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X-zrake i Nobelova nagrada: Röntgen ili Tesla?

X-rays and the Nobel Prize: Röntgen or Tesla?

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SAŽETAK

Prvenstvo otkrića rendgenskih zraka česta je i vječita tema Teslinih pobornika, vezano uz polemiku tko bi zapravo Nobelovu nagradu za njihovo otkriće doista zaslužio, Röntgen ili Tesla? Svrha je članka, temeljem povijesnih činjenica vezanih uz razvoj vakuumskih cijevi i eksperimenata, poznatih Teslinih biografskih činjenica te analize njegova i Röntgenova rada na polju X-zraka provjeriti opravdanost predmetne dileme.

KLJUČNE RIJEČI: **Nikola Tesla**, Nobelova nagrada, vakuumska cijev, Wilhelm C. Röntgen, X-zrake

SUMMARY

The primacy of the discovery of X-rays is a frequent and perennial topic among Tesla's proponents, and it is often tied to the debate over who actually deserved the Nobel Prize for the discovery: Röntgen or Tesla? The purpose of this article is to examine the validity of this dilemma by using historical facts related to the development of vacuum tubes and experiments, known biographical facts about Tesla, and an analysis of his and Röntgen's work in the field of X-rays.

KEYWORDS: **Nikola Tesla**, Nobel Prize, vacuum tube, Wilhelm C. Röntgen, X-rays

UVOD

Među Teslinim zagovornicima o odgovoru na to pitanje nema sumnje, pogotovo otkako je 2006., u povodu 150. obljet-

INTRODUCTION

Among Tesla's proponents, there is no doubt about the answer to the question about the rightful recipient of the Nobel Prize, especially since

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nice Teslina rođenja, objavljeno mišljenje poznatoga hrvatskoga akademika i profesora prema kojem je za Teslina nepriznata otkrića dodijeljeno deset Nobelovih nagrada drugim znanstvenicima [1,2], a slično su kasnije razmišljali i neki drugi hrvatski akademici [3]. Isto se odnosi i na takozvane „X" zrake, koje su kasnije, prema njemačkom fizičaru Wilhelmu Konradu Röntgenu, nazvane rendgenskim zrakama.

Mihajlo Pupin je zapisao: *Nijedno otkriće tokom mog života nije privuklo toliko svjetske pažnje kao otkriće rendgenskih zraka. Svaki je fizičar odbacio svoje vlastite istraživačke probleme i naglavce pojurio u eksperimentiranje*... ([4], str. 306).

KRATAK OSVRT NA POVIJEST RAZVOJA VAKUUMSKIH CIJEVI

Do otkrića rendgenskih zraka dovelo je istraživanje protoka električne struje u plinovima. Čuveni Michael Faraday već je 1838. promatrao električno pražnjenje tijela u razrijeđenim plinovima. Podrobnija istraživanja protoka električne struje kroz takav medij počela je nekolicina istraživača u Njemačkoj već u pedesetim i šezdesetim godinama 19. stoljeća. Sredinom šezdesetih izrađene su prve sprave za razrjeđivanje zraka (vakuumske crpke), s kojima je zračni tlak u staklenim cijevima snižen na jedan milibar. Njemački znanstvenici Julius Plücker (1801. – 1868.) i Johann Wilhelm Hittorf (1824. – 1914.) počeli su promatrati protok električne struje kroz cijevi u koje su ugradili dvije elektrode: katodu i

2006, on the occasion of the 150th anniversary of Tesla's birth, the opinion of a well-known Croatian academic and professor V. Paar stated that ten Nobel Prizes were awarded to other scientists for Tesla's unrecognized discoveries [1,2]. Several other Croatian academicians later thought similarly [3]. Among those unrecognized discoveries are the so-called „X" rays, which are in many languages called „Röntgen Rays" after the German physicist Wilhelm Conrad Röntgen.

Mihajlo Pupin wrote: *„No discovery during my lifetime has attracted so much world attention as the discovery of X-rays. Every physicist abandoned his own research problems and rushed headlong into experimentation..."* ([4], p. 306].

A BRIEF OVERVIEW OF THE HISTORY OF VACUUM TUBES' DEVELOPMENT

The discovery of X-rays was the result of research into the flow of electric current in gases. As early as 1838, the famous Michael Faraday observed the electrical discharge of bodies in rarefied gases. More detailed research into the flow of electric current through such a medium had begun by several researchers in Germany in the 1850s and 1860s. In the mid-1860s, the first devices for rarefaction of air (vacuum pumps) were built, with which the air pressure in glass tubes was reduced to one millibar. German scientists Julius Plücker (1801-1868) and Johann Wilhelm Hittorf (1824-1914) began to observe the flow of electric current through tubes in which they had installed two electrodes: a cathode and an anode. He first observed that the glass tube near the cathode glowed, while the other discovered that „rays" radiated from it in a straight line (the German physicist Eugen Goldstein later named them „cathode rays").

anodu. Prvi je uočio da staklena cijev u blizini katode svjetluca, dok je drugi otkrio da se s nje pravocrtno šire „zrake" (njemački fizičar Eugen Goldstein ih je kasnije nazvao „katodnim zrakama"). Hittorfove su vakuumske cijevi, izrađene od uranijevog stakla, uz ostalo, proizvodile dobro poznati efekt fosforescencije.

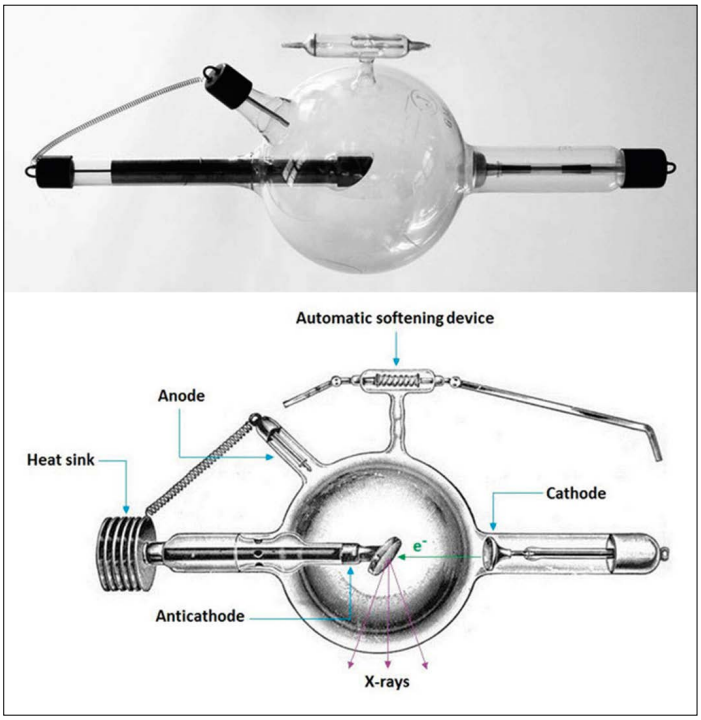
Engleski su se fizičari s tom vrstom istraživanja počeli baviti kasnije. Među njima je najpoznatiji Sir William Crookes (1832. – 1919.), čije su cijevi s vrlo visokim vakuumom (slika 1) emitirale svijetleće katodne zrake. Bio je nesumnjivo prvi koji je zaključio da se katodne zrake sastoje od malih naelektriziranih čestica koje se kreću vrlo visokim brzinama. Pokazalo se da je taj zaključak bio od velikoga značenja. Unatoč iznenađujućoj ljepoti električnih fenomena u vakuumskim cijevima, otkrivenih Crookesovim pokusima, krajem sedamdesetih godina 19. stoljeća nije bilo moguće odrediti nikakve jasne i konačne zaključke. Katodne zrake su istraživane u svim značajnijim fizikalnim laboratorijima. O prirodi tih zraka tekla je žestoka rasprava. Crookes je smatrao da je riječ o molekulama, dok je većina istraživača tu ideju odbijala ([4], str. 303); ([5], str. 291–292).

Poznati njemački znanstvenik Hermann von Helmholtz (1821. – 1894.) je 1878. uspio uvjeriti njemačku Akademiju znanosti da izda izvanredno odobrenje za temeljitu eksperimentalnu provjeru cjelovitih istraživanja koja se odnose na fenomene električnih kretanja u cijevima s visokim vakuumom. Za izvedbu toga projekta izabrali su berlinskoga fizičara,

Hittorf's vacuum tubes, made of uranium glass, among other things, produced the well-known phosphorescence effect.

English physicists later also began to engage in this type of research. The most famous of them was Sir William Crookes (1832-1919), whose tubes with a very high vacuum (Figure 1) emitted luminous cathode rays. He was undoubtedly the first to conclude that cathode rays consist of small electrified particles moving at very high speeds. That conclusion proved to be of great significance. Despite the surprising beauty of the electrical phenomena in vacuum tubes discovered by Crookes' experiments, by the late 1870s it was not possible to draw any clear and definitive conclusions. Cathode rays were investigated in all major physics laboratories. A fierce debate raged over the nature of these rays. Crookes believed that they were molecules, while most researchers rejected this idea ([4], p. 303); ([5], pp. 291–292).

In 1878 the famous German scientist Hermann von Helmholtz (1821-1894) managed to convince the German Academy of Sciences to issue an extraordinary permit for a thorough experimental verification of the complete research concerning the phenomena of electrical motion in high-vacuum tubes. They chose a Berlin physicist, Dr. Eugen Goldstein, to carry out this project. The most significant result of this repeated research was the discovery of the so-called „channel rays" (1880), i.e. the movement of positive electricity in the opposite direction to the negative, which caused cathode rays. To reach this conclusion, Goldstein's chief assistant, the glassblower Müller, had to make countless vacuum tubes of very different shapes. He once said that if he collected all of these tubes in one place, they would fill the house where his



Slika 1. **Crookesova vakuumska cijev za generiranje X-zraka koju je Sir William Crookes poklonio Konradu Röntgenu (muzej u Würzburgu, Njemačka)** https://teslaresearch.jimdofree.com/x-rays/ (Pristupljeno 15. 3. 2024.)

Authomatic softening device – automatski uređaj za omekšavanje; *Heat sink* – hladilo, *Anode* – anoda; *Cathode* – katoda; *Anticathode* – antikatoda; *X-rays* – X-zrake

Figure 1. ***Crookes X-ray vacuum tube given to Konrad Röntgen by Sir William Crookes (Würzburg Museum, Germany)*** https://teslaresearch.jimdofree.com/x-rays/ (Accessed 3/15/2024)

Automatic softening device – automatski uređaj za omekšavanje; *Heat sink* – hladilo, *Anode* – anoda; *Cathode* – katoda; *Anticathode* – antikatoda; *X-rays* – X-zrake

doktora Eugena Goldsteina. Najznačajniji rezultat toga opetovanoga istraživanja bilo je otkriće tzv. „kanalnih zraka" (1880.), tj. kretanje pozitivnoga elektriciteta u suprotnom smjeru od negativnoga, što je uzrokovalo katodne zrake. Da bi se došlo do toga zaključka, Goldsteinov glavni pomoćnik, staklopuhač Müller, morao je izraditi bezbrojne vakuumske cijevi

workshop was located. The Scottish physicist and engineer William Thomson (1824-1907), better known as Lord Kelvin, stated in 1893: *It seems to me that the knowledge derived from experiments on electricity in a high-degree vacuum is the most promising foundation that inspires the greatest hope, if one is to take the first step toward understanding the relationship between the ether and detectable (sensible) mass.*

vrlo različitih oblika. Jednom prilikom je rekao da bi te cijevi, ako bi sve skupio na jednom mjestu, napunile kuću u kojoj se nalazila njegova radionica. Škotski fizičar i inženjer, William Thomson (1824. – 1907.), poznatiji pod imenom Lord Kelvin, je 1893. izjavio: *Čini mi se da je znanje koje proizlazi iz eksperimenata elektriciteta u vakuumu visokog stupnja temelj koji budi najviše nade, ukoliko treba načiniti prvi korak prema razumijevanju odnosa između etera i detektibilne (osjetne) mase.*

Isto je mišljenje već petnaest godina ranije (1878.) izrazio spomenuti Helmholtz. Jedan od glavnih razloga zbog kojega se Goldsteinov rad smatra značajnim jest što je u timsko istraživanje uveo još tri druga njemačka vrlo oštroumna i pronicljiva fizičara. Prvi je Heinrich Rudolf Hertz (1857. – 1894.). Nekoliko godina nakon njegova sjajnog eksperimentalnog dokaza (1888.) elektromagnetske teorije Faradaya i Maxwella, pokazao je da katodne zrake mogu s lakoćom prodirati kroz tanke metalne slojeve, kao npr. zlatnu ili aluminijsku foliju, iako su isti bili potpuno nepropusni za običnu svjetlost. Hertzov je rad nastavio i uvelike razvio njegov učenik Philipp Lenard (1862. – 1947.)[1], kasnije profesor na Sveučilištu u njemačkom Kielu. U prosincu 1895. Wilhelm Konrad Röntgen (1845. – 1923.) obznanjuje da je, eksperimentirajući s Hittorfovom cijevi, otkrio nepoznate zrake koje je imenovao zraka-

[1] Philipp Lenard je za svoja istraživanja katodnih zraka i njihovih svojstava 1905. dobio Nobelovu nagradu za fiziku (poznat je po tipu vakuumske cijevi, tzv. Lenardova cijev, koja je slična Crookesovoj vakuumskoj cijevi).

The same opinion had already been expressed fifteen years earlier (in 1878) by the aforementioned Helmholtz. One of the main reasons Goldstein's work is considered significant is that he brought three other great and insightful German physicists on to the team's research. The first was Heinrich Rudolf Hertz (1857-1894). A few years after his brilliant experimental proof (1888) of the electromagnetic theory of Faraday and Maxwell, he demonstrated that cathode rays could easily penetrate thin metal layers, such as gold or aluminum foil, even though these were completely opaque to ordinary light. Hertz's work was continued and greatly developed by his student Philipp Lenard (1862-1947)[1], later a professor at the University of Kiel, Germany. In December 1895 Wilhelm Konrad Röntgen (1845-1923) announced that he had, experimenting with a Hittorf tube, discovered unknown rays which he named „X" rays. This discovery marked the final step in the research that Goldstein, at Helmholtz's initiative, had undertaken fifteen years before Röntgen's experiments in the field of electrical discharges in high vacuum. It was a great triumph for German science, which in the field of electrical discharges in rarefied gases began in Germany and reached its peak in less than forty years. Due to the dominance of German scientists in this field, it could be called „Made in Germany" ([4], pp. 304–306).

[1] Philipp Lenard was awarded the 1905 Nobel Prize in Physics for his research on cathode rays and their properties (he is known for a type of vacuum tube, the so-called Lenard tube, which is similar to the Crookes tube).

ma „X“. To je otkriće obilježilo zadnji korak u istraživanju kojega se na inicijativu Helmholtza latio Goldstein, petnaest godina prije Röntgenovih eksperimenata na području električnih pražnjenja u visokom vakuumu. Bio je to veliki trijumf njemačke znanosti, koja je na području električnih pražnjenja u razrijeđenim plinovima započela u Njemačkoj i u manje od četrdeset godina dostigla svoj vrhunac. Zbog dominacije njemačkih znanstvenika na tom polju, moglo bi se nazvati ga „Made in Germany“ ([4], str. 304–306).

O RÖNTGENU I NJEGOVU RADU S X-ZRAKAMA

Nakon početka školovanja (1862.) na tehničkoj školi u Utrechtu (Nizozemska) i neuspjela pokušaja studija na tamošnjem Sveučilištu, Röntgen (slika 2) započinje studij strojarstva na državnoj Visokoj politehničkoj školi u Zürichu (1865.). Četiri godine kasnije (1869.) doktorira na gradskom Sveučilištu, iste godine kao asistent profesora Kundta seli u Würzburg, a nakon još tri godine u Strasbourg, gdje 1874. postaje predavač na Sveučilištu. Nakon toga godinu dana drži predavanja na Akademiji u Hohenheimu, a sljedeće, 1876. se kao profesor fizike vraća na Sveučilište u Strasbourgu. Kasnije je predavao i na drugim njemačkim sveučilištima, a 1888. se vraća na Sveučilište u Würzburg, gdje krajem 1895. otkriva X-zrake [6].

Röntgen je bio vrlo spretan amaterski fotograf. S novo otkrivenim zrakama izradio je više fotografija i priložio ih kopija-

ABOUT RÖNTGEN AND HIS WORK WITH X-RAYS

Röntgen (Figure 2) began his education (1862) at the technical school in Utrecht, Netherlands. After the unsuccessfully attempt to study at the local university, he began studying mechanical engineering at the state Polytechnic School in Zurich (1865). Four years later (1869), he received his doctorate from the city's University. And in the same year, he moved to Würzburg as an assistant to Professor Kundt. Three years later he moved to Strasbourg, where he became a lecturer at the University in 1874. After that, he lectured for a year at the Academy in Hohenheim, and the following year, 1876, he returned to the University of Strasbourg as a professor of physics. He later taught at other German universities, and in 1888 he returned to the University of Würzburg where, at the end of 1895, he discovered X-rays [6].

Röntgen was a very skilled amateur photographer. Using the newly discovered rays, he took several photographs and attached them to copies of his paper, which he sent to renowned physicists. Because of this discovery, he soon became famous worldwide.

Experiments with X-rays spread throughout the world. Their potential application in medicine was immediately recognized. Many crowned heads expressed interest in the subject of rays and the experiments with them. In order to continue working in the laboratory without any obstacles, Röntgen refused numerous invitations to give lectures. He could not, however, refuse an invitation to the court of the German Emperor Wilhelm II (1859-1941). Like everyone else, Röntgen was worried that something could go wrong during the demonstration of the experiment. The vacuum tubes of the time were

ma svoga članka kojeg je poslao poznatim fizičarima. Zbog toga otkrića ubrzo postaje poznat diljem svijeta.

Pokusi s X-zrakama proširili su se po cijelom svijetu. Odmah je uočena mogućnost njihove primjene u medicini. Mnoge okrunjene glave iskazale su zanimanje za predmetne zrake i pokuse s njima. Kako bi mogao nesmetano nastaviti s radom u laboratoriju, Röntgen je odbijao brojne pozive za predavanja. Nije, međutim, mogao odbiti poziv na dvor njemačkoga cara Vilima II. (1859. – 1941.). Kao i sve druge i Röntgena je brinulo da bi, prilikom demonstracije pokusa, nešto moglo krenuti po zlu. Tadašnje vakuumske cijevi bile su vrlo osjetljive i bilo je potrebno nekoliko dana kako bi se dostatno evakuirao zrak iz svake nove cijevi. Ali, svi pokusi pred carem su uspjeli. Nakon toga je Röntgen, vezano uz X-zrake, održao još samo jedno javno predavanje, koje je bilo popraćeno burnim odobravanjem.

Godine 1896. objavljeno je više od tisuću članaka o X-zrakama, a sam Röntgen je poslije prvoga napisao još samo dva članka. Nakon toga se vratio drugim pokusima. Godine 1900. postaje direktorom Instituta za eksperimentalnu fiziku u Münchenu, gdje ostaje do kraja života. Sljedeće godine (1901.) dodijeljena mu je Nobelova nagrada za fiziku i uopće prva u povijesti dodjele Nobelovih nagrada ([5], str. 290–291).

Otkriće X-zraka

Prije početka istraživanja fenomena s vakuumskim cijevima, Röntgen se savjetovao kod Phillipa Lenarda, istraživača very sensitive, and it took several days to sufficiently evacuate the air from each new tube. However, all the experiments before the emperor were successful. After that, Röntgen gave only one more public lecture on X-rays, which was met with a thunderous approval.



Slika 2. **Wilhelm Konrad Röntgen (1845. – 1923.), njemački fizičar i dobitnik prve Nobelove nagrade u povijesti**; https://en.wikipedia.org/wiki/Wilhelm_R%C3%B6ntgen (Pristupljeno 20. 3. 2024.)

Figure 2. ***Wilhelm Konrad Röntgen (1845-1923), German physicist and winner of the first Nobel Prize in history;*** https://en.wikipedia.org/wiki/Wilhelm_R%C3%B6ntgen (Accessed 3/20/2024)

By 1896, more than a thousand articles on X-rays were published, and Röntgen himself wrote only two more articles after the first one.

katodnih zraka s najviše iskustva. Godine 1894. Röntgen više nije trebao izrađivati vlastitu cijev, kao što su to prije njega činili svi istraživači, jer su se na tržištu već pojavile prve Lenardove cijevi. U to vrijeme, odnosno početkom devedesetih godina 19. stoljeća, istraživači (osim Nikole Tesle, o čemu će biti riječi u nastavku) za rad s vakuumskim cijevima nisu imali na raspolaganju kvalitetne generatore visokonaponskih (VN) i visokofrekvencijskih (VF) struja. Visoki naponi generirani su s pomoću induktora. Röntgen je (kao i većina drugih) koristio najpoznatiji induktor, tzv. Ruhmkorffov kalem, duljine 50 cm i promjera 20 cm (slika 3).

S kupljenom vakuumskom Lenardovom cijevi prvo je ponovio sve Lenardove pokuse. Lenard je cijev pregradio tankim aluminijskim listićem kako bi odvojio dio cijevi u kojem su zrake nastajale od dijela u kojem je s njima radio pokuse. Ustanovio je i to da zrake mogu kroz aluminijski prozorčić izlaziti iz cijevi na otvoreno. Nakon tih prvih ponovljenih pokusa Röntgen postaje rektorom Sveučilišta u Würzburgu pa nema vremena za istraživanja. Tek krajem sljedeće godine, 1895. ponovno se latio pokusa, ovaj put s Hittorfovom vakuumskom cijevi. Jedne večeri u studenom cijev je pokrio crnom ljepenkom te eksperimentirao u zatamnjenom laboratoriju. Nedaleko od cijevi na stolu se nalazio list papira premazan otopinom barijeva platinocijanida.[2] Nakon priključenja

[2] Kristali barijeva tetracijanoplatinata imaju zanimljiva svojstva: pod utjecajem rendgenskih zraka i radioaktivnog zračenja snažno sjaje žuto-zelenom svjetlošću.

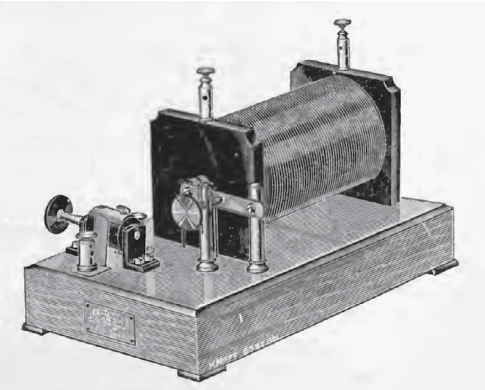
After that, he returned to other experiments. In 1900, he became director of the Institute of Experimental Physics in Munich, where he remained for the rest of his life. The following year (1901) he was awarded the Nobel Prize in Physics, the very first Nobel Prize in physics ever awarded ([5], pp. 290–291).

The discovery of X-rays

Before beginning his research on the phenomenon of vacuum tubes, Röntgen consulted with Philipp Lenard, the most experienced researcher of cathode rays. In 1894, Röntgen no longer had to build his own tube, as all researchers before him had, because the first Lenard tubes had already appeared on the market. At that time, that is in the early 1890s, researchers (with the exception of Nikola Tesla, which will be discussed below) did not have high-quality generators for high-voltage (HV) and high-frequency (HF) currents available for working with vacuum tubes. High voltages were generated using inductors. Röntgen (like most others) used the most well-known inductor, the so-called Ruhmkorff coil, which was 50 cm long and 20 cm in diameter (Figure 3).

With the vacuum Lenard tube he had purchased, Röntgen first repeated all of Lenard's experiments. Lenard had partitioned the tube with a thin aluminum foil to separate the section where the rays were generated from the section where he performed his experiments with them. He also discovered that the rays could escape from the tube into the open air through the aluminum window. After these initial repeat experiments, Röntgen became rector of the University of Würzburg and had no time for research. It was not until the end of the follow-

cijevi na električni napon, Röntgen je uz veliko iznenađenje primijetio da je list počeo sjati.



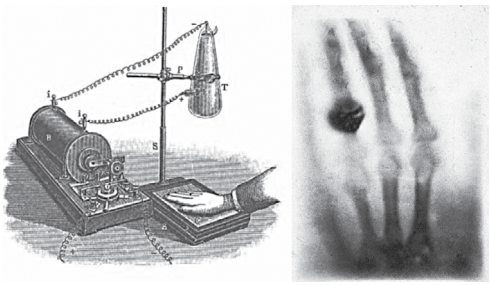
Slika 3. **Ruhmkorffov kalem kakvoga je Röntgen koristio pri otkriću X-zraka;** Ruhmkorffov kalem, L. E. Knott Apparatus Company, Catalogue of Physical Instruments, Boston, p. 469; https://tinyurl.com/2dblhhz7 (Pristupljeno 21. 3. 2024.)

Figure 3. ***Ruhmkorff's coil used by Röntgen in his X-ray discovery experiment;*** *Ruhmkorff's coil, L. E. Knott Apparatus Company, Catalogue of Physical Instruments, Boston, p. 469;* https://tinyurl.com/2dblhhz7 (Accessed 3/21/2024)

Zaključio je da je nešto pogodilo papir i uzrokovalo sjaj. Zbog crne ljepenke to nisu mogle biti ni katodne zrake niti vidljiva svjetlost. Odlučio je istražiti taj fenomen. Papir je svijetlio i u slučajevima kada je bio udaljen od vakuumske cijevi, odnosno kada je između cijevi i papira stavljao različite predmete. Kada je na papir položio svoju šaku, na njemu se pokazao odraz kostiju (slika 4) – tako je otkrio „novu vrstu zraka".

Röntgen je radio sam i tako nastavio još nekoliko dana, držeći u tajnosti svoje otkriće. Nije rekao ništa čak ni svojoj

ing year, 1895, that he returned to the experiments, this time with a Hittorf's vacuum tube. One evening in November, he covered the tube with black paper and experimented in a darkened laboratory. Near the tube on the table was a sheet of paper coated with a barium platinocyanide[2] solution. After connecting the tube to an electrical voltage, Röntgen, to his great surprise, noticed that the paper began to glow.



Slika 4. **Lijevo: Röntgenov pokus s X-zrakama** ([5], str. 293); **Desno: prva Röntgenova medicinska fotografija s X-zrakama – kosti šake ruke njegove supruge Anne Berthe Ludwig, 22.12.1895; Röntgen je fotografiju priložio kopijama svojega članka** https://tinyurl.com/jgz8ksx (Pristupljeno 14. 3. 2024.)

Figure 4. ***Left: Röntgen's experiment with X-rays*** *([5], p. 293);* ***Right: Röntgen's first X-ray medical photograph – hand bones of his wife Anna Bertha Ludwig, 22/12/1895; Röntgen attached the photocopies to his article*** https://tinyurl.com/jgz8ksx (Accessed 3/14/2024)

He concluded that something had struck the paper and caused the glow. Because of the black cardboard, it could not have been either cathode rays or visible light. He decided to investi-

[2] Barium tetracianoplatinate crystals have interesting properties: under the influence of X-rays and radioactive radiation, they strongly glow with a yellow-green light.

supruzi, iako je primijetila njegov veliki zanos. Tek kad je s pomoću fotografija utvrdio svoja saznanja, odlučio ih je objaviti. U prosincu 1895. predao je svoj rukopis članka *O novoj vrsti zraka* Fizikalno-medicinskom društvu u Würzburgu koje ga je tiskalo još iste godine. Fotografske ploče bile su osjetljive za zrake. Neki predmeti su ih propuštali, neki nisu. Zrake su izlazile iz dijela cijevi u kojem su katodne zrake pogodile staklo. Nije ih bilo moguće otkloniti magnetskim poljem, a izgledalo je da nije moguće ni njihovo odbijanje ili refrakcija (slično lomu vidljive svjetlosti). Na kraju je Röntgen pretpostavio da nove, nepoznate zrake predstavljaju longitudinalno elektromagnetsko zračenje. Svjetlost i druge vrste elektromagnetskoga zračenja čine transverzalni valovi. To znači da su električno i magnetsko polje ortogonalni na smjer kretanja, dok se kod novih zraka pretpostavljalo da oba polja imaju isti smjer kretanja u pravcu prostiranja. Pitanje koje se tada pojavilo glasilo je: „Ili čestice ili zračenje?"

Odgovor su dali Max von Laue i njegovi suradnici tek 1911., kada su pokusima s interferencijom pokazali da je riječ o običnom elektromagnetskom zračenju kod kojega je jedina razlika samo u valnoj duljini (frekvenciji), koja je još manja (veća) od one koja je karakteristična za ultraljubičastu svjetlost (recimo manja od nekoliko milijarditih dijelova metra). Zato se u vezi tih zraka govori o rendgenskoj svjetlosti. Sam Röntgen koristio je ime „X-zrake" i to se ime održalo na engle-

gate this phenomenon. The paper also glowed when it was placed far from the vacuum tube, even when various objects were placed between the tube and the paper. When he placed his hand on the paper, the outline of his bones appeared (Figure 4) – this is how he discovered „a new kind of rays."

Röntgen worked alone and continued to do so for several more days, keeping his discovery a secret. He did not tell anyone, not even his wife, although she noticed his great enthusiasm. Only after confirming his findings with photographs he decides to publish them. In December 1895, he submitted his manuscript, „*On a New Kind of Rays,*" to the Physico-Medical Society of Würzburg, which published it later that same year. Photographic plates were sensitive to the rays. Some objects passed through them, while others did not. The rays emerged from the part of the tube where the cathode rays hit the glass. They could not be deflected by a magnetic field, and it seemed that they could not be reflected or refracted (similar to the refraction of visible light). In the end, Röntgen assumed that the new, unknown rays represented longitudinal electromagnetic radiation. Light and other types of electromagnetic radiation are transverse waves. This means that the electric and magnetic fields are orthogonal to the direction of motion, whereas it was assumed that with the new rays, both fields had the same direction of motion along the direction of propagation. The question that arose at the time was: „Either particles or radiation?"

The answer was provided by Max von Laue and his colleagues only in 1911, when they showed through interference experiments that it was ordinary electromagnetic radiation, the only difference being in its wavelength (frequency), which is even shorter (longer) than that charac-

skom govornom području. U vezi pretpostavke o longitudinalnom elektromagnetskom zračenju Röntgen nije bio u pravu. No, pitanje o prirodi nepoznatih zraka činilo mu se manje važnim ([5], str. 292–293).

TESLINO ISTRAŽIVANJE VISOKONAPONSKIH I VISOKOFREKVENCIJSKIH FENOMENA

Škotski fizičar James Clerk Maxwell (1831. – 1879.) uputio je 1873. na postojanje širokog područja elektromagnetskog (EM) titranja iznad i ispod frekvencijskog spektra vidljive svjetlosti. Tu je teoriju 1886. počeo provjeravati njemački profesor Heinrich Rudolf Hertz (1857. – 1894.). Dvije godine kasnije u Bonnu je objavio da je proizveo umjetno EM zračenje i tako eksperimentalno detektirao valove iz Maxwellove teorije. Hertzova oprema korištena u tim pokusima bila je neprecizna. I on je, slično kao Röntgen sedam godina kasnije, koristio spomenuti Ruhmkorffov kalem koji je bio nepraktičan i opasan ([7], str. 60; [8], str. 61).

Tesla je krajem 1889., kao član Američkoga instituta inženjera elektrotehnike (AIEE), posjetio svjetsku izložbu u Parizu, gdje je bio sudionik međunarodnoga kongresa elektrotehničara. Tom je prilikom na izložbi upoznao mladoga norveškoga fizičara Vilhelma Bjerknesa, koji je bio dvije godine asistent Heinricha Hertza na Sveučilištu u Bonnu i s kojim je proučavao fenomen višestruteristic of ultraviolet light (say, smaller than a few billionths of a meter). That is why these rays are referred to as X-rays. Röntgen himself used the name „X-rays," and this name has persisted in the English-speaking world. Röntgen was wrong about the assumption of longitudinal electromagnetic radiation. However, the question of the nature of the unknown rays seemed less important to him ([5], pp. 292–293).

TESLA'S RESEARCH ON HIGH-VOLTAGE AND HIGH-FREQUENCY PHENOMENA

Scottish physicist James Clerk Maxwell (1831-1879) pointed in 1873 to the existence of a broad range of electromagnetic (EM) oscillations above and below the frequency spectrum of visible light. This theory was tested in 1886 by the German professor Heinrich Rudolf Hertz (1857-1894). Two years later in Bonn, Hertz announced that he had produced artificial EM radiation, thereby experimentally detecting the waves predicted by Maxwell's theory. Hertz's equipment used in these experiments was imprecise. He, like Röntgen seven years later, used the aforementioned Ruhmkorff's coil, which was impractical and dangerous ([7], str. 60; [8], str. 61).

In late 1889, as a member of the American Institute of Electrical Engineers (AIEE), Tesla visited the World Exhibition in Paris, where he participated in the International Congress of Electrical Engineers. On that occasion at the exhibition, he met the young Norwegian physicist Vilhelm Bjerknes, who was Heinrich Hertz's assistant at the University of Bonn for two years and with whom he studied the phenomenon of multiple resonance in oscillating electrical

ke rezonancije u oscilacijskim električnim krugovima. On ga je i matematički razradio. Tesla je na izložbi prisustvovao Bjerknesovom demonstracijskom predavanju o titrajućim membranama. Vrlo vjerojatno ga je upravo Bjerknes upoznao s Hertzovim otkrićem ([8], str. 62; [9], str. 117).

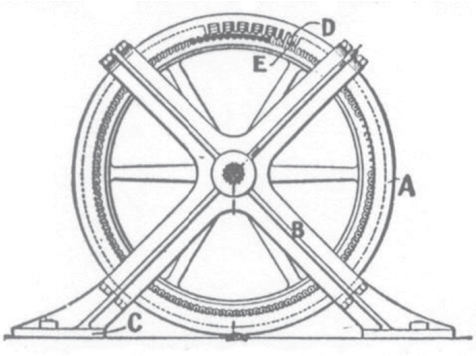
Prije toga, ujesen 1889. Tesla se vratio iz Pittsburgha u svoj novi njujorški laboratorij u ulici Grand Street br. 175. U Pittsburghu je radio s inženjerima tvrtke Westinghouse na adaptaciji električnih strojeva izrađenih prema njegovim patentima. Jedva je čekao da počne ponovno raditi sam. Započeo je istraživanja na brojnim zasebnim, ali povezanim poljima. Kao fizikalni eksperimentator, počeo je proučavati razliku između elektromagnetskih i elektrostatičkih pojava, kao i odnos između strukture etera i elektriciteta, materije i svjetlosti. Između tri mogućnosti različitih smjerova istraživanja: vrlo visoki naponi, vrlo jake struje ili snažna električna titranja s njihovim misterioznim djelovanjem na daljinu, odabrao je potonje – visokofrekvencijske (VF) fenomene od kojih je najviše očekivao. Počeo je konstruirati opremu za proizvodnju izuzetno visokih napona (VN) i visokih frekvencija za transformaciju jednosmjerne (DC) struje u izmjeničnu (AC) i obrnuto, kao i za generiranje ujednačenih oscilacija. Pritom je mogao računati na iskustvo izrade uređaja koje je počeo razvijati već 1888., još prije svojeg odlaska u Pittsburgh. Tada je razmišljao kako svoj motor prilagoditi u odnosu na Westinghousov postojeći jed-

circuits. He also developed it mathematically. At the exhibition, Tesla attended Bjerknes's demonstration lecture on vibrating membranes. It is very likely that Bjerknes introduced him to Hertz's discovery ([8], p. 62; [9], p. 117).

Before that, in the fall of 1889, Tesla returned from Pittsburgh to his new New York laboratory at 175 Grand Street. In Pittsburgh, he worked with engineers at the Westinghouse company to adapt electrical machines built according to his patents. He could hardly wait to start working on his own again. He began research in numerous separate but related fields. As a physical experimenter, he started studying the difference between electromagnetic and electrostatic phenomena, as well as the relationship between the structure of the ether and electricity, matter, and light. Between three possibilities for different lines of research – very high voltages, very strong currents, or powerful electrical oscillations with their mysterious action at a distance – he chose the latter: high-frequency (HF) phenomena, from which he expected the most. He began to construct equipment for producing extremely high voltages (HV) and high frequencies, for transforming direct current (DC) into alternating current (AC) and vice versa, as well as for generating uniform oscillations. He could draw on the device-building experience he had begun developing in 1888, even before his departure to Pittsburgh. At that time, he considered how to adapt his motor to Westinghouse's existing single-phase AC motor, which used an operating frequency of 133 Hz, while also increasing his motor's speed, or revolutions-per-minute. Since his motors were synchronous and operated at the same speed as the AC generators, he designed a new high-frequency AC generator, using 24 stator poles, in-

nofazni AC motor koji je koristio radnu frekvenciju od 133 Hz, a da pritom još poveća brzinu odnosno broj obrtaja svojeg motora. S obzirom na to da su njegovi motori bili sinkroni i da su radili istom brzinom kao AC generatori, konstruirao je novi AC generator visokih frekvencija, koristeći 24 pola statora, umjesto dotadašnja četiri. Tako je Tesla uspio konstruirati struje frekvencije 2 kHz.

Međutim, sada se Tesla upitao koje bi nove izume mogao razviti ako bi koristio struje frekvencija 10 kHz ili 20 kHz. Postojala je granica frekvencije struje iznad koje više nije bila moguća izvedba rotirajućih generatora. Koristeći drugo pravilo induciranja napona Tesla je izradio stabilni mehanički vibrator, koji se napajao komprimiranim zrakom ili parom i koji je mogao generirati struje frekvencije do 20 kHz. Kasnije je u devedesetim godinama 19. stoljeća izradio brojne VF alternatore sa stotinama elektromagneta (varijante do 384 pola) ugrađenih u njihov rotor i stator. Do kraja života detaljno je konstruirao 50 tipova mehaničkih VF alternatora. Pritom je morao optimirati odnos jake struje i zagrijavanja, a pri izradi alternatora koji su radili i sa 20 000 obrt./min, pomoglo mu je znanje i iskustvo koje je stekao u radu s motorima u Edisonovoj tvrtki Edison Machine Works. Nakon toga je VF generatore prvo koristio za proučavanje potencijalnih aplikacija vezanih uz uporabu elektrolučnih svjetiljki i distribucije električne snage. Tako je patentirao svoj prvi VF generator (slika 5) za napajanje elektrolučnih svjetiljki, koje su tada već desetljećistead of the previous four. In this way, Tesla was able to construct currents with a frequency of 2 kHz.



Slika 5. **Teslin visokofrekvencijski mehanički generator radne frekvencije 10 kHz, snage 10 kW, koji je Tesla koristio i na svom prvom demonstracijskom predavanju o VF fenomenima** (održano 20. 5. 1891. na Sveučilištu Columbia u organizaciji Američkoga instituta inženjera elektrotehnike, AIEE); Tesla N: *The True Wireless*, Electrical Experimenter (Radio Department), May **1919**, p. 28.

Figure 5. ***Tesla's high-frequency mechanical alternator, operating frequency 10 kHz, capacity 10 kW, which Tesla also used in his first demonstration lecture on HF phenomena*** *(held at the Columbia College, on May 20, 1891, organized by the American Institute of Electrical Engineers, AIEE);* Tesla N: *The True Wireless*, Electrical Experimenter (Radio Department), May **1919**, p. 28.

However, Tesla now wondered what new inventions he could develop if he used currents at frequencies of 10 kHz or 20 kHz. There was a frequency limit above which rotating generators could no longer be constructed. Using the second law of voltage induction, Tesla built a stable mechanical vibrator, powered by com-

ma bile u širokoj uporabi, ali napajane samo istosmjernom (DC) strujom ([8], str. 67; [9], str. 119–120).

Jednom prilikom Tesla je izjavio da ga je u Parizu „zahvatila vatra entuzijazma koja je snažno gorjela od želje da ugleda čudo (Hertzove EM valove, *nap. a.*) vlastitim očima". Tesla je 1890. ponovio sve Hertzove pokuse i najvjerojatnije je bio prvi istraživač u Americi koji je to učinio. S rezultatima koje je dobio tim pokusima nije bio zadovoljan pa se upitao zašto ne bi koristio mnogo više frekvencije, npr. 10 ili 20 kHz iz njegovih VF generatora. Tako je odlučio mijenjati uvjete pokusa pa je radne frekvencije od par stotina Hz zamijenio s visokim frekvencijama svojih alternatora. Ubrzo je ustanovio da se s povećanjem frekvencije povisuje temperatura indukcijskog (Ruhmkorffovog) kalema i njegove čelične jezgre, zbog čega se počela otapati izolacija između primarne i sekundarne zavojnice, a detektirao je i problem s kondenzatorom u električnom kolu. Te je probleme Tesla riješio svojim genijalnim izumom zračnoga transformatora (bez jezgre), izradom kondenzatora s podešavanjem kapaciteta i njegovim drukčijim vezivanjem u kolo. Eksperimentiranje s kombinacijama podešavanja kapaciteta kondenzatora i indukcije kalema nije mu bilo strano i pritom je primijetio da tako može povisiti radnu frekvenciju na još viši nivo. Koristeći prednosti tzv. rezonancije električnog kruga, Tesla je ubrzo mogao generirati izmjenične struje još viših frekvencija i mnogo viših napona. Fasciniran snažnim utjecajima rezonancije

pressed air or steam, that could generate currents at frequencies up to 20 kHz. Later, in the 1890s, he built numerous HF alternators with hundreds of electromagnets (variants with up to 384 poles) built into their rotor and stator. By the end of his life, he had detailed designs for 50 types of mechanical HF alternators. In doing so he had to optimize the trade-off between high current and heating, and his knowledge and experience working with motors at Edison's Edison Machine Works helped him in designing alternators that ran at 20,000 rpm. He then used the AC generators to study potential applications related to the use of electric arc lamps and the distribution of electrical power. He thus patented his first AC generator (Figure 5) for powering arc lamps, which had been in widespread use for decades but were powered only by direct current (DC) ([8], p. 67; [9], pp. 119–120).

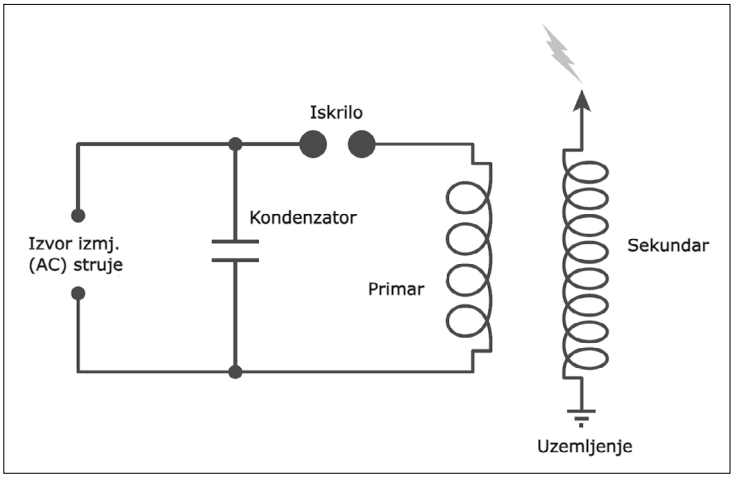
On one occasion, Tesla stated that in Paris he was „struck by a fire of enthusiasm that burned strongly from the desire to see the miracle (Hertz's EM waves, *note a.*) with his own eyes." In 1890, Tesla repeated all of Hertz's experiments and was most likely the first researcher in America to do so. He was not satisfied with the results he obtained from those experiments, so he wondered why he should not use much higher frequencies, for example 10 or 20 kHz from his high-frequency generators. He therefore decided to change the experimental conditions, replacing the working frequencies of a few hundred Hz with the high frequencies of his alternators. He soon discovered that as the frequency increased, the temperature of the induction (Ruhmkorff) coil and its steel core rose, causing the insulation between the primary and secondary windings to begin to melt. He also detected a problem with the capacitor in the electrical circuit. Tesla solved

počeo je istraživati gdje sve to može primijeniti – što ubrzo postaje njegova glavna nit vodilja u radu s VF i VN fenomenima.

Teslini VF alternatori (bili su mnogo bolji od Hertzove jednostavne opreme) mogli su proizvoditi izmjeničnu struju do 33 kHz. Taj izum, koji uključuje i nekoliko manjih izuma koje Tesla nije nikada patentirao (to su kasnije učinili i komercijalizirali drugi), stupanjski transformator koji transformira relativno niskonaponsku struju velike jakosti u visokonaponsku struju male jakosti pri visokim frekvencijama, kasnije je postao poznat pod imenom „Teslin kalem" ili „Teslin transformator" (slika 6). VF uređaj tog tipa bio je zapravo prethodnik velikim VF alternatorima koje su drugi konstruirali za stal-

these problems with his ingenious invention of the air transformer (without a core), by creating a capacitor with adjustable capacitance and its connection in a different circuit. He was no stranger to experimenting with combinations of adjusting the capacitance of a capacitor and the induction of a coil, and he noticed that he could thus raise the operating frequency to an even higher level. Taking advantage of the so-called resonance of an electrical circuit, Tesla was soon able to generate alternating currents of even higher frequencies and much higher voltages. Fascinated by the powerful effects of resonance, he began to investigate where he could apply all this – which soon became his main guiding thread in his work with HF and HV phenomena.

Tesla's HF alternators (which were much better than Hertz's simple equipment) could produce alternating current up to 33 kHz.



Slika 6. **Shema Teslinoga zračnoga transformatora („Teslin kalem")** ([9], str. 122) (obradio autor)

Figure 6. ***The scheme of Tesla's air transformer („Tesla coil")*** *[9, p. 122] (edited by the author)*

Iskrilo – *Sparking*; Izvor izmjenične (AC) struje – *Alternating current (AC) source*; Kondenzator – *Capacitor*; Primar – *Primary*; Sekundar – *Secondary*; Uzemljenje – *Grounding*

nu radiokomunikaciju u tada još dalekoj budućnosti. Tesla je imao osjećaj da je to jedan od njegovih najvećih izuma, koji je predstavljao temelj njegova budućeg rada vezanog uz bežični prijenos električne energije i uspoređivao ga je s osjećajem koji ga je obuzeo prilikom otkrića okretnog magnetskog polja ([7], str. 60–61; [9], str. 119–120).

Kad je započeo svoja VF istraživanja u laboratoriju na Grand Streetu, Tesla je, među ostalima, zaposlio i američkoga staklopuhača Davida Hiergesella, koji mu je izrađivao brojne vakuumske cijevi. Ubrzo je Teslin laboratorijski rad uključivao istraživanja s Geisslerovom cijevi s dvije elektrode od platine na koju je priključio svoj transformator. Kod klasičnoga pokusa, gdje se Ruhmkorffov kalem priključi na Geisslerovu cijev, zbog visokog napona dolazi do ionizacije preostalog plina u evakuiranoj cijevi, u kojoj plin počinje snažno svijetliti. Te je pokuse mnogo prije Tesle proveo i njegov uzor Sir William Crookes, a on ih je ponovio. Teslina je prednost bila, za razliku od Crookesa, Geisslera i ostalih, što je mogao koristiti mnogo kvalitetniji izvor VF struja i još više frekvencije. Očekivao je da će zato moći proizvoditi bitno drugačije fenomene od njihovih, ako bi neobične efekte, koje je primijetio kod svojih struja izuzetno visokih frekvencija, prenio u staklene cijevi. I bio je u pravu. Ubrzo je zaključio da Geisslerova cijev u blizini iskrila svijetli samo u određenim pozicijama, kao posljedica električnog polja u njegovoj okolini, a ne EM (Hertzovih) valova, kako su smatrali Hertz i Sir Oliver Lodge (1851.

This invention, which also included several smaller inventions that Tesla never patented (they were later patented and commercialized by others), a stepped transformer that transforms a relatively low-voltage, high-current supply into a high-voltage, low-current supply at high frequencies, later became known as the „Tesla coil" or „Tesla transformer" (Figure 6). The HF device of this type was actually a precursor to the large HF alternators that others would construct for permanent radio communication in the then still distant future. Tesla felt that this was one of his greatest inventions, which formed the basis of his future work on wireless transmission of electrical energy, and he compared it to the feeling that he overcome him upon the discovery of the rotating magnetic field ([7], pp. 60–61; [9], pp. 119–120).

When he began his HF research in the laboratory on Grand Street, Tesla employed, among others, the American glassblower David Hiergesell, who made him numerous vacuum tubes. Soon, Tesla's laboratory work included experiments with a Geissler tube with two platinum electrodes to which he connected his transformer. In the classic experiment, where a Ruhmkorff coil is connected to a Geissler tube, the high voltage causes the remaining gas in the evacuated tube to ionize, causing the gas to glow brightly. These experiments had been conducted long before Tesla by his role model, Sir William Crookes, and Tesla repeated them. Tesla's advantage, unlike Crookes's, Geissler's, and others, was that he could use a much higher quality source of AC currents and even higher frequencies. He expected that he would therefore be able to produce fundamentally different phenomena than theirs, if he could transfer the un-

– 1940.). Tesla je bio uvjeren da cijev svijetli zbog elektrostatičkih udara ([9], str. 126–127; [10], str. 141). Tako je 1891. patentirao cijev odnosno svjetiljku pod imenom „Električna usijana (inkandescentna) svjetiljka" (u novije doba američka vojska počela ju je koristiti kao dio mobilnog sistema rasvjete visokog intenziteta).

Teslino istraživanje VF i VN izmjeničnih struja dovelo je do razvoja velikog broja različitih vakuumskih cijevi. Osim cijevi Geisslerovog, Lenardovog i Crookesovog tipa, razvio je i patentirao i niz vlastitih vakuumskih cijevi. Zbog različitosti boja koje su isijavale iz cijevi kod raznih plinova, kao i zraka pod različitim tlakovima, ispravno je pretpostavio da sva energija ne isijava kao vidljiva svjetlost, nego djelomice i kao nevidljiva tamna svjetlost. Već je 1889. pomoću nanosa cinkova sulfida te drugih fosforescentnih (slika 7) i fluorescentnih tvari u cijevi, pretvorio do tada nekorištene i nevidljive ultraljubičaste zrake u vidljivu svjetlost. Temeljem električne aktivacije plinskih molekula stvorio je četiri vrste električne rasvjete: 1. cijevi, u kojima kruto tijelo zasja; 2. cijevi u kojima svijetle fosforescentne i fluorescentne tvari; 3. cijevi u kojima sjaje razrijeđeni plinovi; 4. cijevi u kojima se stvara svjetlost u plinovima pod normalnim tlakom ([10], str. 141). Na popisu Teslinih brojnih izuma mogu se pronaći raznolike nove električne svjetiljke, sve predviđene za rad s priključenjem na specijalno konstruirane VF generatore. Među njima se nalaze prethodnice današnjih fluorescentnih (neonskih) i fosforescentnih svjetiljki.

usual effects he had observed with his extremely high-frequency currents into glass tubes. And he was right. He soon concluded that the Geissler tube near the spark glowed only in certain positions, as a result of the electric field in its surroundings, and not from EM (Hertzian) waves, as Hertz and Sir Oliver Lodge (1851-1940) believed. Tesla was convinced that the tube lit up due to electrostatic discharges ([9], pp. 126–127; [10], p. 141). Thus, in 1891, he patented the tube, or lamp, under the name „Electrical Incandescent Light" (in more recent times, the U.S. military began to use it as part of a mobile high-intensity lighting system).

Tesla's research into HF and HV alternating currents led to the development of a large number of different vacuum tubes. In addition to Geissler, Lenard, and Crookes tube types, he also developed and patented a number of his own vacuum tubes. Due to the different colors that were emitted from the tubes by various gases, as well as air under different pressures, he correctly assumed that not all energy was emitted as visible light, but partly as invisible dark light. Because of the variety of colors emitted from the tube with different gases, as well as air at various pressures, he correctly hypothesized that not all energy is emitted as visible light, but also partly as invisible dark light. As early as 1889, using a coating of zinc sulfide and other phosphorescent (Figure 7) and fluorescent substances in the tube, he converted the previously unused and invisible ultraviolet rays into visible light. Based on the electrical activation of gas molecules, he created four types of electric lighting: 1. tubes in which a solid body glows; 2. tubes in which phosphorescent and fluorescent substances glow; 3. tubes in which rarefied gases glow; 4. tubes in which light is generated

Tesla je od 1893. do ožujka 1895. u svoj laboratorij na 5. Aveniji pozivao mnoge poznate i slavne osobe, koje je tom prilikom prema običaju i fotografirao uz uporabu fosforescentnih svjetiljki (slike 8, 9) ([8], str. 127).

Međutim, „čudesna" Teslina svjetiljka koja zaslužuje posebnu pažnju je inkandescentna svjetiljka s ugljikovim dugmetom ili svjetiljka za molekularno bombardiranje, koja vrlo učinkovito proizvodi svjetlo visoke razine svjetlosti.

TESLA I X-ZRAKE PRIJE RÖNTGENOVA OTKRIĆA

Tesla je svoju svjetiljku s ugljikovim dugmetom prvi put opisao u spomenutom predavanju (AIEE) u svibnju 1891.: *Elektrostatički fenomeni mogu se upotrijebiti za proizvodnju svjetlosti na razne načine. ... A možemo dati takvo tijelo i u staklenu kuglu koju smo jako evakuirali; pri upotrebi vrlo visoke frekvencije i visokog potencijala tijelo će sijati prema našoj volji.*

Ta je svjetiljka bila samo jedna od brojnih koje je Tesla s drugim važnim novitetima uključio u prikaz svoga rada. Primijetio je da ispoljava brojne vrlo zanimljive i značajne fenomene, a najvažnije među njima je 1892. opisao u svojim čuvenim predavanjima o VF i VN fenomenima u Londonu i Parizu. Izjavio je da njegova svjetiljka emitira „vidljivu svjetlost, tamnu svjetlost i *neko specijalno isijavanje*". Teslina „čudesna" svjetiljka ispoljava najmanje pet važnih fenomena koji se mogu tretirati kao važna znanstvena otkrića: 1. kozmičke zrake; 2. umjetna radioaktivin gases under normal pressure ([10], p. 141).

Tesla's list of numerous inventions includes a variety of new electric lamps, all designed to operate when connected to specially constructed HF generators. Among them are the forerunners of today's fluorescent (neon) and phosphorescent lamps.

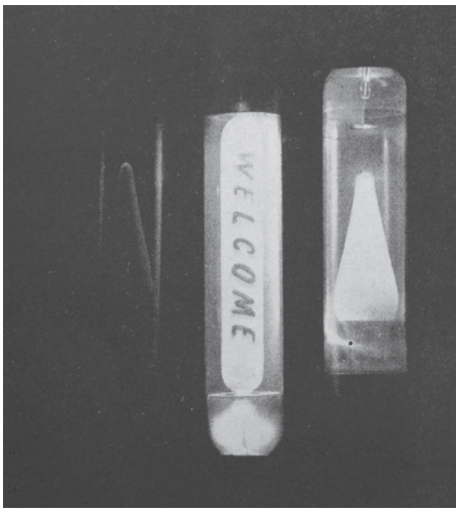
From 1893 to March 1895, Tesla invited many well-known, famous people to his laboratory on Fifth Avenue. There, as it became his custom, he photographed them using phosphorescent lamps (Figures 8, 9) ([8], p. 127).

The „miraculous" Tesla's lamp that deserves special attention, however, is the incandescent lamp with a carbon button, or the molecular bombardment lamp, which efficiently produces light of a high intensity.

TESLA AND X-RAYS BEFORE RÖNTGEN'S DISCOVERY

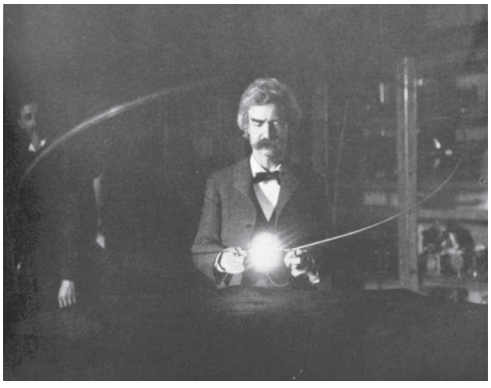
Tesla first described his carbon-button lamp in the aforementioned AIEE lecture in May 1891: *Electrostatic phenomena can be used to produce light in various ways. ... And we can make such a body even in a glass globe which we have strongly evacuated; by using a very high frequency and a high potential the body will shine according to our will.*

That lamp was just one of many that Tesla, along with his other important innovations, included in the demonstrative presentation of his work. He noticed that it exhibited numerous interesting and significant phenomena, the most important of which he described in 1892 in his famous lectures on HF and HV phenomena in London and Paris. He stated that his lamp emits „visible light, dark light, and some special radiation". Tesla's „mi-



Slika 7. **Tri Tesline fosforescentne žarulje, fotografirane pod utjecajem vlastita svjetla** https://tinyurl.com/26spbzeu (Pristupljeno 25. 3. 2024)

Figure 7. ***Three Tesla phosphorescent bulbs, photographed under the influence of their own light*** https://tinyurl.com/26spbzeu (Accessed 3/25/2024)



Slika 8. **Mark Twain u Teslinu laboratoriju na 5. Aveniji, 26. 4. 1894.; Tesla je u pozadini na lijevoj strani slike** https://tinyurl.com/23mqtx9b (Pristupljeno 25. 3. 2024)

Figure 8. ***Mark Twain in Tesla's laboratory on 5th Avenue, 4/26/1894; Tesla in the background on the left side of the picture*** https://tinyurl.com/23mqtx9b (Accessed 3/25/2024)



Slika 9. **Prva fotografija ikada načinjena fosforescentnim svjetlom; na njoj je Teslin obraz; vrijeme ekspozicije: osam minuta, nadnevak: siječanj 1894.** https://tinyurl.com/294vyzra (Pristupljeno 25. 3. 2024)

Figure 9. ***The first photograph ever taken with phosphorescent light; on it is Tesla's face; exposure time: eight minutes, date: January 1894*** https://tinyurl.com/294vyzra (Accessed 3/25/2024)

nost; 3. atomski akcelerator (ciklotron); 4. elektronski mikroskop; 5. „specijalna vrsta radijacije" (X-zrake). Za bar četiri od tih otkrića, koja su ponovno „otkrivena" u razdoblju do 40 godina nakon toga, Nobelove su nagrade dobili drugi znanstvenici, dok se Teslino ime u vezi s njima ni ne spominje.

Bez obzira na ta otkrića, Teslina svjetiljka s ugljikovim dugmetom već sama po sebi, kao svjetiljka, predstavlja sjajan znanstveni izum. Thomas A. Edison otkrio je npr. samo temperaturno otporni materijal za nit žarne (usijane) žarulje te na toj osnovi izradio i patentirao svoj tip praktične žarulje. Za taj uspjeh stekao je opće stručno, ali i novčano priznanje. Tesla je izumio posve originalan tip predmetne svjetiljke, koji uz jednako jaku struju daje dvadeset puta više svjetlosti, ali je njegov izum ostao nepoznat ([10], str. 146–147, 153–154).

Teslu s X-zrakama posredno povezuju još dvije neiskorištene prilike. Prva se prilika pojavila krajem 1894., kada je odlučio istražiti snagu fotokemijskog učinka svojih fosforescentnih svjetiljki, tj. utječu li na fotografske ploče na jednaki način kao svjetlo kojega emitira sunce ili drugi izvori osvjetljenja. U tu svrhu zatražio je pomoć Dickensona D. Alleya, fotografa zaposlenog u tvrtki Tonnele & Company (fotografi te tvrtke radili su za časopis *Century* kojega je urednik bio Teslin dobar osobni prijatelj Robert U. Johnson). U razdoblju od nekoliko mjeseci testirali su brojne vrlo različite fosforescentne svjetiljke, Crookesove cijevi i vakuumske žarulje s različitim tipovima elektroda.

raculous" lamp exhibits at least five important phenomena that can be regarded as important scientific discoveries: 1. cosmic rays; 2. artificial radioactivity; 3. atomic accelerator (cyclotron); 4. electron microscope; 5. a „special type of radiation" (X-rays). At least four of these discoveries were „rediscovered" in the period up to 40 years after, and other scientists were awarded Nobel Prizes, while Tesla's name is not even mentioned in connection with them.

Regardless of these discoveries, Tesla's carbon-button lamp, in itself as a lamp, represents a brilliant scientific invention. Thomas A. Edison, for example, discovered only a temperature-resistant material for the filament of an incandescent lamp and on that basis developed and patented his own type of practical light lump. For this achievement he received widespread professional as well as financial recognition. Tesla invented a completely original type of such lamp, which, with the same current strength, gives twenty times more light, but his invention remained unknown ([10], pp. 146–147, 153–154).

Tesla is indirectly connected with X-rays by two other unused opportunities. The first opportunity arose in late 1894, when he decided to investigate the power of the photocatalytic effect of his phosphorescent lamps, i.e., whether they affect photographic plates in the same way as the light emitted by the sun or other light sources. For this purpose, he enlisted the help of Dickenson D. Allay, a photographer employed by Tonnele & Company (the company's photographers worked for the *Century magazine*, whose editor was Tesla's good personal friend, Robert U. Johnson). Over a period of several months, they

Budući da im to nije bio glavni projekt, Tesla i Alley su na tome radili povremeno, a Alley je u uglu laboratorija, u originalnim metalnim kutijama skladištio rezervne staklene fotografske ploče. Pa ipak, primijetili su da neizložene ploče sadrže čudne „neobjašnjive mrlje i defekte" koji su indicirali da su bile na neki način „oštećene". Tesla se letimice zapitao je li moguće da su na ploče utjecale katodne zrake koje, u nekima od njegovih vakuumskih cijevi, predstavljaju tok nabijenih čestica pri prolazu između elektroda pod električnim naponom. Nedugo prije toga je o tome čitao da je Philipp Lenard, mađarski student poznatoga Heinricha Hertza, dobio zanimljive rezultate koristeći vakuumske cijevi s aluminijskim prozorčićem koji omogućuje zrakama prolaz iz cijevi. Tesla, međutim, nije detaljnije istražio razlog za taj fenomen ([11], str. 175; [10], str. 154; [9], str. 220–221; [7], str. 101; [8], str. 168).

Još detaljniji opis te neiskorištene prilike ponudio je sam Tesla na predavanju 6. 4. 1897. Zaslugu za to nosi vrijedna dokumentacijska ostavština Lelanda Andersona, poznatoga američkoga istraživača Teslina života i rada, koji je posjedovao dijelove Teslinih rukopisa za to predavanje i pokušao ga rekonstruirati, mada isto nije bilo nikada u cijelosti objavljeno. Sukladno tome Tesla je te događaje opisao riječima: *Krajem 1894. ... došao sam na ideju da istražim fotokemijski učinak fosforescentnih tijela. Činilo se da do tada još nije vršeno istraživanje na tu temu, pa sam počeo na tome odmah raditi... U te pokuse sam uključio poboljšane*

tested numerous, very different phosphorescent lamps, Crookes tubes, and vacuum tubes with various types of electrodes. Since this was not their main project, Tesla and Alley worked on it intermittently, and Alley stored spare glass photographic plates in original metal boxes in a corner of the laboratory. They noticed, however, that the unexposed plates contained strange „unexplained spots and defects" that indicated that they had been „damaged" in some way. Tesla wondered briefly whether the plates might have been affected by cathode rays, which, in some of his vacuum tubes, are streams of charged particles passing between electrodes under electrical voltage. Shortly before this, he had read that Philipp Lenard, a Hungarian student of the famous Heinrich Hertz, had obtained interesting results using vacuum tubes with an aluminum window that allowed rays to pass through the tube. Tesla, however, did not investigate the reason for this phenomenon in more detail ([11], p. 175; [10], p. 154; [9], p. 220–221; [7], p. 101; [8], p. 168).

A more detailed description of this unused opportunity was offered by Tesla himself in a lecture on April 6, 1897. Credit for this goes to the valuable documentary legacy of Leland Anderson, the renowned American researcher of Tesla's life and work, who possessed parts of Tesla's manuscripts for that lecture and attempted to reconstruct it, although it was never fully published. Accordingly, Tesla described these events in the following words: *„At the end of 1894... I came up with the idea of investigating the photochemical effect of phosphorescent bodies." It seemed that no research had been done on this topic until then, so I immediately began working on it... I included in*

uređaje za generiranje snažnih električnih titraja kao i jedan od mojih VF generatora starije izvedbe... Kako smo fotografi i ja bili zauzeti i ostalim stvarima, često smo [fotografske] ploče u njihovom običnom [originalnom] pakovanju držali u pojedinim kutovima laboratorija, dok se nije pojavila prikladna prilika za izvedbu pokusa. Tijekom tih pokusa mnoge ploče su iskazale [pozitivan] rezultat, dok su mnoge druge bile uništene i na nekima od njih obojica, g. Alley, koji mi je tada asistirao, i ja primijetili smo neobjašnjive mrlje i defekte. Posebno g. Alley je smatrao neobičnim da su, usprkos njegovoj brizi, mnoge ploče iskazale negativan rezultat i defekte... Upravo tada, kada je moja pažnja bila obuzeta tom pojavom, moj laboratorij, sa gotovo svime što se u njemu nalazilo, bio je uništen [u požaru]; i nekoliko sljedećih mjeseci je prošlo u intenzivnim aktivnostima zbog kojih sam privremeno zaboravio na moje projekte. S velikim naporima sam završio rad na rekonstrukciji i obnovio pravac mojih ideja, kada su do mene doprle vijesti o Roentgenovom dostignuću. ([12], str. 32; [9], str. 222; [2], str. 212–213)

Ovdje valja napomenuti da se ta prva opisana prilika pojavila u Teslinu laboratoriju na Južnoj 5. Aveniji 33-35, kojega je Tesla koristio do požara (prema službenoj verziji požar je izbio spontano), dana 13. 3. 1895. (u 2,30 ujutro) u kojem je potpuno izgorio. Prema Teslinoj izjavi, u neformalnom osobnom razgovoru sa slovenskim elektrotehničkim stručnjakom dr. Milanom Vidmarom, 41 godinu nakon požara, Tesla se požalio da su

these experiments improved devices for generating powerful electrical oscillations, as well as one of my older-model HF generators... Since the photographer and I were busy with other matters, we often kept the [photographic] plates in their ordinary [original] packaging in various corners of the laboratory, until a suitable opportunity arose to perform the experiment. During these experiments, many plates showed a [positive] result, while many others were destroyed, and on some of them, both Mr. Alley, who was assisting me at the time, and I noticed unexplained spots and defects. Mr. Alley, in particular, found it unusual that, in spite of his care, many plates showed negative results and defects... It was just then, when my attention was occupied with this phenomenon, that my laboratory, with almost everything in it, was destroyed [in a fire]; and the next few months were spent in intense activity which temporarily forgot my projects. With great effort I had completed the work of reconstruction and renewed the direction of my ideas, when news of Roentgen's achievement reached me. ([12], p. 32; [9], p. 222; [2], pp. 212–213)

It should be noted here that this first described occasion took place in Tesla's laboratory at 33-35 South 5th Avenue, which Tesla used until the fire (according to the official account, the fire broke out spontaneously) on March 13, 1895 (at 2:30 a.m.) in which it was completely destroyed. According to Tesla's statement, in an informal personal conversation with the Slovenian electrical engineer Dr. Milan Vidmar, 41 years after the fire, Tesla complained that malicious and cruel[3] peo-

[3] There is little doubt that Tesla had in mind the fierce competitors at the time on the line Edison – the General Electric Company – John P. Morgan.

mu zlonamjerni i okrutni ljudi[3] laboratorij digli u zrak dinamitom ([13], str. 47). Tesla predmetni fenomen nije istražio ponajprije stoga jer je prije požara njegov rad imao zaprepašćujući obim, uključujući istraživanja različitih vrsta svjetiljki, radijskih valova – bežične komunikacije, bežičnog prenošenja energije, navođenih vozila, potencijalno veoma isplative industrijske proizvodnje tekućeg kisika te postizanje efekata s onim što će svijet kasnije ipak upoznati kao X-zrake odnosno rendgenske zrake ([7], str. 96–97). Njegova pozornost i rad na žalost nisu bili dovoljno fokusirani na X-zrake.

Druga neiskorištena prilika pojavila se (navodno) nekoliko mjeseci kasnije, što bi značilo prvih mjeseci 1895.[4] Tesla i Edward Ringwood Hewitt, sin Abrahama Hewitta, gradonačelnika New Yorka, raspravljali su o spomenutim fotografskim pokusima. Edwardov brat Peter Cooper Hewitt bio je također elektrotehnički izumitelj. Proučavao je električno pražnjenje plinskih cijevi pri niskom tlaku, čime se bavio i njemački fizičar Julius Plücker te njegov kolega i staklopuhač Heinrich Geissler (1814. – 1879.). Krajem 1890-ih Cooper je počeo razvijati cijevi sa živom, izumivši kasnije sijalicu sa živinim parama. Zanimljivo je da je upravo s kapitalom Teslina investito-

[3] Nema mnogo sumnje da je Tesla pritom imao na umu tada žestoke konkurente na liniji Edison – tvrtka General Electric – John P. Morgan.

[4] U nastavku će se pokazati da taj podatak, uvažavajući poznate i provjerene činjenice, nije i ne može biti točan.

ple had blown up the laboratory with dynamite ([13], p. 47). Tesla did not investigate the phenomenon in question primarily because, before the fire, his work had astonishing scope, including research on various types of lamps, radio waves – wireless communication, wireless energy transmission, guided vehicles, potentially very profitable industrial production of liquid oxygen, and achieving effects that the world would later come to know as X-rays or Röntgen rays ([7], pp. 96–97). Unfortunately, his attention and work were not sufficiently focused on X-rays.

Another unused opportunity supposedly arose a few months later, meaning in the early months of 1895.[4] Tesla and Edward Ringwood Hewitt, son of Abraham Hewitt, mayor of New York, discussed the aforementioned photographic experiments. Edward's brother, Peter Cooper Hewitt, was also an electrical engineer. He studied the electrical discharge in low-pressure gas tubes, a field also pursued by German physicist Julius Plücker and his colleague, glassblower Heinrich Geissler (1814-1879). In the late 1890s Cooper began developing tubes with mercury, later inventing the mercury vapor lamp. Interestingly, it was with the help of capital from Tesla's investor, George Westinghouse, that the Cooper Hewitt Vapor Lamp Company was formed in 1902 to manufacture and sell these lamps [14]. Thus, Edward became familiar with the operation of Geissler's tubes through his brother's research, and during a conversation with Tesla, they decided to try to take several photographs using

[4] It will be shown below that this information, taking into account known and verified facts, is not and cannot be accurate.

ra Georga Westinghousa, godine 1902. formirana tvrtka Cooper Hewitt Vapor Lamp Company za proizvodnju i prodaju tih sijalica [14]. Tako se Edward preko bratova istraživanja upoznao s djelovanjem Geisslerovih cijevi i tijekom razgovora s Teslom odlučili su pokušati izraditi nekoliko fotografija koristeći te cijevi kao izvor svjetlosti. Vjerojatno znajući da je Mark Twain prethodne godine već pozirao za fotografije (slika 8), Edward je s Teslom dogovorio njegov dolazak u laboratorij za novu fotografsku seansu. Budući da je svjetlo iz Geisslerove cijevi bilo slabog intenziteta, Twain je morao za dulju ekspoziciju (15 minuta), sjediti mirno, koristeći pritom naslon za glavu. Kako bi ga za to vrijeme zabavila, Edwardova žena mu je čitala. Nekoliko dana kasnije Hewitt je nazvao Teslu da provjeri kako je ispao „Twainov" portret, a ovaj mu je rekao da pokus nije uspio jer su staklene fotografske ploče na neki način bile upropaštene. Edward je popustio i prestao se baviti tom fotografijom sve do nekoliko mjeseci kasnije, kada je saznao za [Röntgenovo] otkriće X-zraka. Čim je pročitao tu vijest odjurio je u Teslin laboratorij i zamolio ga da mu pokaže fotografsku ploču koju su koristili prije nekoliko mjeseci za izradu Twainova portreta. Hewitt je taj događaj opisao kasnije u svojoj knjizi ([9], str. 221–222; [7], str. 101):

Tesla je donio ploču iz tamne sobe i podržavajući je okrenuo prema svjetlu. Na njoj sam ugledao snimak okruglih leća objektiva, s vijkom za podešavanje objektiva kamere sa strane, kao i okrugle točkice koje su

these tubes as a light source. Probably knowing that Mark Twain had already posed for photographs the previous year (Figure 8), Edward arranged to meet Tesla at the laboratory for another photographic session. Since the light from Geissler's tube was of low intensity, Twain had to sit still for a longer exposure (15 minutes), using a headrest. To keep him entertained during this time, Edward's wife read to him. A few days later, Hewitt called Tesla to check on how the „Twain" portrait turned out, and he told him that the experiment had failed because the glass photographic plates had somehow been ruined. Edward relented and stopped working on the photograph until a few months later, when he learned of [Roentgen's] discovery of X-rays. As soon as he read the news, he rushed to Tesla's laboratory and asked him to show him the photographic plate that had been used to make the Twain portrait a few months earlier. Hewitt described the incident later in his book ([9], pp. 221–222; [7], p. 101):

Tesla brought the plate from the darkroom and, holding it up, turned it toward the light. On it I saw an imprint of the round lenses of the objective elements, with the camera's focus-adjustment screw on the side, as well as the round dots representing the metal screws in the wood on the front of the wooden camera. Tesla cast only one glance at the image. After that, he slammed the glass plate on the floor, shattering it into a thousand pieces, and exclaimed: „Damned fool! I never noticed that." ([15], p 199)

Tesla and Hewitt overlooked the fact that Geissler's tube generated not only visible light but also invisible radiation – X-rays, which „ruined" the photographic plate before the objective cap was even removed

predstavljale metalne vijke u drvu na prednjoj strani drvene kamere. Tesla je bacio na snimak samo jedan pogled. Nakon toga je tresnuo staklenu ploču o pod, pri čemu se razbila i razletjela na tisuću komadića, te uzviknuo: „Prokleti glupan! Nikada to nisam uočio". ([15], str. 199)

Tesla i Hewitt previdjeli su činjenicu da Geisslerova cijev nije generirala samo vidljivu svjetlost nego i nevidljivu radijaciju – X-zrake, koje su „upropastile" fotografsku ploču prije nego je kapa objektiva uopće skinuta s leća, odnosno već prije početka ekspozicije. Mark Twain je tako uzalud sjedio nepomično 15 minuta, a Tesla je propustio razotkriti još jedno kapitalno i značajno znanstveno otkriće. Na već spomenutom predavanju, 13-14 mjeseci nakon toga (travanj 1897.), koje je održao u njujorškoj Akademiji znanosti, Tesla se sam na taj račun požalio, tj. priznao da je previdio odnosno prekasno shvatio utjecaj X-zraka na fotografske ploče. U nastavku gornjeg citata (prva neiskorištena prilika!) je tako izjavio: *Momentalno* (odmah nakon što je saznao za Roentgenovo otkriće, *nap. a.*) *je istina sinula kroz moje misli. Pojurio sam ponoviti njegove eksperimente, o kojima nisu postojali potpuni izvještaji, i onda sam i sam ugledao čudo. Tada – prekasno – shvatio sam da mi je moj vodički duh, ponovo suflirao i da ja nisam uspio razumjeti njegove misteriozne znakove.* ([12], str. 32; [9], str. 222)

Međutim, izgleda da Tesla u tom predavanju, ipak nije bio posve iskren. Očito je, naime, da je (po prilici svjesno) prešutio da je prije početka ekspozicije skinuo kapu objektiva s leća. Mark Twain je tako uzalud sjedio nepomično 15 minuta, a Tesla je propustio razotkriti još jedno kapitalno i značajno znanstveno otkriće. Na već spomenutom predavanju, 13-14 mjeseci nakon toga (travanj 1897.), koje je održao u njujorškoj Akademiji znanosti, Tesla se sam na taj račun požalio, tj. priznao da je previdio odnosno prekasno shvatio utjecaj X-zraka na fotografske ploče. U nastavku gornjeg citata (prva neiskorištena prilika!) je tako izjavio: *Momentalno* (odmah nakon što je saznao za Roentgenovo otkriće, *nap. a.*) *je istina sinula kroz moje misli. Pojurio sam ponoviti njegove eksperimente, o kojima nisu postojali potpuni izvještaji, i onda sam i sam ugledao čudo. Tada – prekasno – shvatio sam da mi je moj vodički duh, ponovo suflirao i da ja nisam uspio razumjeti njegove misteriozne znakove.* ([12], str. 32; [9], str. 222)

Međutim, izgleda da Tesla u tom predavanju, ipak nije bio posve iskren. Očito je, naime, da je (po prilici svjesno) prešutio

from the lens, that is, before the exposure began. Mark Twain thus sat motionless for 15 minutes to no avail, and Tesla failed to reveal yet another major and significant scientific discovery. At the aforementioned lecture, 13-14 months later (April 1897), which he gave at the New York Academy of Sciences, Tesla himself complained about this, i.e., he admitted that he had overlooked or realized too late the effect of impact of X-rays on photographic plates. In the continuation of the above quote (the first missed opportunity!), he stated: *Immediately* (as soon as he learned of Roentgen's discovery, *note a.*) *the truth flashed through my mind. I rushed to repeat his experiments, for which there were no complete reports, and then I saw the miracle for myself. Then – too late – I realized that my guiding spirit had prompted me again and that I had failed to understand its mysterious signs*. ([12], p. 32; [9], p. 222)

However, it seems that Tesla in that lecture was not entirely honest. It is obvious, in fact, that he (probably consciously) omitted the described event and experience with Edward Hewitt (the second opportunity!), which took place in the new laboratory (46 Houston Street, in September or October 1895), that is, after the fire at the 5th Avenue laboratory (the first opportunity) and before the announcement of Röntgen's discovery (December 1895).

TESLA AND X-RAYS AFTER RÖNTGEN'S DISCOVERY

After the fire, in which all of Tesla's previous work – in the form of various working models and apparatus, all documents, per-

tio opisani događaj i iskustvo s Edwardom Hewittom (druga prilika!), do kojega je došlo u novom laboratoriju (ul. Houston br. 46, oko rujna/listopada 1895.), dakle nakon požara laboratorija na 5. Aveniji (prva prilika) i prije objave Röntgenova otkrića (prosinac 1895).

TESLA I X-ZRAKE NAKON RÖNTGENOVA OTKRIĆA

Nakon požara, u kojem je sav Teslin dotadašnji rad – u obliku raznovrsnih radnih modela i aparata, svih dokumenata, osobnih bilješki i slično, pretvoren u pepeo, on nije bio više u mogućnosti nastaviti s istraživanjima. Taj je požar bila jedna od najvećih Teslinih osobnih tragedija u životu, zbog čega je – fizički već ionako iscrpljen radom, mahom krahirao i psihički. Međutim, poslije početnog šoka i depresije, samo nekoliko dana nakon požara Tesla je počeo tražiti lokaciju za novi laboratorij. Zanimljiva je, ironična i možda licemjerna činjenica, što je Thomas Alva Edison, ondašnji Teslin glavni konkurent u takozvanom „ratu struja (AC/DC)", bio prvi koji je Tesli ponudio privremenu uporabu svoga laboratorija. Tesla je, unatoč svemu, ponudu prihvatio i nekoliko sljedećih tjedana koristio Edisonov laboratorij u Llewellyn Parku (New Jersey), do kojeg su inače imali pristup samo Edison i njegovi asistenti [16].

Uz pomoć prijatelja i poslovnih partnera koji su mu pomogli i financijski, ponajprije Edward Dean Adams, nakon četiri mjeseca, u srpnju 1895., Tesla je aktivirao svoj novi laboratorij na adresi East Hosonal notes and the like – was reduced to ashes, he was no longer able to continue his research. This fire was one of the greatest personal tragedies of Tesla's life. That caused him – already physically exhausted from his work, to mostly mentally collapse. However, after the initial shock and depression, just a few days after the fire, Tesla began looking for a location for a new laboratory. It is an interesting, ironic, and perhaps hypocritical fact that Thomas Alva Edison, Tesla's main competitor at the time in the so-called „War of the Currents (AC/DC)," was the first to offer Tesla the temporary use of his laboratory. Despite everything, Tesla accepted the offer and used Edison's laboratory in Llewellyn Park, New Jersey, for the next few weeks, a place which was otherwise accessible only to Edison and his assistants [16].

With the help of his friends and business partners who also helped him financially, primarily Edward Dean Adams, after four months, in July 1895, Tesla activated his new laboratory at 46 East Houston Street. It took him at least a year to completely renovate the laboratory and the necessary equipment ([10], p. 123; [9], p. 218; [17], p. 90).

In the period following the fire Tesla was unable to devote himself to research for a number of reasons. However, it is clear that the aforementioned attempt to photograph Mark Twain in front of a Geissler tube took place in the new laboratory. As mentioned, Edward Hewitt wrote in his memoirs that this experiment was carried out only a few months before Röntgen's discovery (December 1895), probably in September/October 1895 – that is, two to three months after the new laboratory was activated! If this

uston Street br. 46. Do potpune obnove laboratorija i potrebne opreme, trebalo mu je bar godinu dana ([10], str. 123; [9], str. 218; [17], str. 90).

U periodu nakon požara, Tesla se zbog niza razloga nije mogao posvetiti istraživanjima. Jasno je međutim da se je spomenuti pokušaj fotografiranja Marka Twaina ispred Geisslerove cijevi dogodio upravo u novom laboratoriju. Kao što je rečeno, Edward Hewitt je u knjizi svojih uspomena napisao da su taj pokus izvršili samo nekoliko mjeseci prije Röntgenova otkrića (prosinac 1895.), vjerojatno u rujnu/listopadu 1895. odnosno dva do tri mjeseca nakon aktiviranja novoga laboratorija! Da se to dogodilo u laboratoriju na 5. Aveniji, Tesla ne bi ni mogao Hewittu pokazati „upropaštenu" fotografsku ploču jer bi ona bila uništena u požaru, a i Hewittova izjava se ne bi vremenski podudarala s realnim događajima koje je opisao u svojoj knjizi. Iz tih se razloga opisana druga neiskorištena prilika nije mogla dogoditi nekoliko mjeseci nakon prve (krajem 1894.) ([9], str. 221), jer bi to značilo da je bila izvedena još u laboratoriju na 5. Aveniji i devet mjeseci prije objave otkrića X-zraka! Poznajući Teslin genijalni um i snagu intuicije, zaista je teško vjerovati da prilikom opisanih neiskorištenih prilika nije uočio efekte X-zraka i posljedično, mogućnost njihove primjene (u medicini) jer su mu obično bili dovoljni i mnogo manji ili lošiji „tragovi" ili „simptomi". S druge strane, imajući na umu opisani tadašnji spektar i repertoar istraživanja na kojima je radio, tome se ne bi trebalo čuditi.

had happened in the 5th Avenue laboratory, Tesla would not have even been able to show Hewitt the „ spoiled" photographic plate, as it would have been destroyed in the fire, and Hewitt's statement would not have been temporally consistent with the actual events he described in his book. For these reasons, the described second unused opportunity could not have occurred a few months after the first one (in late 1894) ([9], p. 221), because that would mean that it had still been performed in the laboratory on 5th Avenue and nine months before the discovery of X-rays was announced! Knowing Tesla's brilliant mind and intuitive power, it is truly difficult to believe that during the described missed opportunities he did not notice the effects of X-rays and, consequently, the possibility of their application (in medicine), as much smaller or worse „traces" or „symptoms" were usually enough for him. On the other hand, considering the spectrum and repertoire of research he was working on at the time, this should not be surprising.

After the announcement of the discovery of X-rays, Tesla showed far more enthusiasm and optimism about their application than Röntgen himself. Disappointed that he wasn't the first to publicly discover X-rays, he seemed to want to make up for lost time. A few weeks later, he told *The New York Times* that he had begun his experiments half an hour after Röntgen's discovery was announced in America. When he learned of Hertz's experiments with EM waves (1886), Tesla immediately repeated them with his own equipment, which was much better than Hertz's. In doing so, he saw the nature of EM waves holistically, much more

Međutim, nakon objave otkrića X-zraka, Tesla je u vezi njihove primjene pokazao mnogo više entuzijazma i optimizma nego sam Röntgen. Loše raspoložen što nije prvi javno otkrio X-zrake, činilo se da želi nadoknaditi izgubljeno vrijeme. Nekoliko tjedana kasnije izjavio je za časopis *The New York Times* da je počeo sa svojim pokusima pola sata nakon objave Röntgenova otkrića u Americi. Kada je saznao za Hertzove pokuse s EM valovima (1886.), Tesla ih je odmah ponovio sa svojom opremom, mnogo boljom od Hertzove (pri tome je prirodu EM valova vidio cjelovito, mnogo šire od Hertza, koji je u njima vidio ponajprije matematičku interpretaciju Maxwellovih jednadžbi). Sada je slično tome ponovio i Röntgenove pokuse, s mnogo naprednijom opremom. Za napajanje svojih vakuumskih cijevi umjesto jednostavnih Ruhmkorffovih kalema ili elektrostatičkih generatora, Tesla je koristio napajanje svoga novoga kompaktnog oscilirajućeg zračnog transformatora. Koristeći prednosti mnogo višeg napona (4 MV) i frekvencije, Tesla je mogao stvarati mnogo jače X-zrake od svih tadašnjih suvremenika ([9], str. 223; [8], str. 168). U ožujku 1896. izjavio je: *Prilikom slikanja dijelova ljudskog tijela* (glave, *nap. a.*) *sa X-zrakama stvaram sjene na razdaljini od 12 m. Ponavljam, 12 m i čak više.* ([18], str. 147)

Tesla se usredotočio na izradu najboljih mogućih snimki, a svoju snimku izrađenu s pomoću X-zraka nazvao je „sjenograf“, o egzistencijalnom filozofu Sørenu Kierkegaardu, koji ga je opisao u svom eseju *Either/Or*. Za isti je članak izjavio da je

broadly than Hertz, who primarily saw in them a mathematical interpretation of Maxwell's equations. Now he similarly repeated Röntgen's experiments, with much more advanced equipment. To power his vacuum tubes, instead of simple Ruhmkorff coils or electrostatic generators, Tesla used the power supply of his new compact oscillating air transformer.

Using the advantages of a much higher voltage (4 MV) and frequency, Tesla was able to produce much stronger X-rays than all of his contemporaries ([9], p. 223; [8], p. 168). In March 1896, he stated: *When photographing parts of the human body* (head*, note a.*) *with X-rays, I produce shadows at a distance of 12 m. I repeat, 12 m and even more.* ([18], p. 147)

Tesla focused on making the best possible images, and he named it „Shadowgraph“ (Sjenograf), after the existential philosopher Søren Kierkegaard, who described it in his essay *Either/Or*. He stated in the same article that he exposed his X-rays to photosensitive paper from a distance of as much as 18 m from the source of the rays. He also tested different metals to see which of them best reflected the rays (energy). The magnificent X-ray of Tesla's chest and shoulders in the article made a striking (and frightening) impression (Figure 10).

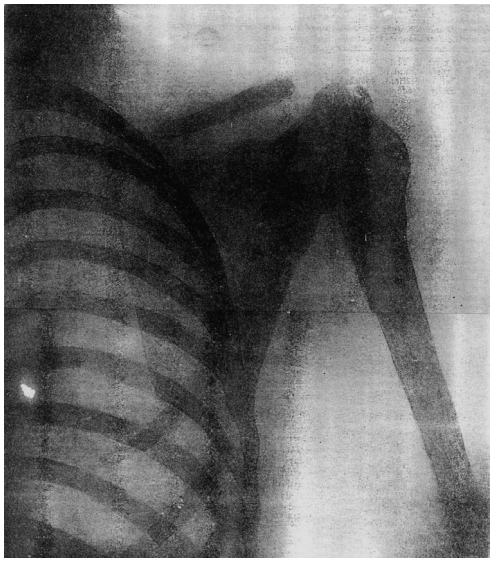
After the announcement of Röntgen's discovery, numerous scientists rushed to verify the newly discovered type of rays. It is interesting how, following Tesla, researchers like Thomas A. Edison and Mihajlo Pupin approached their investigations – their methods were a reflection of their different personalities. Edison immediately saw the financial

svojim X-zrakama djelovao na fotoosjetljivi papir s udaljenosti čak 18 m od izvora zrâka. Testirao je i različite metale da bi vidio koji od njih najbolje odbija (reflektira) zrake (energiju). Raskošna rendgenska snimka Teslina prsnog koša i ramena u članku, odavala je upečatljivo (zastrašujući) dojam (slika 10).

Nakon objave Röntgenova otkrića brojni su znanstvenici požurili provjeriti novo otkrivenu vrstu zrâka. Zanimljivo je na koji način su uz Teslu svojim istraživanjima pristupili npr. Thomas A. Edison i Mihajlo Pupin – njihov je pristup bio odraz njihovih različitih osobnosti. Edison je odmah vidio financijske mogućnosti, pa je svoga bivšega partnera pozivao na hitno istraživanje X-zraka kako bi našli njihovu primjenu i to patentirali.

Pupin je, pak, zabilježio u svoj dnevnik da su američki fizičari obratili premalo pozornosti na pražnjenje vakuumskih cijevi, osim njega samoga. Tvrdio je da je u SAD-u dobio prve rendgenske zrake 2. siječnja 1896., samo dva tjedna nakon objave njihova otkrića u Njemačkoj ([4], str. 306). Uzgred rečeno, pojavilo se još tucet onih koji su tvrdili da su otkrili X-zrake prije Röntgena. Tesla nije nikada tvrdio ništa slično, iako je bilo posve jasno da je pretekao Pupina i sve ostale ([7], str. 100–101; [8], str. 167). Ne samo da se Pupin pravio neuk, jer je bez sumnje znao za pionirsku ljubav svoga zemljaka Tesle prema vakuumskim cijevima, kao i za seriju njegovih predavanja 1891., 1892. i 1893., nego za njega Tesla očito nije ni postojao. To dokazuje i Pupinova autobiografska knjiga

possibilities, so he called his former partner to urgently research X-rays in order to find their application and patent them.



Slika 10. **Jedna od prvih Teslinih snimki s X-zrakama („sjenograf“) – snimka vlastitoga prsnoga koša i ramena, kroz odijelo;** snimljeno s udaljenosti od 1,2 m, uz izloženost zrakama 40 minuta; na vrhu ramena vidljivo je dugme košulje [18]

Figure 10. ***One of Tesla's first X-ray radiograph („shadowgraph“) – a shot of his own chest and shoulders, through the suit;*** *taken from a distance of 1,2 m, with a 40-minute exposure; at the top of the shoulder, the button of the shirt is visible [18]*

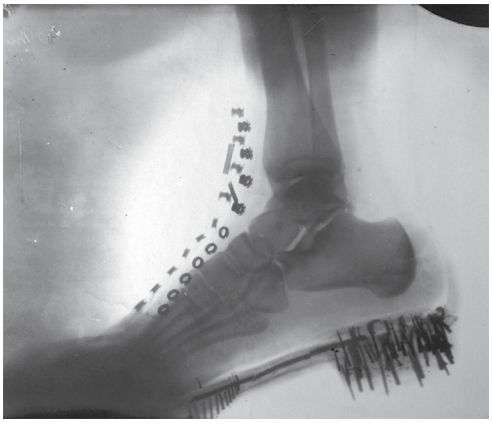
Pupin, on the other hand, noted in his diary that American physicists paid too little attention to the discharge of vacuum tubes, except for himself. He claimed that he produced the first X-rays in the U.S. on January 2, 1896, just two weeks after the announcement of their discovery in Germany ([4], p. 306). Incidentally, a dozen others appeared

od 387 stranica u kojoj svoga zemljaka, odnosno njegov indukcijski motor, nakratko spominje samo jednom ([4], str. 285). Tesla je kao iskusni fizikalni eksperimentator izradio brojne rendgenske snimke – vlastite glave, prsnog koša i udova (stopala, šake, slike 11, 12), ali i svojih radnika te životinja poput zečeva i ptica.

Budući da je snimanje objekata trajalo po čitav sat, Tesla je ponekad i zaspao tijekom bombardiranja X-zraka iz njegove sprave (slika 13). Njegova inače briljantna intuicija u ovom ga je slučaju iznevjerila – odbio je vjerovati da postoji ikakva opasnost od toga zračenja. Bio je čak uvjeren da je otkrio (novi) način stimulacije mozga, pa je glavu često izlagao zračenju.

Posljedično, slijedile su izjave: *Obris lubanje lako se dobiva prilikom izlaganja od 20-40 minuta...* Tesla je primijetio i čudne efekte: ... *potrebu za spavanjem, osjećaj da brzo protječe vrijeme, opći smirujući efekt i osjećaj topline u gornjem dijelu glave*. Na temelju tih efekata bio je više nego uvjeren da zračenje čine materijalni elementi koji prodiru kroz kosti. Bio je prvi koji je navijestio da će se X-zrake koristiti u terapeutske svrhe – možda da „unesu kemikalije u ljudsko tijelo". Zapravo je začuđujuće što Tesla nije imao veće posljedice svojih čestih, pa i dugotrajnih izlaganja X-zrakama. Manje sreće imao je njegov bivši poslodavac i rival T. A. Edison, koji je X-zrakama oštetio oči (primijetivši da izazivaju neke nadražaje kod slijepih, vjerovao je da stimulacija očiju X-zrakama može na neki način povratiti vid), dok je

who claimed to have discovered X-rays before Röntgen. Tesla never claimed anything like that, although it was quite clear that he was ahead of Pupin and everyone else ([7], pp. 100–101; [8], p. 167). Not only did Pupin pretend to be ignorant, because he no doubt



Slika 11. **Teslina rendgenska snimka donjeg dijela vlastite noge i stopala s visokom cipelom;** Tesla je snimku izradio 1896. s vakuumskom cijevi na udaljenosti od 2,4 m od noge; na snimci se vide i metalne zakovice za žnirance; Muzej Nikole Tesle, Beograd

Figure 11. ***Tesla's X-ray of the lower part of his own leg and foot with a high shoe;*** *Tesla made the shadowgraph in 1896 with a vacuum tube at a distance of 2,4 m from the leg; the photo also shows metal rivets for shoelace Nikola Tesla Museum, Belgrade; document no. MNT, VI/II, 122*

knew about his countryman Tesla's pioneering love for vacuum tubes, as well as about his series of lectures in 1891, 1892 and 1893, but for him Tesla apparently did not even exist. This is also proven by Pupin's 387-page autobiographical book, in which he briefly mentions his countryman, that is, his induction motor, only once ([4], p. 285). As an experi-

jedan od njegovih pomoćnika dobio rak kože koji se postepeno proširio pa je kasnije i umro.

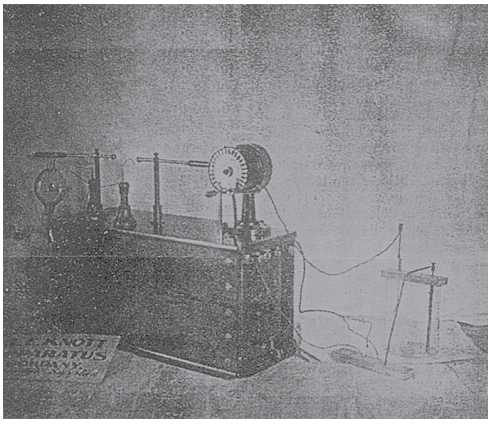


Slika 12. **Rendgenska snimka Tesline šake, izrađena 1896.;** Muzej Nikole Tesle https://tinyurl.com/5n7aus4h (Pristupljeno 30. 3. 2024.)

Figure 12. ***Shadowgraph of Tesla's hand, made in 1896;*** *Nikola Tesla Museum* https://tinyurl.com/5n7aus4h (Accessed 3/30/2024)

Tesla je pažljivo opisivao učinke X-zraka na vlastite oči, ruke i mozak, praveći razliku između opekotina i onoga što je smatrao unutrašnjim efektima. Primijetio je npr. bol u centru glave, ali je isprva razlog za sve simptome pripisao stvaranju ozona u zraku. Na proljeće 1897. tajanstveno se razbolio, nekoliko tjedana. Izjavio je da je imao iznenadne i bolenced physical experimenter, Tesla made numerous X-rays – of his own head, chest and limbs (feet, hands, Figures 11, 12), but also of his workers and animals such as rabbits and birds.

Since the exposure of the objects took a full hour, Tesla would sometimes fall asleep during the bombardment of X-rays from his device (Figure 13). His otherwise brilliant intuition failed him in this case – he refused to believe that there was any danger from this radiation. He was even convinced that he had discovered a (new) way to stimulate the brain, so he often exposed his head to the radiation.



Slika 13. **Novi Teslin kalem za rad s X-zrakama** – fotografija iz časopisa *Electrical review*, 22. 7. 1896.

Figure 13. ***Tesla's new coil for working with X-rays*** *– photo from the journal* Electrical review*, 07/22/1896*

Consequently, the statements followed: *The outline of the skull is easily revealed after 20–40 minutes of exposure...* Tesla also noticed strange effects: *...a need for sleep, a feeling*

ne očne šokove od rendgenske aparature, a i ruke su mu bile stalno izložene. Znao je i za druge simptome: *U težim slučajevima koža postaje tamnija, crni na pojedinim mjestima, i pojavljuju se ružni, bolni plikovi; otpadaju debeli slojevi kože, stvaraju se otvorene rane... Jaka bol, groznica i slični simptomi prirodni su pratioci ovih pojava. Imao sam nesreću da prisustvujem jednoj jedinoj povredi ove vrste koju je u predjelu želudca dobio dragi i vrijedni pomoćnik – jedinoj nesreći koja se desila za sve vrijeme moga laboratorijskog eksperimentiranja nekom drugom a ne meni.*

To se dogodilo nakon petominutnog izlaganja visoko naelektriziranoj cijevi, na udaljenosti 28 cm. Tesla je s gorčinom zabilježio nesreću kako bi smanjio opasnost za druge. Srećom, česte tople kupke, aplikacije vazelina, čišćenje i opća dobra njega tijela ubrzo su pomogle asistentu i popravile štetu razornih zraka. Tesla je odahnuo. No, osim oštećenja kože, primijetio je da je takvo zračenje uzrokovalo i osjećaj topline u tijelu, što je inspiriralo njegov stalni rad na terapeutici. Istraživanja su ga međutim brzo uvjerila da su pritom potrebne mjere sigurnosti.

Na predavanju u njujorškoj Akademiji znanosti, koje je održao 6. 4. 1897., na temu praktične izrade i sigurne uporabe rendgenske opreme, Tesla je izvijestio i o opasnostima od zračenja. Preporučio je korištenje uzemljenog aluminijskog štita – oklopa oko cijevi s X-zrakama, održavanje određene veće udaljenosti od cijevi i ograničeno vrijeme izlaganja zračenju. U tom je smislu već eksperimen-

that time was passing quickly, a general calming effect, and a sensation of warmth in the upper part of the head. Based on these effects, he was more than convinced that the radiation consisted of material elements that penetrated bone. He was the first to predict that X-rays would be used for therapeutic purposes – perhaps to „introduce chemicals into the human body." It is actually astonishing that Tesla did not suffer greater consequences from his frequent, and even prolonged, exposures to X-rays. His former employer and rival T. A. Edison was less fortunate. He damaged his eyes with X-rays (noticing that they caused some irritation in the blind, he believed that stimulating the eyes with X-rays could somehow restore vision), while one of his assistants developed skin cancer that gradually spread and later died.

Tesla carefully described the effects of X-rays on his own eyes, hands, and brain, distinguishing between burns and what he considered internal effects. He noticed, for example, pain in the center of his head, but initially attributed the cause of all the symptoms to the formation of ozone in the air. In the spring of 1897, he mysteriously fell ill for several weeks. He stated that he had sudden and painful eye shocks from the X-ray apparatus, and his hands were also constantly exposed. He was also aware of other symptoms: *In severe cases, the skin becomes darker, blackening in spots, and ugly, painful blisters appear; thick layers of skin fall off, open sores form... Severe pain, fever, and similar symptoms are natural companions to these phenomena. I had the misfortune of witnessing the only injury of this kind that occurred in the stomach region to a dear and valuable assistant – the only accident*

tirao s različitim metalnim zaštitama, a ubrzo potom su olovni štitnici ušli u opću uporabu. Sva Teslina istraživanja bila su evidentno temeljna i jako dobro dokumentirana. Vezano uz tu temu Tesla je u roku od dvije godine nakon Röntgenove objave otkrića X-zraka, napisao najmanje deset opširnih članaka[5] koji su objavljivani u časopisu *Electrical review*. Točnije, u manje od devet mjeseci, samo u razdoblju od 11. 3. 1896. do 1. 12. 1896., objavio ih je osam. U njima je opisao svoj rad te prikazao svoje spomenute rendgenske snimke. Sadržaj tih članaka objavljivan je (u manjem ili većem dijelu) i u brojnim drugim tiskovinama (*The New York Herald*, *The New York Tribune*, *The New York Times*, *The New York Sun* i drugima) ([8], str. 169–170; [7], str. 103–105; [9], str. 222–224). Valja ponoviti da je općenito samo 1896. napisano više od tisuću članaka na temu rendgenskih zraka!

[5] **Članci Nikole Tesle u časopisu *Electrical Review*, New York (19, A27-A75):** *On Roentgen rays (1) – Tesla's startling results in radiography at great distances through considerable thicknesses of substance*, 11. 3. 1896., (A)27–31; *On Roentgen rays (2) – Latest results*, 18. 3. 1896., (A)32–33; *On reflected Roentgen rays*, 1. 4. 1896., (A)34–38*; On Roentgen radiations*, 8. 4.1896., (A)39–42; *Roentgen ray investigations, 22. 4. 1896.,* (A)43–48; *An interesting feature of X-ray radiations*, 8.7.1896., (A)49–50; *Roentgen rays or streams*, 12.8.1896, (A)51–55; *On the Roentgen streams*, 1. 12. 1896., (A)56–61; *On the hurtful actions of the Lenard and Roentgen tubes,* 5. 5. 1897., (A)62–68; *On the source of Roentgen rays and the practical construction and safe operation of Lenard tubes*, 11. 8. 1897., (A)69–75.

that happened to anyone other than myself during all my laboratory experiments.

This happened after a five-minute exposure to a highly electrified tube, at a distance of 28 cm. Tesla bitterly recorded the accident to reduce the danger for others. Fortunately, frequent warm baths, applications of Vaseline, cleaning, and general good body care soon helped the assistant and repaired the damage from the destructive rays. Tesla was relieved. However, in addition to the skin damage, he noticed that such radiation also caused a sensation of warmth in the body, which inspired his ongoing work on therapeutics. Research, however, soon convinced him that safety measures were necessary.

In a lecture at the New York Academy of Sciences on April 6, 1897, on the practical construction and safe use of X-ray equipment, Tesla also reported on the dangers of the radiation. He recommended using an earthed aluminum shield – an armor around the X-ray tube – maintaining a certain greater distance from the tube, and limiting the time of exposure to the radiation. In this regard, he had already experimented with various metal shields, and soon afterward, lead shields came into general use. All of Tesla's research was evidently fundamental and very well documented. On this topic, within two years of Röntgen's publication of the discovery of X-rays, Tesla wrote at least ten extensive articles[5]

[5] **Nikola Tesla's articles in the Electrical Review, New York (19, A27-A75):** *On Roentgen rays (1) – Tesla's startling results in radiography at great distances through considerable thicknesses of substance*, 11. 3. 1896., (A)27–31; *On Roentgen rays (2) – Latest results*, 18. 3. 1896., (A)32–33; *On reflected Roentgen rays*, 1. 4. 1896., (A)34–38*; On*

Nakon toga Teslin interes za X-zrake ubrzo prestaje. Unatoč najkvalitetnijim izvorima snage za napajanje cijevi koje je posjedovao i na kojima je inzistirao, nije ponudio komercijalno izvedivu cijev za generiranje X-zraka. S druge strane, pojavile su se proizvodne tvrtke poput General Electrica koje su imale iskustvo u proizvodnji žarulja i manjih znanstvenih instrumenata, a imale su distribucijsku mrežu kojom su opskrbljivale znanstvenike i liječnike. Osim toga, Tesla je uvidio da mu X-zrake ne mogu biti od koristi pri bežičnom prijenosu energije na daljinu, o čemu je razmišljao prije požara u laboratoriju, pa je svu pozornost ponovno posvetio tom pitanju ([9], str. 224).

ZAŠTO NEKI VJERUJU DA TESLA ZASLUŽUJE NOBELOVU NAGRADU ZA OTKRIĆE X-ZRAKA?

Dugogodišnjim praćenjem informacija i zbivanja vezanih uz Teslin život i rad, autor ovoga članka zaključio je da se u (velikom) dijelu javnosti steklo mišljenje prema kojemu bi zapravo bilo poštenije da je Nobelova nagrada za otkriće X-zraka dodijeljena Tesli, a ne Röntgenu. Istini za volju, takvo je mišljenje i sâm dijelio niz godina (do 2015.) te ga promovirao u raznim prilikama. Uzrok tome može se pripisati dvama argumentima, koji su takvu mišljenju pridonijeli.

Prvi argument, za kojega se vjeruje da opravdava takvo mišljenje, Teslini pobornici nalaze u izjavi koju je Tesla dao

that were published in the journal *Electrical Review*. More precisely, in less than nine months, between March 11, 1896, and December 1, 1896, he published eight of them. In them, he described his work and presented his aforementioned X-ray images. The content of these articles was also published (in whole or in part) in numerous other publications (*The New York Herald*, *The New York Tribune*, *The New York Times*, *The New York Sun*, and others) ([8], pp. 169–170; [7], pp. 103–105; [9], pp. 222–224). It should be reiterated that, in general, only in 1896 were more than a thousand articles written on the subject of X-rays!

After that, Tesla's interest in X-rays soon waned. Despite having and insisting on the highest-quality power sources to supply the tubes, he did not offer a commercially viable tube for generating X-rays. On the other hand, manufacturing companies like General Electric emerged, which had experience producing light bulbs and smaller scientific instruments and had a distribution network to supply scientists and doctors. Furthermore, Tesla realized that X-rays could not be useful for wireless transmission of energy over long distances, which he considered before the laboratory fire, and he refocused his attention back to this issue ([9], p. 224).

Roentgen radiations, 8. 4.1896., (A)39–42; *Roentgen ray investigations, 22. 4. 1896.*, (A)43–48; *An interesting feature of X-ray radiations*, 8.7.1896., (A)49–50; *Roentgen rays or streams*, 12.8.1896, (A)51–55; *On the Roentgen streams*, 1. 12. 1896., (A)56–61; *On the hurtful actions of the Lenard and Roentgen tubes*, 5. 5. 1897., (A)62–68; *On the source of Roentgen rays and the practical construction and safe operation of Lenard tubes*, 11. 8. 1897., (A)69–75.

na svom predavanju pred njujorškom Akademijom znanosti u travnju 1897. Nakon što je predstavio (opisanu) prvu neiskorištenu priliku za otkriće X-zraka, u kojoj on i Dickenson Alley, fotograf tvrtke Tonnele & Company, nisu shvatili da su X-zrake uzrokovale primijećene mrlje na fotografskim pločama. Tesla prema zapisu u časopisu *Electrical Review* izjavljuje: *Upravo kada sam počeo proučavati prirodu tog fenomena moj laboratorij je izgorio. Prije negoli je moj rad u potpunosti nastavljen u novom laboratoriju objavljeno je Roentgenovo otkriće.* ([12], str. 175)

Još podrobnije tu izjavu, iz predavanja u travnju 1897., navodi L. Anderson ([12], str. 32; [9], str. 222; [2], str. 212–213). Teslina nepotpuna izjava u časopisima mnogima nesporno predstavlja povod i argument za spekulacije o tome što bi bilo, ako bi bilo..., tj. da bi Tesla bez sumnje otkrio X-zrake prije Röntgena da zbog požara nije ostao bez svojeg laboratorija. Navedena kompletna Teslina izjava na predavanju (travanj 1897.) mnogo je manje poznata, ali čak ni ona nije dovoljna za brojne zanesenjake. Međutim, očito se ipak previđaju ili prešućuju već spomenute činjenice koje je u tim predavanjima i sam Tesla naveo. Iz opisanoga proizlazi da su se predmetni pokusi i zapažanja dogodili ujesen 1894., u laboratoriju na 5. Aveniji, što znači da je nakon toga do objave Röntgenova otkrića prošlo više od godinu dana! Nakon požara u ožujku 1895. i uspostave novoga laboratorija u ulici Houston, u srpnju iste godine, Tesla je uz Edwarda Hewitta, slika-

WHY DO SOME BELIEVE TESLA DESERVES THE NOBEL PRIZE FOR THE DISCOVERY OF X-RAYS?

After years of following information and events related to Tesla's life and work, the author of this article concluded that a (large) part of the public has formed the opinion that it would actually be fairer if the Nobel Prize for the discovery of X-rays had been awarded to Tesla, not Röntgen. To be honest, the author himself held this opinion for many years (until 2015) and promoted it on various occasions. The reason for this can be attributed to two arguments that contributed to such an opinion.

The first argument, which is believed to justify such an opinion, Tesla's proponents find in the statement Tesla made in his lecture before the New York Academy of Sciences in April 1897. After presenting the first unutilized opportunity for the discovery of X-rays, in which he and Dickenson Alley, a photographer for Tonnele & Company, did not realize that the X-rays had caused the observed spots on the photographic plates. Tesla states, according to a record in the *Electrical Review* journal: *„ Just as I had begun to study the nature of this phenomenon, my laboratory burned down. Before my work could be fully resumed in a new laboratory, Roentgen's discovery was announced."* ([12], p. 175)

This statement, from a lecture in April 1897, in even more detail provides L. Anderson ([12], p. 32; [9], p. 222; [2], pp. 212–213). Tesla's incomplete statement in the magazines undoubtedly serves as the basis and argument for speculation about „what might have been if..." that Tesla would undoubtedly have discovered X-rays before

njem Marka Twaina novom opremom, dobio novu, od prve prilike posve nezavisnu, drugu priliku za otkriće, koju je nažalost također previdio. Taj događaj Tesla nije spomenuo u svom predavanju pred njujorškom Akademijom znanosti! Uvažavajući sve navedeno i vremenski okvir događaja, cjelokupna slika i utisak su drugačiji. Takav dojam ostavlja i jedan od najboljih Teslinih američkih biografa, koji imajući na umu opisanu prvu priliku navodi: *Iako je nekoliko godina prije toga* (Röntgenova otkrića, *nap. a.*) *vjerojatno i sam primijetio te zrake* (X) *i njihovo djelovanje na fotografskom papiru, Tesla s tim istraživanjima nije nastavio i zato nije ostavljao nikakvu dvojbu u vezi toga da je Wilhelm Roentgen otkrio ono, što je sam volio nazvati „sjenografi" (shadowgraphs).* ([8], str. 168)

Drugi, uobičajen i najčešći argument Teslinih pristalica u kontekstu nedodijeljene Nobelove nagrade Röntgenovo je pismo, u kojemu njemački znanstvenik zahvaljuje Tesli za poslane mu snimke (navodno) izrađene s pomoću X-zraka. Sadržaj toga pisma autor (ovoga članka, *op. ur.*) dobro poznaje, jer je za nj saznao iz jedne od prvih Teslinih biografija koje je pročitao. U njoj je Teslin osobni prijatelj i biograf John J. O'Neill zapisao: *Kada je Tesla proučavao razne modele tih i svojih drugih plinskih žarulja, primijetio je da se količina emitirane vidljive svjetlosti mijenja u odnosu na različite okolnosti pri djelovanju. Znao je da žarulje emitiraju vidljive i nevidljive zrake. Koristio je razne fosforescentne i fluorescentne materije za otkrivanje ultraljubičastih ili ta-*

Röntgen, if he not lost his laboratory due to a fire. Tesla's complete statement from the lecture (April 1897) is much less well-known, but even that is not enough for many enthusiasts. However, the aforementioned facts, which Tesla himself cited in those lectures, are apparently still overlooked or omitted. From the above, it follows that the experiments and observations in question took place in the fall of 1894, in the laboratory on 5th Avenue, which means that more than a year passed between then and the announcement of Röntgen's discovery! After the fire in March 1895 and the establishment of a new laboratory on Houston Street in July of that same year, Tesla, along with Edward Hewitt, by photographing Mark Twain with the new equipment, was given a new, from the first occasion completely independent, second opportunity for the discovery, which he unfortunately also overlooked. Tesla did not mention this event in his lecture before the New York Academy of Sciences! Considering all of the above and the timeline of events, the overall picture and impression are different. This is the impression left by one of Tesla's best American biographers, who, keeping the described first occasion in mind, states: *Although a few years before that* (Röntgen's discoveries, *note a.*) *he probably himself noticed these rays (X) and their effect on photographic paper, Tesla did not continue with these investigations and therefore left no doubt that Wilhelm Roentgen had discovered what he himself liked to call „shadowgraphs".* ([8], p. 168)

The second, most common argument of Tesla's proponents in the context of the unawarded Nobel Prize is Röntgen's letter, in

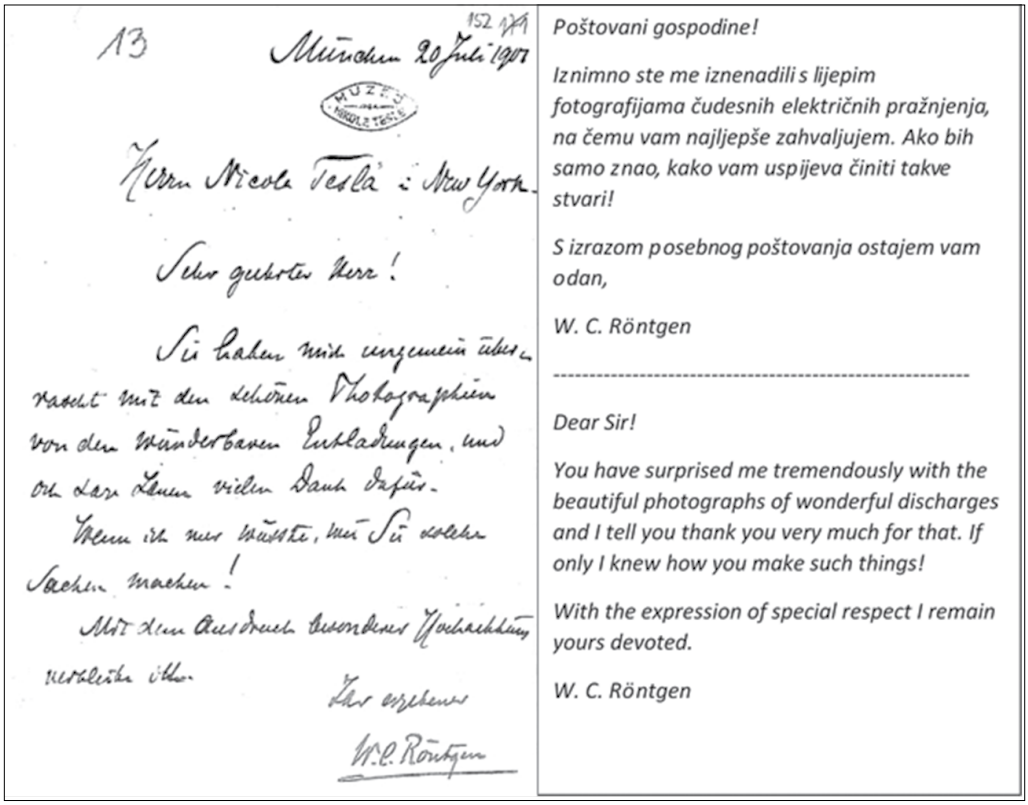
mnih zraka. ... Kod svoje žarulje za molekularno bombardiranje je, kako je navodio [već] u svojim predavanjima 1892. godine, otkrio „vidljivu svjetlost, tamnu svjetlost i neke posebne zrake". Pri eksperimentiranju tim zrakama u svom laboratoriju, prije negoli ga je u ožujku 1895. god. uništila vatra, dobio je sjenovite slike („sjenografe") na fotografskim pločama, koje su bile zatvorene u metalnim kutijama. Te „posebne zrake" tada nije opisivao dalje u raspravama koje je objavio. Međutim, kada je prof. Wilhelm Konrad Roentgen u Njemačkoj, u prosincu 1895., objavio otkriće zraka X, Tesla je mogao odmah dobiti jednake uspjehe pomoću svojih „posebnih zraka". Iz toga je zaključio, da imaju njegove posebne zrake i zrake X vrlo slična svojstva, iako nastaju različito. Kada je pročitao Roentgenovu obavijest, odmah je poslao njemačkom učenjaku nekoliko sjenovitih slika, koje je dobio pomoću svojih „posebnih zraka". Roentgen mu je odgovorio (slika 14): *Slike su vrlo zanimljive. Ako biste bili samo tako ljubazni i razotkrili mi način na koji ste ih dobili?* ([10], str. 154)

Kada je O'Neill pisao o tome da Tesline X-zrake nastaju različito od onih koje je koristio Röntgen, mislio je na razliku u opremi i načinu na koji je ona generirala zračenje te vrste. Iz prije opisanoga proizlazi da je Röntgen generirao X-zrake uporabom jednostavnoga Ruhmkorffovoga kalema i cijevi ispunjene plinom, u kojoj dolazi do katodnih zraka (mlaz elektrona) koje izbijaju iz nje. Tesla je pak svojim mnogo boljim VN i VF izvorima X-zrake stvarao temeljem vrlo jakoga

which the German scientist thanks Tesla for the images he sent him, which were allegedly made with the help of X-rays. The author (of this article, *note ed.*) knows the contents of this letter well, because he learned about it from one of the first Tesla biographies he read. In it, Tesla's personal friend and biographer John J. O'Neill wrote: *When Tesla studied various models of these and his other gas lamps, he noticed that the amount of visible light emitted changed under different operating conditions. He knew that the lamps emitted both visible and invisible rays. He used various phosphorescent and fluorescent materials to detect ultraviolet or dark rays. ... With his molecular bombardment lamp, as he [already] stated in his lectures in 1892, he discovered „visible light, dark light, and some special rays." While experimenting with these rays in his laboratory, before it was destroyed by fire in March 1895, he obtained shadow images („shadowgraphs") on photographic plates that were enclosed in metal boxes. He did not further describe these „special rays" in the papers he published. However, when Prof. Wilhelm Konrad Roentgen in Germany announced the discovery of X-rays in December 1895, Tesla was able to immediately achieve the same results using his „special rays." From this, he concluded that his special rays and X-rays had very similar properties, although they were produced differently. When he read Roentgen's announcement, he immediately sent the German scientist several shadow images that he had obtained using his „special rays". Roentgen replied to him* (Figure 14)*: The pictures are very interesting. If you would be so kind as to reveal to me the way in which you obtained them?* ([10], p. 154)

električnoga polja u kvalitetno evakuiranoj cijevi, koje su u tom slučaju bile najefikasnije.

When O'Neill wrote that Tesla's X-rays are produced differently from those used by Röntgen, he was referring to the difference



13 München 20 Juli 1901

Herrn Nicola Tesla in New York.

Sehr geehrter Herr!

Sie haben mich entzückt über-
rascht mit den schönen Photographien
von den wunderbaren Entladungen, und
ich kann Ihnen vielen Dank dafür.
Wenn ich nur wüsste, wie Sie solche
Sachen machen!
Mit dem Ausdruck besonderer Hochachtung
verbleibe ich
Ihr ergebener
W. C. Röntgen

Poštovani gospodine!

Iznimno ste me iznenadili s lijepim fotografijama čudesnih električnih pražnjenja, na čemu vam najljepše zahvaljujem. Ako bih samo znao, kako vam uspijeva činiti takve stvari!

S izrazom posebnog poštovanja ostajem vam odan,

W. C. Röntgen

Dear Sir!

You have surprised me tremendously with the beautiful photographs of wonderful discharges and I tell you thank you very much for that. If only I knew how you make such things!

With the expression of special respect I remain yours devoted.

W. C. Röntgen

Slika 14. **Pismo koje je Wilhelm C. Röntgen napisao Tesli 20. 7. 1901.!** https://tinyurl.com/ymxnfbsh (Prijevod i obrada autor)

Figure 14. ***Wilhelm C. Röntgen's letter to Tesla wrote on 7/20/1901!*** https://tinyurl.com/ymxnfbsh *(Translated and edited by the author)*

Nema sumnje da sadržaj Röntgenova pisma, predstavljenoga na taj način, stvara utisak o tome da ni on sam nije znao kako je mogao netko s otkrićem, za koje je on primio Nobelovu nagradu, izraditi tako zanimljive i mnogo bolje snimke.

in equipment and the way in which it generated radiation of this type. From the above description it follows that Röntgen generated X-rays using a simple Ruhmkorff's coil and a gas-filled tube, in which cathode rays (a stream of electrons) were emitted from it. Tesla, on the other hand, with his much better

Takvo uvjerenje, navođenjem toga pisma dodatno utvrđuju i pojedine druge Tesline svjetski poznate američke biografije, u kojima autori takoreći prepisuju navod prvoga Teslina biografa J. O'Neilla te ga povezuju s opisanom prvom prilikom za otkriće X-zraka. Unatoč tome, nitko navedeno nije smatrao kao dokaz da je Tesla pionir toga otkrića ([7], str. 101; [17], str. 88). Obmanuti O'Neillovom pričom, na to su se pismo i na našim prostorima oslonili brojni istraživači Teslina života i rada, među njima i odlični biografi ([20], str. 98–99; [21], str. 169–170), ugledni hrvatski akademici, npr. ([22], str. 249) i drugi.

U ispravnost razumijevanja toga pisma autor (ovoga članka, *op. ur.*) je počeo sumnjati kada je prvi put vidio kopiju izvornoga pisma (Muzej Nikole Tesle, Beograd). Njegova se sumnja temeljila na ova dva razloga: prvi se pojavio kada je O'Neillov zapis usporedio s cjelovitim prijevodom Röntgenova pisma. Usporedba je pokazala da je prijevod prve rečenice, nakon pozdrava, površan i nepotpun, iako pismo sadrži samo dvije bitne rečenice. Röntgen se naime u prvoj rečenici divi lijepim fotografijama „čudesnih električnih pražnjenja", vidljivih na fotografijama, o kojima u O'Neillovu prijevodu nema ni traga!

Drugi je razlog nadnevak pisma, tj. 20. 7. 1901. Oba razloga izazivaju snažnu sumnju u vjerodostojnost O'Neillove priče o pismu jer je u njima odmah uočio veliku proturječnost. Naime, Röntgen je svoje otkriće X-zraka javno obznanio sredinom prosinca 1895., dok je Nobelovu nagradu za to postignuće primio 10. 12. 1901. (to se dogodilo na 1. svečano-

HV and HF sources, generated X-rays based on a very strong electric field in a well-evacuated tube, which was the most efficient in that case. There is no doubt that the content of Röntgen's letter, presented in that way, creates the impression that even he himself did not know how someone with a discovery, for which he received the Nobel Prize, could produce such interesting and much better images.

Such a belief is further confirmed by citing that letter in certain other world-famous American biographies of Tesla, in which the authors, as it were, copy the statement of Tesla's first biographer, J. O'Neill, and connect it with the described first opportunity for the discovery of X-rays. Despite this, no one considered the above as proof that Tesla was the pioneer of this discovery ([7], p. 101; [17], p. 88). Deceived by O'Neill's story, numerous researchers of Tesla's life and work in our region also relied on that letter, among them excellent biographers ([20], pp. 98–99; [21], pp. 169–170), prominent Croatian academics, e.g. ([22], p. 249) and others.

The author (of this article, *note ed.*) began to doubt the accuracy of his understanding of that letter when he first saw a copy of the original (Nikola Tesla Museum, Belgrade). His doubt was based on two reasons: the first arose when he compared O'Neill's record with the complete translation of Röntgen's letter. The comparison showed that the translation of the first sentence, after the greeting, was superficial and incomplete, although the letter contains only two essential sentences. Namely, in the first sentence, Röntgen admires the beautiful photographs

sti dodjela Nobelovih nagrada u povijesti uopće, pet godina nakon Nobelove smrti) [23]. Da mu je Tesla doista poslao svoje predmetne fotografije odmah nakon te objave (kako navodi O'Neill), opravdano se postavlja pitanje: „Zašto je Röntgen sa zahvalnim pismom čekao punih pet i pol godina?!" Isto tako se opravdano valja pitati: „Što je Röntgen imao na umu kada je pisao o „čudesnim električnim pražnjenjima"? Tko poznaje tehniku nastajanja X-zraka i svojstva snimki izrađenih s opisanom opremom, zna da se na njima ne vide nikakva električna pražnjenja. O njima bi se eventualno moglo govoriti ako bi se mislilo na katodne zrake u vakuumskoj cijevi, koje bi se opisalo kao pražnjenje putem mlaza elektrona. Međutim, taj fizikalni fenomen nije moguće vidjeti neposredno na rendgenskoj snimci koja pokazuje samo posljedice njegova djelovanja na ozračeni objekt. U pismu Röntgen zasigurno nije mislio na taj fenomen, koji mu je bio dobro poznat iz osobnoga iskustva.

Kao Teslin biograf, autor ovoga članka, lako je povezao poznate činjenice i vremenska događanja. Svaki prosječno dobar poznavatelj Teslina života i rada zna za Teslinu znanstveno istraživačku misiju u američkom Colorado Springsu (Denver), koju je provodio u razdoblju od 15. 5. 1899. do 7. 1. 1900. Prilikom tih istraživanja Tesla je određeno vrijeme [ponovno] posvetio i fotografskim pokusima (ovoga puta drukčije vrste) jer su mu vidljivi efekti njegovih ranijih pokusa bili vrlo korisni i zanimljivi. Bio je zapravo opsjednut vidljivim efektima električnih

of „wonderful electrical discharges", visible in the photographs, which are not even mentioned in O'Neill's translation!

The second reason is the date of the letter, namely July 20, 1901. Both reasons raise strong doubts about the credibility of O'Neill's story about the letter, because he immediately noticed a major contradiction in them. Namely, Röntgen publicly announced his discovery of X-rays in mid-December 1895, while he received the Nobel Prize for this achievement on December 10, 1901 (this happened at the first Nobel Prize ceremony in history, five years after Nobel's death) [23]. If Tesla had indeed sent him his photographs in question immediately after this announcement (as O'Neill states), the question is justified: „Why did Röntgen wait a full five and a half years to send a thank-you letter?!" It is also justified to ask: „What did Röntgen have in mind when he wrote about, wonderful electrical discharges'"? Anyone who is familiar with the technique of X-ray generation and the properties of the images made with the described equipment knows that no electrical discharges are visible in them. They could possibly be spoken of if one were thinking of cathode rays in a vacuum tube, which would be described as a discharge by a jet of electrons. However, this physical phenomenon cannot be seen directly on an X-ray, which only shows the effects of its action on the irradiated object. In his letter, Röntgen was certainly not referring to this phenomenon, which was well known to him from personal experience.

As Tesla's biographer, the author of this article easily connected the known facts and historical events. Any reasonably well-informed person familiar with Tesla's life and

munja (cijeli život je volio promatrati prirodne električne munje koje je obožavao) jer su snažna pražnjenja (umjetne električne munje) koje su do tada sijevale samo u njegovoj mašti, pred njegovim očima iznenada postale vidljiva realnost. Električni napon njegova tamošnjega uvećavajućega odašiljača (TMT) dostizao je do 12 milijuna volti (MV). Električna pražnjenja u obliku brojnih umjetnih munja koje su izbijale, kako između kalema u laboratoriju (slika 15) tako i s vrha visoke vanjske antene, nisu bila samo vrlo dugačka (nekoliko desetina metara) nego i posve fascinantna. Iako su Tesli predstavljale samo „sporedni učinak" u fazi razvoja TMT-a, već u Colorado Springsu je znao da će ih uporabiti kao sredstvo za prikupljanje investitora nakon povratka u New York, gdje je planirao izgraditi svoj prvi takav, samo još mnogo veći odašiljač za bežični prijenos električne energije na velike udaljenosti (projekt *Wardenclyffe* na Long Islandu).

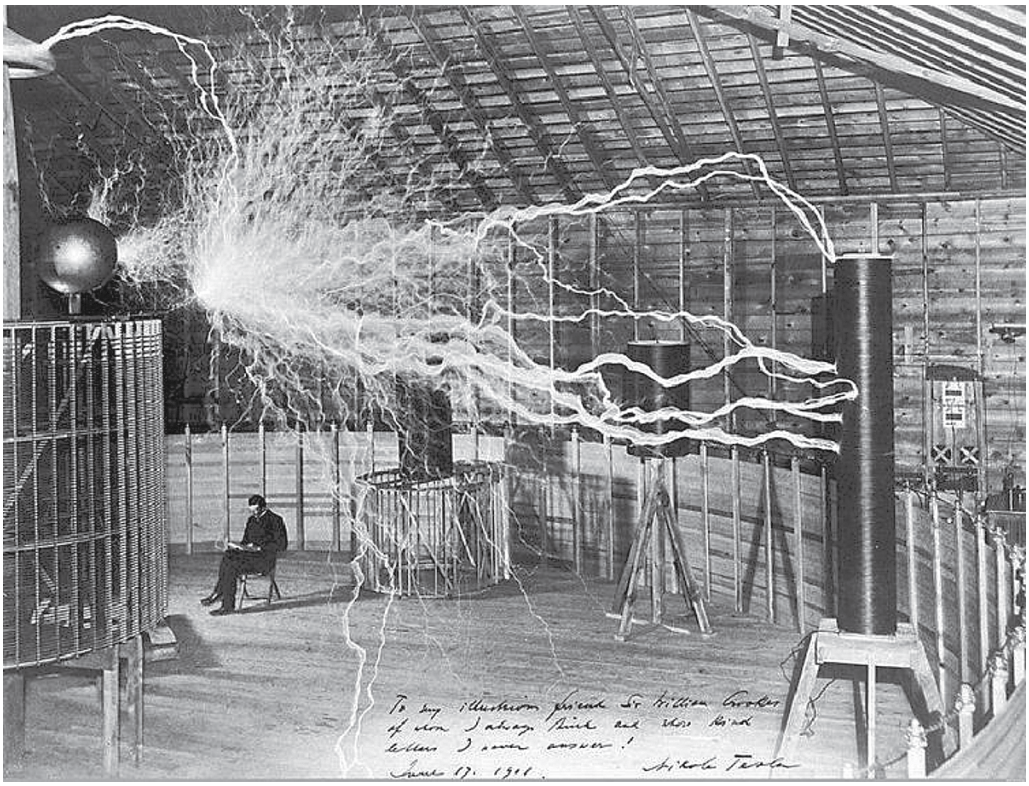
Tesla je bio svjestan da mu za izvedbu tako megalomanskoga projekta treba senzacija s dramatičnim efektima kojima je namjeravao privući pozornost potencijalnih investitora. Dio rješenja za postizanje toga cilja bile su spektakularne fotografije na kojima su vidljivi efekti tih pokusa. Zamišljene fotografije realizirao je uz pomoć već spomenutoga fotografa Dickensona Alleya iz New Yorka u kojeg je imao puno povjerenja. Kako bi postigli željene vizualne efekte uporabili su nekoliko trikova, ne samo dulju vremensku ekspoziciju (1-2 sata), nego i dvostruku ekspoziciju. Krajnji je rezultat bio bolji od onoga koje-

work knows about his scientific research mission in Colorado Springs (Denver), which he conducted from May 15, 1899, to January 7, 1900. During these experiments Tesla also [re]devoted some time to photographic experiments (this time of a different kind) because the visible effects of his earlier experiments were very useful and interesting to him. He was actually obsessed with the visible effects of electrical discharges (he loved to observe natural electric lightning all his life,) because the powerful discharges (artificial electrical lightning) that had until then only flashed in his imagination suddenly became a visible reality before his eyes. The electrical voltage of his local transmitting multiplier tube (TMT) reached up to 12 million volts (MV). The electrical discharges in the form of numerous artificial lightning flashes that erupted, both between coils in the laboratory (Figure 15) and from the top of a tall outdoor antenna, were not only very long (several tens of meters) but also completely fascinating. Although for Tesla they were merely a „side effect" in the development phase of the TMT, he already knew in Colorado Springs that he would use them as a means of attracting investors after returning to New York, where he planned to build his first such, only much larger transmitter for the wireless transmission of electrical power over long distances (the *Wardenclyffe* project on Long Island).

Tesla was aware that in order to carry out such a megalomaniacal project he needed a sensation with dramatic effects with which he intended to attract the attention of potential investors. Part of the solution to achieve this goal were spectacular photographs showing the effects of these experiments. He

mu su se obojica nadala. Svi koji su kasnije vidjeli te fotografije bili su zapanjeni, ali i ushićeni.

realized the imagined photographs with the help of the aforementioned photographer Dickenson Alley from New York, in whom



Slika 15. **Spektakularna fotografija Nikole Tesle među brojnim električnim pražnjenjima u obliku umjetnih munja u njegovu laboratoriju u Coloradu Springsu 1899.**; Tesla je fotografiju s posvetom (vidljiva na slici desno dolje) poslao Sir Williamu Crookesu, 17. 6. 1901., ali i W. C. Röntgenu koji se Tesli zahvalio povratnim pismom od 20. 7. 1901! https://tinyurl.com/mwje3bbn

Figure 15. ***Spectacular photograph of Nikola Tesla among numerous electrical discharges in the form of artificial lightning in his laboratory in Colorado Springs 1899****; Tesla sent a photo with a dedication (visible in the picture on the right below) to Sir William Crookes on 17/06/1901, but also to W. C. Röntgen who thanked Tesla with a return letter dated 20/07/1901*! https://tinyurl.com/mwje3bbn

Osim investitore, Tesla je s tim fotografijama želio impresionirati i određene kolege znanstvenike i prijatelje! Tako je 29. 10. 1899. neke od tih fantastičnih snima-

he had great confidence. In order to achieve the desired visual effects, they used several tricks, not only a longer exposure time (1-2 hours), but also a double exposure. The

ka, tada još pod velom tajnosti, poslao na razne američke adrese. Primatelji su bili John J. Astor, H. D. Havemeyer (tzv. kralj šećera), gđa. E. F. Winslow, arhitekt Standford White, Mary Mapes Dodge i obiteljski prijatelji, bračni par Johnson. Nešto kasnije, u lipnju 1901. Tesla šalje kopije tih fotografija i svojim europskim kolegama: Lord Kelvin, Sir William Crookes, Sir James De War, Philip Lenard, William Röntgen i Adolph Slaby.

Nakon što je fotografije primio npr. profesor Adolf (Karl Heinrich) Slaby („otac" radija u Njemačkoj), odgovorio je da je Tesla morao otkriti nešto unikatno jer nešto slično još nije vidio! S obzirom na pismo upućeno Tesli nakon mjesec dana, 20. 7. 1901., i Röntgena, kojega je Tesla jako cijenio, su te fotografije fascinirale na sličan način ([24];[8], str. 231). U svjetlu tih podataka, sadržaj i nadnevak Röntgenova pisma dokazuju da nemaju nikakve veze s Teslinim rendgenskim snimkama!

O tome je li O'Neill priču s predmetnim pismom greškom ili svjesno plasirao može se samo nagađati. Nema sumnje da se temeljem i te anegdote desetljećima neopravdano stvarao mit o famoznomu Röntgenovu pismu, koje javnost samo dodatno obmanjuje. Navedenim argumentima može se dodati još nekoliko, javnosti mnogo manje poznatih ali ilustrativnih informacija, koje potvrđuju opisane činjenice. Naime, već početkom ožujka 1896. (dva i pol mjeseca nakon objave Röntgenova otkrića!), u New Yorku je organiziran *Röntgenov simpozij* posvećen rendgenskim zrakama, pod okriljem časopisa

end-result was better than either of them had hoped for. Everyone who later saw these photographs was amazed, but also delighted.

In addition to investors, Tesla also wanted to impress certain fellow scientists and friends with these photographs! So, on October 29, 1899, he sent some of these fantastic shots, then still under a veil of secrecy, to various American addresses. The recipients were John J. Astor, H. D. Havemeyer (the so-called sugar king), Mrs. E. F. Winslow, architect Stanford White, Mary Mapes Dodge and family friends, the Johnson couple. Somewhat later, in June 1901, Tesla sent copies of these photographs to his European colleagues: Lord Kelvin, Sir William Crookes, Sir James De War, Philip Lenard, William Roentgen and Adolph Slaby.

After receiving the photographs, for example, Professor Adolf (Karl Heinrich) Slaby (the „father" of radio in Germany), replied that Tesla must have discovered something unique because he had never seen anything like it before! Considering the letter sent to Tesla a month later, on July 20, 1901, even Röntgen, whom Tesla greatly respected, was similarly fascinated by these photographs ([24];[8], p. 231). In light of this information, the content and date of Röntgen's letter prove that they have nothing to do with Tesla's X-rays!

Whether O'Neill published the story with the letter in question by mistake or consciously can only be speculated. There is no doubt that this anecdote has been used for decades to unjustifiably create a myth about the famous Röntgen's letter, which only further misleads the public. To the above arguments, one can add several other, much less well-known but illustrative pieces of infor-

Century Magazin čiji je urednik bio Teslin dobar osobni prijatelj Robert U. Johnson. On i Teslin drugi osobni prijatelj i poslovni partner Thomas Commerford Martin (1856. – 1924.) bili su glavni organizatori simpozija, a pomagao im je i sam Tesla. Röntgen se odazvao pozivu, iako je nakon objave svoga otkrića, praktički preko noći postao izuzetno slavan diljem svijeta i pozivan sa svih strana. Stigavši u Ameriku, sudjelovao je na simpoziju, a u gradu je ostao nekoliko tjedana. U tom su se razdoblju Röntgen i Tesla upoznali, sprijateljili i družili, ponajviše na večerama kod Teslinih prijatelja, bračnoga para Johnson. Tesli se njemački kolega bez sumnje jako svidio jer nije mario za novonastalu slavu, nego je svoje vrijeme kao i Tesla radije provodio u laboratoriju.

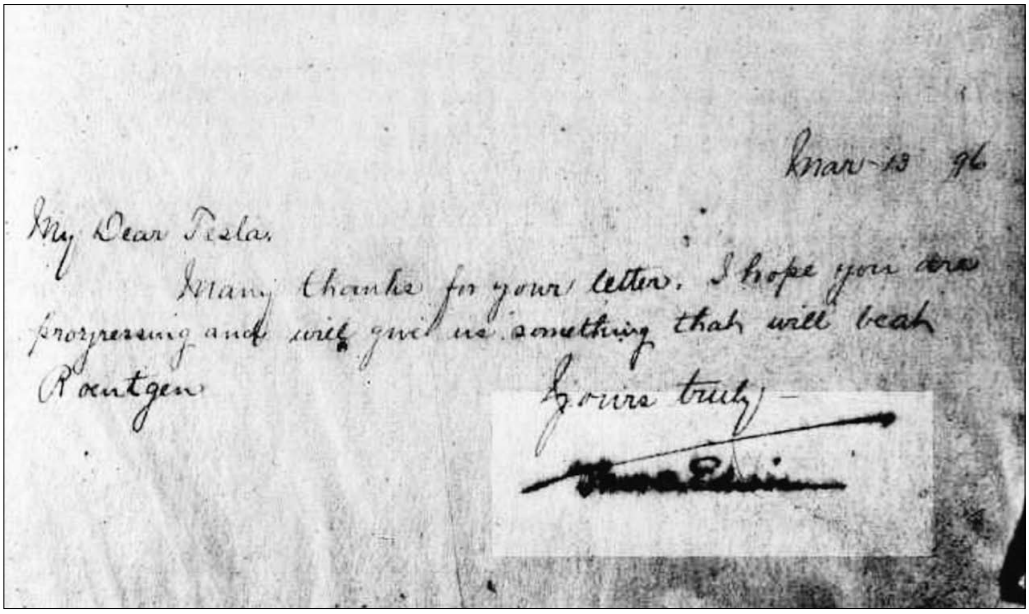
Međutim, prije njegova dolaska u SAD, u javnosti su se rasplamsali verbalni sukobi između Tesle, T. A. Edisona, Elihuja Thomsona i M. Pupina, a upravo u vrijeme početka simpozija nesuglasice su dostigle vrhunac. U povodu otvaranja simpozija, dana 13. 3. 1896., organizirana je svečana večera za sve sudionike. Budući da su na večeri bili i Teslini spomenuti neformalni protivnici, odbio je poziv. Svom prijatelju Johnsonu napisao je kratku poruku: *Ne mogu vam to objasniti, ali zaista mi nije moguće da vam se pridružim.* ([26], str. 402–403; [8], str. 178)

S obzirom na navedene nesuglasice i činjenicu koja autoru jako upada u oko, tj. da je večera održana točno na prvu obljetnicu Tesline osobne tragedije – požamation that confirm the facts described. Namely, as early March 1896 (two and a half months after the publication of Röntgen's discovery!), a *Röntgen symposium* dedicated to X-rays was organized in New York, under the auspices of the *Century Magazine*, whose editor was Tesla's good personal friend Robert U. Johnson. He and Tesla's other personal friend and business partner Thomas Commerford Martin (1856-1924) were the main organizers of the symposium, and Tesla himself helped. Röntgen accepted the invitation, although after the publication of his discovery, he became extremely famous throughout the world and was invited all over the world. Arriving in America, he participated in the symposium, and stayed in the city for several weeks. During this period, Röntgen and Tesla met, became friends, and socialized, mostly at dinners at the homes of Tesla's friends, the Johnson couple. Tesla undoubtedly liked his German colleague very much because he did not care about his newfound fame, but, like Tesla, preferred to spend his time in the laboratory.

However, before his arrival in the USA, verbal conflicts flared up in public between Tesla, T. A. Edison, Elihu Thomson, and M. Pupin, and it was precisely at the beginning of the symposium that the disagreements reached their peak. On the occasion of the opening of the symposium, on March 13, 1896, a gala dinner was organized for all participants. Since Tesla's aforementioned informal opponents were also at the dinner, he declined the invitation. He wrote a short message to his friend Johnson: *I cannot explain it to you, but it is really impossible for me to join you.* ([26], pp. 402–403; [8], p. 178)

ra laboratorija na 5. Aveniji i na Teslino odbijanje poziva na večeru, došlo je do zanimljiva događaja, poprilično ironičnoga, iako su se Tesla i Edison, neovisno o novinskim člancima, navodno dopisivali vezano uz rendgenske zrake. Thomas A. Edison je upravo te večeri Tesli napisao pismo (slika 16) u vezi s Röntgenom: *Dragi moj Tesla, puno hvala na vašem pismu. Nadam se da napredujete i da ćete nam dati nešto što će nadmašiti Röntgena.* [26]

Considering the above disagreements and the fact that the author is very aware of that the dinner was held exactly on the first anniversary of Tesla's personal tragedy, the fire at his laboratory on 5th Avenue, and Tesla's refusal of the invitation to dinner was understandable. An additional, event occurred quite ironic, although Tesla and Edison were, independently of the newspaper articles, supposedly corresponding regarding X-rays. Thomas A. Edison wrote Tesla a letter (Figure 16) re-



Slika 16. **Povratno pismo T. A. Edisona N. Tesli u vezi W. C. Röntgena** [26]
Figure 16. ***T. A. Edison's return letter to N. Tesla regarding W. C. Röntgen*** *[26]*

Bez obzira na propuštenu svečanu večeru i prvu priliku za upoznavanje, Tesla je, nesumnjivo, Röntgena ubrzo upoznao i susretao kod Johnsonovih. To dokazuje npr. jedno od njegovih pisama Robertu

garding Röntgen that very evening: *My dear Tesla, many thanks for your letter. I hope you are making progress and will give us something that will surpass Röntgen.* [26]

U. Johnsonu (za kojeg je koristio nadimak Luka Filipov) dvije sedmice kasnije (28. 3. 1896.): *Dragi Luka, slučajno sam slobodan večeras. Ako imate posjetitelje (obične smrtnike) neću doći. Ako imate Padarewskog, Röntgena ili gospođu Anthony, doći ću. S poštovanjem, TGI.* (Skraćenica TGI znači *Tesla Great Inventor* – Tesla veliki izumitelj) [27].

Iz navedenoga je evidentno da su se Tesla i Röntgen osobno upoznali i družili u New Yorku već u ožujku 1896.! Mogli su razgovarati o svemu vezano uz X-zrake odnosno tada već rendgenske zrake, i da je želio Tesla mu je mogao osobno uručiti svoje bilo kakve „posebne" snimke, izrađene „svojim" zrakama, zbog čega nije postojao nikakav razlog za njihovo slanje i dopisivanje. Samo do večere 28. 3. 1896., kada su se vjerojatno sreli, Röntgen je mogao vidjeti nekoliko Teslinih rendgenskih snimki već u nekoliko članaka objavljenih u časopisu *Electrical Review* i mnogim drugim njujorškim novinama.

Kao što je već rečeno, Tesla nije nikada osporavao Röntgenovo postignuće, niti je smatrao da ima prvenstvo u vezi toga. Nasuprot tome, prema njemačkom kolegi je gajio visoko poštovanje koje je iskazivao u brojnim javnim nastupima, kao npr. i na proslavi otvaranja prvih generatora hidrocentrale na vodopadima Niagare (13. 1. 1897.) (kada se poklonio i izumitelju vakuumske cijevi Phillipu Lenardu), a još veću čast mu je iskazao objavom rendgenske snimke, na kojoj je bakrenom žicom oblikovano Röntgenovo prezime u drvenoj kutiji (slika 17), već u

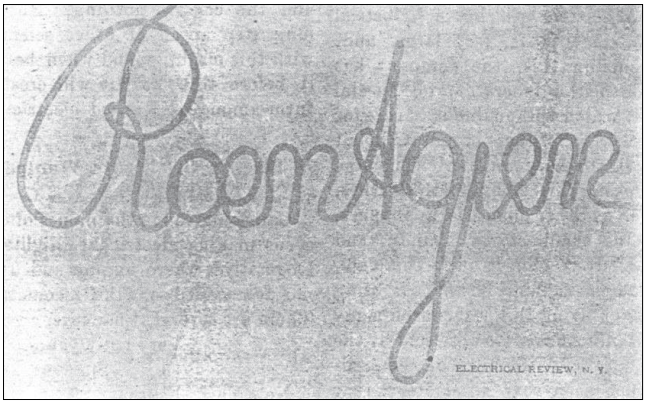
Regardless of the missed formal dinner and the first opportunity to meet, Tesla, undoubtedly, soon came upon Röntgen and met him at the Johnsons' house. This is proven, by one of his letters to Robert U. Johnson (for whom he used the nickname Luka Filipov) two weeks later (March 28, 1896): *Dear Luka, I happen to be free tonight. If you have visitors (mere mortals) I will not come. If you have Padarewski, Röntgen or Mrs. Anthony, I will come. Sincerely, TGI.* (The abbreviation TGI stands for *Tesla Great Inventor*) [27].

From the above, it is evident that Tesla and Röntgen met and socialized in New York as early as March 1896! They could have talked about everything related to X-rays and if Tesla had wanted to, he could have personally delivered to him any of his „special" images, made with „his" rays, which is why there was no reason to send them and correspond. Only by dinner on March 28, 1896, when they probably met, Röntgen could have seen several of Tesla's X-ray images in several articles published in the *Electrical Review* journal and many other local newspapers.

As already stated, Tesla never contested Röntgen's achievement, nor did he consider himself to have priority over it. In contrast, he had a high regard for his German colleague, which he showed in numerous public appearances, such as at the celebration of the opening of the first generators of the hydroelectric power plant at Niagara Falls (January 13, 1897), when he also paid tribute to the inventor of the vacuum tube, Phillip Lenard. He showed Röntgen an even greater honor by publishing an X-ray on which Röntgen's surname was shaped with a copper wire in a

prvom od svojih članaka o rendgenskim zrakama u reviji *Electrical Review*, 11. 3. 1896., str. 131.

wooden box (Figure 17) already in the first of his articles on X-rays in the journal *Electrical Review*, March 11, 1896, p. 131.



Slika 17. **Teslina snimka žičanoga potpisa posvećena Röntgenu;** izvor X-zraka udaljen 3,35 m od drvene kutije i ekspozicija 30 min; *Electrical Review*, 11. 3. 1896., p. 131

Figure 17. ***Tesla's photograph of a wire sign dedicated to Röntgen****; X-ray source 3,35 m away from the wooden cover, with one-half hour's exposure;* Electrical Review*, 3/11/1896, p.131*

ZAKLJUČAK

Zasluge za otkriće X-zraka odnosno onoga što danas zovemo rendgenskim zrakama, bilo bi teško, ako ne i nemoguće, pripisati samo jednom znanstveniku ili izumitelju. Naime, to otkriće ne bi bilo moguće da mu nije prethodio dugotrajan razvoj ne samo tehnologije potrebne za stvaranje tih zraka (elektrostatičke sprave, induktori, zračni transformator, cijevi za izbijanje, vakuumske/rendgenske cijevi, kondenzator), nego i parcijalni pokusi i otkrića (rezonancija, katodne zrake) kojima se prije toga u prošlosti bavio niz istraživača. Moglo bi se reći da je za fenomen i otkriće X-zraka bila potrebna čitava evolucija prije nego je W. C. Röntgen

CONCLUSIONS

It would be difficult, if not impossible, to attribute the credit for the discovery of X-rays, or what many now call „Röntgen rays", to just one scientist or inventor. Namely, this discovery would not have been possible if it had not been preceded by a long-term development of both the technology needed to create these rays (electrostatic devices, inductors, air transformer, discharge tubes, vacuum/X-ray tubes, condenser), and of partial experiments and discoveries (resonance, cathode rays) that had been previously studied by a number of researchers in the past. It could be said that the phenomenon and discovery of X-rays required an entire evolution before W. C. Röntgen conscious-

svjesno došao do njihova otkrića i ideje za moguću primjenu (npr. u medicini). Iako bi se to dogodilo slučajno ili spletom sretnih okolnosti, po nečemu se je ipak morao razlikovati od drugih fizičara. Uz znanje koje je posjedovao, posvetio je istraživanjima dovoljno pozornosti, vremena i energije; bio je jedan od rijetkih, ako ne i jedini, među eksperimentatorima svjesno fokusiranima na događanja sa zračenjem u prostoru izvan vakuumske cijevi! Pretpostavio je da će se izvan cijevi, kod dovoljno visokoga električnoga napona, uz katodne zrake detektirati i drugi fenomeni. U tom smislu svjesno je tražio „čimbenik koji može napustiti cijev" ([5], str. 295).

Tesla se, međutim, tom pitanju svjesno nije posvetio niti dovoljno, niti na taj način, iako je već prije Röntgena bio svjestan činjenice da njegove cijevi emitiraju i „neke posebne zrake" koje je detektirao. Štoviše, te posebne zrake propustio je otkriti prije Röntgena, u smislu njihovih potencijalnih utjecaja i mogućnosti uporabe, unatoč najmanje dvije dokumentirane prilike koje su mu se ponudile, što je i sam priznao. Prirodni ili fizikalni fenomen kojega znanstvenik nije svjesno otkrio i sadrži samo slučajno postizanje sporednih efekata, ne može se definirati kao znanstveno otkriće. Zato takvi događaji ne mogu opravdati, niti zaslužuju dodjelu visoke nagrade i/ili priznanja (u tom slučaju Nobela). U tom smislu Röntgenu je Nobelova nagrada dodijeljena potpuno zasluženo, što je svojim izjavama i činima nesumnjivo potvrdio i sam Tesla. Mnogi se s tim slažu, ali istovremeno tvrde da

ly came to their discovery and the idea for a possible application (e.g. in medicine). Even if this happened by chance or a combination of fortunate circumstances, he would still have to be different from other physicists in some way. In addition to the knowledge he possessed, he devoted sufficient attention, time and energy to research; he was one of the few, if not the only, experimenters consciously focused on radiation events in the space outside the vacuum tube! He assumed that outside the tube, at a sufficiently high electric voltage, other phenomena would be detected in addition to cathode rays. In this sense, he consciously searched for „a factor that could leave the tube" ([5], p. 295).

Tesla, however, did not devote himself to this issue either consciously or sufficiently, although he was already aware before Röntgen that his tubes also emitted „some special rays" that he had detected. Moreover, he failed to discover these special rays before Röntgen, in terms of their potential effects and possible uses, despite at least two documented opportunities that were offered to him, which he himself admitted. A natural or physical phenomenon that a scientist did not consciously discover and that contains only the accidental achievement of side effects, cannot be defined as a scientific discovery. Therefore, such events cannot justify or deserve a high award and/or recognition (in this case, the Nobel Prize). Therefore, the Nobel Prize was awarded to Röntgen quite deservedly, which Tesla himself undoubtedly confirmed with his statements and deeds. Many agree with this, but at the same time claim that the first photograph in the world using X-rays was never-

je Tesla nesvjesno snimio prvu fotografiju s pomoću X-zraka na svijetu. Prema saznanju autora ni ta informacija nije točna ([28], str. 658; [29], str. 182–186; [30], str. 635–639; [31], [32], [33], str. 5–15, [34], str. 30).

Detaljno je istraživanje pokazalo i to da bi mit o famoznomu Röntgenovu pismu zahvale Tesli i čuđenja za (navodno rendgenske) fotografije, trebalo u budućnosti prestati koristiti kao argument za svjesno ili nesvjesno obmanjivanje, kako javnosti tako i onih koji su manje ili lošije upoznati s povijesnim znanstvenim činjenicama te Teslinom biografijom i radom. U najboljem slučaju trebali bi ga promijeniti u mit o čuđenju pojavama i rezultatima Teslina fenomenalnoga eksperimentalnoga rada u Colorado Springsu.

S druge strane, već kroz sve navedeno, jasno je koliko je daleko sa svojim istraživanjima dopirao Tesla, kako su već tada bila napredna i koliko ispred svoga vremena. Uz to nema sumnje da je već prije objave otkrića X-zraka posjedovao unikatnu i daleko najbolju opremu za VN i VF istraživanja. Uz to, i njegov doprinos nakon otkrića X-zraka je ogroman. Ako se izdvoji samo najbitnije, usavršio je i osmislio nekoliko novih uređaja za stvaranje X-zraka i tvrdio da će oni: *...omogućiti ljudima da proizvode mnogo jače Röntgenove zrake od onih koji se dobivaju običnim spravama. Onda neće više postojati nikakve prepreke na putu širokoj i učinkovitoj primjeni tog divnog otkrića koje se mora na kraju dokazati od najviše vrijednosti, ne samo u rukama kirurga, nego i elektro-terapeuta, i što je najvažnije, bakteriologa.* ([35], str. 481)

theless taken by Tesla, albeit unconsciously. To the author's knowledge, this information is also incorrect ([28], p. 658; [29], pp. 182–186; [30], pp. 635–639; [31], [32], [33], pp. 5–15, [34], p. 30).

Detailed research also shows that the myth of Röntgen's famous letter of thanks to Tesla and amazement at (allegedly X-ray) photographs should stop being used in the future as an argument for knowingly or unknowingly deceiving both the public and those who are less familiar with historical scientific facts and Tesla's biography and work. At best, they should turn it into a myth of wonder at the phenomena and results of Tesla's phenomenal experimental work in Colorado Springs.

On the other hand, with all the above, it is clear how far Tesla reached with his research, how advanced and ahead of his time his research was even then. In addition, there is no doubt that even before the publication of the discovery of X-rays, he possessed unique and by far the best equipment for HV and HF research. In addition, his contribution after the discovery of X-rays is enormous. To mention only the most important, he perfected and designed several new devices for producing X-rays and claimed that they would: *...enable men to produce much stronger Röntgen rays than those obtained by ordinary devices. Then there would be no more obstacles to the wide and effective application of this wonderful discovery which must ultimately prove of the highest value, not only in the hands of surgeons, but also of electro-therapists, and, most importantly, of bacteriologists.* ([35], p. 481) Proof of this is the present-day application of X-rays in modern medicine,

Dokaz je tomu današnja primjena X-zraka u suvremenoj medicini, kemiji, fizici (astrofizici), biologiji i tehnologiji – čije je značenje nemjerljivo.

Uz to, Tesla je konstruirao svoju vlastitu, specijalnu vakuumsku cijev, s jednom (disk) elektrodom, za generiranje X-zraka; osmislio je način hlađenja rendgenskih cijevi; istraživao je kako različiti uvjeti (udaljenost i ekspozicija) utječu na kvalitetu rendgenskih snimki; prvi je proučavao refleksiju X-zraka na različitim materijalima, što je uvelike utjecalo na razvoj kristalografije; predložio je uporabu X-zraka za detekciju plućnih bolesti i stranih tijela; prvi je upozorio na opasnost pri radu s rendgenskim zrakama i predložio osnove njihove zaštite – potrebna udaljenost, vrijeme izlaganja i primjerna vrsta štita. Nekoliko godina prije kvantnih fizičara nadahnuto je uočio da te moćne zrake energije imaju svojstva čestica i valova. Te zrake mogu biti i *izvrstan top za ispaljivanje projektila tisuću puta probojnijih od granate, i to na ogromne daljine*. ([8], str. 169)

Može se, dakle, reći da je obiman pionirski rad najmanje što bi se moralo uvažiti u vezi X-zraka odnosno rendgenskih zraka i Nikole Tesle. Taj rad je toliko opsežan da mu nisu potrebna nikakva dodatna, nepotrebna i populistička uveličavanja, kao i dokazivanja zasluga za dodjelu Nobelove nagrade. Kod nje bi se bez sumnje razveselio samo visokoj novčanoj nagradi koju bi mogao iskoristiti za ulaganja u svoje projekte, jer je inače dobro poznato kakvo mišljenje je imao o toj nagradi. Kad je 1915. bio s T. A. Edisonom [na-

chemistry, physics (astrophysics), biology and technology – the significance of which is immeasurable.

In addition, Tesla constructed his own, special vacuum tube, with a single (disk) electrode for generating X-rays; he devised a method of cooling X-ray tubes; he investigated how different conditions (distance and exposure) affect the quality of X-ray images; he was the first to study the reflection of X-rays on different materials, which greatly influenced the development of crystallography; he proposed the use of X-rays for the detection of lung diseases and foreign bodies; he was the first to warn of the dangers of working with X-rays and proposed the basics of their protection – the required distance, exposure time and an appropriate type of shield. Several years before quantum physicists he inspiredly noticed that these powerful rays of energy have properties of particles and waves. These rays can also be an *excellent cannon for firing projectiles a thousand times more penetrating than a shell, and over enormous distances.* ([8], p. 169)

Therefore, it can be said that the extensive pioneering work of Nikola Tesla in relation to X-rays should at least be appreciated. His work is so comprehensive that it does not need any additional, populist glorification, nor the Nobel Prize, as proof of merit. Yet, had he been the one to receive it, he would no doubt be happy with a high monetary reward that he could use to invest in his projects. It is otherwise well known what opinion he had about that award. When he was [allegedly] unofficially nominated for the award in 1915 with T. A. Edison, congratulations immediately started pouring in.

vodno] neslužbeno nominiran za tu nagradu, počele su mu odmah pristizati čestitke. U odgovoru na pismo prijatelja Roberta U. Johnsona napisao je: ...*U toku više tisuća godina biće mnogo primalaca Nobelovih nagrada. Ali, ja nemam manje od četiri tuceta mojih djela koja su potpisana mojim imenom u oblasti tehničke literature. To su počasti stvorene i trajne koje ne dodjeljuje nekolicina koja je sklona da pogriješi, već cijeli svijet koji rijetko pravi greške, i za bilo koje od tih počasti ja bih dao sve Nobelove nagrade koje bi se dodijelile u toku sljedećih tisuću godina.* [36]

Stoga bi Tesla bio mnogo sretniji i ponosniji da je doživio da njegovim prezimenom Tesla (simbol „T“) bude nazvana mjerna jedinica za jakost magnetskoga polja Međunarodnoga sustava mjernih jedinica, skraćeno SI[U] (*Systeme International*). Nikola Tesla je jedini znanstvenik slavenskoga podrijetla u grupi svjetski poznatih znanstvenika po kojima standardne mjerne jedinice nose imena. To je najveća počast koja mu je mogla biti dodijeljena i mnogostruko nadmašuje bilo koju Nobelovu nagradu! O tome se premalo govori i premalo se ističe.

Nakon što je prijedlog za takvo imenovanje prihvatila Međunarodna elektrotehnička komisija (MEK) TC24, kao i Međunarodni Odbor za mjere i utege, put do konačne potvrde na 11. Generalnoj konferenciji za mjere i utege u Parizu, 18. 10. 1960., bio je vrlo dug i naporan. Najveće zasluge za taj poduhvat pripadaju dr. Francetu Avčinu, slovenskom profesoru s Fakulteta za elektrotehniku u Ljubljani, koji je svojim djelovanjem i uz po-

In response to a letter from his friend Robert U. Johnson, he wrote: ...*In the course of thousands of years, there will be many recipients of Nobel Prizes. But I have no less than four dozen of my works signed with my name in the field of technical literature. These are honors created and lasting, bestowed not by a few who are prone to error, but by the whole world and people who rarely make mistakes, and for any one of these honors I would give all the Nobel Prizes that would be awarded during the next thousand years.* [36]

Therefore, Tesla would have been much happier and prouder if he had lived to see the unit of measurement for the magnetic field strength of the International System of Units, SI[U] (*Systeme International*), named after his surname Tesla (symbol „T“). Nikola Tesla is the only scientist of Slavic origin in the group of world-famous scientists after whom standard measurement units are named. This is the greatest honor that could have been awarded to him and it by far surpasses any Nobel Prize! This is not talked about enough and or emphasized enough.

After the proposal for such a designation was accepted by the International Electrotechnical Commission (MEK) TC24, as well as the International Committee for Weights and Measures, the path to final confirmation at the 11th General Conference on Weights and Measures in Paris, on October 18, 1960, was very long and arduous. The greatest credit for this undertaking belongs to Dr. France Avčin, a Slovenian professor from the Faculty of Electrical Engineering in Ljubljana, who, through his actions and with the help of certain colleagues, managed to convince the necessary

moć određenih kolega za Teslin izbor uspio uvjeriti potrebnu većinu upravo na toj konferenciji, unatoč jakom protivljenju brojnih stranih fizičara. Zanimljiva sjećanja na ta događanja opisao je sam Avčin ([37], str. 213–229).

IZJAVA O SUKOBU INTERESA

Ovaj rad u istom obliku nije objavljen niti ponuđen za objavljivanje nekoj drugoj periodičnoj ili neperiodičnoj publikaciji. Autor izjavljuje da nije u sukobu interesa.

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majority at that very conference in favor of Tesla's selection, despite the strong opposition of numerous foreign physicists. Avčin himself described interesting memories of these events ([37], pp. 213–229).

STATEMENT OF CONFLICT OF INTEREST

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