016.10.001.
2. Sandhu, S.; Fan, S. Current-Voltage Enhancement of a Single Coaxial Nanowire Solar Cell. ACS Photonics 2015, 2, 1699–1704, 10.1021/acsphotonics.5b00526.
3. van Dam, D.; Van Hooft, N. J. J.; Cui, Y.; Van Veldhoven, P. J.; Bakers, E. P. A. M.; Gómez Rivas, J.; Haverkort, J. E. M. High-Efficiency Nanowire Solar Cells with Omnidirectionally Enhanced Absorption Due to Self-Aligned Indium-Tin-Oxide Mie Scatterers. ACS Nano 2016, 10, 11414–11419, 10.1021/acsnano.6b06874.
4. Luo, S.; Yu, W. B.; He, Y.; Ouyang, G. Size-Dependent Optical Absorption Modulation of SiGe and Ge/ Si Core/shell Nanowires with Different Cross-Sectional Geometries. Nanotechnology 2015, 26, 085702, 10.1088/0957-4484/26/8/085702.
5. Yu, P.; Yao, Y.; Wu, J.; Niu, X.; Rogach, A. L.; Wang, Z. Effects of Plasmonic Metal Core-Dielectric Shell Nanoparticles on the Broadband Light Absorption Enhancement in Thin Film Solar Cells. Sci. Rep. 2017, 7, 7606, 10.1038/s41598-017-08077-9.
6. Gouda, A. M.; Allam, N. K.; Swillum, M. A. Efficiency Fabrication Methodology of Wide Angle Black Silicon for Energy Harvesting Applications. RSC Adv. 2017, 7, 26974–26982, 10.1039/C7RA03568C.
7. Branz, H. M.; Yost, V. E.; Ward, S.; Jones, K. M.; To, B.; Stradins, P. Nanostructured Silicon Nanowires with Controllable Diameters for Energy Conversion Applications. Sci. Rep. 2013, 3, 1250, 10.1038/srep01250.
8. Branz, H. M.; Yost, V. E.; Stradins, P.; Jones, K. M.; To, B. Nanostructured Silicon Nanowires. Sol. Energy Mater. Sol. Cells 2013, 118, 90–95, 10.1016/j.solmat.2013.07.036.
9. Lin, H.; Xia, F.; Fang, M.; Yip, S.; Cheung, H. Y.; Wang, F.; Han, N.; Chan, K. S.; Wong, C. Y.; Ho, C. Rational Design of Inverted Nanopencil Arrays for Cost-Effective, Broadband, and Omnidirectional Light Harvesting. ACS Nano 2014, 8, 3752–3760, 10.1021/nn400541x.
10. Garnett, E.; Yang, P. Light Trapping in Silicon Nanowire Solar Cells. Nano Lett. 2010, 10, 1082–1087, 10.1021/nl100161z.
11. Misra, S.; Yu, L.; Foldyna, M.; Roca I Cabarrocas, P. High Efficiency and Stable Hydrogenated Amorphous Silicon Radial Junction Solar Cells Built Achieved through Control of Carrier Recombination in Nanostructures. Nat. Photonics 2012, 6, 743–748, 10.1038/nphoton.2012.166.
12. Bowers, J. W.; Yao, S.; Li, K.; Kim, Y.; Shi, J.; Wang, Z. High efficiency and broadband omnidirectional light absorption enhancement in amorphous silicon random fractal arrays. Nano Lett. 2016, 16, 10602–10607, 10.1021/acs.nanolett.6b01662.
13. Georgiev, D. G.; Baird, R. J.; Avrutsky, I.; Auner, G.; Newaz, G. Controllable Excimer-Laser Nanostructuring of Wide-Angle Amorphous Silicon Nanowires: Fabrication and Characterization. J. Nanosci. Nanotechnol. 2015, 15, 7119–7124, 10.1016/j.jnn.2015.07.051.
14. Adikaari, A. A. D. T.; Silva, S. R. P. Thickness Dependence of Properties of Excimer Laser Crystallized Nanopoly-Silicon Crystal. J. Appl. Phys. 2005, 97, 114305, 10.1063/1.1898444.
15. Adikaari, A. A. D. T.; Disanayake, D. M. N. M.; Hatton, R. A.; Silva, S. R. P. Efficient Laser Textured Nanopoly-Silicon-Polymer Bilayer Solar Cells. Appl. Phys. Lett. 2007, 90, 203514, 10.1063/1.2739365.
16. Pedraza, A. J.; Fowlkes, J. D.; Lowndes, D. H. Silicon Microwire Arrays Grown by Nanosecond Pulsed-Excimer Laser Irradiation. Appl. Phys. Lett. 1999, 74, 2322–2324, 10.1063/1.123838.
17. Pedraza, A. J.; Fowlkes, J. D.; Jesse, S.; Mao, C.; Lowndes, D. H. Surface Micro-Structuring of Silicon by Excimer-Laser Irradiation in Reactive Environments. Appl. Surf. Sci. 2000, 168, 251–257, 10.1016/S0169-4332(00)00611-5.
18. Porte, H. P.; Turchinovich, D.; Persheyev, S.; Fan, Y.; Rose, J. M.; Jepsen, P. U. On Ultrafast Photodetector Dynamics and Crystallinity of Black Silicon. IEEE Trans. Terahertz Sci. Technol. 2013, 3, 331–341, 10.1109/TTHZ.2013.2255917.
19. Georgiev, D. G.; Baird, R. J.; Avrutsky, I.; Auner, G.; Newaz, G. Controllable Excimer Laser Fabrication of Conical Nano-Tips on Silicon Thin Films. Appl. Phys. Lett. 2004, 84, 4881–4883, 10.1063/1.1762978.
20. Eizenkop, J.; Avrutsky, I.; Georgiev, D. G.; Chaudhary, V. Single-Pulse Excimer Laser Nanostucturing of Silicon Nanowires: A Heat Transfer Problem and Surface Morphology. J. Appl. Phys. 2008, 103, 094311, 10.1063/1.2910196.
21. Eizenkop, J.; Avrutsky, I.; Georgiev, D. G.; Chaudhary, V. Single-Pulse Excimer Laser Nanostucturing of Thin Silicon Films: Nanochap Cones Formation and a Heat Transfer Problem. J. Phys. Chem. C 2007, 111, 49301, 10.1021/jp061228x.
22. Hong, L.; Wang, X. C.; Zheng, H. Y.; He, L.; Wang, Z.; Yu, H. Y.; RusliFemtosecond Laser Induced Nanocoate Structure and Simultaneous Crystallization of 1.6 μm Amorphous Silicon Thin Film for Photovoltaic Application. J. Phys. D. Appl. Phys. 2013, 46, 195109, 10.1088/0022-3727/46/19/195109.
23. Hong, L.; Wang, X.; Rusli, W.; Zheng, H.; Zhou, Y.; Choo, H. Heating and Surface Texturing of Amorphous Si Induced by UV Laser for Photovoltaic Application. J. Appl. Phys. 2012, 111, 043106, 10.1063/1.3686612.
24. Magdi, S.; Swillum, M. A. Broadband Absorption Enhancement in Amorphous Si Solar Cells Using Metal Gratings and Surface Texturing. Prog. SPIE 2017, 10099, 1009912, 10.1117/12.2253326.
Heidari A (2020) Liénard-wiechert field study of interaction of synchrotron radiation emission as a function of the beam energy and seaborgium nanoparticles using 3d finite element method (FEM) as an optothermal human cancer cells, tissues and tumors treatment.

116. Heidari, “Pharmacological and Analytical Chemistry Study of Cadmium Oxide (CdO) Nanoparticles Synthesis Methods and Properties as Anti-Cancer Drug and its Effect on Human Cancer Cells”, Pharm Anal Chem Open Access 2: 113, 2016.

117. Heidari, “A Chemotherapeutic and Biospectroscopic Investigation of the Interaction of Double-Standard DNA/RNA-Binding Molecules with Cadmium Oxide (CdO) and Rhodium (III) Oxide (RhO₂) Nanoparticles as Anti-Cancer Drugs for Cancer Cells’ Treatment”, Chemo Open Access 5: e129, 2016.

118. Heidari, “Pharmacokinetics and Experimental Therapeutic Study of DNA and Other Biomolecules Using Lasers: Advantages and Applications”, J Pharmacokinet Exp Ther 1: e005, 2016.

119. Heidari, “Determination of Ratio and Stability Content of DNA/RNA in Human Cancer Cells and Cadmium Oxide (CdO) Nanoparticles Complexes Using Analytical Electrochemical and Spectroscopic Techniques”, Insights Anal Electrochem 2: 1, 2016.

120. Heidari, “Discriminate between Antibacterial and Non-Antibacterial Drugs Artificial Neural Networks of a Multilayer Perceptron (MLP) Type Using a Set of Topological Descriptors”, J Heavy Met Toxicity Dis. 1: 2, 2016.

121. Heidari, “Combined Theoretical and Computational Study of the Belousov-Zhabotinsky Chaotic Reaction and Curtius Rearrangement for Synthesis of Mchlorethamine, Cisplatin, Streptozotocin, Cyclophosphamide, Melphalan, Busulphan and BCNU as Anti-Cancer Drugs”, Insights Med Phys. 1: 2, 2016.

122. Heidari, “A Translational Biomedical Approach to Structural Arrangement of Amino Acids’ Complexes: A Combined Theoretical and Computational Study”, Transl Biomed 7: 2, 2016.

123. Heidari, “Ab Initio and Density Functional Theory (DFT) Studies of Dynamic NMR Shielding Tensors and Vibrational Frequencies of DNA/RNA and Cadmium Oxide (CdO) Nanoparticles Complexes in Human Cancer Cells”, J Nanomedicine Biotherapeutic Discov 6: e144, 2016.

124. Heidari, “Molecular Dynamics and Monte-Carlo Simulations for Replacement Sugars in Inulin Resistance, Obesity, LDL, Cholesterol, Triglycerides, Metabolic Syndrome, Type 2 Diabetes and Cardiovascular Disease: A Glycobiological Study”, J Glycobiol 5: e111, 2016.

125. Heidari, “Synthesis and Study of 5-[(Phenylsulfonyl)Amino]-1,3,4-Thiadiazole-2-Sulfonamide as Potential Anti-Pertussis Drug Using Chromatography and Spectroscopic Techniques”, Transl Med (Sunnyvale) 13: e138, 2016.

126. Heidari, “Nitrogen, Oxygen, Phosphorus and Sulphur Heterocyclic: Anti-Cancer Nano Drugs Separation in the Supercritical Fluid of Ozone (O₃) Using Soave-Redlich-Kwong (SRK) and Peng-Robinson (PR) Equations”, Electronic J Biol 12: 4, 2016.

127. Heidari, “An Analytical and Computational Infrared Spectroscopic Review of Vibrational Modes in Nucleic Acids”, Austin J Pharm Chem. 3 (1): 1058, 2016.

128. Heidari, C. Brown, “Phase, Composition and Morphology Study and Analysis of Os/Pd/HJC Nanocomposites”, Nano Res Appl. 2: 1, 2016.

129. Heidari, C. Brown, “Vibrational Spectroscopic Study of Intensities and Shifts of Symmetric Vibration Modes of Ozone Diluted by Camene”, International Journal of Advanced Chemistry, 4 (1): 5–9, 2016.

130. Heidari, “Study of the Role of Anti-Cancer Molecules with Different Sizes for Decreasing Corresponding Bulk Tumor Multiple Organs or Tissues”, Arch Can Res. 4: 2, 2016.

131. Heidari, “Genomics and Proteomics Studies of Zolpidem, Necopidem, Alpidem, Saripidem, Miroprofen, Zolimidine, Olprinone and Abafungin as Anti-Tumor, Peptide Antibiotics, Antiviral and Central Nervous System (CNS) Drugs”, J Data Mining Genomics & Proteomics 7: e125, 2016.

132. Heidari, “Pharmacogenomics and Pharmacoproteomics Studies of Phosphodiestease-5 (PDE5) Inhibitors and Paclitaxel Albumin-Stabilized Nanoparticles as Sandwiched Anti-Cancer Nano Drugs between Two DNA/RNA Molecules of Human Cancer Cells”, J Pharmacogenomics Pharmacoproteomics 6: e153, 2016.

133. Heidari, “Bisotranslational Medical and Biospectroscopic Studies of Cadmium Oxide (CdO) Nanoparticles-DNA/RNA Straight and Cycle Chain Complexes as Potent Anti-Viral, Anti-Tumor and Anti-Microbial Drugs: A Clinical Approach”, Transl Biomed 7: 2, 2016.

134. Heidari, “A Comparative Study on Simultaneous Determination and Separation of Adesorbed Cadmium Oxide (CdO) Nanoparticles on DNA/RNA of Human Cancer Cells Using Biospectroscopic Techniques and Dielectrophoresis (DEP) Method”, Arch Can Res. 4: 2, 2016.

135. Heidari, “Chemoinformatics and System Chemistry of Cisplatin, Carboplatin, Nedaplatin, Oxaliplatin, Hepiplatin and Lobaplatin as Anti-Cancer Nano Drugs: A Combined Computational and Experimental Study”, J Inform Data Min 1: 3, 2016.

136. Heidari, “Linear and Non-Linear Quantitative Structure–Activity-Relationship (QSAR) Study of Hydroux Ruthenium (IV) Oxide (RuO₂) Nanoparticles as Non-Nucleic Reverse Transcriptase Inhibitors (NNRTIs) and Anti-Cancer Nano Drugs”, J Integr Oncol 5: e110, 2016.

137. Heidari, “Synthesis, Characterization and Biospectroscopic Studies of Cadmium Oxide (CdO) Nanoparticles-Nucleic Acids Complexes Absence of Soluble Polymer as a Protective Agent Using Nucleic Acids Condensation and Solution Reduction Method”, J Nanosci Curr Res 1: e110, 2016.

138. Heidari, “Cpulanlarity and Collinearity of 4’-Dimonyl-2’-Bithiazole in One Domain of Blyoecyomin and Pingyungycin to be Responsible for Binding of Cadmium Oxide (CdO) Nanoparticles to DNA/RNA Bidentate Ligands as Anti-Tumor Nano Drug”, J Int J Drug Dev Res 8: 007-008, 2016.

139. Heidari, “A Pharmacovigilance Study on Linear and Non-Linear Quantitative Structure (Chromographic) Retention Relationships (QSSR) Models for the Prediction of Retention Time of Anti-Cancer Nano Drugs under Synchrotron Radiations”, J Pharmacovigil 4: e161, 2016.

140. Heidari, “Nanotechnology in Preparation of Semipermeable Polymers”, J Adv Chem Eng 6: 157, 2016.

141. Heidari, “A Gastrointestinal Study on Linear and Non–Linear Quantitative Structure (Chromographic) Retention Relationships (QSSR) Models for Analysis 5–Aminosalicylates Nano Particles as Digestive System Nano Drugs under Synchrotron Radiations”, J Gastroint Dig Syst 6: e119, 2016.

142. Heidari, “DNA/RNA Fragmentation and Cytolysis in Human Cancer Cells Treated with Diphthamide Nano Particles Derivatives”, Biomedical Data Mining 5: e102, 2016.

143. Heidari, “A Successful Strategy for the Prediction of Solubility in the Construction of Quantitative Structure–Activity Relationship (QSAR) and Quantitative Structure–Property Relationship (QSPR) under Synchrotron Radiations Using Genetic Function Approximation (GFA) Algorithm”, J Mol Biol Biotechnol 1: 6, 2016.

144. Heidari, “Computational Study on Molecular Structures of C₂₅H₂₄O₉, C₂₅H₂₄O₈, C₂₅H₂₄O₇ and C₂₅H₂₄O₆ Fulleren Nano Molecules under Synchrotron Radiations Using Fuzzy Logic”, J Material Sci Eng 5: 282, 2016.

145. Heidari, “Graph Theoretical Analysis of Zigzag Polyhexamethylene Biguanide, Polyhexamethylene Aldipamide, Polyhexamethylene Biguanide Guaz and Polyhexamethylene Biguanide Hydrochloride (FHM) Boron Nitride Nanotubes (BNNTs) Amorphous Boron Nitride Nanotubes (a–BNNTs) and Hexagonal Boron Nitride Nanotubes (h–BNNTs)”, J Appl Comput Math 5: e143, 2016.

146. Heidari, “The Impact of High Resolution Imaging on Diagnosis”, Int J Clin Med Imaging 3: 100e101, 2016.

147. Heidari, “A Comparative Study of Conformational Behavior of Isotretinoin (13-Cis Retinoic Acid) and Tretinoin (All-Trans Retinoic Acid (ATRA)) Nano Particles as Anti-Cancer Nano Drugs under Synchrotron Radiations Using Hartree-Fock (HF) and Density Functional Theory (DFT) Methods”, Insights in Biomed 2: 1, 2016.

148. Heidari, “Advances in Logic, Operations and Computational Mathematics”, J Appl Comput Math 5: 5, 2016.

149. Heidari, “Mathematical Equations in Predicting Physical Behavior”, J Appl Comput Math 5: 5, 2016.

150. Heidari, “Chemotherapya a Last Resort for Cancer Treatment”, Chemo Open Access 5: 4, 2016.

151. Heidari, “Separation and Pre-Concentration of Metal Cations-DNA/RNA Chelates Using Molecular Beam Mass Spectrometry with Tunable Vacuum Ultraviolet (VUV) Synchrotron Radiation and Various Analytical Methods”, Mass Spectrom Purif Tech 2: e101, 2016.

152. Heidari, “Yoctosecond Quantitative Structure–Activity Relationship (QSSAR) and Quantitative Structure–Property Relationship (QSPR) under Synchrotron Radiations Studies for Prediction of Solubility of Anti-Cancer Nano Drugs in Aqueous Solutions Using Genetic Function Approximation (GFA) Algorithm”, Insight Pharm Res. 1: 1502–1506, 2016.

153. Heidari, “Cancer Risk Prediction and Assessment in Human Cells under Synchrotron Radiations Using Quantitative Structure Activity Relationship (QSSAR) and Quantitative Structure Properties Relationship (QSPR) Studies”, Int J Clin Med Imaging 3: 516, 2016.
Heidari A (2020) Liénard-wiechert field study of interaction of synchrotron radiation emission as a function of the beam energy and seaborgium nanoparticles using 3d finite element method (FEM) as an optothermal human cancer cells, tissues and tumors treatment.
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286. 284. 282. 281. 280. 289. 288. 287. 285. 283. 282. 281. 280. 289. 288. 287. 285. 283. 282.

288. Heidari, A. Heidari, V. Hodaei, M. R. R. Gobato, A. Heidari, A. Mitra, “Spectroscopy and Dipole Moment of the Molecule 1, 1'-Benzil SeSi via Quantum Chemistry Using Ab Initio, Hartree–Fock Method in the Base Set CC-pVTZ and 6–311G**/3df, 3pd”, Arq Org Inorg Chem Sci 3 (5), Pages 402-409, 2018.

289. Heidari, “C, C–Encapsulating Carbon Nanotubes Incorporation into the Nano Polymeric Matrix (NPM) by Immersion of the Nano Polymeric Modified Electrode (NPME) as Molecular Enzymes and Drug Targets for Human Cancer Cells, Tissues and Tumors Treatment under Synchrotron and Synchrocyclotron Radiations”, Glob Imaging Insights, Volume 3 (4): 1–8, 2018.

290. Heidari, “Two-Dimensional (2D) 1H or Proton NMR, 13C NMR, 15N NMR and 3P NMR Spectroscopy Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation with the Passage of Time”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

291. Heidari, “A Modern and Comprehensive Investigation of Inelastic Electron Tunneling Spectroscopy (IETS) and Scanning Tunneling Spectroscopy on Malignant and Benign Human Cancer Cells, Tissues and Tumors through Optimizing Synchrotron Microbeam Radiotherapy for Human Cancer Treatments and Diagnostics: An Experimental Biophotonic Spectroscopic Comparative Study”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

292. Heidari, “A Hypertension Approach to Thermal Infrared Spectroscopy and Photothermal Infrared Spectroscopy Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation with the Passage of Time”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

293. Heidari, “Incredible Natural–Abundance Double–Quantum Transfer Experiment (INADEQUATE), Nuclear Overhauser Effect Spectroscopy (ROESY) Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

294. Heidari, “A Novel Approach to Correlation Spectroscopy (COSY), Exlusive Correlation Spectroscopy (ECOST), Total Correlation Spectroscopy (TOCSY), Infrared Nuclear Overhauser Effect (INOE) and Optical Nuclear Overhauser Effect Spectroscopy (OESY) Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation”, Glob Imaging Insights, Volume 3 (5): 1–9, 2018.

295. Heidari, “A Modern and Comprehensive Investigation of Inelastic Electron Tunneling Spectroscopy (IETS) and Scanning Tunneling Spectroscopy on Malignant and Benign Human Cancer Cells, Tissues and Tumors through Optimizing Synchrotron Microbeam Radiotherapy for Human Cancer Treatments and Diagnostics: An Experimental Biophotonic Spectroscopic Comparative Study”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

296. Heidari, “Spectroscopy and Dipole Moment of the Molecule C13H20BeLi2SeSi via Quantum Chemistry Using Ab Initio, Hartree–Fock Method in the Base Set CC-pVTZ and 6–311G**/3df, 3pd”, Arq Org Inorg Chem Sci 3 (5), Pages 402-409, 2018.

297. Heidari, “Incredible Natural–Abundance Double–Quantum Transfer Experiment (INADEQUATE), Nuclear Overhauser Effect Spectroscopy (ROESY) Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.

298. Heidari, “Small–Angle X–Ray Scattering (SAXS) and Ultra–Small Angle X–Ray Scattering (USAXS) Comparative Study on Malignant and Benign Human Cancer Cells and Tissues under Synchrotron Radiation”, Glob Imaging Insights, Volume 3 (6): 1–8, 2018.
341. Heidari, J. Esposito, A. Caissutti, "Okadaic Acid Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Int J Analyt Bioanalytical Methods 1 (1): 1–19, 2019.

342. Heidari, "Investigation of the Processes of Absorption, Distribution, Metabolism and Elimination (ADME) as Vital and Important Factors for Modulating Drug Action and Toxicity", Open Access J Oncol, 2 (1): 180010–180012, 2019.

343. Heidari, J. Esposito, A. Caissutti, "Perspectives on Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Chemistry Reports, Vol. 1, Iss. 2, Pages 1–5, 2019.

344. R. Gobato, M. R. R. Gobato, A. Heidari, "Rhodochrous as Crystal Oscillator", Am J Biomed Sci & Res. 3 (2), 187, 2019.

345. Heidari, J. Esposito, A. Caissutti, "Tetrodotoxin (TTX) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", American Journal of Medical Science, Vol. 2019, Issue 01, pp. 26–48, 2019.

346. Heidari, J. Esposito, A. Caissutti, "The Importance of Analysis of Vibronic–Mode Coupling Structure in Vibrational Spectra of Supramolecular Aggregates of Cytotoxic Acids (CA)*M Cytochrome (CA) and Melamine (M) beyond the Frisch–Condon Approximation", Journal of Clinical and Medical Images, 2 (2): 1–20, 2019.

347. Heidari, J. Esposito, A. Caissutti, "Microcystin–IR Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Malaysian Journal of Chemistry, Vol. 21 (1), 70–95, 2019.

348. Heidari, J. Esposito, A. Caissutti, "Botulimum Toxin Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Journal of Mechanical Design and Vibration, 7, Iss. 1: 1–15, 2019.

349. Heidari, J. Esposito, A. Caissutti, "Domestic Acid (DA) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Clinical Oncology Journal 1, 2: 03–07, 2019.

350. Heidari, J. Esposito, A. Caissutti, "Surugatoxin (SGTX) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Clinical Oncology Journal 1, 2: 14–18, 2019.

351. Heidari, J. Esposito, A. Caissutti, "Ochratoxin (OCTX) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Clinical Oncology Journal 1, 2: 19–23, 2019.

352. Heidari, J. Esposito, A. Caissutti, "Gonyautoxin (GTX) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Clinical Oncology Journal 1, 2: 24–28, 2019.

353. Heidari, J. Esposito, A. Caissutti, "Hidroxicotonin (HTX) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Clinical Oncology Journal 1, 2: 38–42, 2019.

354. Heidari, J. Esposito, A. Caissutti, "Dihydrokainic Acid Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 01–06, 2019.

355. Heidari, J. Esposito, A. Caissutti, "Ochratoxin B1 (AFB1), B2 (AFB2), G1 (AFG1), G2 (AFG2), M1 (AFM1), M2 (AFM2), Q1 (AFQ1) and P1 (AFP1) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 07–12, 2019.

356. Heidari, J. Esposito, A. Caissutti, "Kainic Acid (Kainite) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 13–18, 2019.

357. Heidari, J. Esposito, A. Caissutti, "Bufotinoc Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 19–24, 2019.

358. Heidari, J. Esposito, A. Caissutti, "Botulinum Toxin Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 25–32, 2019.

359. Heidari, J. Esposito, A. Caissutti, "Calcium Ion (Calcium) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 33–38, 2019.

360. Heidari, J. Esposito, A. Caissutti, "Botulinum Toxin Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 39–45, 2019.

361. Heidari, J. Esposito, A. Caissutti, "Calcium Ion (Calcium) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 46–51, 2019.

362. Heidari, J. Esposito, A. Caissutti, "Botulinum Toxin Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 52–57, 2019.

363. Heidari, J. Esposito, A. Caissutti, "Calcium Ion (Calcium) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 58–63, 2019.

364. Heidari, J. Esposito, A. Caissutti, "Calcium Ion (Calcium) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 64–70, 2019.

365. Heidari, J. Esposito, A. Caissutti, "Calcium Ion (Calcium) Time–Resolved Absorption and Resonance FT–IR and Raman Biospectroscopy and Density Functional Theory (DFT) Investigation of Vibrioc–Mode Coupling Structure in Vibrational Spectra Analysis", Scientific Drug Delivery Research 1, 1: 71–76, 2019.
