Наслов оригинала: РАЗВОЈ И ПРИМЕНА РЕНДГЕНСКЕ ТЕХНОЛОГИЈЕ КОД СРБА – ОД ТЕСЛЕ И ПУПИНА ДО ДАНАС

DEVELOPMENT AND APPLICATION OF X-RAY TECHNOLOGY IN SERBS

- FROM TESLA AND PUPIN TO MODERN TIMES -

VISARIS

MUSEUM OF SCIENCE AND TECHNOLOGY

Belgrade, 2021

DEVELOPMENT AND APPLICATION OF X-RAY TECHNOLOGY IN SERBS

- FROM TESLA AND PUPIN TO MODERN TIMES -

Catalogue

CATALOGUE PUBLISHED BY
Museum of Science and Technology
Visaris d.o.o.

FOR THE PUBLISHERS
Rifat Kulenović
Marko Petrović

AUTHORS OF THE CATALOGUE
Jelena Jovanović Simić
Aleksandar Vl. Marković
Vladimir Petrović

EDITOR
Anja Radaković

REVIEWER
Prof. Dr Jovica Šaponjski

GRAPHIC DESIGN
Miloš Janković, BORN

TRANSLATION
Katarina Spasić, KAUKAI

PHOTOGRAPHS
Miloš Jurišić

PRINTING
Birograf Comp, Zemun

PRINT RUN
200 copies

Exhibition

EXHIBITION ORGANISED BY
Museum of Science and Technology
Visaris d.o.o.

AUTHORS OF THE EXHIBITION
Jelena Jovanović Simić
Aleksandar Vl. Marković

AUTHORS OF THE EXHIBITION LAYOUT
Ozarija Marković Lašić
Nebojša Vasiljević

MUSIC FOR THE EXHIBITION
Aleksandar Vl. Marković

DESIGN AND PRODUCTION OF DIGITAL CONTENTS
Nordeus
Crater Studio

VIRTUAL REALITY
Joakim Tasić in the role of Nikola Tesla
VR Photo Team

LIGHTING DESIGN
Zoran Popović

EXPERT ASSOCIATE AND ORGANISER
Anja Radaković

CONSERVATION AND RESTORATION
Zoran Lević
Dejan Vračarević

PHOTOGRAPHS
Miloš Jurišić

PUBLIC RELATIONS
Ivan Stanić
EARTH PR

TECHNICAL REALISATION
Dejan Krstevski

Support

Nordeus Hub

Crater Training Center

Organisation of this exhibition has been funded by the Ministry of Culture and Information of the Republic of Serbia.

For the help in research and preparation of the exhibition, the authors and organisers of the exhibition would like to thank Dušan Jovančević (Library of *Matica srpska*), Dr Dušica Bojić and Štefica Radmanović (Historical Museum of Serbia), Zorica Civrić and Daniela Pejović (Museum of Science and Technology), prof. Dr Ljiljana Radošević Jelić, retired professor at the Faculty of Medicine in Belgrade; Ivana Zorić and Milica Kesler (Nikola Tesla Museum), Dragana Mitrašinović (Historical Archives of Belgrade), Ratka Bjelanović and Jelena Nikčević (State Archives of Serbia), Nenad Karamijalković (Institute for Protection of Cultural Monuments Kragujevac) and Vuk Jovićević.

For loaned objects, documentary material and photographs, organisers of the exhibition would like to thank Goran Radojković (*EI akcionarsko društvo za proizvodnju rendgen aparata, uređaja i pribora EI Jugorendgen Niš*), Miloš Jurišić, Nikola Tesla Museum, Historical Museum of Serbia, State Archives of Serbia and Company Medicom Ltd.


V
100
150
200
250
3
4

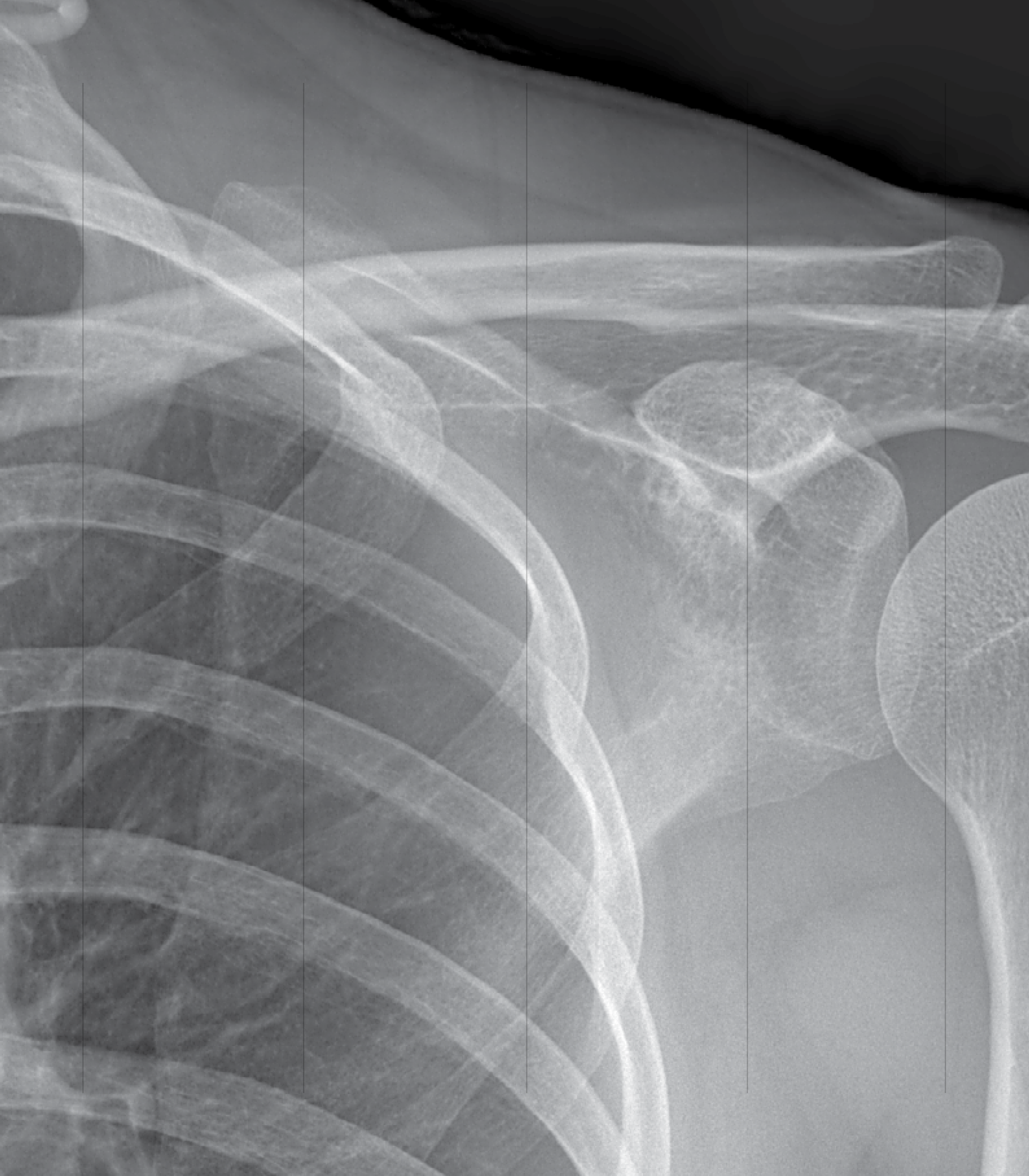

V
45
mAT
Mrežni napon


NEC
ŠTAMPANJE
SISTEM
Temp: 41°C
Status: Pripravan
1062
531

Contents

But these discoveries of Roentgen, exactly of the order of the telescope and microscope, his seeing through a great thickness of an opaque substance, his recording on a sensitive plate of objects otherwise invisible, were so beautiful and fascinating, so full of promise, that all restraint was put aside, and everyone abandoned himself to the pleasures of speculation and experiment. Would but every new and worthy idea find such an echo! One single year would then equal a century of progress.

Nikola Tesla, *Electrical Review*, April 1, 1896



Jelena Jovanović Simić

RAYS THAT TURN *INVISIBLE* INTO *VISIBLE*

Wilhelm Conrad Roentgen
(1845–1923)

(Source: wikimedia.org)

Wilhelm Conrad Roentgen – Discovery of X-Rays

Like very few discoveries in the history of science, just after its announcement in 1896, Roentgen's discovery of X-rays (1895) has achieved such global affirmation and came into practical use in numerous fields of science and technology, starting from medicine, on which it had an essential impact, through palaeontology, archaeology and art history to industry. For the first time, physicians could, without the use of surgical knife, see the inside of a live human body, study the work of individual organs, localise and, with greater certainty, treat a disease or an injury of the tissue, while soon afterwards it was discovered that the rays themselves also have a therapeutic effect. Besides, Roentgen's discovery inspired scientists to further research that has led to new discoveries. Already in 1896, Henri Becquerel discovered radioactivity, Thomas Edison invented radioscopy (observing the inside of the body using a fluorescent screen), Mihajlo Pupin and Nikola Tesla discovered certain characteristics of X-rays and improved the technology for obtaining X-ray images, while in 1897, Joseph J. Thomson discovered electrons. The chance to see inside the body was the starting point for development of new methods of biomedical visualisation in the 20th and 21st century, based not just on the use of X-rays, but other physical phenomena as well.

Roentgen was the first winner of the Nobel Prize for Physics (1901), which was awarded to him "in recognition of exceptional services that he has provided by discovering incredible rays that were later named after him". One third of the monetary part of the prize, which was 150,000 Swedish kroner,[1] he bequeathed in his will to the University Julius Maximilian in Wurzburg, where he was teaching physics at the time of his discovery. He did not patent his discovery because he wanted it to be freely used for the benefit of the mankind.

It is usually said that Roentgen has discovered the X-rays by accident, during an experiment with cathode rays, which, by the way, at the time, have been extensively studied by scientists for over two decades. Based on certain phenomena that they have observed during experiments, some researchers assumed that

1 In today's value, around one million dollars.

there was another kind of radiation, but Roentgen was the first one who recognised it as a special kind of radiation and studied it systematically. The main apparatus for experiments consisted of electrostatic machine or an induction coil (Ruhmkorff's coil was the most commonly used) and a glass tube with low air pressure with metal electrodes sealed on its ends—negative cathode and positive anode. When high-voltage current is released through the tube, electrons escape the cathode and move towards the other end, the anode, with great speed. When they collide with the gas molecules, anode or the glass wall, fluorescent light appears in the tube. The glass tubes for these experiments, whose forerunner was Geissler tube from 1857,[2] had multiple modifications, the most famous of which and the most commonly used was the Crookes tube.[3] Since until the discovery of electrons, it had been believed that atoms are the smallest, indivisible particles of matter, the scientists tried to explain this appearance of fluorescent light-called cathode rays in 1876—in various ways. Some believed that these were electrically charged atoms, while others thought that it was a new kind of electromagnetic waves. However, it was known that the rays do not pass through the wall of the glass tube and that they change direction in a magnetic field. In 1892, Heinrich Hertz discovered that cathode rays pass through a piece of aluminium foil placed inside the tube, after which the question arose regarding their penetrating power and the capability to propa-

2 It is an ion tube with a low gas pressure invented by German glassblower and physicist Heinrich Geissler, upon the request of physicist Julius Plücker. It was used for studying the effects of high-voltage current on various gasses. Since the vacuum in the tube was low, no cathode rays were generated in it.

3 William Crookes, English chemist and physicist, made a cathode tube by increasing vacuum in the Geissler tube. A similar tube was invented before him by German physicist Johann Hittorf in 1869 and that is why Crookes tube is also called Hittorf-Crookes tube.

Wilhelm Conrad Roentgen was born on March 27, 1845 in Lenep (today, part of Remscheid), in the Rhein-Westphalia, Germany. He was the only child of Friedrich Roentgen, cloth merchant and Dutch woman Charlotte Constanze Roentgen. He spent most of his childhood and youth in Netherlands, where the Roentgens moved in 1848. He went to Technical School in Utrecht, but he was expelled in 1863 because he refused to reveal the name of his friend who drew a caricature of a professor in the classroom. Without passing the graduation exam, he didn't manage to continue his education until 1865, when he enrolled at Polytechnic School in Zurich, which did not require graduation certificate for enrolment. He obtained his mechanical engineer diploma in 1868 and the following year, he defended his doctoral thesis based on the studies of gasses. After that, he became an assistant to physics professor August Kundt, with whom, in 1870, he transferred to the University of Wurzburg. However, it turned out that due to his irregular education, the University authorities there did not grant him the status of lecturer, so after two years, he went to Strasbourg, where, as a private docent, he taught at the University until 1874. In 1875, he taught in Hohenheim, then again in Strasbourg (1876–1878) and Giessen (1879–1888). He returned to Wurzburg in 1888 where he became the head of the Institute for Physics and dean of the University (1893/94). From 1900 to 1920, he taught at the University Ludwig Maximillian in Munich.

Apart from the Nobel Prize for Physics (1901), Roentgen was also awarded Rumford Medal by the Royal Society in London (1896). He was elected honorary citizen of Wurzburg in 1921. With his wife Bertha, he had an adopted daughter Josephine Bertha. He died on February 10, 1923 in Munich and he was buried in the Roentgen family tomb in Giessen.

Die Presse.

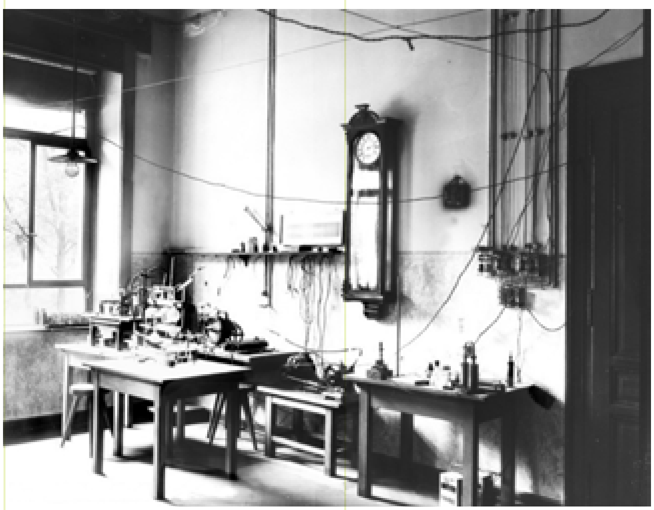
Nr. 5. Wien, Sonntag den 5. Jänner 1896. 49. Jahrgang.

Wien, 4. Jänner.

Eine sensationelle Entdeckung.

Viennese newspaper *Di Presse* was the first in the world to publish the news of the discovery of X-rays, in an article titled “Sensational Discovery”, on January 5, 1896.

(Source: assets.diepresse.com)



Wilhelm Conrad Roentgen’s laboratory at the University of Würzburg where he discovered X-rays.

(Source: commons.wikimedia.org)

gate in the air. Hertz’s assistant Phillip Lenard then constructed a tube with a small aluminium “window”. During an experiment in 1894, which he conducted in a dark room, whereby he covered the tube with a dark cardboard, Lenard noticed that the rays (light) exit through the aluminium “window”. Using a fluorescent paper, he managed to measure that they propagate through air in the length of eight centimetres. However, he noticed that the electroscope,[4] which was at a distance of 30 cm from the tube, has discharged. Lenard could not explain that phenomenon, but it was, in fact, caused by the X-rays, which were still unknown at the time.

In October 1895, Roentgen began researching cathode rays. He also conducted experiments in a dark room, with a tube covered by black cardboard and for the study of the penetrative capacity of the cathode rays, he prepared a paper covered in barium platinocyanide (he called it a fluorescent screen). On November 8, 1895, he observed an unusual phenomenon: fluorescent screen, which was still unused and about one metre away from the tube, began to glow during the experiment. Since he knew that the cathode rays don’t penetrate glass, Roentgen realised that apart from the cathode rays, some other unknown and invisible rays have been created in the tube, which have the power to penetrate glass and cardboard and that propagate to a larger distance that the cathode rays. He called them X-rays, after the mathematical symbol for unknown, because he could not precisely determine their nature. First, he assumed that those were “longitudinal vibrations in ether”, but he soon became convinced that they are identical to light rays, whose nature is transversal. In the following few

4 Instrument used to determine the presence of electric charge.

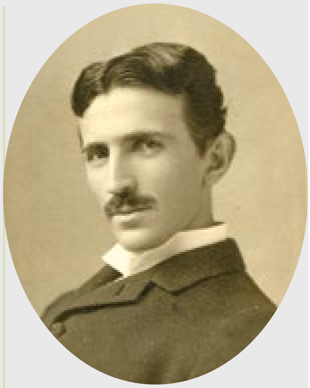
weeks, he fervently studied the characteristics of the new rays: possibility of penetration though various materials, effects on photographic plates and various fluorescent screens, behaviour in a magnetic field, etc. Between the tube and the fluorescent screen, he would place objects made of wood, paper, metal, glass and other materials, then glass containers with water and metallic salt solutions, and he observed their shadows on the screen. Based on the intensity of the shadows, he would conclude if and to what extent, the rays penetrate the tested matter. He observed that the penetrativeness of the rays depends on the thickness and density of the material, so that a 1.5 cm thick lead plate is practically impenetrable. He determined that the rays do not change direction in the magnetic field and based on that, he concluded that they are not identical to cathode rays, but rather that they are created when the cathode rays hit the tube walls. When he exposed his hand to the radiation, on the screen, he saw “darker shadows of bones in only slightly lighter shadow of the hand”. He also discovered that dry photographic plates are sensitive to X-rays, even in unopened boxes, and that they can be used for taking pictures of objects using X-rays. That is how, on December 22, he took a picture of his wife’s hand, and then a set of laboratory weights in a closed box, a compass, a coil with a wire wrapped inside, door frame in the laboratory, welded zinc stripes and other objects. The published the results of his work in an article (“previous announcement”) titled “On a New Kind of Rays” (“Ueber eine neue Art von Strahlen”), which was published in the journal of Physical-Medical Society (*Physikalisch-Medizinische Gesellschaft)* of Wurzburg on December 28, 1895. In the article, Roentgen listed all the pictures he took but did not publish and he soon realised that he had missed the opportunity to document his discovery. That is why,

Picture of Bertha Roentgen’s hand, the first roentgenogram made by Wilhelm Conrad Roentgen on December 22, 1895.

(Source: Wellcome Library no. 32971i, wellcomecollection.org) on January 1, 1896, he sent the pictures, together with the article excerpts, to a few of his colleagues, which included Franz S. Exner, professor of physics in Vienna.[5] Exner showed the picture to his friends, one of them being a son of the editor of the most influential Viennese daily newspapers Die Presse. On January 5, 1896, those newspapers published the first ever article on this epochal discovery, titled "Sensational Discovery". The power of press, at the time the most influential mass media, immediately proved itself in action—in just a few days, the news travelled around the world and it caused excitement in both scientific circles and general public. Certain researchers, whose inventions and observations have contributed to the knowledge on cathode rays, felt bad that Roentgen did not mention them in his article. Lenard, whose research he did mention, congratulated him at first, but later, overwhelmed by jealousy, he stated that the X-rays could have been discovered by "anyone", if he used his tube and was observant enough. However, Roentgen was the first one to understand that he has generated rays that are different from cathode rays, named them, determined their certain characteristics, took the first pictures, out of which, the medical one has proven to be the most important, and published his findings.

And while "Roentgen fever" was spreading around the world—numerous laboratories conducted experiments with X-rays, public demonstrations were organised, numerous articles and scientific papers were published—Roentgen, a man who didn't like public appearances, refused almost all the calls for lectures. In January 1896, he presented his pictures at the meeting of the Physicists Society in Berlin; he made one demonstration of the experiment on the Court, upon the invitation of Kaiser Wilhelm II and the other at the meeting of the Physical-Medical Society in Wurzburg. On that occasion, they accepted the proposal of professor Albert Kölliker, famous anatomist and physiologist, to rename the X-rays to Roentgen rays. Roentgen published only two more announcements on X-rays and after 1897, he completely stopped his work in that field.

5 Apart from Exner, they also included Lord Kelvin in Glasgow, Emil Warburg in Berlin, Franz Schuster in Manchester, Henri Poincaré in Paris and Hendrik Lorentz in Leiden. Later, he also sent that same material to his numerous colleagues in Germany.



Nikola Tesla (1856–1943)

(Source: Nikola Tesla Museum, VI / V, 10)

Nikola Tesla – High Potentials – Clearer Images – Taking Pictures at Greater Distances

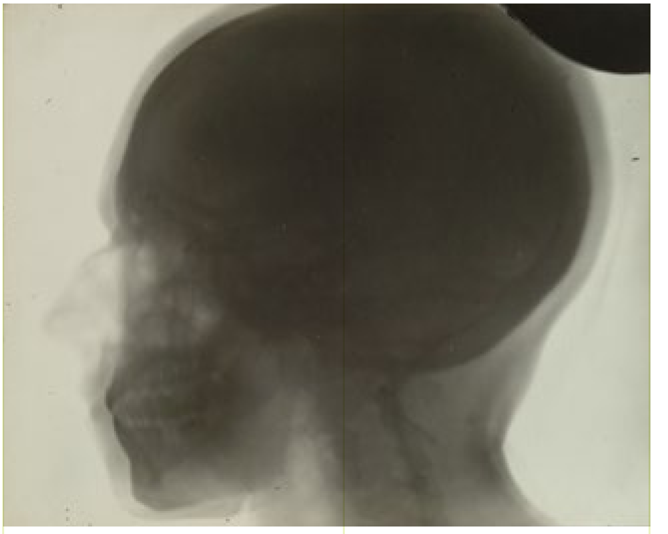
When he learned of Roentgen's discovery, Nikola Tesla realised that in late 1894, during the examination of fluorescent light, he himself was on the path of the discovery of X-rays. In his experiments, he used one of his high-frequency transformers, Crookes tube and a photographic plate. It turned out that emulsion on some of the plates that were standing unpacked in the far away corner of the laboratory got damaged. Tesla noticed that strange phenomenon but he did not try to discover what caused it. He failed to see, as he later said, something that someone else in his place "might have noticed", but he had to stop further research for a while because of a fire that destroyed his laboratory on March 18, 1895. That is why, after he heard of Roentgen's discovery, he dedicated himself with great enthusiasm to "study of the nature" of X-rays and "perfecting the means for their production". Between March 11, 1896 and August 11, 1897, he published ten articles (all ten in the journal *Electrical Review*) in which he described his experiments and presented his observations and conclusions in great detail.

Regarding the nature of X-rays, from the day one, Tesla was firmly convinced that they consist of material particles and not waves in the ether, as other researched had thought.[6] He based his conviction on the observation that small defects can be seen on the glass at the point where the rays exit the tube. He was not sure of the origin of those particles, and his idea that it was "dissolvement of matter into some primary form" almost anticipated the discovery of electrons and photons. He also thought that cathode rays consist of particles as well, and that the strongest X-rays are generated in the point of the first impact of cathode rays either on anode, some body inside the tube or its glass wall. In contrast to Roentgen, who claimed that X-rays do not reflect, he determined their reflection properties and documented them with photographs.

6 Today, it is known that X-rays belong to the spectrum of elctromagnetic radiation.

Tesla understood from the very start of the study of X-rays that the quality of images obtained on screen or a photographic plate depends on the strength of the cathode rays and that in order to obtain cathode rays of high intensity, it was necessary to have high-voltage and high-frequency current. Besides, he observed that the use of high potentials significantly decreases the time that the body is exposed to radiation during shooting, and that it also enables the rays to act from a much larger distance, which proved to be very important for the use of radiation in medicine. That is why in his experiments he used his resonant transformer with spark discharge of a capacitor and he also constructed a special tube which was adjusted to the application of high potentials.

Roentgen also tried out Tesla's transformer in his experiments and he published his observations in his second announcement on March 9, 1896. He determines that the use of Tesla transformer had three advantages: the tube is less heated, the vacuum inside it is sustained for longer and the obtained X-rays are of higher intensity. Already in 1897, the company *Reiniger, Gebbert & Schall* (later, part of the Siemens company), by the by, the first manufacturer of Roentgen equipment in Europe, apart from the "complete Roentgen instrumentation", also offered "Tesla's instruments for generating X-rays for educational institutions".



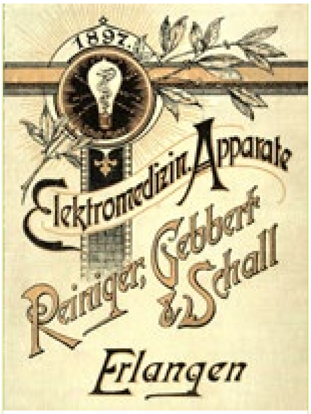
Head Roentgenogram, picture taken by Nikola Tesla in 1896 or 1897

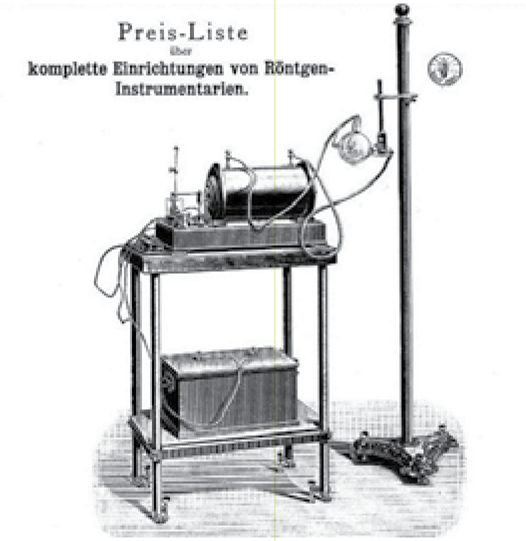
(Source: Nikola Tesla Museum, VI /II, 121)

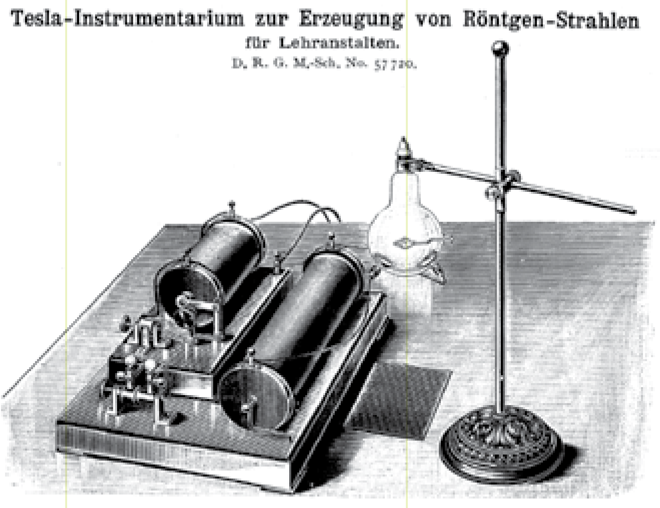
Roentgenogram of a foot in a shoe, picture taken by Nikola Tesla in 1896 or 1897

(Source: Nikola Tesla Museum, VI /II, 123)

Based on his own and the experience of his collaborators, Tesla also described the effects of X-rays on human organism. He and his associates observed that sleepiness, calmness, warm sensation in the upper part of the head and the sensation that the time passes quickly, all occur during longer exposures of the head to strong radiation. Tesla also thought that cessation of long-term coughing and improvement of general health, which he personally experienced during experiments, could also be a consequence of the effect of X-rays and he was also pretty convinced that their bactericidal power will also be proven in the future. He thoroughly studied the effect on skin and undoubtedly, he was among the first people to describe radiation dermatitis—damage of the skin that occur due to irradiation (redness, inflammation, blisters, bleeding, tissue necrosis). For the protection purposes, he constructed screens made of aluminium plates and aluminium mesh, with grounding. However, despite today's ingrained opinion that Tesla was the one to first observe the detrimental potential of the X-rays, he ascribed the skin damage to other causes.

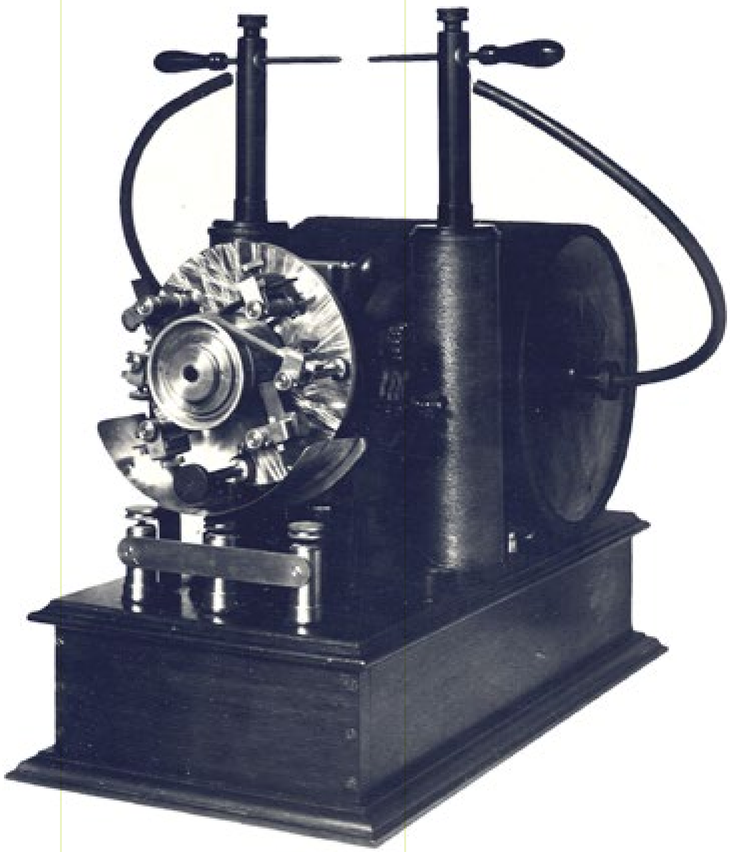






From the product catalogue of the company *Reiniger, Gebbert & Schall* (1897) — complete equipment for X-ray apparatus (left) and "Tesla's Instrumentation for generation of X-rays" (right)

(Source: *Elektromedizin. Apparate und Ihre Handnabung*, sechste Auflage. Erlangen: Reiniger, Gebbert & Schall,1897)

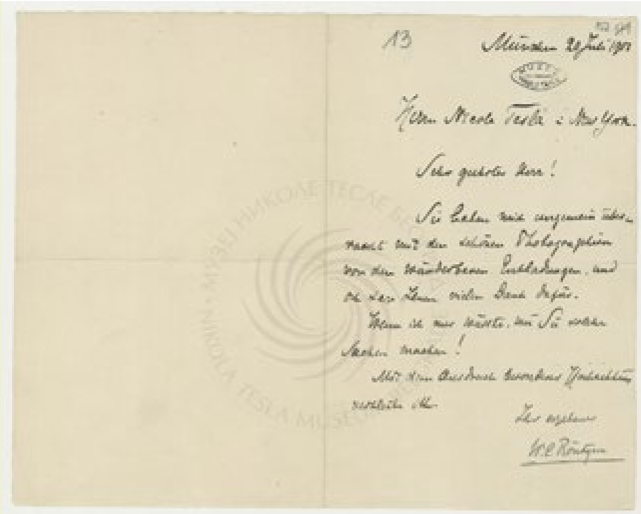


Great oscillator intended for wireless transmission experiments, generation of X-rays and scientific research. Nikola Tesla presented this invention in front of the New York Academy of Sciences in 1897.

(Source: Nikola Tesla Museum, VI/II, 19)

Ruhmkorff's coil, 1960s

(Source: Museum of Science and Technology, Study Collection)



13

München 20 Juli 1901

Herrn Nikola Tesla in New York.

Sehr geehrter Herr!

Sie haben mich ungemein überrascht mit den schönen Photographien von den wunderbaren Entladungen, und ich sage 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

Roentgen's letter to Nikola Tesla from July 20, 1901, in which he expresses his gratitude for sent photographs of "wonderful discharges". "If I only knew", he continued, "how you make such things!" Since at the time, neither Roentgen nor Tesla no longer dealt with X-rays, those were most likely photographs of discharges of very-high-power transformers that Tesla constructed in 1899 in Colorado Springs. He sent photographs of transformers in operation to his friends, among others Crookes and Lord Kelvin, and probably Roentgen as well.

(Source: Nikola Tesla Museum, CXLIV, K1 144, 152 A)

POSTAL TELEGRAPH – COMMERCIAL CABLES

TELEGRAM

TELEGRAMS TO ALL AMERICA

CABLEGRAMS TO ALL THE WORLD

Roentgen

Munich (Germany)

Tiefgefühltes Beileid am Tode des ... Entdeckers ... neue und bezaubernde Welten enthüllte

Nikola Tesla

Concept of Nikola Tesla's telegram in which he expresses "his deepest condolences on the death of the famous inventor who discovered new and enchanting worlds to ordinary people". The telegram was sent on the occasion of Roentgen's death, most likely to his daughter.

(Source: Nikola Tesla Museum, CXLIV, K1 144, 151 A)

"According to my opinion", he wrote in one of his articles, "experimenters should not be discouraged in their research of X-rays by the fear of poisonous or generally detrimental effects because it seems it is reasonable to conclude that it would take centuries to build up enough of such matter that could seriously threaten life process of a person". Skin damages, he explains, "are not the consequence of X-rays, but more of ozone that develops in contact with the skin", and "the responsibility also falls, in a lesser extent, to nitric acid". Tesla did recommend caution during the use of X-rays, especially because he predicted that "new devices, capable of developing incomparably more powerful radiation" would be constructed, but he thought that it is necessary to protect the body from electrostatic effects created during the operation of X-ray apparatus and not the X-rays themselves.

Mihajlo Idvorski Pupin
(1954–1936)

(Source: sh.wikipedia.org)

Mihajlo Pupin – Technology for Amplifying X-Ray Images and Secondary X-Ray Radiation

One of the pioneers in the field of radiology was also the great Serbian scientist Mihajlo Pupin. At the time of Roentgen's discovery, he was a professor of mathematical physics at the University of Columbia in New York and one of the very few scientists in America who studied cathode rays. He began researching that problem in 1888 in Berlin, during his advancement and preparation of doctoral thesis. Since he already had all the necessary instruments, in January 1896, Pupin began studying X-rays. In his autobiography, he said that the "rush on experiments with X-rays" in America reminded him of Golden Rush and that he had to lock himself up in the laboratory because journalists and physicians hounded him day and night. "The doctors", he stated, "brought me all kinds of cripples so that I would take pictures of their bones or examine them using the fluorescent screen". While taking a picture of a hand of a patients sent to him by certain doctor Bull, Pupin came up with an ingenious idea. Namely, the patient who was injured during a hunt, had in his hand "almost one hundred small pellets" and he was so "weak and nervous" that he could not sustain one-hour shooting, for that is how long it would take to get an image on a photographic plate. Using a few "exceptional" fluorescent screens, sent to him by his friend Thomas Edison, Pupin very clearly saw the pellets. He concluded that "the combination of eyes and screen is more sensitive than a photographic plate", so he decided to make a different "combination", this time of the screen and the photographic plate. The idea was excellent because he managed to make a very good image and in only a few seconds! Using the image, doctor Bull successfully completed the surgery. Pupin stated that that was "the first image obtained using X-rays in this manner and the first surgical operation in the USA in which the course of the operation was determined based on a photograph", and that all of this happened "in early February 1896". Pupin's invention was the forerunner of the X-ray image amplifiers that developed later and which are still an indispensable part of the X-ray equipment.

Discovery of the secondary radiation was Pupin's second important contribution to radiology, both in the field of theoretical radiation physics and in the practical field, because it has found application in the development of protection against X-rays. Pupin discovered secondary radiation during his study of reflexion and refraction of X-rays and on April 6, 1896, he informed the New York Academy of Science about it. "Every matter exposed to the effects of X-rays becomes the radiator of those rays", he wrote in his announcement, which was later published in journals *Science* and *Electricity*.

Pupin's intensive research of X-rays was abruptly cut short by the events in his family. On April 14, 1896, he got a severe pneumonia and, as he wrote in his autobiography, during fever, he was haunted by "horrible green fluorescent vacuum tubes, X-rays, fluorescent screens and arms, feet and rib skeletons". Pupin's wife, who nursed him, also got sick and passed away soon afterwards. Pupin never again worked on X-rays.

Photograph of the patient's hand with lead pallets taken by Pupin using X-rays, with the help of a fluorescent screen, 1896

(Source: *Pupin – od fizike ka duhovnoj realnosti*, ed. Aleksandra Ninković Tašić. Belgrade: Istorijski Muzej Srbije, 2016)

Literature

Bajić, Dejan. "Teslin doprinos medicini". *Zbornik radova = Proceedings. / Peta međunarodna konferencija Tesla III Millennium, Beograd, 15-18. oktobar 1996 = Fifth international conference Tesla III Millennium, [Belgrade, October 15-18, 1996];* chief editor Petar Miljanić, IV-1 – IV-15. Belgrade: [Institute "Nikola Tesla"], 1996.

Zonneveld, F. W. "Spectacular rediscovery of the original prints of radiographs Roentgen sent to Lorentz in 1896". *Insights Imaging 11*, 46 (2020). https://doi.org/10.1186/s13244-020-00846-x.

Levntal, Z. "Doprinos Mihajla Pupina radiologiji". *Zbornik radova XIX naučnog sastanka, 14–15. decembra 1968, Novi Sad*, ed. Slobodan Đorđević, 251–259. Belgrade. Naučno društvo za istoriju zdravstvene kulture Jugoslavije, 1969.

Mould, R. F. "Rontgen and the discovery of X-rays". *The British Journal of Radiology 1995*; 68(815):1145–1176. Available on: https://www.birpublications.org/doi/pdf/10.1259/0007-1285-68-815-1145.

Panaotović, Jovan P. *Rentgenovi X-zraci*. Novi Sad: Štamparija Dra Svet. Miletića, 1896.

Pupin, Mihajlo. *Sa pašnjaka do naučenjaka*. Belgrade: Zavod za udžbenike i nastavna sredstva, 1996.

Röntgen Rays. *Memoires by Röntgen, Stokes and J. J. Thomson*, translated and edited by George F. Barker. New York and London: Harper & Brothers Publishers, 1899.

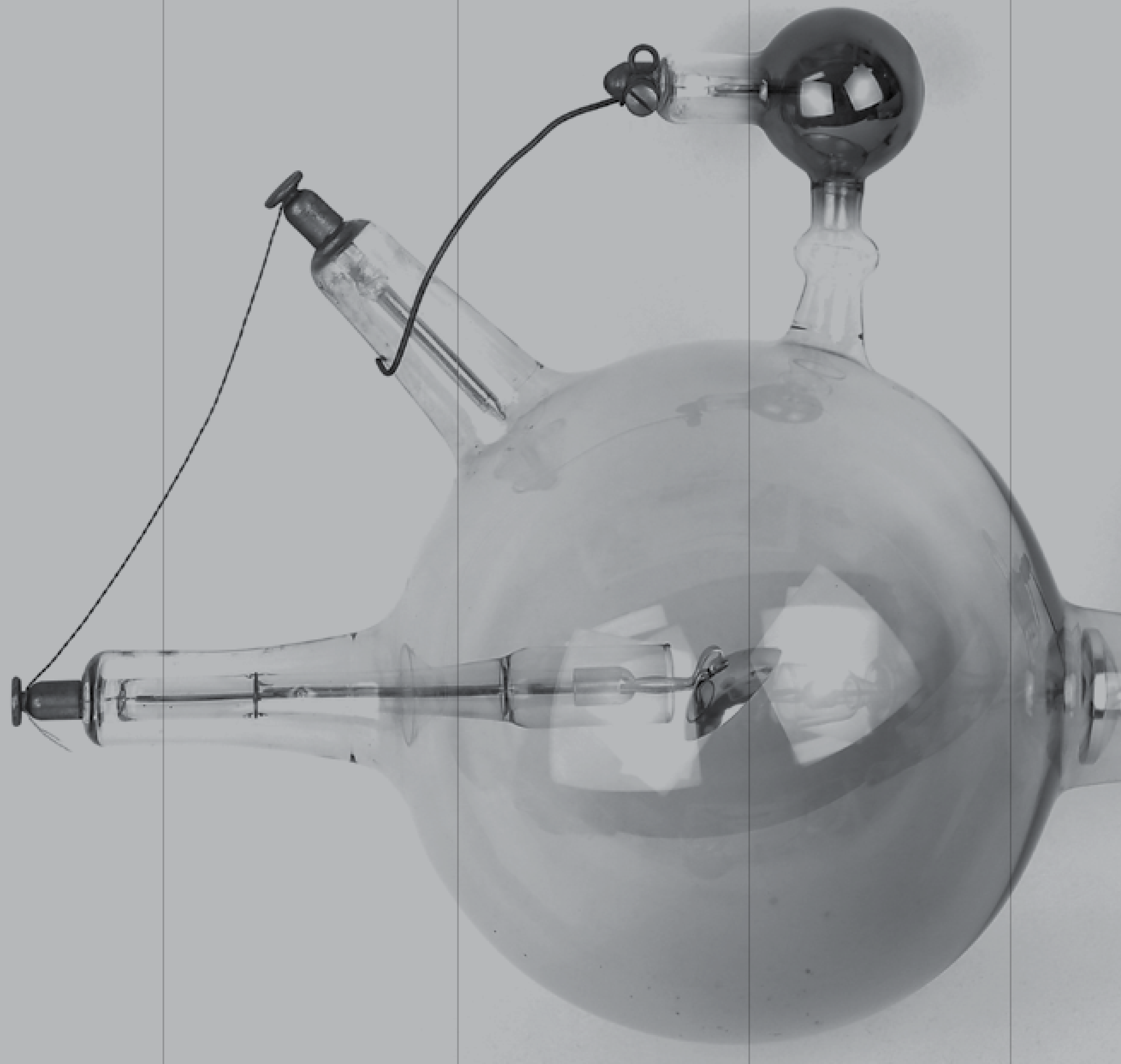
Roentgen, Wilhelm Konrad. "On A New Kind of Rays". From the translation in *Nature* [53: 274-276, 1896] by Arthur Stanton from Sitzungsberichte der Wuerzburger Physik-medic. Gesellschaft. 1895. Reprinted from *Science* NS3: 227-231. 1896.

Tesla, Nikola. *Predavanja*, ed. Vojin Popović. Belgrade: Zavoda za udžbenike i nastavna sredstva, 1995.

Tesla, Nikola. *Članci*, chief editor Aleksandar Marinčić. Belgrade: Zavoda za udžbenike i nastavna sredstva, 1995.

"The Nobel Prize amounts". NobelPrize.org. *Nobel Prize Outreach AB 2021*. Sun. 22 Aug 2021. https://www.nobelprize.org/prizes/about/the-nobel-prize-amounts.

"Wilhelm Conrad Röntgen: Biographie". *Julius-Maximilians-Universität Würzburg*. Accessed on August 20, 2021. https://www.physik.uni-wuerzburg.de/ueber-uns/fakultaetsgeschichte/nobelpreistraeger/wilhelm-conrad-roentgen/.



Jelena Jovanović Simić

X-RAY TUBE AND CREATION OF X-RAYS

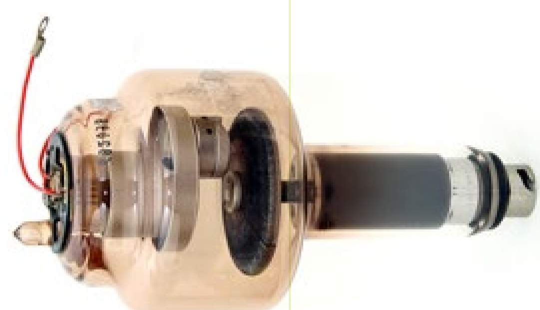
Gas (ion) tubes were used for production of X-rays until the 1920s. They were pushed out of use by thermoelectric tube constructed in 1913 by William D. Coolidge. The electrons in the gas tube were released from the cold cathode by positive ions which bombarded it, while in thermoelectric tube, they are released from a heated cathode. In order to direct the electrons towards the focus, the cathode, which was made of tungsten wire shaped like a spiral, was placed in the Coolidge tube in a parabolic mirror made of molybdenum sheet, as in a metal cup. The cathode was connected to two transformers, low-voltage and high-voltage. The low-voltage transformer heats up and when the temperature reaches 1,600°C, the cathode begins to emit electrons. Current from the low-voltage transformer squeezes the electrons into a dense beam.

Anode is the target for electrons, which heat it up significantly during bombardment. That is the reason why ion tubes have a relatively short lifespan. In the Coolidge tube, the anode was made of metal with a high melting point, such as platinum or tungsten, and it was also cooled (by air, water or oil).

In the X-ray machine, when a high-voltage circuit is turned on after the low-voltage circuit, the saturation current begins to flow in the X-ray tube. That means that all the electrons released from the cathode bombard the anode and thus produce the X-rays. With lower voltage, less than 0.1% of kinetic energy of electrons is transformed into X-rays and 99.9% is transformed into heat; at 100 kV, around 1% of kinetic energy transforms into X-rays.

X-ray tube *Reiniger, Gebbert & Schall* from the 1920s, donation by the Bošković family from Ruma (2016).

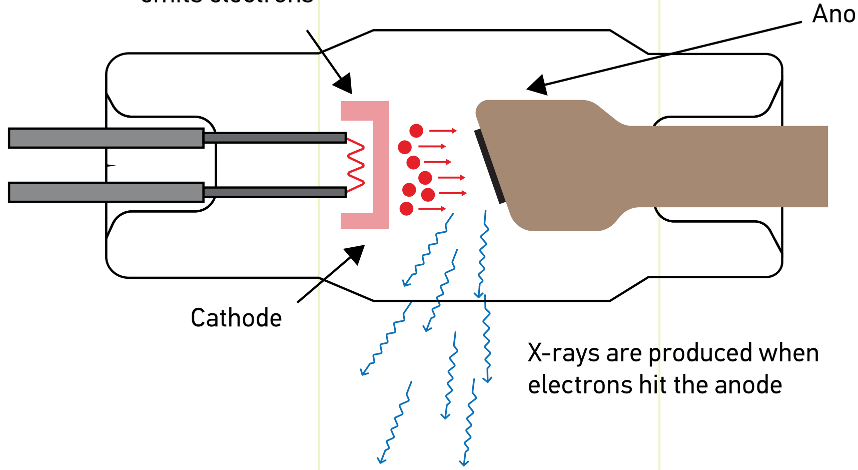
(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT.T:11.1.400)



X-ray tube *Philips*, with a rotating anode and a lithium-beryllium-boron cover from the 1970s, donation by Prof. Dr Branislav Goldner (2012)

(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT.T:11.1.398)

X-ray generation in an X-ray tube



For the X-ray images to be sharp, the electron beam in the tube must be squeezed as much as possible so that the focus on the anode would be as small as possible. In order to decrease the focus, and at the same time, protect the anode from overheating and damages caused by the bombarding electron beam, in 1929, a rotating anode in the shape of a ring was constructed. While the anode rotates, a new surface always gets impacted by the electron beam.

Unlike ion tubes which had no physical protection, modern tubes are placed in an "armour" made of porcelain with the addition of lead. On the armour, there is a "window" with a screen that opens to let in the X-ray beam. In that way, both patient and the medical staff are protected from the effects of radiation.

Literature

Magarašević, Mileta i saradnici. *Radiologija*, III edition. Belgrade: Zavod za stručno usavršavanje i izdavačku delatnost "Beograd", 1987.

Jelena Jovanović Simić

FROM THE HISTORY OF MEDICAL APPLICATION OF X-RAYS IN SERBIA

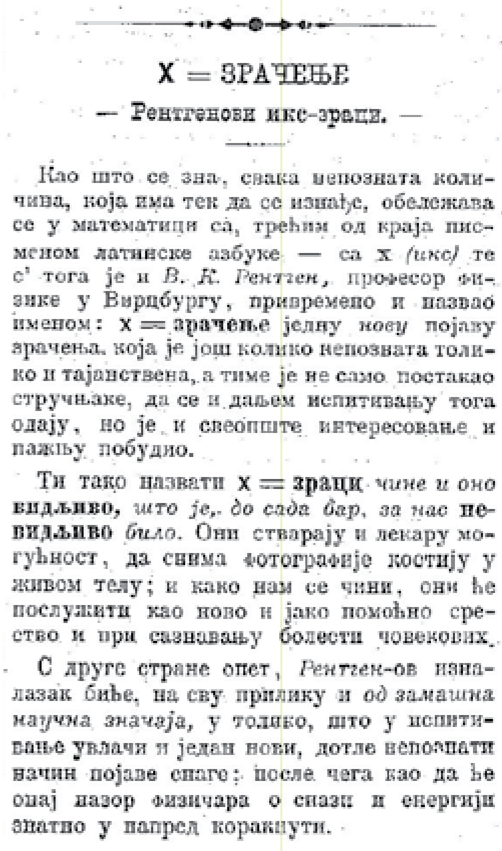
The first articles on Roentgen's discovery of X-rays appeared in the Serbian press in the early 1896. In the February edition of *Narodno zdravlje*, popular-medical supplement to the Serbian Medical Archives, organ of the Serbian Medical Society, in the section *News*, a short, unsigned article was published, titled "Roentgen Rays", which was probably written by the journal's editor, Dr Jovan Danić:

> *German scientist Roentgen has discovered a special kind of light rays, which penetrate even the opaque materials. Based on that discovery, he found a way to photograph certain kind of objects even through opaque walls. This is important for physicians—because in that way, they can, to some extent, photograph the inside of the body as well, therefore, we shall soon also be able to see the changes in internal organs and parts.*

The news was certainly noticed in the Serbian Medical Society, but in the minutes of the Society's meetings published in the *Serbian Medical Archives*, the discussion on the topic of X-rays did not appear until early 1898. In the meantime, the journal published several articles taken over from foreign medical journals. The first of them, published in the May edition from 1896, was "On Roentgen Rays in the Diagnosis of Internal Diseases—by Professor Dr E. Grunmach",[1] and later came "Roentgen's Rays in Veterinarian Practice—Translation from *The Veterinarian*" by doctor Anton Kobliška, veterinarian (July issue from 1897) and "On Impact of X-Rays on Retina—H. Dor. Russian Journal of Ophthalmology for December 1897" (in the January issue for 1898, probably translated by Dr Đorđe Nešić).

The first article on the Roentgen's discovery of X-rays published in *Srpske novine* on March 9 [21], 1896

(Source: https://digitalna.nb.rs)



X = ЗРАЧЕЊЕ

— Рентгенови икс-зраци. —

Као што се зна, свака непозната количина, која има тек да се изнађе, обележава се у математици са, трећим од краја писменом латинске азбуке — са x *(икс)* те с' тога је и *В. К. Рентген*, професор физике у Вирцбургу, привремено и назвао именом: **x = зрачење** једну *нову* појаву зрачења, која је још колико непозната толико и тајанствена, а тиме је не само постакао стручњаке, да се и даљем испитивању тога одају, но је и свеопште интересовање и пажњу побудио.

Ти тако названи **x = зраци** *чине и оно* **видљиво,** *што је, до сада бар, за нас* **невидљиво** *било.* Они стварају и лекару могућност, да снима фотографије костију у живом телу; и како нам се чини, они ће послужити као ново и јако помоћно средство и при сазнавању болести човекових.

С друге стране опет, *Рентген*-ов изналазак биће, на сву прилику и *од замашна научна значаја*, у толико, што у испитивање увлачи и један нови, дотле непознати начин појаве снаге; после чега као да ће онај назор физичара о снази и енергији знатно у напред коракнути.

1 Emil Grunmach (1849–1919) was a professor in Berlin, internist, surgeon and radiologist, one of the pioneers of radiology, founder of the first Roentgen Instutute at the Charité Hospital.

In the issue from March 9 [21], 1896, the official newspapers *Srpske novine* published the article “Roentgen’s X-rays”, taken over from German journal *Die Gartenlaube – Illustriertes Familienblatt*, translated by Pavle V. Vujić.[2] Apart from Roentgen’s biography, description of the apparatus and the procedure by which he made his discovery, the article also explains the importance of X-rays for natural sciences in general and especially for their practical application in medicine. It is said that with this discovery “it is truly easy to find and clearly define all the changes: both thickening and broken bones, and also, in this manner, the physician may precisely determine the position of foreign bodies that got into the interior of an organism in any manner (needles, broken knives, gunshots, etc.). [...] It is almost certain that in this way it would be possible to define gallbladder or kidney stones and when it gets perfected, this discovery will also lift the curtain of secrecy of all our internal organs that have so far been and still are, covered by it”.

The same journal, in the issue from March 28 [April 6], published the article “The Latest Edison’s Invention” (unsigned, but not taken over, but rather edited based on the writings in the American press), which deals with the Edison’s invention of roentgenoscopy (fluoroscopy): “Edison has found a way and means to see with a simple eye all the organs of the human body, especially heart and lungs, using Roentgen rays”. Edison invented the fluorescent screen with the purpose of “making photography obsolete” and thus speed up the diagnosing process. Roentgenoscopy found wide application but it turned out that it did not push out roentgenoscopy.

The first brochure on Roentgen’s discovery in Serbian language. Jovan P. Panaotović. *Rentgenovi X-zraci*. Novi Sad: Srp. Štamparija Dra. Svet. Miletića, 1896.

(Source: Librabry of Matica srpska)

2 Pavle V. Vujić was a natural sciences teacher in high schools; in 1882 and 1883, he taught at the Real Grammar School in Gornji Milanovac; in 1892, he published his professional article “General External Conditions for Plant Life, according to Sax and others” (in journal *Otadžbina and as a study*), and in *Prosvetni glasnik*, in 1895 and 1896, he published articles and translations of natural science articles.

During 1896, several more articles were published that were edited by professors of natural sciences—Pavle V. Vujić, Jelenko Mihailović[3] and Jovan P. Panaotović[4]. Vujić's article "Professor Roentgen and the New X-Rays (from *Ueb. L. & M*)" was published in the March issue of *Prosvetni glasnik*, in the section "Scientific Attachments"; Jelenković's in April issue of *Delo – list za nauku, književnost i drušveni život*, in the section "Scientific Chronicles" ("Roentgen's Rays (Photograph of the Invisible), edited by Jelenko Mihailović, professor, according to P. Spies, Lenard, Petit, C. Flammarion and others"), while Jovan P. Panaotović's discussion was first printed in the journal from Novi Sad, *Zastava*, and then it was published as a separate brochure under the same title.

In the issue from August 1896, *Ženski svet – list dobrotvornih zadruga Srpkinja*, which was also published in Novi Sad, announced important news: "Serb in America, Nikola Tesla" also researches X-rays. Articles and discoveries of Mihajlo Pupin were not mentioned by the press at the time, and today it is virtually unknown that in 1896, Jovan Panaotović also conducted experiments with X-rays in Berlin and made a few X-ray images. At the time, local natural scientists, perhaps due to the lack of equipment, did not engage in the research of X-rays. "The Balkans is silent", commented Panaotović in his discussion, while he described successes achieved in that field in the European countries. But the following year brought changes because two X-ray machines[5] arrived in the Kingdom of Serbia—one in Belgrade and the other one in Šabac.

3 Jelenko Mihailović (1869–1956) was one of the founders of seismology in Serbia, professor at the Facutlty of Philosophy, honorary professor at the Faculty of Agriculture and Forestry, author of textbooks in physics, meteorology, spectroscopy and other fields and a popularizer of science.

4 Jovan P. Panaotović (1868 – ?) was a chemist, doctor of science (Rostok, 1896), assistant professor at the Agricultural Academy in Bonn (1895), then at the University of Göttingen (1898) and in Berlin (1899). In Serbia, he worked as a chemist at the Technical Department of the Military Technical Institute in 1908 and in 1909, at the Foundery Administration in Obilićevo. He left the public service in 1910. He worked in the fields of history of industry, lighting issues and photography.

5 For the machines that were in use in the first years after the discovery of X-rays, it might be more suitable to use the word apparatus. All the components of the "apparatus" could be used independently of each other for other purposes as well, for example, for experiments that are not in connection to X-rays; compared to later machines, the entire apparatus was far simpler and smaller in dimensions, and the first stands appeared in 1898. The price of the apparatus in 1896 was around 1,000 marcs or 600 Austrian forints, which was equal to around three monthly salaries of physicians who worked in the public practice in the Kingdom of Serbia. Today, it would be around 6,700 euros.

Dr Avram Vinaver (1865–1915), private physician in Šabac, owner of the first X-ray machine in Serbia. Portrait from the photograph of the participants from the Surgical Section at the First Congress of Serbian Physicians and Natural Scientists in 1904.

(Source: Museum of Science and Technology, Collection of the Museum of Serbian Medical Society)

The First X-Ray Machines in Serbia

In the literature on the history of radiology and the history of Šabac, it is most often said that the first X-ray machine in Serbia was brought in by Avram Vinaver, private physician in Šabac, father of the famous journalist and writer Stanislav Vinaver. He purchased it in Vienna, according to most sources, in 1897, but 1899 is also mentioned as the year of purchase. We could not find the precise information in the archival material and the year of purchase was not mentioned not even by Vinaver himself in the articles that he presented at the First Congress of Serbian Physicians and Natural Scientists in 1904 in Belgrade. He participated in the Congress with three articles, two of which were from the field of radiology. The subjects were “Diagnostic Importance of Roentgen Rays in Lung Diseases, Especially Early Tuberculosis” and “Five Years of Treatment with Roentgen Rays”. In the second article, he presented his observations and results of treatment of 62 patients, most of which were treated for skin conditions and a few of them for carcinoma and trachoma. From the very title it can be concluded that Vinaver began using X-rays for treatment in 1899, but that does not exclude the possibility that he also performed X-ray diagnostics earlier. Either way, it is an undisputed fact that Avram Vinaver was the first private physician in Serbia who owned an X-ray machine; that he was the first among the Serbian physicians who took X-ray images by himself, applied X-ray therapy and conducted “clinical” research and that based on his observations and the results of his work, he published the first professional articles in the field of radiology.[6]

House in Šabac in which Dr Avram Vinaver worked and lived. X-ray machine was located in a small house next to it (marked by an arrow).

(Source: *Jedan vek radiologije u Srbiji 1895–1995*)

6 The first was the case study of a patient suffering from lupus erythematosus, published upon the author’s request, as “previous announcement” in the Serbian *Medical Archives* in 1902.

Dr Mihajilo Mika Marković (1847–1911), Medical Corps colonel, Chief of the Medical Corps (1886–1903), procured the first X-ray machine in Belgrade in 1897 for the Medical Corps.

Dr Vojislav Subbotić (1857–1923), Head of the Surgical Department of the General State Hospital and initiator of the procurement of the first hospital X-ray machine, photograph from 1891.

Unlike the X-ray machine in Šabac, the other one that arrived in Belgrade is much less mentioned in the literature. It was procured upon the initiative of the Medical Corps colonel Dr Mihajilo Mika Marković, long-term and very esteemed chief of the Medical Corps, who introduced numerous novelties in the military medicine, established the first institution for preventive medicine in Serbia—Pasteur's Institute in Niš (1900) and began construction of a modern complex of the Military Hospital in Belgrade ("Old Military Medical Academy", today, part of the Clinical Centre of Serbia). Marković procured the X-ray machine for the Military Hospital, but it turned out that in order for it to operate, it had to use electricity from the city electrical grid to which the Hospital was still not connected. That is why, and probably also because the Hospital did not have an employee who knew how to handle the machine, the machine was installed at the Institute of Physics of the Great School and it was entrusted to Đorđe Stanojević, professor of physics and the head of the Institute. Although it was the property of the Medical Corps, the machine was at the disposal of all the physicians. Stanojević took the X-ray images of the patients sent or brought to him by physicians and he developed the pictures himself (by the by, he was a passionate photographer). Since in one appeal to the minister of education from May 15 [27], 1899, he wrote that the "examinations using X-rays" have been undergoing for two years, mid-1897 could be established as the most accurate approximation of the start of operation of the "Belgrade" X-ray machine. Marković mentions that same year in his memoirs,[7] so it can be reliably determined that the X-rays were used in Serbia for medical diagnostics just under two years since their discovery.

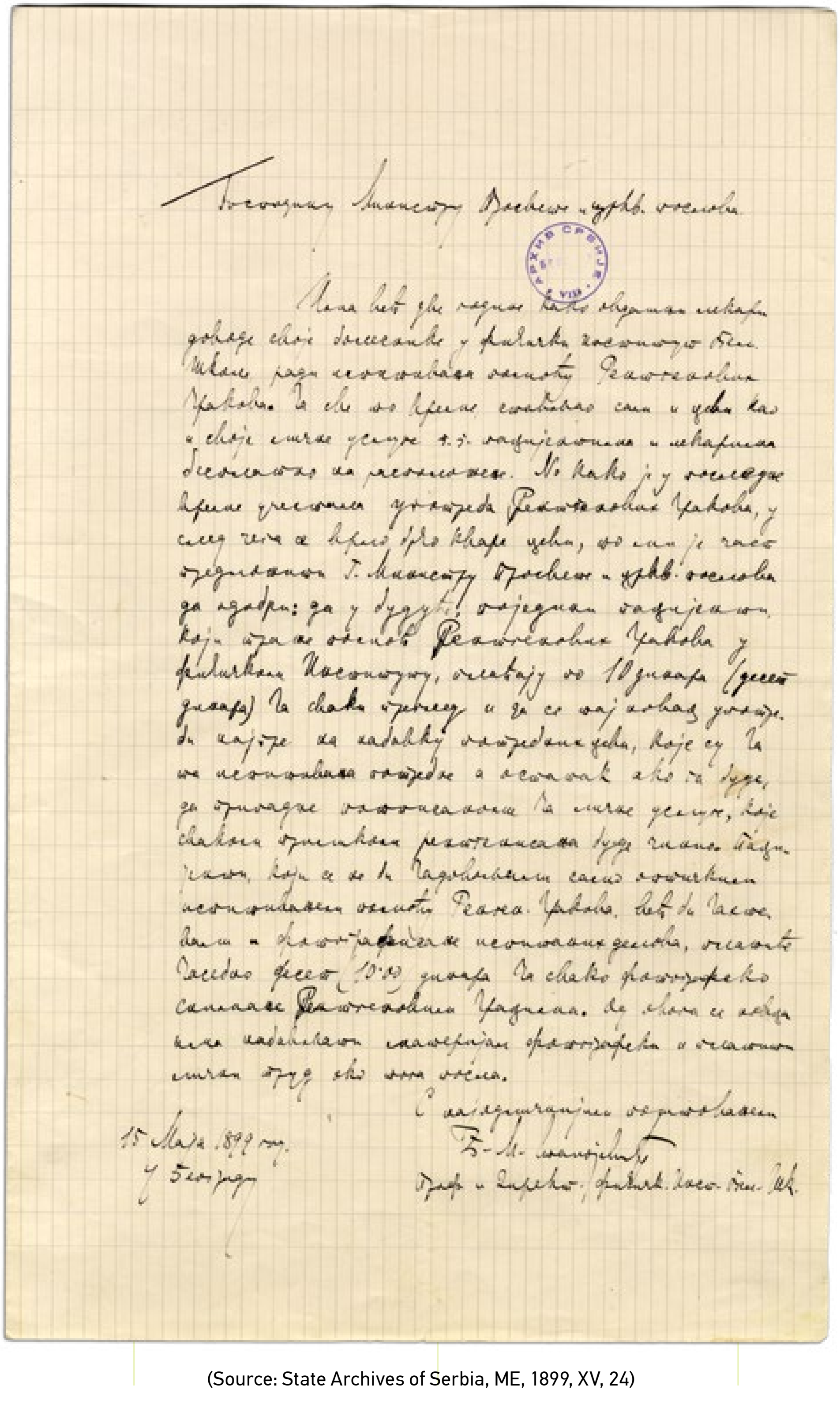
> *Since I've seen in the foreign scientific journals and newspaper how immensely valuable the discovery of X-rays is for surgery and how it might be valuable in the future for internal medicine, in 1897, I procured an X-ray machine. Not having electrical installations in the Belgrade Military Hospital, I've lent this machine to our Great School under the condition that it is used by both military and civil physicians whenever they need it.*
>
> *By the courtesy and kindness of Mr Professor of the Great School Đoka Stanojević, our physicians have used this machine so many times so far and they shall use it in the future as well. If I'm not mistaken, this machine that the Ministry of Defence procured eight years ago is still the only public X-ray machine in Serbia.*
>
> (Mihaijlo Marković, *Moje uspomene*, 1906)

7 The literature also wrongly mentions years 1898 ("Radiološki institut", in *Medicinska akademija Jugoslovenske narodne armije 1950–1960.* Belgrade, Vojnoštamparsko preduzeće, 1960, 93) and 1899 (Aleksandar Marković, „Moja radiološka iskustva u ratovima od 1912–1918", in Vladimir Stanojević, *Istorija srpskog vojnog saniteta: Naše ratno sanitetsko iskustvo*, 717. Belgrade: V. Stanojević, 1925).

According to the minutes of meetings of the Serbian Medical Society published in *Serbian Medical Archive*, X-ray image was first demonstrated at the Society on February 14 [26], 1898. Doctor Vojislav Subbotić, Head of the Surgical Department of the General State Hospital, presented to his colleagues a patient—girl with deformities of the left forearm, hand and fingers, which were a consequence of burns inflicted several years earlier. Apart from the patient, Dr Subbotić also presented a "diagram according to Roentgen made by prof. Mr Đ. Stanojević". Two months later, he also presented "a roentgenogram of a fracture, which became a subject of law proceedings" and then he continued to send his patients to do X-ray images at the Great School over the following years. However, it would so happen that Stanojević was away, so the patients had to wait for the images. That is why, in November 1901, Subbotić proposed to get an X-ray machine for the Hospital. Since the Hospital building was electrified in 1899, it appeared that the most important condition was met. But, the proposal, which the Hospital management sent to the competent authority, the Medical Department of the Ministry of Internal Affairs, ended up—"ad acta"!

Đorđe Stanojević (1858–1921), professor of physics at the Great School and the University of Belgrade, photographed in early 20th century in his study. Stanojević was the first person in Belgrade, starting from 1897, who took X-rays images.

(Source: Historical Museum of Serbia, Collection of Đorđe Stanojević, Inv. no. 4406-45)


Господину Министру Просвете и цркв. послова

С најодличнијим поштовањем

15 Маја 1899 год.
У Београду

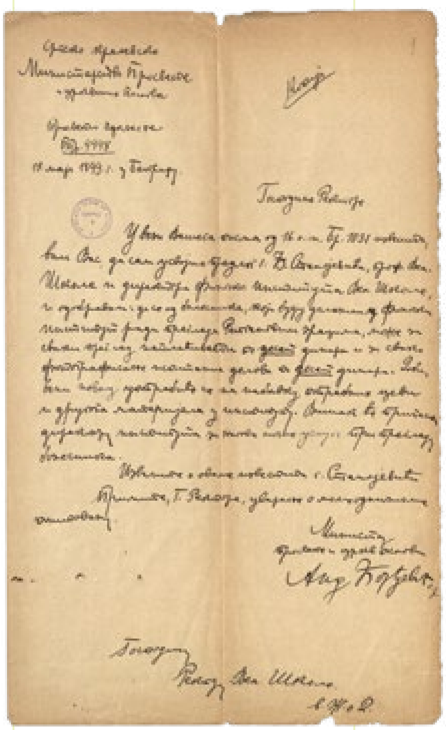
Ђ. М. Станојевић
Проф. и Управ. Физичк. Каб. Вел. Шк.

(Source: State Archives of Serbia, ME, 1899, XV, 24)

To Mr Minister of Education and Church Affairs

It's been two years since the local physicians have been bringing their patients to the Institute of Physics of the Great School for examination using X-rays. For all that time, I've been putting tubes, as well as my personal services at the disposal of patients and physicians free of charge. However, since the use of X-rays has recently become quite frequent, which causes frequent breakage of the tubes, it is my honour to suggest to Mr Minister of education ad church affairs to approve: that in the future, certain patients who seek the help of X-rays at the Institute of Physics, pay 10 dinars for each examination and to use that money, first of all, for the procurement of the necessary tubes, which are required for those examinations and for the rest, if there is any, to go to the bellow-signed for personal services that he has provided on every X-ray examination. The patients who are not satisfied with only the optical examination using X-rays, but also require taking photographs of the examined parts, shall pay additional ten dinars for each photograph taken with the X-rays. Photographic material and personal efforts invested in this shall be paid from that money.

With the most excellent respect, Đ. M. Stanojević
Prof. and Head of the Institute of Physics at the Great School
May 15, 1899
In Belgrade



(Source: State Archives of Serbia, GS, 1899, 1053)

Serbian Royal Ministry of Education and Church Affairs

Education Department EN0. 4448, May 18, 1899 in Belgrade

Mr Rector,

In regards to your letter from May 16, no. 1031, I inform you that I have accepted the proposal of Mr Đ. Stanojević, professor at the Great School and head of the Institute of Physics at the Great School and I approve to charge the patients who come at the Institute of Physics for X-ray examination, ten dinars for each examination and ten dinars for each taken photograph of the examined parts. The obtained money shall be used for the procurement of tubes and other material at the Institute. The surplus shall be given to the head of the Institute for his personal services in the examination of the patients.

Please, inform Mr Stanojević of this.
Be assured, Mr Rector, of my excellent respect.
Minister of Education and Church Affairs
And.[ra] Đorđević, signed

Dr Nikola Krstić (1878–1947), photograph from the World War I

(Source: Museum of Science and Technology, Collection of the Museum of Serbian Medical Society)

We can only assume why the suggestion was laconically dismissed—whether due to the lack of the appropriate budget item in the annual budget, the usual "frugality" of the state (the machine would inevitably cause expenses for consumables, training and hiring of additional personnel, etc.), current issue of the lack of space in the Hospital building or current investment in the construction of the new hospital complex in the part of the city that was at the time called West Vračar.[8] And perhaps, together with all that, one of the reasons was also "our incomprehensible indifference towards Roentgen rays", which Vinaver critically mentioned in 1904. The issue of procurement of X-ray machine for General State Hospital, renewed in 1905, was not positively resolved until 1907. And while the General State Hospital was "battling" against the competent ministry, in August 1906, the second X-ray machine arrived in Belgrade. 26-year-old Nikola P. Krstić, physician at the Surgical Department of the General State Hospital and pupil of Vojislav Subbotić, later founder of Serbian orthopaedics, bought the machine for his private practice. It was perhaps that same year[9] that Krstić made a roentgenogram of the hand of king Petar I Karađorđević, which contained a bullet logged there for over three decades after he had been injured in the Franco-Prussian war in 1870.

ROENTGEN INSTITUTE
FOR EXAMINATION AND TREATMENT
With Roentgen's X-rays
Dr N. P. Krstić

SECUNDARY PHYSICIAN AT THE SURGICAL DEPARTMENT OF THE STATE HOSPITAL
Introduced in his practice

X-RAY MACHINE
Examination of surgical, orthopaedic and internal diseases shall be performed using illumination (Roentgenoscopy) and taking pictures (Roentgenography).

X-ray irradiation shall be used for treatment of skin cancer (epithelioma) and other skin diseases.

WORKING HOURS 2 – 4
32 Makedonska Street.
Telephone no. 908.

Advertisement for Roentgen Institute of Dr Nikola P. Krstić,
(Source: *Politika*, August 19 [31], 1906; digitalna.nb.rs)

8 Today, it is a part of complex of the Clinical Centre of Serbia and it belongs to the territory of the Savski Venac Municipiality.

9 It is usually erroneously stated that Krstić procured the machine in 1904 and took the image of the King's hand in 1905.

Petar I Karađorđević (1844–1921), King of Serbia (1903–1918) and Kingdom of Serbs, Croats and Slovenes (1919–1921)

(Source: https://bs.wikipedia.org/wiki)

Therefore, that image was not, as it is often stated, the first roentgenogram made in Belgrade, but Nikola Krstić was the first physician in the capital who independently operated an X-ray machine and used the X-rays not just in diagnostic, but in therapeutic procedures as well.

Until the onset of the World War I, X-ray machines were also procured for their private practices by Dr Venceslav Stejskal Junior, physician of the Trnavski District of the Čačanski County (Čačak, 1910), as well as private physicians Josif Nedok (Kragujevac, around 1910),[10] Staniša Simić (Belgrade, 1912) and Dušan Radojković (Požarevac, 1914). Stejskal and Nedok's X-ray machines "survived" wars and occupation and they operated in the interbellum period as well.

Photograph of the roentgenogram of the left hand of king Petar I Karađorđević made by Dr Nikola Krstić. Petar Karađorđević was wounded in the Battle of Sedan, in the Franco-Prussian war (1870), in which he participated as a member of the Foreign Legion. He was not the ruler of Serbia at that time. The image shows a bullet in the 3rd bone of the wrist.

(Source: Museum of Science and Technology, Collection of the Museum of Serbian Medical Society)

10 Aleksandar S. Nedok, „Nedok, Josif, S". In *Srpski biografski rečnik*, vol. 7, ed. Branko Bešlin (Novi Sad, Matica srpska, 2018), 239–240. There is a different information in the literature—that the first "private" X-ray machine in the Šumadijski county came later, during the 1920's, in the private practice of Dr Anton Dlabač in Lapovo; See Dragoljub Milanović, Milan Stanković, *Lapovo: (monografija)* (Lapovo: Mesna zajednica, 1991), 145, 317; Nenad Karamijalković,*Česi u Srbiji i Crnoj Gori i Česi u Šumadiji* (Kragujevac: Centar za kreativni razvoj "Prsti", 2013), 152–153.

Dr Života Janković (1859–1932), Head of the first Department of Roentgenology in Serbia—Department of Roentgenology and Orthopaedics of the General State Hospital in Belgrade (1907)

(Source: Museum of Science and Technology, Collection of the Museum of Serbian Medical Society)

The First X-ray Departments in Serbia

The first X-ray department in Serbia was established on July 9 [21], 1907, on the day when Dr Života Janković, who was until then the head of the County Hospital in Kragujevac, was appointed by a Royal decree, head of the Department for Roentgenisation and Orthopaedics of the General State Hospital in Belgrade. According to the information from the archival material, that same year, "things for roentgenisation" and X-ray tubes were procured from the company *Rudolf Siebert* from Vienna for the newly established department. So far, we have no reliable data on the accommodation and the operation of the Department. It was most likely located in one of the five new surgical pavilions of the General State Hospital that were opened in the new hospital circle in 1907. The name of the department was changed the following year to Department of Roentgenisation, Photo-Therapy and Radiography; after the World War I, until the establishment of the Surgical-Orthopaedic Department on July 6, 1919,[11] it was called Department of Roentgenology-Orthopaedics and then, Department of Roentgenology. Doctor Janković, who advanced his knowledge in roentgenology and orthopaedics in Vienna and Munich, was the head of the Department for a long time, with a pause during the occupation in the World War I. He also managed the department after March 18, 1919, when he was appointed head of the General State Hospital. He performed both duties until retirement in 1922.

The same as the civilian health service, which delayed the procurement of an X-ray machine until the General State Hospital moved to the new hospital circle, the Medical Corps waited to start equipping the X-ray cabinet at the Military Hospital until the completion of construction of the new hospital complex, which was constructed in 1904 right next to the General State Hospital in West Vračar. Heads of the Medical Corps, Medical Corps colonel Dr Mihajlo Marković and his successors, Medical Corps colonels Dimitrije Gerasimović and Roman Sondermajer cooperated with the architect Danilo Vladisavljević in the designing of the pavilion. It was Sondermajer to whom the contemporaries have attributed the construction of the "magnificent" Surgical pavilion. And in that pavilion, quite likely thanks to Sondermajer's "great interest in the advancement of radiology", the rooms for "radiography" and a dark room were planned already in the designing phases of construction.

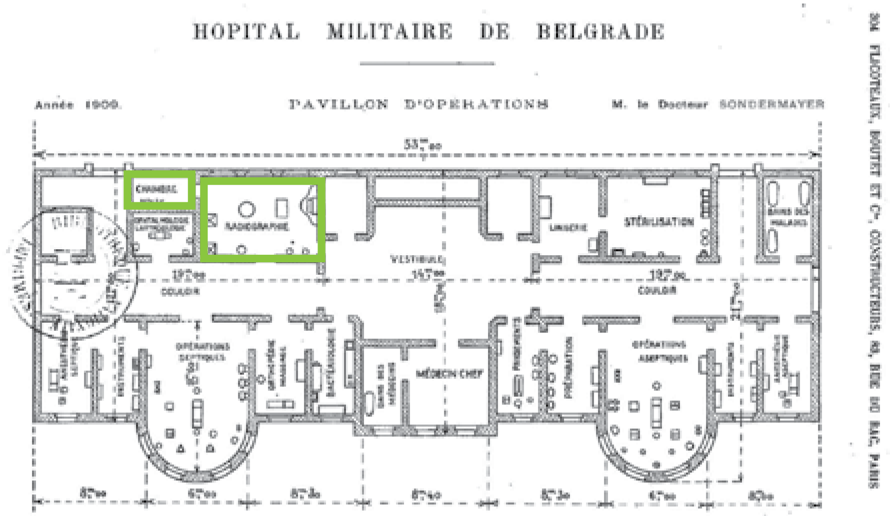
11 By the Decree from July 6, 1919, Dr Nikola Krstić was appointed head of the Surgical-Orthopaedic Department.

In 1909, the Hospital was moved from the old building in Cvetni trg and that same year, Medical Corps colonel Dr Aleksandar Marković was sent for specialisation as a trainee of the Ministry of Defence in Vienna, to study under professor Guido Holzknecht (1872–1931), one of the leading radiologists in the world. After Marković's return, on May 1 [13], 1910, "Radiological station", a unit of the Surgical department, began to operate, equipped with a new X-ray machine procured thanks to the efforts of the head of the Medical Corps at the time, Medical Corps colonel Dr Lazar Genčić. That "first good X-ray machine", remembered Marković, "held on for the entire occupation" in the World War I and until 1923, it "served for the entire work (diagnostic and therapeutic—author's note)". Aleksandar Marković managed the station, which from August 1919 to June 1920 became a separate unit, as well as Roentgenology Department from 1922,[12] until his retirement on March 6, 1939.

Before the onset of the World War I, certain hospitals in the interior of the country also got X-ray machines, including County Hospital in Šabac (1910) and both hospitals in Niš—civilian and military (after 1910). The X-ray machine in the County Hospital in Niš was a donation by tradesmen Nikolić brothers.

Dr Aleksandar S. Marković (1878–1961), Medical Corps brigadier-general, the first specialist roentgenologist in the Medical Corps (1922), founder of the Roentgenology Department of the Military Hospital in Belgrade.

(Source: University of Defence in Belgrade, Institute for Scientific Information, Department of Library and Archival Activity)



Layout of the Surgical Pavilion of the Military Hospital in Belgrade, 1909 (the designer was architect Danilo Vladisavljević). Rooms for "radiography" and dark room are marked in green.

(Source: *Appareils spéciaux pour hopitaux.* Paris: Flicoteaux, Boutet & Cie, 1911, 304; gallica.bnf.fr)

12 By the Decree from June 18, 1922, Marković was appointed head of the Roentgenology Department of the Permanent Military Hospital of the 1st Army area and by the Decree from June 4, 1930, head of the Department of Roentgenology and Physical Therapy of the Main Military Hospital. In truth, his previous position was only confirmed by this, but the previous names of the department and the hospital have changed.

Balkan Wars and the World War I

It is well-known that Serbia entered the Balkan wars, and especially the World War I, without adequate medical equipment. Military radiology service had only two “radiological stations”, in hospitals in Belgrade and Niš. They were both stationary, while mobile machines weren’t even available in the civilian medical service. Before the retreat across Albania and occupation of Serbia in 1915, all X-ray machines were used for examination of the wounded. Certain foreign medical missions had their own machines, but they were mostly out of commission because of the inadequate electrical installations. The lack of professional staff was also a problem because due to the insufficient number of physicians, even those few doctors who did have roentgenology experience were assigned to troops, dressing stations and field hospitals. “Radiology work on the battlefield or around it”, according to Aleksandar Marković, “was out of the question until we arrived at the Salonika Front”. It was only then that the Serbian Army got small, mobile X-ray machines, which were attached to army field hospitals—one to the First Field Surgical Hospital of the 2nd Army, which was stationed from 1916, first in Vasilica and then in Dragomanci,[13] and the second in the field hospital in Sorović (later Skočivir), which served the 1st and the 3rd Army. The X-ray machines, as well as other equipment, were donated by two French benefactors—to the hospital in Dragomanci, Comtesse de Chabannes de La Palice,

Building for X-ray machine installation in the circle of the First Surgical Hospital of the 2nd Army in the village of Dragomanci, at the Salonika Front, between 1916 and 1918. Photograph taken by Đorđe J. Žujović.

(Source: mladenzujovic.com)

Đorđe J. Žujović, medical student and André Gay, engineer who managed the X-ray installations at the hospital in Dragomanci. The photograph was taken between 1916 and 1918.

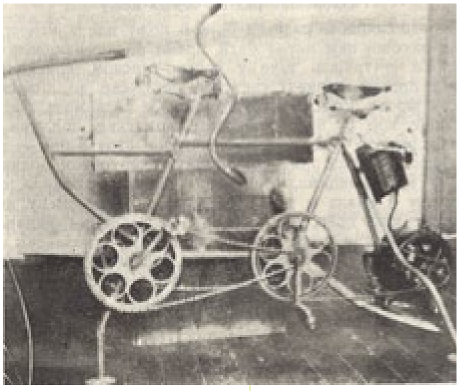
(Source: T. D. Jovanović. „Rendgenska dijagnostika u srpskom vojnom sanitetu od 1914.-1918)

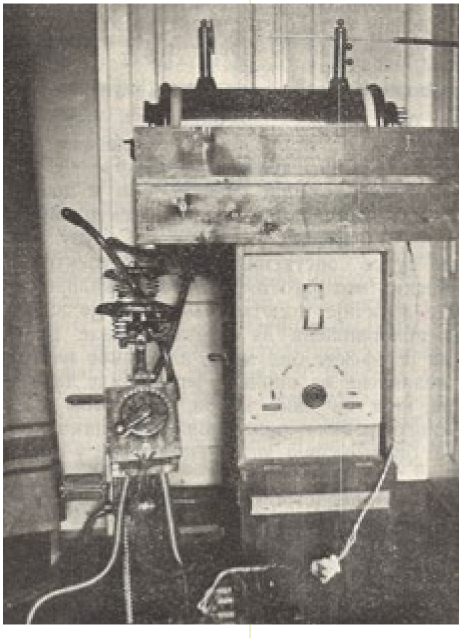
13 In the famous hospital in the village of Dragomanci (today, Apsalos) the surgical activities were managed by Dr Mihailo Petrović as a surgeon-consultant, and his teacher, Dr Vojislav Subbotić, also came occasionally to perform surgeries. After the establishment of the Faculty of Medicine in Belgrade, they both became professors of surgery. Among others, serving at the hospital was also medical student Đorđe Žujović, later professor of radiology at the same faculty.

and to the hospital in Skočivir, countess De Rénac. The machine in Dragomanci proved to be more useful, first of all, because it was operated by "an engineer from the X-ray machine factory", André Gay, who was able to quickly determine and fix any malfunction. There was no such expert in the second hospital and these small machines would often break down.

> *Out of all the modern aids, we had a small X-ray cabinet, which was, together with a mobile operating room and sterilisers, donated to us by Mrs Comtesse de Chabannes de La Palice, which has helped the Serbian Medical Corps and the Serbian wounded tremendously with this gift. Thanks to that cabinet and its roentgenologist, Mr Gay, who worked the entire time, we could at least use it to adjust broken limbs and pinpoint the places where the foreign bodies were located, and extract them in due time.*
>
> *Unfortunately, roentgenograms, which remained organised in boxes at the Surgical Department of the Military Hospital in Niš in 1918, were destroyed. It appears that the hospital thought that it would be better to use those glasses, which were, with the images, the only document of the X-ray work, to tile the table for bacteriological work.*
>
> Medical Corps colonel Dr Mihailo Petrović, 1925
>
> (Source: "Moja hirurška iskustva u ratovima 1912 – 1918", in Vladimir Stanojević, *Istorija srpskog vojnog saniteta: Naše ratno sanitetsko iskustvo*, 624. Belgrade: V. Stanojević, 1925)

However, the Serbian soldiers were also treated in Allied hospitals, French, British and Italian, which were mostly equipped with X-ray cabinets. The problems in their operation were frequently related to the power sources. French hospitals in Thessaloniki used city electrical grid, British their own sources in the shape of gasoline engines and batteries, while the Italian hospitals used "live force"—muscle work for powering a dynamo machine.





Mobile "X-ray installation", invented by Dr Aleksandar Marković (1920). The top picture shows the power-generating device, while the picture below shows the X-ray device. Although the Commission consisting of representatives of the Ministry of Army and Navy and the Ministry of Public Health gave a very positive review of this device in 1921 and recommended the procurement of several of these devices, the order was never made.

(Source: Marković, Aleksandar. "Moja radiološka iskustva u ratovima od 1912–1918", in Vladimir Stanojević, *Istorija srpskog vojnog saniteta: Naše ratno sanitetsko iskustvo*, 715–725. Belgrade: V. Stanojević, 1925)

It was precisely upon the model of Italian installations, which have proven to be “the most independent in operation”, that after the war, Aleksandar Marković constructed a mobile X-ray machine, which he then offered to the Medical Department of the Ministry of Army and Navy free of charge.

Entrance gate of the Serbian Hospital of the Crown Prince Aleksandar in Thessaloniki, between 1916 and 1918

(Source: Museum of Science and Technology, Collection of the Museum of Serbian Medical Society)

Serbian Hospital of the Crown Prince Aleksandar, established in 1917 in Thessaloniki, also had an X-ray cabinet, with a machine manufactured by French company *Gaiffe*. In that cabinet, under the management of Aleksandar Marković, around 4,000 roentgenisations were performed in 20 months—the period in which the hospital was working until the breakthrough of the Salonika Front. Different diagnostic and therapeutic procedures were performed on patients suffering from surgical, internal and dermatological diseases. In order to enable the most precise possible localisation of bullets in shooting injuries, they applied stereo-radiography and Hirtz compass; extractions of bullets and foreign bodies were performed with the control using X-rays and X-ray therapy was also applied in the treatment of skin diseases.

Here, we should also mention that no description of the location of the bullet nor the image can give such a topographic idea of its localisation as the joint observation in the X-ray cabinet. Professor Dr Subbotić did not want to extract a single bullet unless he previously informed himself of its position in relation to its surroundings in the X-ray cabinet. And for every such operation, he wanted to be assisted by a roentgenologist. The bullet would be quickly found and removed. Other surgeons did not fare so well because they would satisfy themselves with a description of the location of the bullet and they would not make sure of its location nor they called a radiologist to assist them during operation.

Medical Corps colonel Dr Aleksandar Marković, 1925

Interbellum Period

After the end of the World War I, in the new state, Kingdom of Serbs, Croats and Slovenes, later Yugoslavia, significant efforts were made to develop the health system and medical education. Ministry of Public Health and Ministry of Social Politics were established,[14] as well as a network of preventive and curative health institutions, three faculties of medicine—in Belgrade, Zagreb and Ljubljana, medical chambers, and apart from the existing medical societies, new professional associations were also established. However, the material factor was limiting; in the early 1920s, the country exhausted by war did not manage to meet all the needs, and by the end of the same decade, the Great economic crisis hit. Still, it is indisputable that even in those circumstances, a significant improvement was made in the field of medicine and health care. Medical protection of the population was advanced, the number of physicians increased and the faculties began scientific work.

Development of radiology, which in this period acquired the status of a separate medical discipline, was marked by establishment of specialist departments and institutes at the larger hospitals, and then the Institute of Radiology of the Faculty of Medicine and Institute for Radium Therapy in Belgrade; procurement of modern devices; equipping a large number of private practices and sanatoriums with X-ray machines; professional training of physicians for work with X-ray machines and acquiring titles of roentgenologist specialists; election of the first teachers of radiology and roentgenology and establishment of the Department of Clinical Radiology and Roentgenology at the Faculty of Medicine in Belgrade, as well as establishment of Yugoslav Society for Research and Suppression of Cancer (1927), Radiology Section of the Serbian Medical Society (1929) and Yugoslav Society of Radiology (1930), which organised two congresses of the Yugoslav radiologists, one in Split (1930) and the other in Belgrade (1935).

By the Decree on specialist physicians (October 29, 1919), for the first time, the doctors were given a possibility to acquire a title of a specialist in a certain medical discipline, whether based on their previous work and experience or by medical specialty training. Doctor Sava O. Janković, who acquired his roentgenology specialist title on March 8, 1922, was probably the first specialist in his field. Janković advanced his knowledge in Geneve and Paris and from December 1920,

14 In 1929, the ministries were merged into a single institution called the Ministry of Social Politics and Public Health.

Dr Sava O. Janković (1887–1942), the first specialist radiologist (1922), Head of the Institute of Roentgenology (1928–1942), private docent for roentgenology at the Faculty of Medicine in Belgrade (1933–1942)

(Source: *Srpski biografski rečnik*, vol. 4, ed. Čedomir Popov, 305–306. Novi Sad: Matica srpska, 2009)

he worked in Belgrade as a secondary physician at the Roentgenology Department of the General State Hospital. He was appointed head of the department in 1923, after Dr Života Janković had retired. The Department had diagnostic and therapy section. Diagnostic section was equipped with two Siemens machines, one of which was used for roentgenography and the other for roentgenoscopy. Therapy section conducted deep, postoperative therapy of gynaecological and surgical patients (using the 200 kV Siemens machine *Stabilipan*), as well as surface therapy of malignant and non-malignant skin diseases. In 1928, the Department transformed into the Institute of Roentgenology, which was headed, until his death in 1942, by Sava Janković. Under his management, the first roentgenologists completed their education and they were later founders of specialist services in health institutions in Belgrade and the interior of the country. Since 1933, Janković was also a private docent of roentgenology at the Faculty of Medicine.

Another two important radiological institutions were established in Belgrade in the late 1920s—Institute of Radiology at the Faculty of Medicine[15] and the Institute for Radium Therapy (1928).[16] The Institute of Radiology was established on October 7, 1927, by appointment of Dr Dragoljub K. Jovanović,[17] former assistant at the Institute for Radium in Paris, as part-time professor of radiology and head of the Institute. At the Institute of Radiology, right after the procurement in Czechoslovakia in 1928, a single gram of radium, procured for the purpose of treatment of all oncological patients in the country, was stored in special conditions. The Faculty of Medicine in Belgrade was given 550 mg, while the Faculty of Medicine in Zagreb obtained 450 mg. The original plan was for the Institute, apart from its scientific and educational activities, to serve as a “radiological station”, i.e., besides storing the radium, to also prepare therapeutical doses, while the therapy itself would be administered at the Institute for Radium Therapy. However, this plan was changed just before the Institute for Radium Therapy, which took over the radium in May 1932, finally began to operate.

15 The name of the Institute was changed in 1932 to Institute of Radiology and Physics; in 1937, to Institute of Physics; in 1977, to Institute of Biophysics and in 2004, to Institute of Biophysics in Medicine.

16 The original name was Institute for Research and Suppression of Cancer and the Institute was a part of the Central Hygienic Institute until 1932, when it was attached to the General State Hospital.

17 Dragoljub K. Jovanović (1891–1970) graduated in 1919 at the Faculty of Philosophy in Belgrade (Department of Physics, Physical Chemistry and Chemistry) and that same year, he was appointed assistant for the subject Chemistry. After that, he advanced his knowledge in Paris and worked as an assistant to Marie Curie at the Institute of Radium (*Institut du radium,* today *Institut Curie*) and in 1925, he obtained his doctoral degree at Sorbonne with a thesis on the subject of radiology. He was elected regular professor for the subject Physics in 1939 and after the World War II, he was the head of the Institute of Physics until 1964. He also taught at the Faculty of Natural and Mathematical Sciences, Faculty of Dental Medicine and Faculty of Pharmacology. He was elected corresponding member of SASA in 1948.

Due to numerous difficulties, preparations for the start of operation of the Institute for Radium Therapy lasted almost four years. In the medical circles, for a long time there was no consensus regarding the organisation and scope of activities of the Institute; they discussed the most adequate accommodation and it was also necessary to educated the professional staff for the work with the radium. Before the start of operation, the Institute had four different managers. One of them was Dr Jelena Alković,[18] who worked as a radiologist since 1923, and advanced her knowledge in the field of radiotherapy in 1930 at the best radiotherapy centres in Europe—Prague, Paris, Erlangen and Munich. Although she did not obtain the official title of "radiology/roentgenology specialist" until March 3, 1932, Jelena Alković was most likely the first Serbian woman specialist in this field.

Advertisement for Philips X-ray machine *Metalix Super T*, 1935

(Source: *II jugoslovenski radiološki sastanak, Beograd 18, 19 i 20. maja 1935:* Izveštaj. Belgrade: [Jugoslovenski radiološko društvo], 1935)

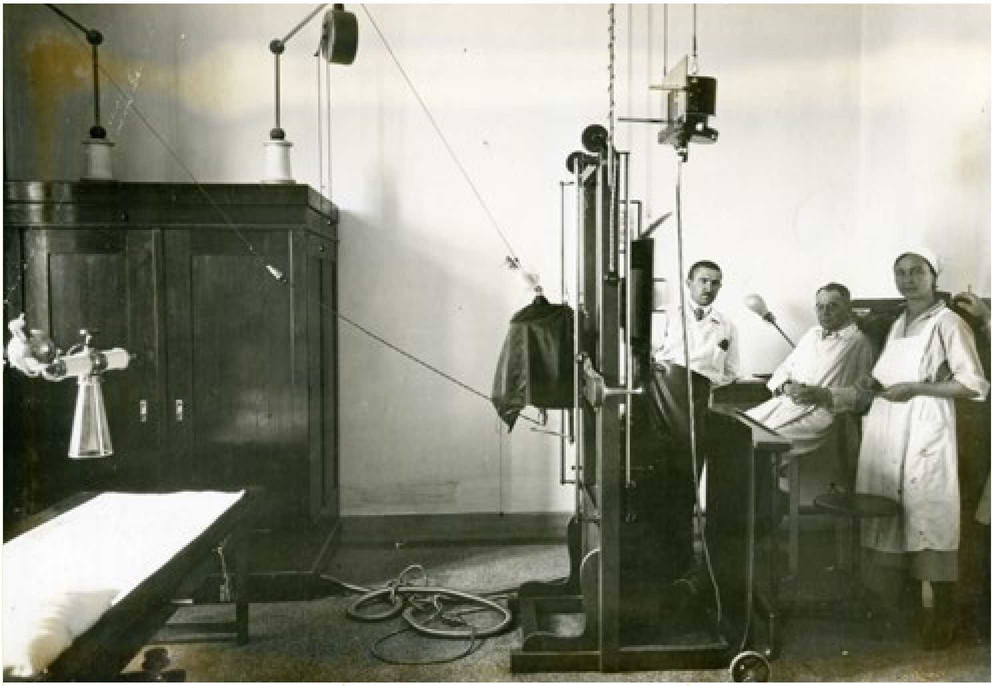
May 23, 1932 is considered to be the date of the start of operation of the Institute for Radium Therapy because on that day, doctor Dimitrije Miodragović[19], who was appointed head of the Institute a month earlier, performed the first application of radium on a patient with a cervical cancer. During the first year of operation, over 500 applications were performed, but it was clear already then that the Institute's capacity does not meet the needs of the population. After the World War II, its organisation went through significant changes.

In the early 1920s, all the clinics of the Faculty of Medicine got X-ray cabinets, but due to the lack of expert radiologists, some of them were operated by internists and surgeons. The most modern machine manufactured by the company *Siemens*, *Heliopsos*, with a table for a Bucky grid[20] that directs the X-rays, was obtained after the move to a new building in 1929 by the Internal Propaedeutic Clinic.

18 Jelena Alković (Ub, 1894 – ?, after 1946) studied medicine in Italy, Russia and in Paris, where she graduated in 1923 and completed a one-year course of roentgenology. As a roentgenologist, she worked at the Military Hospital in Belgrade (1923–1924), the First Clinic for Internal Diseases (1924–1925) and the Centre of National Health in Peć (1925–1929). From November 1, 1929 to November 1, 1931, she was a physician at the Institute for Research and Suppression of Cancer (from April 18, 1931 as acting head of the Institute). As a private roentgenologist, she then worked in Teslić (1932–1938) and in Skopje (1938–1941). After the World War II, she was the head of the Department of Roentgenology at the County Hospital in Prizren. She was married to Dr Gedeon Geza Alković, epidemiologist.

19 Dimitrije J. Miodragović (Niš, 1889–1959), son of the educator and writer Jovan Miodragović, specialised in gynaecology and obstetrics (1922) and radium therapy (1932); he was the head of the Institute until February 1945.

20 Gustav Bucky (1880–1963) was a German-American radiologist, constructor of the "Bucky grid" (1913),which enabled obtaining good-quality diagnostic images of the thicker parts of the body. The grid made of lead, which is placed between the patient and the film, directs the beam of X-rays by absorbing the scattered rays.



X-ray cabinet of the 4th Propaedeutic Clinic of the Faculty of Medicine in Belgrade, photograph from 1936

(Source: Museum of Science and Technology, Collection Museum of the Serbian Medical Society)

The cabinet was managed by Dr Stojan Dedić, from 1935, the head of the Department of Clinical Radiology and Roentgenology at the Faculty of Medicine. Dr Mileta Magarašević, later also a professor of radiology, trained alongside him. Since 1938, in the cabinet, they used a tube with a rotating anode and precise focus (Siemens *Pantix*), the first of its kind in Yugoslavia.

> *In the left corner of the room, there is a closet with a high-voltage transformer with four ventilation tubes, while two high-voltage insulators and a milliampermeter are located on the closet. A trochoscope is located in front of the closet, with a 'Metalix' X-ray tube and a lead tube, while underneath it is a horizontally placed illumination tube. A Bucky grid is installed in the trochoscope. On the right is the stand with an X-ray tube without the hood, which is covered by a black cloth so that light could not be seen when it's on. The tube is connected to two bare wires which conduct high voltage and above it is a round glass flask with water which is used to cool down the tube. In front of the stand is a screen 40 x 40 cm in which the cassettes are places [containing the film—author's note]. If needed, a Berg's device for target shooting of bulbus duodeni is lowered down from the ceiling. It contains six 9 x 12 cm cassettes. Behind the protective cart are sitting, from left to right, Dr Mileta Magarašević and assistant prof. Dr Stojan Dedić, and standing is the laboratory technician Olga Jablanova.*

Description by Prof. Dr Mileta Magarašević
(Source: *Jedan vek radiologije u Srbiji* 1895–1995, 27)

Part of the General State Hospital circle. At the end of the street is the building which housed the Institute of Roentgenology (on the ground floor) and Institute of Radium Therapy (on the first floor).

(From the collection of Miloš Jurišić)

In 1923, Roentgenology Department at the Military Hospital in Belgrade obtained a “modern” X-ray machine, probably the first one with a thermoelectric Coolidge tube in Serbia. At the time when it moved to its own building, which was officially opened on July 6, 1930, in the presence of king Aleksandar Karađorđević, the Department had at its disposal five machines, some of which were acquired on the account of war reparations.

For the Hospital in Zemun, which had an X-ray machine already in 1901, the new Siemens machine was purchased in 1930. In Belgrade, X-ray machines were also possessed by Railway Workers Infirmary (1925), private sanatoriums Vračar, *Pantović*, *Simić*, *Farkić* and *Stanković*, as well as numerous private practices. The City Hospital, endowment of Nikola Spasić, which was opened in 1935, was equipped with half-wave X-ray machine, but it did not have a roentgenologist, so the imaging was done by internists. Just before the April war in 1941, the most modern Siemens *Tridoros* machine with six ventilation tubes and a seriograph was procured.

Participants at the 2nd Congress of the Yugoslav radiologists, in front of the St. George Church in Oplenac, 1935

(Source: *II jugoslovenski radiološki sastanak*, Beograd 18, 19 i 20. maja 1935: Izveštaj)

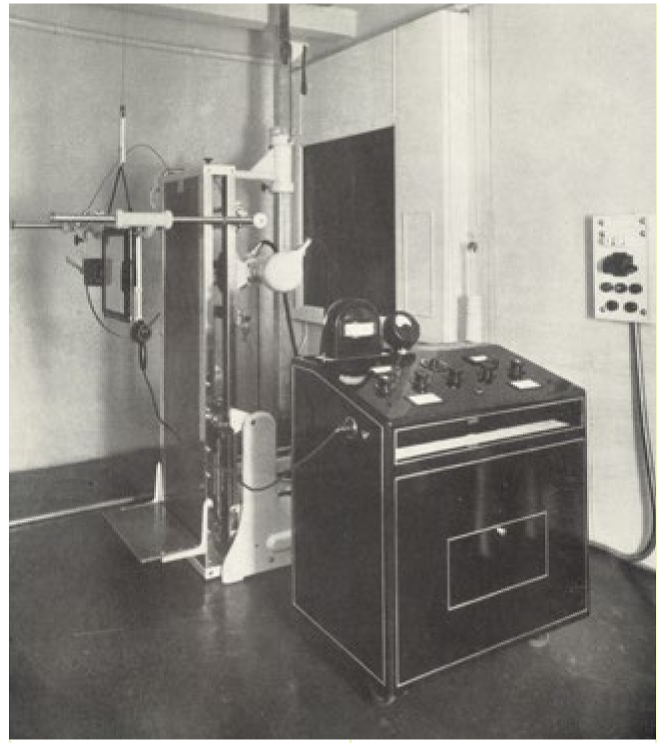
The process of equipping the hospitals in the interior of the country was quite slow. From the review of condition and operation of all the civilian hospitals in the state for year 1923,[21] which was published by Dr Dobrivoje Gerasimović Popović, Chief of the Ministry of Public Health, it can be seen that in that year, apart from the General State Hospital, the hospitals in Novi Sad, Zemun, Subotica, Zaječar and Niš also had the X-ray machines, but only those in Zemun and Subotica were in commission. Popović emphasized that each hospital should have at least one and many even two machines. However, the hospitals were in such state that the machines were not even on their minds yet—the buildings were mostly old and unsuitable, many of them had no electricity nor running water, and there was also a lack of beddings and other basic necessities. The example of the County Hospital in Kragujevac is quite illustrative—in 1923, it moved to a new building, but they used petroleum for lighting and brass furnaces for heating, while the water was brought in buckets.

21 Dobrivoje Ger. Popović, "O bolnicama". *Glasnik Ministarstva narodnog zdravlja – vanredno izdanje*. Belgrade: Štamparija Drag. Gregorića, 1923.

Three years later, three machines were procured, for the hospitals in Kragujevac, Šabac and Valjevo, and several roentgenology departments were established—in Šabac (1926), Novi Sad (1928), Kragujevac (1929), Subotica (1937) and Zrenjanin (1938). Institute of Roentgenology was established at the County Hospital in Niš (1932), while the hospitals in Vranje (1937, a donation by tradesman Jovan Jovanović Lunge) and in Požarevac (1939) also got X-ray machines. Anti-tuberculosis dispensaries and public health centres were also equipped with X-ray machines.

In numerous towns in Vojvodina, X-ray machines were in use at the time when that province was still a part of the Austrian-Hungarian empire. The first machine, procured in 1899, was at the hospital in Sremska Mitrovica. However, most of the X-ray machines, not just in Vojvodina, but also on the territory of today's narrow Serbia and Kosovo and Metohija, were until the onset of the World War II, a private property.

X-ray machines and equipment were purchased from various European manufacturers, but most often from Siemens and Philips, not just because of their quality, but also because the procurement was facilitated by their companies in Yugoslavia—*Jugoslovesko Simens JSC* and *Filips jugoslovensko trgovačko akcionarsko društvo*.



Advertisement for Philips' diagnostic X-ray machine *Metalix Super D* ("the shortest exposure times, uniform results, the greatest savings on the tubes"), 1935. година

(Source: *II jugoslovenski radiološki sastanak, Beograd 18, 19 i 20. maja 1935: Izveštaj*)

Advertisement for Shoe store *Boston* in Belgrade, *Politika*, September 5, 1930. X-ray shoe-fitter device Pedoscope, which was used to check if the shoes fit the feet, was invented by American Clarence Karrer in 1924. The device was particularly popular in American shoe stores and it remained in use until the 1970s.

(Source: digitalna.nb.rs)

X-ray tube housing (early form of a protective casing) made of leaded glass, wood and leather. The “leaded” glass protects the medical staff against radiation and an X-ray beam goes through the rectangular opening on the bottom of the housing. The pole on the cover was used to position the X-ray housing above the body part whose image is being taken. The housing was probably made in the first decades of the 20th century.

(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT:T: 11.1.374)

X-ray tube *Energie Rörhe N^0 20 D.R.G.M. 22765*, around 1930

(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT:T: 11.1.375)

Personal protective equipment for protection against X-rays — lead apron and lead gloves manufactured by *Picker X-Ray Corporation*, around 1940

(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT:T: 11.1.352; 353; 354)

After the World War II

In the second half of the 20th century, a huge advancement was made in the world in the field of radiology, first of all, thanks to the application of computer technology which enabled improvement of classical radiological methods, as well as implementation of new diagnostical and therapeutic procedures. The radiologist's scope of activities was significantly broadened and today, it includes both application of certain methods of biomedical visualisation ("imaging"), which are not based on the use of ionising radiation (ultrasonography, nuclear magnetic resonance) and the radiological procedures in the therapy of various diseases. Modern approach in the therapy of oncological patients implies team work of radiologists and other specialty physicians. Diversification of the fields of activity and the need to master specific knowledge and skills impacted the radiologists to make advancements in narrow professional fields and work in certain fields of radiology.

Starting from the end of the World War II until modern times, the health system in Serbia tries to follow the global trends in the field of radiology, first of all by implementation of modern procedures, but a significant "breakthrough" was also made in the early 1950s in the field of X-ray machine manufacture, when the company *Jugorendgen*, part of the EI Niš concern, began operating. The same as in all other areas of social life, during the crisis in the 1990s, at the time of the break-up of Yugoslavia, economic sanctions by the United Nations Security Council and NATO bombarding, the work in the field of radiology was plagued by numerous difficulties. After a whole decade of stagnation, the development continued in the early 21st century.

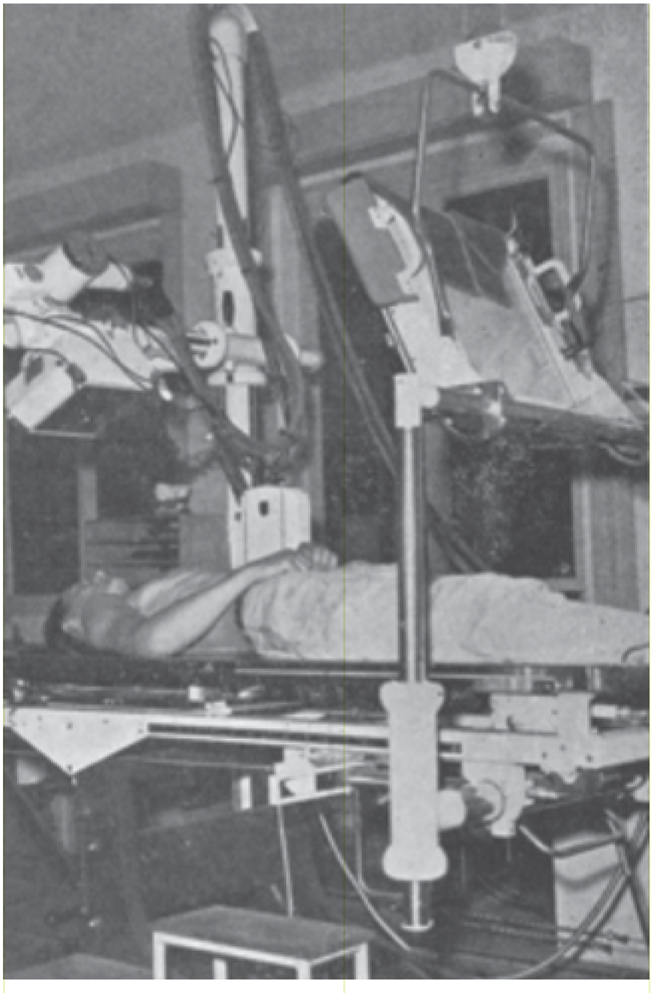
Tomographic imaging of a patient at the Institute of Radiology of the Military Medical Academy in Belgrade, 1950s

(Source: *Vojnomedicinska akademija Jugoslovenske narodne armije 1950 – 1960*. Belgrade: Vojnoštamparsko preduzeće, 1960)

In accordance with the subject of our exhibition, in the continuation of the text, we will present the history of application and development of roentgenology technologies, i.e., technologies based on the use of X-rays, while the radiotherapy procedures based on the use of other sources of radiation (radium and artificial isotopes) will not be discussed.

Early post-war years were marked by efforts to capacitate the health institutions to work in the field of X-ray diagnostics. A certain number of X-ray machines was obtained as help from the UNRRA,[22] and the goal was largely achieved when the production of machines, X-ray tubes and other equipment began in *Jugorendgen*. The locally manufactured machines, especially the first models *Morava*, *Selenos*, *Neretva*, *Telestatix* and others, were the most common X-ray machines on the territory of Serbia starting from 1953 until the 1990s. Right after the abolition of private medical practice in 1959, a shortage of available machines and physicians who operated them was felt, but due to the spreading of tuberculosis, the state tried to "cover" even the health stations in small towns with X-ray machines. However, although it increased, the number of radiologists was still insufficient compared to the needs. Not only small, but the large health institutions as well, including certain clinics of the Faculty of Medicine, didn't have a permanent radiologist for years. The condition in that regard has improved when apart from the Faculty of Medicine in Belgrade, Institute of Radiology at the Military Medical Academy (1950) and newly founded faculties of medicine in Niš (1960), Novi Sad (1960), Priština (1969) and Kragujevac (1977), also became centres for specialty advancement.

22 United Nations Relief and Rehabilitation Administration, active between 1943 and 1947, helped the war victims in terms of food, fuel, clothes, medical equipment and other necessities.



Imaging of a patient at the Radiography Department of the Institute at Radiology of the Military Medical Academy in Belgrade, 1950s

(Source: *Vojnomedicinska akademija Jugoslovenske narodne armije 1950 – 1960*. Belgrade: Vojnoštamparsko preduzeće, 1960)

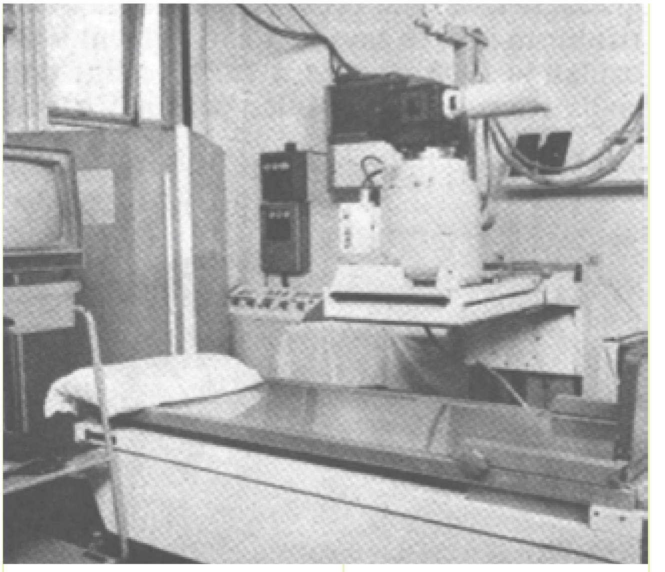
Education of professional staff with secondary level of education, X-ray technicians, which began in school year 1951/52 at the Medical School in Belgrade, was interrupted in 1957/58 in accordance with the provisions of the Law on Protection against Ionising Radiation. After that, for eight years, the Faculty of Medicine in Belgrade held 4-month courses in order to educate this kind of professional staff. In school year 1974/75, after several years of preparations, at the Medical College in Belgrade, the Department for X-ray technicians began to operate. In this period, professional associations also intensified their work. Radiology section of the Serbian Medical Society was reconstituted on December 15, 1946, while the Radiology Technicians Association of Serbia, as well as a section of the Health Workers Association of Serbia, were founded in 1964. Main objectives of both associations were advancement of radiology and professional advancement of the members.

The health institutions in the capital had the most developed radiology services. Just after the merger of the General State Hospital and the Clinical Hospital of the Faculty of Medicine, that same year, 1947, the Institute of Roentgenology and Institute for Radium Therapy were also merged in a single institution called Institute of Radiology at the Faculty of Medicine. The first head of the Institute, prof. Dr Stojan Dedić, managed the Institute until 1955. The Institute was an expert institution of the level of Yugoslavia and it performed examinations in the domain of general radiology, imaging for the purpose of planning radiation therapy, as well as education in the field of radiology. Under the same roof, at 14 Pasterova Street, was also the Institute of Oncology Ksenofon Šahović, and the integration of those two institutions into today's Institute of Oncology and Radiology of Serbia was done in 1980. Apart from the existing institutions, today's clinical hospital centres Dr Dragiša Mišović (1952) and Bežanijska kosa (1956), with their own radiology departments, were also established. Institute of Radiology at the Military Medical Academy was one of the leading radiology centres in the country. Numerous procedures of minimally invasive diagnostics, which were first introduced in the field of vascular radiology in the 1950s, were performed in this Institute, as the first in Yugoslavia or in Belgrade.

More intensive equipping of the radiological centres with modern machines which enabled the implementation of new diagnostical procedures, began in the 1960s. Different devices were procured, including devices for classical tomography (imaging of tissue sections for more precise localisation of pathological changes), devices with electronic image enhancers and a TV chain (with the possibility of making serial images under the control of radioscopy) and automatic X-ray film processors. Diagnostical radiology got a new momentum in the 1970s, when perfected and less toxic contrasts came into use, but first of all, when the method of computerised tomography (CT) was introduced. A year after the application of this method began in the Mayo Clinic in the USA (1973), the first computerised tomography device arrived in Serbia and it was installed at the Neurosurgical Clinic in Belgrade.

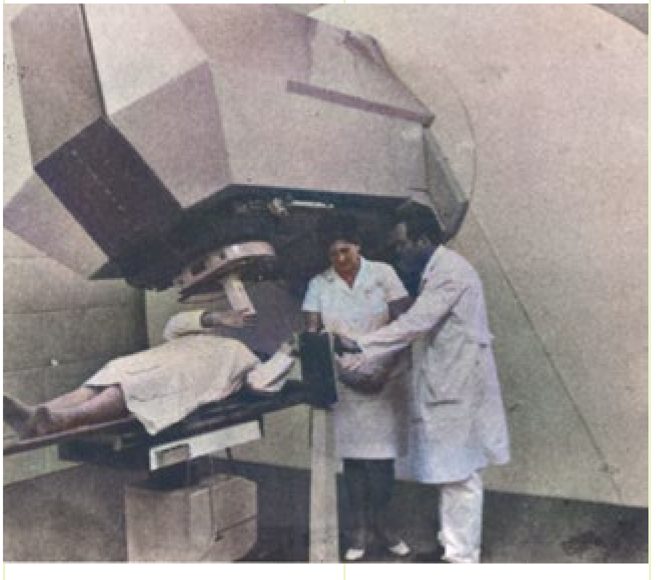
The same as in the field of X-ray diagnostics, in the early post-war years, the foundations were also placed for the further development of radiation therapy. Between 1946 and 1948, the Institute of Radiology got, as a donation from UNRRA, devices for surface and deep X-ray therapy, as well as 4.5 grams of radium. The procurement of modern devices continued successively in the following decades as well, mostly from the company Siemens. In 1970, the first linear accelerator,[23] 42 MeV *Betatron*, for X-ray and beta irradiation, was purchased from the same company. It was the strongest teletherapy device in the word at the time. Radium, which was predominantly used in the treatment of oncological patients, was removed from use in 1977 when the artificial radioactive isotopes were introduced. At the time, Institute of Radiology was, on a global level, one of the institutions with the greatest number of treated patients annually. Centres for radiation therapy in Belgrade also included Belgrade City Gynaecological Hospital (today, Obstetrics and Gynaecology Clinic Narodni Front), Skin and Venereal Disease Clinic and Central Dispensary for Skin and Venereal Diseases (from 1963, City Institute for Skin and Venereal Diseases).

23 Medical linear accelerator speeds up the electrons and adjusts the high-energy X-rays to the shape of the tumour. In that way, it destroys tumorous cells and spares the surrounding healthy tissue from radiation.



X-ray machine *Philips GDR* with transistorized TV chain, from 1963 (Clinical Hospital Centre Zemun)

(Source: *Jedan vek radiologije u Srbiji 1895–1995*)

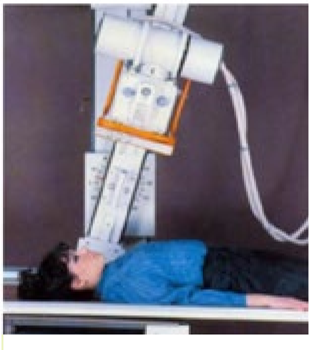


The first accelerator in Serbia — 42 MeV *Siemens Betatron*, procured for the Institute for Oncology and Radiology of Serbia in 1970.

(Source: *Jedan vek radiologije u Srbiji 1895–1995*)

Diagnostic X-ray machine *Bukigraf 2*

(Source: *Bukigraf 2*, El Jugorendgen (brochure), [n.d.])



X-ray therapy and radiation therapy were also performed in the interior of Serbia. Apart from the regional health institutions in Novi Sad, Niš and Kragujevac, hospitals in Užice, Subotica, Zrenjanin and Regional Institute of Oncology and Radiology in Kladovo were also equipped with machines for X-ray therapy. Further development was achieved only in larger centres by introducing into practice the radioactive isotope therapy, in Novi Sad (1967), Niš (1969), Kragujevac (1981) and Kladovo.

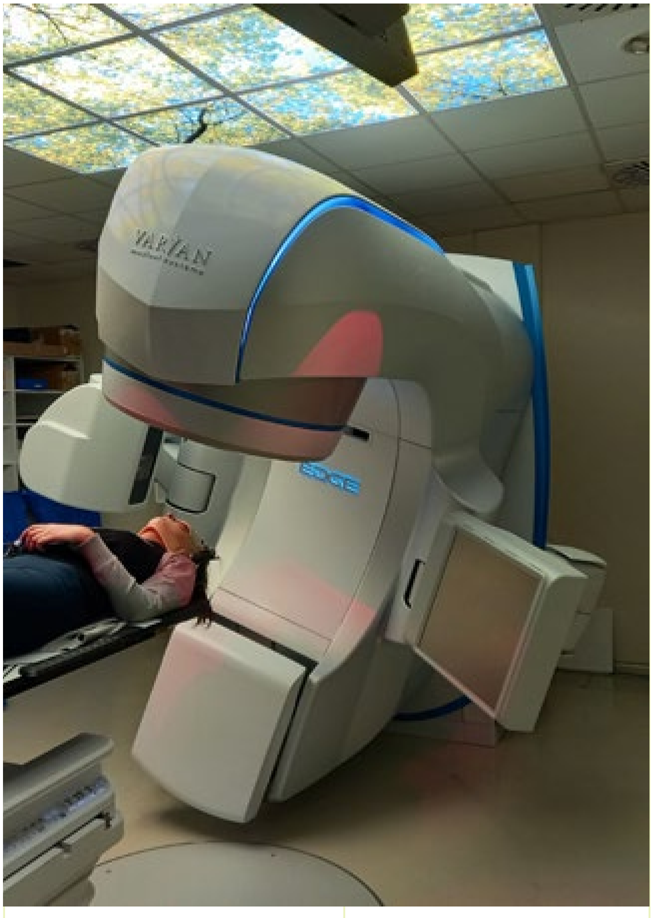
During the last two decades of the 20th century, there were some significant changes regarding the institutional organisation of work—two new radiological centres were established—already mentioned Institute of Oncology and Radiology (1980), under the management of prim. Dr Kuzman Granić and Radiological Diagnostics Service of the University Clinical Centre (1991), which included, under the management of prof. Dr Branislav Goldner, X-ray departments and cabinets of all the clinics. Four years later, the Service transformed into the Institute of Radiology of the Clinical Centre of Serbia.[24] After the Military Medical Academy moved to a new building in 1980, its Institute of Radiology got modern equipment and new staff, which further enabled implementation of new procedures, especially in the field of interventional radiology. After several years of unsuccessful attempts to organise a radiation therapy service, in 1982, application of X-ray therapy in oncological patients began in Priština. Institutes in Novi Sad (1984), Niš (1986) and Kragujevac (1988) were equipped with linear accelerators.

24 University Clinical Centre, which was created in 1983 by the merger of clinics and institutes of the Faculty of Medicine, changed its name in 1992 into Clinical Centre of Serbia.

The 1980s were also the time of implementation of digital technologies which significantly sped up the work, especially in the area of diagnostics. Also, application of computerised tomography became wider—ultrasound diagnostics was introduced in the medical practice and in 1990, University Clinical Centre in Belgrade procured a nuclear magnetic resonance device, the first in Serbia.

Over time, the specificities of working in both main fields of radiological profession, diagnostic and therapeutic, have led to their clearer demarcation. That is why the members of the Radiology Section of the Serbian Medical Society who performed radiation therapy founded a new section in 1988—Radiation Therapy Section, and in 1994, the Radiology Section changed its name to Radiological Diagnostics Section. Upon the initiative of prof. Dr Branislav Goldner and prof. Dr Željko Marković, in 1992, the Section launched a professional journal titled *Radiološki arhiv Srbije* (RAS), which was published until 2003.

By the end of the first decade of the 21st century, the most modern method of medical imaging—Positron emission tomography (PET), which is primarily used in patients with oncological, neurological and cardiovascular diseases, was introduced in the medical practice in Serbia. In the treatment of oncological patients, radiation surgery methods based on the use of gamma irradiation of radioactive isotopes (Gamma knife, since 2015), or application of high-energy X-radiation (X-knife/Cyber knife, since 2018) are applied. In the field of manufacture of X-ray devices and equipment, there were also some significant changes. In cooperation with the company Visaris from Belgrade, in 2005, Jugorendgen founded a joint company JR Digital X-Ray, which, that same



X knife *Varian*, Clinical Centre of Serbia — Centre for Stereotaxic Surgery and Stereotaxic Radiation Therapy, 2021

(The photograph was obtained by the courtesy of Prof. Dr Jovica Šaponjski and Dr Biljana Šeha) year, manufactured the first digital X-ray machines. However, faced with financial difficulties, in 2007, Jugorendgen exited the joint business and after a few years, it ceased to operate completely.

Visaris has continue to develop the production of digital X-ray machines, first through cooperation with company JR Digital X-Ray, and then, from 2008, independently.

Today, Visaris is the only manufacturers of digital X-ray machines in the Balkans and apart from the local, they are also present in the foreign market.

Sources

Archives of Yugoslavia, Fund of the Ministry of Social Politics and Public Health of the Kingdom of Yugoslavia—Personalia.

State Archives of Serbia, funds: Ministry of Internal Affairs—Medical Service, Ministry of Public Health of the NR Serbia, Ministry of Education and Church Affairs—Department of Education and Great School.

Historical Archives of Belgrade, Medical Chamber Fund.

Literature

"I redovni sastanak – držan 14. Februara 1898". Srp Arh Celok Lek 1898; IV (6):258–263.

"IV redovni sastanak – držan 2. Aprila 1898". Srp Arh Celok Lek 1898; IV (8):360–4.

"V redovni sastanak – držan 18. Aprila 1898". Srp Arh Celok Lek 1898; IV (9):404–5.

Alković, Jelena. "Saradnja praktičnih lekara sa Zavodom za rak i o lečenju najčešćih formi raka". Srp Arh Celok Lek 1930; XXXII (12):1020–1928.

Banjac, N. "Mihailović, Jelenko". In *Srpski biografski rečnik*, vol. 6, ed. Čedomir Popov and Branko Bešlin, 867–868. Novi Sad: Matica srpska, 2014.

Bogdanović, M., D. Kermeci. "Panajotović, Jovan". In *Srpski biografski rečnik*, vol. 7, ed. Branko Bešlin, 849. Novi Sad: Matica srpska, 2018.

Bogićević, Aleksandar P. *Osnovi iz rentgenologije*. Belgrade: Štamparska radionica Ministarstva Vojske i Mornarice, 1934.

Vinaver, Avram. "Pet godina lečenja Rentgenovim zracima". In *Prvi kongres srpskih lekara i prirodnjaka pod najvišom zaštitom Njegovog Veličanstva Kralja Petra I: u Beogradu 5, 6 i 7 septembra 1904 god*. Vol. 1, Lekarsko-apotekarska sekcija, ed. Vojislav M. Subotić and Vojislav Kujundžić, 364–373. Belgrade: Državna štamparija Kraljevine Srbije, 1905.

Vinaver, Avram. "Prilog lečenju Rentgenovim zracima. Lupus erythematodes". Srp Arh Celok Lek 1902; VIII (7): 296–7.

Ivanović, Dragan. *Kolevka zdravstva u Srbiji*. Ruma: Srpska knjiga, 2003.

Institut za onkologiju i radiologiju Srbije: od osnivanja do 2015. godine, ed. Radan Džodić. Belgrade: Institut za onkologiju i radiologiju Srbije, 2015.

Jedan vek radiologije u Srbiji: 1895 – 1995, ed. Branislav Goldner. Belgrade: Srpsko lekarsko društvo, Sekcija za radiološku dijagnostiku, 1995.

Jovanović, Stanka. *Dragoljub K. Jovanović - život jednog fizičara*. Belgrade: B. Gerzić, 2015.

Karamijalković, Nenad. *Česi u Srbiji i Crnoj Gori i Česi u Šumadiji*. Kragujevac: Centar za kreativni razvoj "Prsti", 2013.

Marković, Aleksandar. "Moja radiološka iskustva u ratovima od 1912–1918", in Vladimir Stanojević, *Istorija srpskog vojnog saniteta: Naše ratno sanitetsko iskustvo*, 715–725. Belgrade: V. Stanojević, 1925.

Marković, Mihajilo. *Moje uspomene*. Belgrade: Štamparija Dositije Obradović, 1906.

Marković, Predrag, Čedomir Antić, Danilo Šarenac. *Korak ispred vremena: 125 godina Simensa u Srbiji* [1887-2012]. Belgrade: Simens: Institut za savremenu istoriju, 2014.

Medicinski fakultet Univerziteta u Beogradu 1920–1935. Belgrade: Stručno tehnička litografija "Lito štampa", 1935.

Milanović, Dragoljub, Milan Stanković. *Lapovo: (monografija)*. Lapovo: Mesna zajednica, 1991.

Nedok, A. S. "Nedok, Josif, S". In *Srpski biografski rečnik*, vol. 7, ed. Branko Bešlin, 239–240. Novi Sad: Matica srpska, 2018.

Petrović, Mihailo. "Moja hirurška iskustva u ratovima 1912 – 1918", in Vladimir Stanojević, *Istorija srpskog vojnog saniteta: Naše ratno sanitetsko iskustvo*, 623–666. Belgrade: V. Stanojević, 1925.

„Radiološki institut", in *Medicinska akademija Jugoslovenske narodne armije* 1950–1960, 93–95. Belgrade: Vojnoštamparsko preduzeće, 1960.

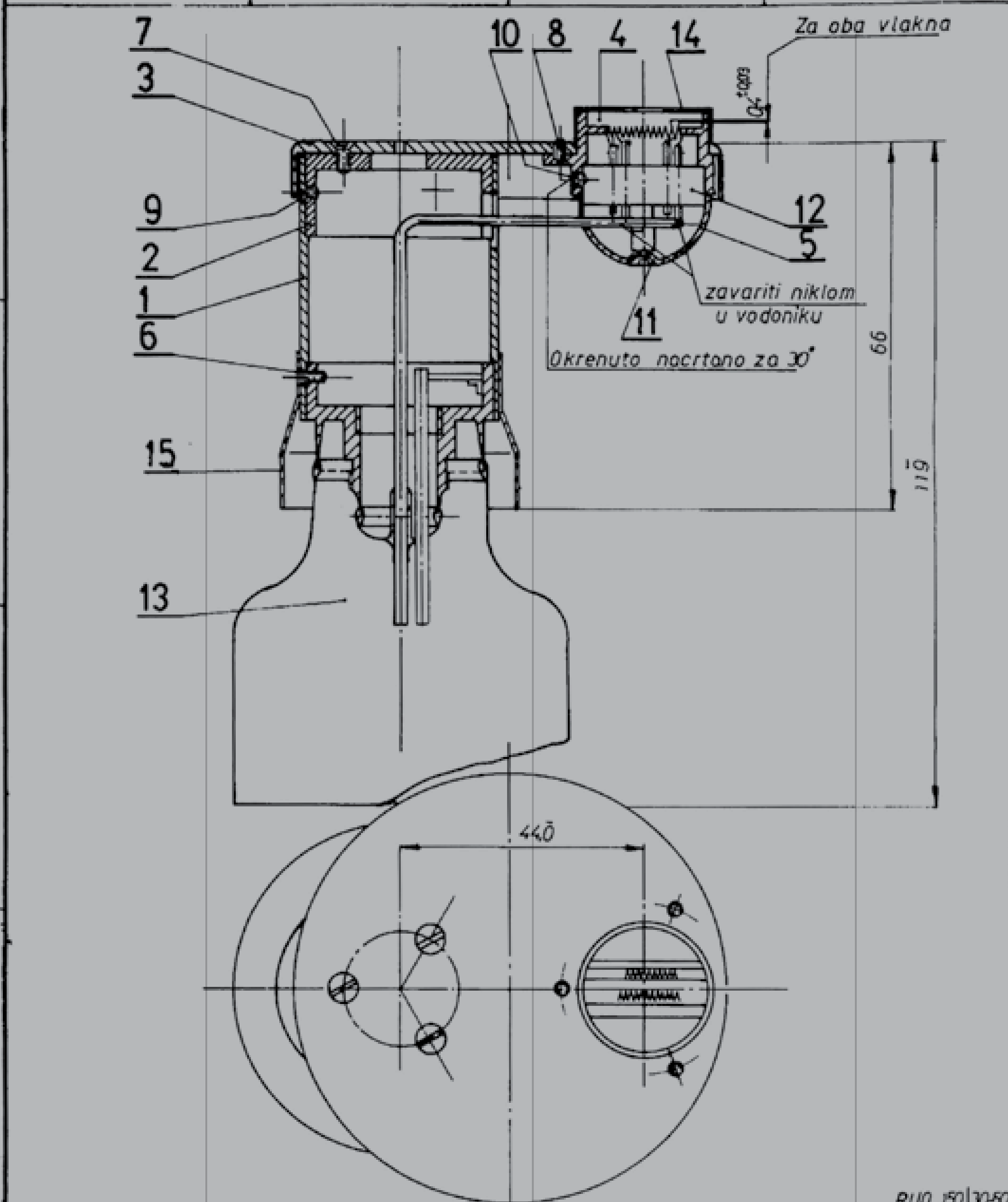
Stojiljković M. P, Zeljković, J, M. Životić-Vanović. "Iz istorije Vojnomedicinske akademije: VIII – Rendgenologija, fizikalna medicina i apoteka". Vojnosanit Pregl 2005; 62(6):495–501.

50 godina Medicinskog fakulteta Univerziteta u Beogradu, ed. Stanoje Stefanović et all. Belgrade: Galenika, Farmaceutsko-hemijska industrija, 1970.

Čikarić, Slobodan. *Radioterapija: ilustrovana istorija*. Belgrade: Ecolibri, 2006.

The Press

Vreme; Glasnik Ministarstva narodnog zdravlja; Ženski pokret; Zastava; Narodno zravlje; Prosvetni glasnik; Službene novine Kraljevine Srba, Hrvata i Slovenaca; Srpske novine.



Tolerancija slobodnih mera	Merilo 1:1
Materijal	
Šifra	

Term. obrada – Površ. zaštita

	Datum	Potpis
Izrad.	8.1.91	
Kont.	8.1.91	
K.std.		
Odob.		

Izm.	Datum	Br. izm.	Overio

Naziv

Katoda, sklop

ELEKTRONSKA INDUSTRIJA
OOUR 5.1

Šifra 6831936

Dok. 39 Je. 10

List ___ L

Klasif. 39 3205 0180

Zamena za: X3 844 00

EIS 010 003

Aleksandar Vl. Marković

X-RAY MACHINE FACTORY / RR ZAVOD / EI JUGORENDGEN NIŠ

1948 — Beginnings

The first years after the end of the World War II brought general shortage and great difficulties in the procurement of new machines, as well as spare parts for the existing X-ray machines. The use of old machines without the new X-ray tubes was practically impossible. The idea of construction of a factory that would satisfy the local needs for electronic material existed since 1946, but its realization did not begin until 1947. That same year, Government of the Republic of Serbia sent Dr Lazar Petrović to *Siemens* company in Germany to secure the necessary tubes. However, upon the advice of their management, Dr Petrović has decided to accept the idea of the German experts and instead of procuring spare X-tubes, he took over the entire facility for complete production of X-ray tubes, radio tubes and devices.

With the formation of the Institute for Production of Radio Equipment and X-ray Tubes in 1948, the company *RR Zavod Niš* was also established and it included several subsidiary companies from Niš, Belgrade and other cities in Serbia.

The city of Niš was selected as the place where the factory was going to be built. The laying of foundation stone in 1948, seven kilometres from Niš towards Niška Banja, marked the start of construction of the Institute for Production of Radio Equipment and X-ray Tubes—*RR Zavod*, but also a more serious industrialization of the city of Niš. Thanks to the construction of *RR Zavod*, which later transformed into *Elektronska Industrija*, Niš has become a Serbian industrial and university centre south of Belgrade.

The *RR Zavod*'s employees gained their first experiences and training in Germany, on the overhaul of a facility for production of X-ray tubes damaged in the war. Preparations for the start of the tube production took place in a small department of the *RR Zavod* in the early 1950s. Further development and work have shown that it was precisely this area of production that was going to become primary and recognisable activity of the company *EI Niš*.

After the war, there were not enough experts in Serbia, so over one hundred German experts and experienced workmen were hired to work as both instructors and advisers at the *RR Zavod*. They came to Niš together with their families and in order to attract them to come to Serbia, the managers of the Serbian economy secured good wages for them. For the purpose of hiring German expert employees, the Directorate of Metal and Radio Industry in Belgrade even established its own agency in FR Germany in order to find expert work force of various profiles to work at the Institute in Niš. During 1949/1950, there were 148 engineers and workmen in Niš.

German workers intermittently stayed in Niš until 1952, and their presence has facilitated the start of production at the *RR Zavod*. It was not just about the usual start of production and running-in of the manufacturing process, it was also a strong encouragement to the development of complex electromedical devices. Since the 1950s, this initial cooperation with the German economy and *Siemens* itself, was given a systematic shape which, over time, transformed into a strategic partnership. Namely, *EI Niš* went through several severe crises in its history and that also reflected on its cooperation with foreign partners, but two companies, *Philips* and *Siemens*, have marked every stage of its production. In the meantime, the country began opening towards the West, which also included Germany, in the academic sense as well. Upon invitation, German engineers, among others, F. Glieb, engineer at the German company *Siemens* Schuckert, also gave lectures at the faculties of the Belgrade University.

In 1950, based on the laws that were in force at the time, the management of the company *RR Zavod* was given over the workers, which is also testified by a plaque on the building of the EI Holding.

Plaque “Factories to Workers” from 1950; it still stands on one of the buildings of EI Niš

(Photographed by Rifat Kulenović, 2021)

In the production facility, 1950s

(Source: Documentation of *EI Jugorendgen*)

Before they have mastered the technology and production of the first X-ray tubes and machines, the primary task of the small collective at the X-ray manufacturing facility was maintenance of the imported machines. A special momentum in the development of this organization was gained in 1952, after the hiring of adequate expert staff directly from the university, when the department hired many electrical and mechanical engineers with university degrees, as well as physicists, chemists and workers from vocational schools.

Mastering the Technology

Until 1952, the production process was in the run-in phase and the working collective was acquiring initial experience. Most of the German workers were working in management positions, while the best local workers worked as their deputies. The construction and equipping of the production and auxiliary facilities has continued, all with the purpose of mastering the production of the first products and their components, as well as organization of serial production and conquering the market. Financial conditions and the number of staff available for this were quite modest, but the construction of all the facilities necessary for the full production process and especially the equipping of the production facilities in order to commission them, was set as an imperative. Organisational policy stipulated going from the investment phase to the phase of production and selling of their own products, i.e., the phase of profitable operation, as soon as possible.

After four years of working at *RR Zavod*, from 1948 to 1952, the contracts with most of the workers brough in from Germany had expired, so during 1952, they successively began to leave the production facilities of *RR Zavod* and return to their homes. However, the contract was extended to a small number of German experts, so they remained at *RR Zavod* for a little longer.

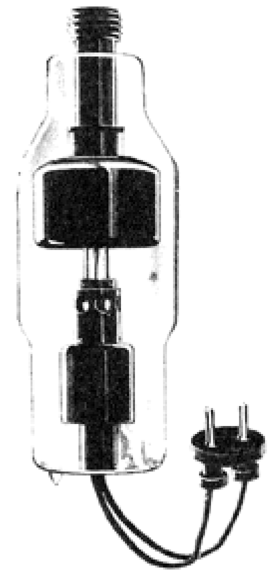
The Production of the First X-Ray Tube *Vul 120/800*

In 1952, there was a sharp turn in the production policy of the *RR Zavod*. Operational teams have already been fully capacitated to work with successfully mastered prototypes of certain products, while the fresh energy was introduced by the first post-war generation of university-educated experts. Everything was ready for organisation of individual and serial production of the first products.

After mastering the technology and successful testing and examination in the development laboratories of the factory, the first locally manufactured X-ray tube, with a commercial name *Vul 120/800*, was produced that same year, which practically set the foundations of the X-ray industry in Yugoslavia.

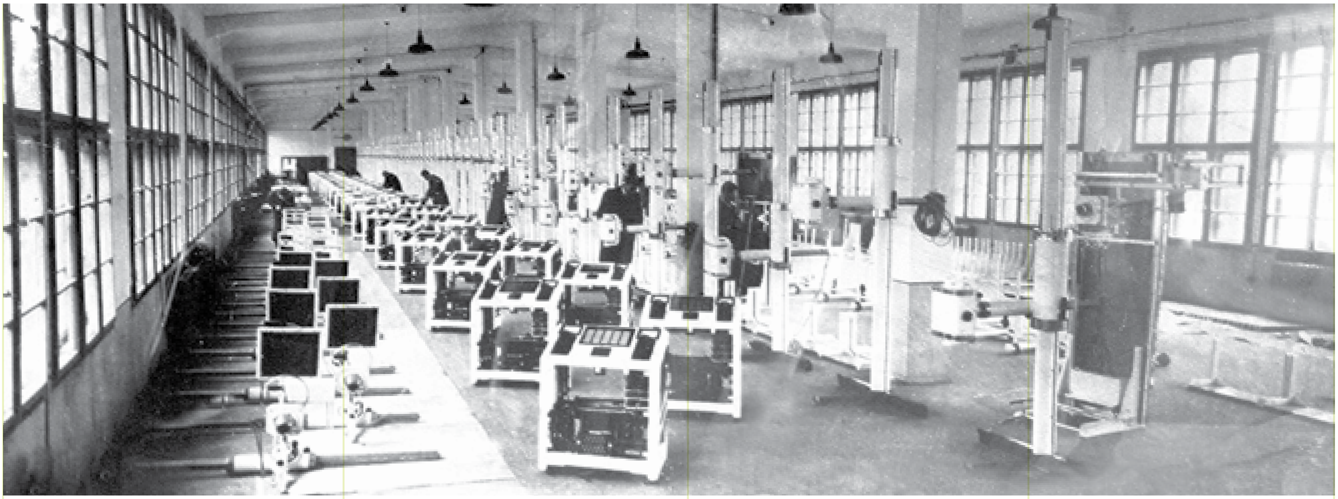
However, mastering the production of the X-ray tubes did not cause a sensation in the public. It was only the installation of the first X-ray machine, made mostly out of imported parts, that has managed to arouse greater interest. After the installation at the *RR Zavod* was complete, on May 1 1953, this product was exhibited at the Shopping Centre *Napred* in Niš, which wasn't yet finished, and it stirred a huge attention of the curious passers-by. After that, it was more than logical to expect the quick mastering of the mass production of this attractive product.

A weekly newspaper from Niš, *Narodne novine*, reported the following in relation to the efforts to master the new products: "With its construction, *RR Zavod* has also developed its own production with which it mastered new products that had been previously imported from abroad. They mastered six kinds of radio tubes, as well as X-ray machine *Morava*, whose serial production will start during this year. Besides, the collective has also mastered a new product, acetylene gas generator". Therefore, they already had a series of products for the market and the most important components for those products. With this kind of business and development policy, *RR Zavod* slowly but surely, came out of the anonymity and began conquering the local market which has displayed a huge interest in the products made by the electronic engineers from Niš.



The first X-ray tube *Vul 120/800*

Source: Ranđelović, *Pola veka u korak sa svetom 1948–1998*.



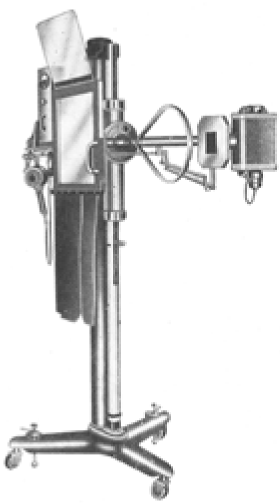
Assembly department, 1955

(Source: Ranđelović, *Pola veka u korak sa svetom* 1948–1998)

1953 — Production of the First Local X-Ray Machine

After the start of production of the first product—the X-ray tube, the previous year, in 1953, they continued to master new products and expand the assortment of X-ray tubes. That is how the department of X-ray tube production began to manufacture kenotrons, which immediately found their practical use. The hospital in Niš gave a good grade to the quality of this article and certain quantities were sold immediately. That same year, they also began serial production of X-ray tubes and the scope of production would increase continuously each year.

The year 1953 will be marked as historical due to the start of production of the first final products. The first locally manufactured X-ray machine, *Morava,* was produced at that time and its first series, which included 10 pieces, was completed already in the fall of that same year. The design, first of the 5 prototypes and the first 10-piece series, was done by the *RR Zavod*'s engineers— engr. Aleksandar Lukirić, engineers and technicians Miodrag Pavićević, Đorđe Orlić, Krsta Mihajlović, Miodrag Apostolović, Vukadin Bokić, Ozren Parkajić, Jovica Čelić, Miodrag Zdravković and Đorđe Radenković, as well as two German engineers Reihold Erler and Nyman, who participated in the creation of the conceptual design and concept of the electrical part of the machine.



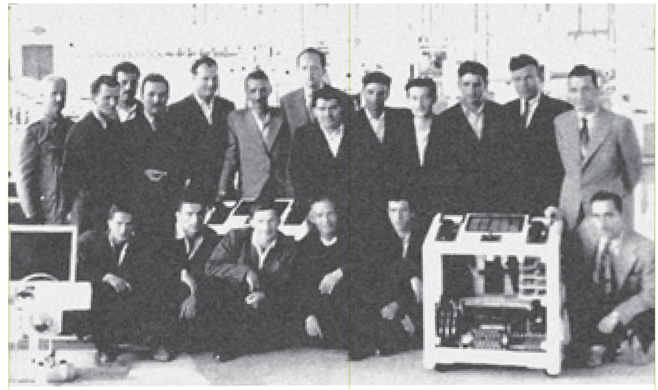
Рендгенски апарат *Moravica*

(Извор: *Rendgen aparati, pribor i el. med. uređaji.* Niš: Elektronska industrija, [1966])

That same year, they produced a light, mobile universal X-ray machine *Moravica*, first of all, for the needs of Yugoslav National Army. It was primarily intended for use in field hospitals in wartime. The machine had less power and it could be powered from field generators. Soon after *Moravica*, they developed a portable universal X-ray machine *Neretva* in several variants with increased power—30 mA, 85 kV.

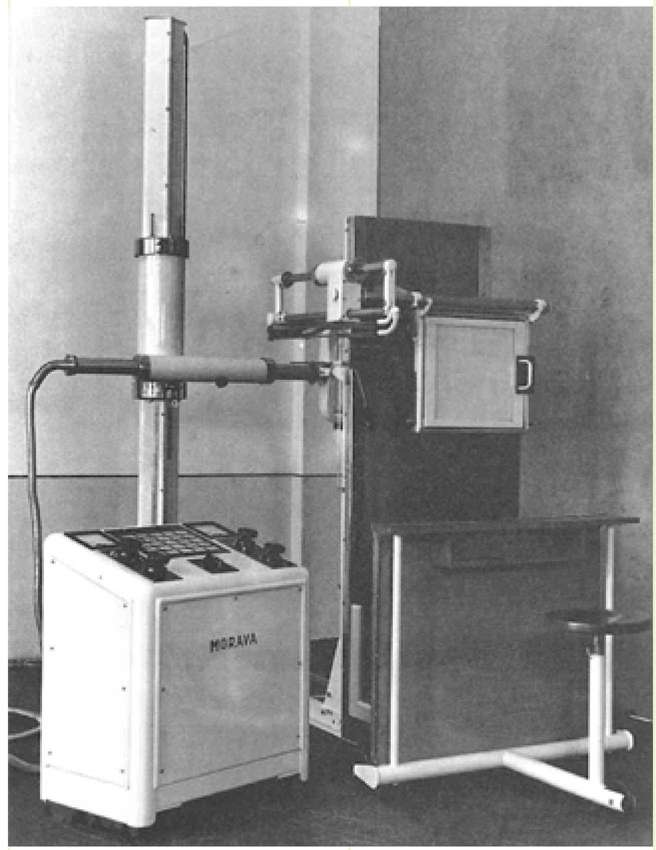
The first locally manufactured stable universal diagnostic X-ray device *Morava* (with 150 mA power at 70 kV), was manufactured in a series of 1,500 pieces. This quantity of X-ray machines did not just meet the local needs of health institutions in the 1960s, but certain quantities of this product were also exported to several other countries. However, the *RR Zavod*'s ambitions included improvement of the existing and mastering of the new products. Since their staff was not yet sufficiently trained, in order to realise that kind of ambitions, it was necessary to rely on renowned foreign companies.

With successive employment and training of the staff, since its foundation until mid-1953, the collective of the *RR Zavod* has grown to over 600 employees, third of whom were women. Mastering technology and preparation of X-ray machine production started in a small department (in the 1950s), which would later grow into an economic unit (in the 1960s), then basic organisation of associated labour (1970s), up until the transformation into a social company (1990s) and finally, a shareholder company (late 1990s) and joint-stock company (*EI Akcionarsko društvo za proizvodnju rendgen aparata, uređaja i pribora EI Jugorendgen Niš*, in 2003).



Employees at the Assembly department with the X-ray machine *Morava*, 1955

(Source: Ranđelović, *Pola veka u korak sa svetom 1948–1998*.)



X-ray machine *Moravica*

(Source: *Rendgen aparati, pribor i el. med. uređaji*, Niš, Elektronska industrija, 1966)

X-ray tube *VVL 150/500* manufactured at RR Zavod in Niš in 1956, in its original transport packaging. A donation by the Faculty of Electrical Engineering at the University of Belgrade, 2005

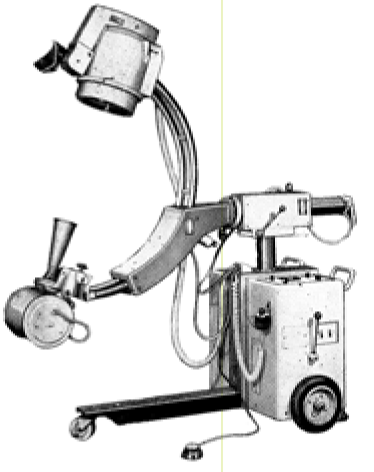
(Source: Museum of Science and Technology, Collection of medical technology, Inv. no. MNT:T: 11.1.391)

1960 — New products

In the 1960s, the company first established business and technical cooperation with the German company *Siemens* and then, a little later, with the Dutch company *Philips* as well. From the later production of the local X-ray machines, the following stand out: *Hipos*, which was, in a way, a “forerunner” of the future family of portable X-ray machines with electronic image enhancer; *Dent*, dental X-ray machine; *Unifos*, stable diagnostic X-ray generator with increased power (100 mA, 100 kV); *Buki sto bs3*, diagnostic stand, and *Fluorograf*, a special X-ray system, i.e., an X-ray machine for serial chest X-ray imaging of a large number of persons on a film tape. Namely, fluorography means taking pictures of a small-format images obtained using X-ray machine on a fluorescent screen using a film. It was used for taking chest X-ray screening of a large number of persons, mostly with the goal of eradication of pulmonary tuberculosis. It was possible to install the machine in a bus, which enabled the examination of patients even in the most remote places in the country.

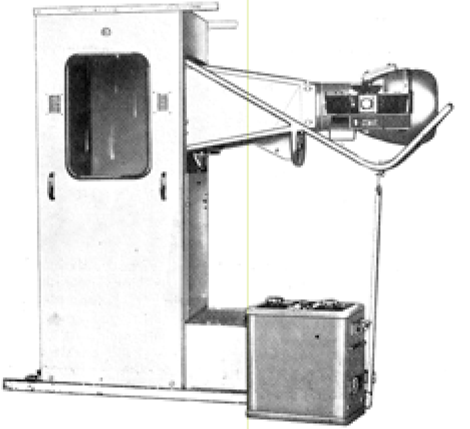
They also manufactured two machines that were also used for radiation therapy: *Terix* – surface therapy machine and *Kobaltron*—a deep therapy device. For the industry, they also produced *Irax 300*—industrial X-ray machine for examination of materials.

After the exchange of experts with the *Siemens* (staff from Niš would go for advancement in Germany, while the *Siemens* staff would come to *RR Zavod* and do the training “on the spot”). they mastered the production of several top-quality products of greater power: *Grafoskop, Selenos 4, Buki sto bs3* and others. The first one was advanced and complemented over time, so it



Hipos — X-ray machine with a 7” image enhancer on a movable stand, intended for use in surgery

(Source: *Rendgen aparati, pribor i el. med. Uređaji*. Niš: Elektronska industrija, 1966)



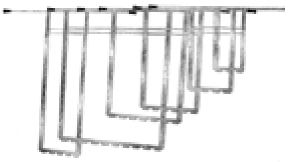
X-ray machine *Fluorograf* for mass chest X-ray imaging

(Source: *Rendgen aparati, pribor i el. med. Uređaji*. Niš: Elektronska industrija, 1966) changed its name to *Dijastatiks* and it was successfully complemented with *Selenos 4* and *Superx 800* device. There were also diagnostic stands type *Stub-G, Stub-U, Rastiks, Bukistat-2n, Bukimob, Bukigraf* and others. Of course, we should not forget the strongest X-ray generators *Superx 1250* and *Superx 712/1012 MP*, manufactured based on a *Siemens* licence.

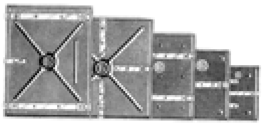
X-ray machines manufactured by *RR Zavod* became a synonym for quality. The demand for them on both local and foreign market has grown, but the available capacities of the factory could not meet the needs, so some buyers had to wait for delivery for several months and not so rarely, even a whole year. At one point, there was a crisis in the relationship with the *Siemens*, but the management of the X-ray factory found a solution in establishing cooperation with *Philips*, with which they also mastered the production of six-valve X-ray machines, which were considered higher class compared to the four-valve machines that they had been producing until then.

In 1969, *RR Zavod* and *Siemens* signed a new contract on cooperation which would later turn into a long-term partnership of mutual interest and to a mutual satisfaction. Based on this contract, among other things, *Siemens* was obliged to take over the parts and assemblies manufactured according to its specifications in the factory in Niš and after the installation into its own products, distribute them to its partners around the globe. In the 1970s and 1980s, in cooperation with foreign companies, *RR Zavod* also mastered the production of six-pulse and twelve-pulse X-ray machines type *Plafostat, Superx 800, 1000* and *1250,* as well as modern X-ray stands *Telestatix*, *Unistat* and other top-quality X-ray machines.

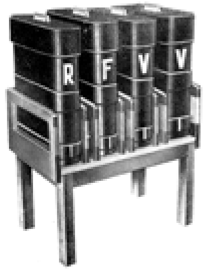
In terms of organization, from 1948 to 1962, as well as later, as part of the *EI Niš*, up until 1968, the X-ray machine factory (created by merger of *RR Zavod* and *Beogradska elektronska industrija Belind*) operated as a joint facility with *Elektromedicina*. At that time, on the level of EI, the so-called groups were formed, so the X-ray machine factory (RA) and the electromedical device factory (EM) in Niš, with the medical device factory *Sutjeska* in Belgrade, obtained a certain higher level of independence within the Electromedicine group.



Frames to hold the films during development in deep tank and during storing in closets



Cassettes for placing films for imaging



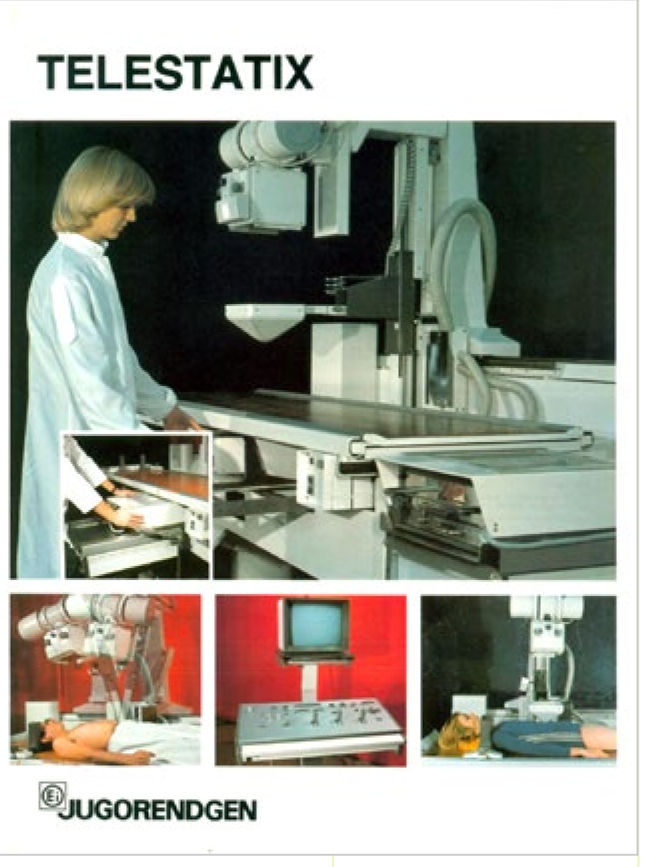
Film developing tanks

(Source: *Rendgen aparati, pribor i el. med. Uređaji*. Niš: Elektronska industrija, 1966)

1970s — Development and Increase of Capacity

In 1970, *Eletromedicina* got its own facility and from January 1, 1973, the X-ray machine factory was organized as a basic organisation of associated labour, within the EI, and from then on it was called *EI Jugorendgen*.

Regardless of the organizational changes, reorganisations and transformations, the X-ray factory increased the scope of production each year, improved the quality of the existing and mastered new products. In the meantime, the technical staff was fully capacitated, so apart from the machines made in cooperation with foreign partners, they also mastered the production of devices of their own construction. That is how in the 1970s, not just on the local, but also on the foreign market (especially in the so-called “developing countries”), the locally manufactured X-ray machine *Mobilix 4* became quite popular. Not far behind it were the other machines constructed in this factory: *Hipos*, *Tomograf,* dental machine *Bukistat* and others. And the new market for these products opened not just because of the increase of health culture in our country and the developing countries and the increasing number of X-ray machine users, but also because of the need to replace outdated and amortised machines, whose lifespan was between 8 and 10 years. As it is written in the publication issued on the occasion of the 30th anniversary of the liberation of Niš, “today, in Yugoslavia, there are over 800 health institutions that have the X-ray machine *Grafoskop* with *Selenos 4*, and also, it is known that in our country there are 1,500 more institutions that have the first locally produced X-ray machine *Morava*.



Universal diagnostic X-ray stand *Telestatix*

(Source: *Telestatix*, EI Jugorendgen (brochure), [n.d])

So far, out of that number, around 800 X-ray machines *Morava* have been replaced with new, more modern machines, and there are around 700 more that are yet to be replaced”.

Export to Foreign Markets

Given that there was only a dozen of X-ray machine manufacturers in the world at that time, demand for *RR Zavod*’s (*EI Jugorendgen* since 1973) X-ray machines on the foreign market grew almost exponentially. That is how already in the 1970s, over 20% of the total production was sold on the foreign market and the export value has reached five million German marks. Until 1985, the scope of X-ray machine export has reached 50% of the total production and the export value was over 20 million German marks. In those years, the X-ray machines from Niš were exported to almost all of the Eastern countries, then to South America, Africa, China, India, Libya, Cuba and other developing countries. With certain large buyers in these countries, they concluded contracts on long-term cooperation, technical assistance, issuing licences for production of X-ray equipment and other, while often, they also agreed on construction on health facilities within engineering system. That is how, for example, through the consortium of co-operators from Yugoslavia, they constructed and equipped 10 health facilities in Libya, while in the USSR, they completely equipped a dozen of health facilities with X-ray and other medical devices.

Universal diagnostic stand *Undistat 3U*, with automatic device for target imaging

(Source: *Undistat 3U*, EI Jugorendgen (brochure), [n.d])

1980s — New Factory

Continuous expansion of the assortment and conquering of new markets in almost all the corners of the world have imposed the need to construct a new factory. The works on construction of 18.000 m^2 of total, out of which 15.000 m^2 of modern production space, began on the occasion of marking the three decades of the *Elektronska Industrija*, in April 1978, and this investment amounted to 14 billion dinars. The realization of this capital investment lasted several years, so 630 workers of the factory moved in the new facilities in 1982. With much improved production conditions, they also established export cooperation with new partners and worked on the mastering of new products. In 1986, they concluded a contract with the American company *Diasonics – Sonotron*, with which they mastered the production of a series of ultrasound devices type *DRF 200*. A little later, in 1989, they concluded an agreement on production cooperation with a famous Dutch company that manufactured ultrasound devices, *Pie Medical.* Based on that cooperation, they produced a larger series of devices *Skener-150/200*, which were of extremely high quality.

During its half-a-century long history, the X-ray machine factory was almost always one of the most profitable factories not just in the EI system, but much wider as well.

Нова зграда фабрике, 1982. година

(Извор: Ранђеловић, *Пола века у корак са светом 1948–1998)*

1990s — Economic Decline

The last decades of the existence and operation of the X-ray machine factory were marked by a sharp decline in production and a decade of serious economic crisis caused, first of all, by the sanctions and the embargo during the break-up of Yugoslavia. Namely, after the separation of Slovenia, Croatia, Bosnia and Macedonia, the so-called "local" market that previously existed was significantly reduced and after the introduction of the sanctions by the international community, the export market of the factory was also completely blocked. Therefore, the scope of production has decreased several times (while the number of employees remained the same), which caused emptying of the budget and an imminent economic decline. The efforts of the *EI Corporation* and *Jugorendgen*'s management to consolidate this respectable factory did yield some results and thus, gave room for moderate optimism. That is how, in early 1998, they signed the contract on the delivery of X-ray machines to medical institutions in Belorussia in the value of eight million dollars, which was, after the years of import blockage, more than encouraging.

Quality technical resources, expert staff potential and rich half-a-century experience were the postulates upon which the faith in the better future of the factory was based upon.

Portable universal X-ray machine *Neretva 86 MP*

(Source: *X-Ray Units Manufacturing Plant*. Belgrade Technitrade; Niš: Jugorendgen, 1999)

Bukigraf 2, 1960

(Source: *X-Ray Units Manufacturing Plant*. Belgrade Technitrade; Niš: Jugorendgen, 1999)

2000s — New Hope

By the start of the new millennium, *EI Jugorendgen* got an offer from a young local high-tech company *Visaris* from Belgrade, to join forces and produce digital X-ray machines, which were just starting to be developed in the world. In 2005, they established a joint company *JR Digital X-Ray* which soon, after the joint development and merger of hardware X-ray components manufactured in *EI Jugorendgen* and *Visaris*' software for processing of digital images, began testing the first series of digital machines *Digraf*. At that time, they successfully tested devices *Digraf D* and *Digraf C* at the Institute of Oncology and Radiology of Serbia and *Digraf X* at the Institute for Orthopaedic-Surgical Diseases *Banjica*.

Soon after this, due to internal staffing and economic issues, *Jugorendgen* left the project leaving the young Serbian scientists from *Visaris* to fight with the challenges of the new digital radiology which was even in the world, still at its infancy.

In 2010, the company went in administration and the following year, the Commercial Court in Niš accepted the reorganization plan submitted by the company's shareholders; the administrative procedure was stopped, but the recovery did not happen and the production was not relaunched.

In the following high-tech digital era, Serbian radiology continues in a new direction. Young Serbian scientists of the digital age are coming out onto the world stage and global digital market, which will soon present multiple advanced possibilities for the development of modern X-ray technology and digital diagnostics.

Literature:

Petrović, Olgica. "Kako smo gradili Zavode RR - Sećanje prvog direktora Borivoja Stojanovića", *EI NOVINE*, no. 354, Niš, February 17, 1998.

"Prvi proizvođač domaćeg rendgen-aparata", *30 GODINA PRIVREDNOG RAZVOJA NIŠA*, Belgrade: Privredni pregled, 1975.

Ranđelović, Novica S. *Pola veka u korak sa svetom 1948–1998*. Niš: Ei Korporacija, 2003.

Marković, Predrag, Čedomir Antić, Danilo Šarenac. *Korak ispred vremena: 125 godina Simensa u Srbiji [1887-2012]*. Belgrade: Simens: Institut za savremenu istoriju, 2014.

Nešković, Milutin. "Elektronska industrija – EI 'Jugorendgen' EI". In *Jedan vek radiologije u Srbiji: 1895 – 1995*, ed. Branislav Goldner, 211–215. Belgrade: Srpsko lekarsko društvo, Sekcija za radiološku dijagnostiku, 1995.

Vladimir Petrović

DEVELOPMENT OF DIGITAL X-RAY INDUSTRY IN SERBIA: COMPANY VISARIS

November 2002

The Idea and Dream of Digital X-Ray Machines

Group of young, scientifically active engineers and experts was thinking about forming a partnership company in order to realize their knowledge and skills in the field of digital medicine on the Serbian market. As one of the potential projects, in that phase mentioned only as a possibility, they also considered digital roentgenology. The knowledge in digital imaging and signal processing assured them that they can create a digital X-ray imaging system, which was until then, developed only in a handful of large companies in the world.

November 2002

The Idea of Partnership for Realisation of Digital X-Ray Machines

Company *Jugorendgen* was identified as a potential partner on the path to development of a digital X-ray machine and after that, the negotiations regarding cooperation began.

May–August 2003

Visaris Gets its Form

On May 26, 2003, a new company called *Visaris* was registered and, with the help of partners and investors, it considered various projects in the field of digital medicine, which also included digital roentgenology. Research and technical development have been directed towards the following questions: what are the components that the machines consist of, how to connect them and how to obtain digital image. At the time, there was only one manufacturer of the key component, the digital flat-panel detector, in the world—the French company *Trixell*, which was also the only company which cooperated with smaller companies.

September 2003

To Leap or Not to Leap, When Everyone Doubts

During the negotiations with *Trixell* and manufacturers of other key components, *Visaris* realized that the project requires great investments and sacrifices. *Trixell Pixium 4600* flat-panel detector was very expensive, while the sensor required such power (± 50 MV) that there was a great chance that it might burn out during the development. However, Slobodan Petrović, one of the partners, believed in the team and secured the funds to make the dream come true. However, *Trixell* did not agree to sell the detector to an inexperienced team, thinking that they would only "waste time". Still, in the end, the difficult negotiations ended successfully and by the end of 2003, *Trixell*'s digital detector arrived in Belgrade.

December 2003

Home for a New Digital X-Ray Machine

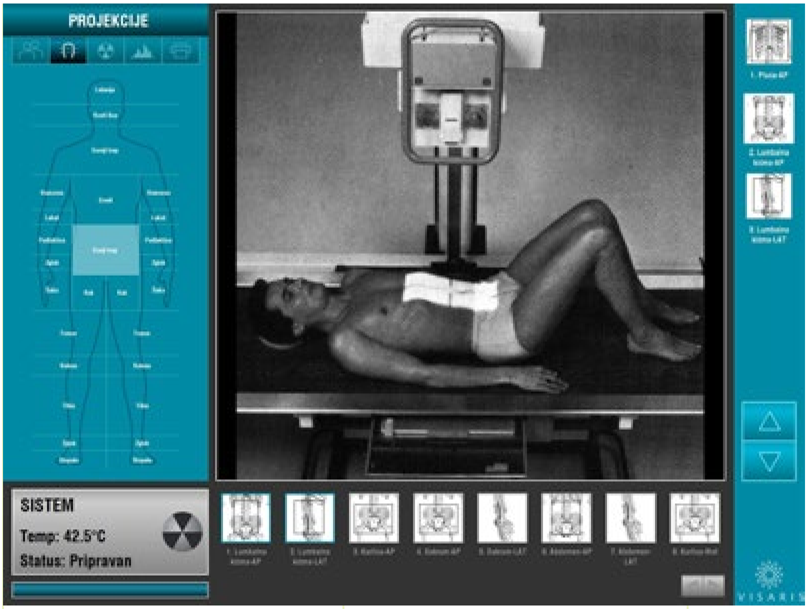
A Protocol of Cooperation was signed with the Institute for Orthopaedic-Surgical Diseases *Banjica*[1] for installation of a new, for the moment, still only potential digital X-ray machine *Digraf X* (Digital RadioGRAphic Device X) and its clinical trial. The joint project of *Visaris* and the Institute, *Digraf X*, officially began on December 15, 2003. *Jugorendgen* made a commitment to adjust simple mechanical platform *Bukigraf 2* and secure X-ray source for the purpose of digital imaging, while *Visaris* recruited software engineers who would work on the development of a control software and digital imaging for the new machine. It became clear that the new digital device would contain multiple smart computer components that need to be handled carefully.

January–March 2004

Progress, the Idea Spreads

Not realizing how complex the development process is and how much time and effort it took the large companies to develop digital imaging, the development team of *Visaris* and *Jugorendgen* progressed quickly, obtained the first digital images and formed a digital work process and the prototype of the machine was created in the *Jugorendgen*'s facility in Niš. Encouraged by the progress, *Visaris* and *Jugorendgen* also considered developing dynamic imaging—digital fluoroscopy.

1 Today, the Institute of Ortopadics Banjica.



User interface of the *Visaris Avanse DR* software from 2004. The software controls the complete operation of the digital X-ray machine, which was an incredible level of automatization at that time. Scanned images from the *Jugorendgen*'s radiographic atlas were used to illustrate the positioning on the machine. The concept of a simple working process developed for this machine is still in use.

April–May 2004

The Dream Becomes a Reality

Installation of the X-ray machine *Digraf X* began on April 1, 2004 at the Institute in Banjica. X-ray technicians and physicians at the Institute closely followed the imaging tests on a new machine. On the other hand, partners have prepared the production documentation and *Visaris* sent the general manager of *Jugorendgen* a letter of intentions with a proposal to establish a joint company.

NIGHT ACTION

Encouraged by the progress, in May 2004, *Visaris* contacted *Trixell* for the expansion of business activities and supply for the production of new digital devices. *Trixell* did not believe that the new digital machine was ready because in the meantime, *Visaris* did not ask for any help from their engineers. Although unwillingly, *Trixell* sent its experts to Belgrade. However, *Digraf X*, which took the images of patients at the Institute *Banjica* every day, “has stopped” a night before the arrival of the *Trixell*'s team due to a malfunction of a *Sedecal* high-voltage generator. Aware of the situation and upon his own initiative, *Jugorendgen*'s engineer Slobodan Ilić, went to Belgrade and worked with Nikola Golović from *Visaris* all night to repair the damage. One hour before the arrival of the French experts, *Digraf X* was once again operational. *Trixell*'s team became convinced of the technical capabilities and the cooperation was never again burdened by doubts and misbelief. *Visaris* and *Trixell* have continued to cooperate to this day.

Digital imaging on *Digraf X* device during the summer of 2004. Operator's computer console, as well as a touch monitor for management of the work process, presented a revolution at the time. All radiology technicians at the Institute *Banjica* got very quickly accustomed to the new way of working.

June–August 2004

The Baptism of Fire, JR Digital and Great Ambitions

Installed *Digraf X* went into regular use at the Institute *Banjica*, to which X-ray diagnostics is of primary importance. *Digraf X* took images of around 200 people a day and it proved the advantages of a digital working process. Such flow of patients on classic X-ray machines had been unimaginable before. The project of digital fluoroscopy, *Digraf D-Stream*, also officially began. The agreement on establishment of *JR Digital X-Ray Ltd*, joint company of *Jugorendgen* and *Visaris* directed towards the production of digital X-ray machines, was signed on August 16, 2004. Dragan Miletić, one of the main advocates of the digital vision in *Jugorendgen*, became the general manager of the new company.

November 2004

One Step Forward, One Step Back

The first Serbian digital X-ray machine became the foundation in the X-ray diagnostics at the Institute *Banjica*. However, the Institute lacked the infrastructure for digital working process and instead of computer, the digital images were printed on “digital” films. That is why *Visaris* developed a software for archiving and display of digital images (PACS). The development of digital fluoroscopy also progressed and in the *Jugorendgen*’s facility, they assembled the prototype of device *Digraf D-Stream*.

User interface of the digital fluoroscopic device *Digraf D-Stream* was significantly more complex than the previous radiographic devices and it had advanced functionalities, such as editing of recorded video material and digital image processing in real time.

January–March 2005

New Home, Partners and Horizons

In the early 2005, the first Serbian digital X-ray machines arrived at the Institute of Oncology and Radiology of Serbia in Belgrade. During March, the first digital fluoroscopic device *Digraf D-Stream* was commissioned. In cooperation with the Institute, *Visaris* and *Jugorendgen* developed a joint project in order to develop a new device *Digraf C*, whose performances were meant to match at the time, the best digital radiographic device manufactured by Siemens—*Aristos FX*.

August–October 2005

Completely Digital Diagnostics

The development teams were joined by a team of roboticists from the Faculty of Electronic Engineering in Niš, which was in charge of developing the control of the completely robotised and automatised device *Digraf C.* After a lot of work, the prototype of a robotic device with a possibility of 13-axes motor movement was created at the *Jugorendgen*'s factory in Niš. By the end of August, it was transported to the Institute of Oncology and Radiology of Serbia. After obtaining the official permit by the Institute of Nuclear Sciences *Vinča,* a demonstrational centre for the new Serbian X-ray equipment, digital radiographic and radioscopic devices *Digraf C* and *Digraf D-Stream*, as well as software for digital diagnostics, were formed. The Institute of Oncology and Radiology of Serbia completely transferred to digital X-ray diagnostics.

November–July 2006

Entering the Market

Based on the successful installation of prototypes, by the late November 2005, *JR Digital X-Ray* appeared at a tender for the first time and with the Ministry of Health of the Republic of Serbia, signed the first commercial contract on the purchase of the *Digraf C* device for the Institute of Rheumatology, which marked the start of the production of this first serial machine. The Institute of Oncology and Radiology of Serbia and the Institute of Rheumatology have remained *Visaris*' partners in the development of new X-ray machines to this day.

2007

The Turnaround Year

When the first commercial products entered the market, *Visaris*' young development team became aware of the differences between the prototype and commercial installations. Besides the new jobs and installations of devices *Digraf X, Digraf C* and *D-Stream* at the Health Centre *Novi Beograd*, Health Centre *Studenica* in Kraljevo, Institute *Niška Banja* and other institutions in Serbia, the *Visaris*' development team worked hard to prepare the device prototype projects for the market and make them reliable and sustainable and their production profitable.

During 2007, there was a turmoil in *Jugorendgen*, to which the promising success of the new digital devices was not enough to help them survive in the current organization inherited from the times of social ownership. Quickly afterwards, *Jugorendgen* abandoned the development process, so *Visaris* was forced to find alternative sources for mechanical components for digital devices. However, not being able to find a partner among the various foreign manufacturers, they decided to start the development of their own mechanical platforms. They developed new radiographic mechanical platform with a simpler electrical and mechanical architecture, smaller weight, better movement and simpler use than the previous models.

2008

The First Commercial Success

The turbulent period between 2007 and 2008 was followed by a significant commercial success on the Serbian market. In early 2008, *Visaris* and *JR Digital X-Ray* appeared at the European Radiologists Congress in Vienna for the first time and introduced *Digraf C.*

By the end of that year, a new version of the digital radiographic device, which was one of the lightest of its kind, and simultaneously, with the best performances, came out. It was called *Vision C*, and it was the first launched under *Visaris*' trade mark.

Mastering Technology

The improvement of the key technologies for software, mechanical and electronical parts began and partnerships were made with manufacturers of mechanical components. A new robotized device intended for health centres, *Vision U*, comes out on the market.

Convinced that they can compete with the world, *Visaris*' engineers followed the needs of the users, changed the previous rules and their progress gave visible results. *Avanse DR* became the simplest-to-use radiographic software on the market. A new generation of *Vision* devices consumed less power, had half of the cables, weighted 220 instead of 560 kg and supported easier work with wireless detectors. Software made in 2006 were improved in order to bridge the gap between the classic X-ray film and digital images. *Visaris PACS* enabled digital work on practically all installations in Serbia.

Still, even with the production costs being halved, the small scope of sales meant that for the business to progress, the company could only count on the Serbian market, so they intensified the contacts with the potential distributers in the world. In late 2013, *Visaris* moved to a new production hall and offices at Batajnički Road in Zemun.

New radiographic system with a U arm *(Vision U)*

Visaris Diagon work station for diagnostic processing of digital images at the Institute for Treatment and Rehabilitation *Niška Banja*

2014–2019

Global Market

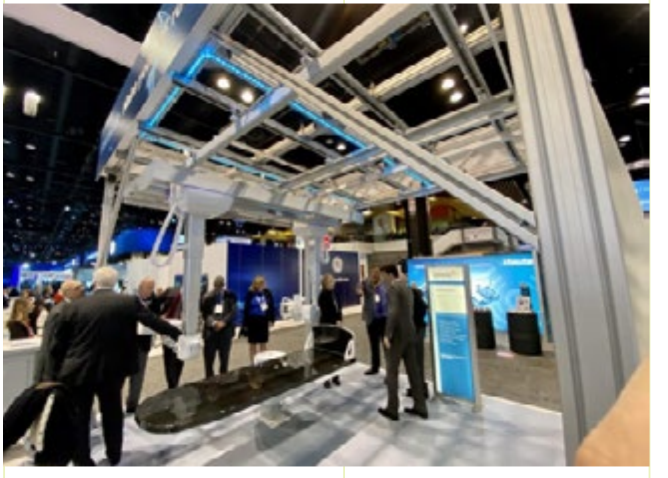
A dozen of visits around the world paid off and in May 2014, Swiss company *Polymed* did an assessment of the *Visaris Avanse DR* for digitalization of their devices and concluded that the system from Belgrade had an easier and better automatized work process than all the German competitors. *Polymed* ordered the first system and the Swiss MTC (*Medical Therapy System*) ordered the first service development project for design of control electronics. This success opened the doors of the global market to *Visaris* and by the end of 2014, they install several more digital systems in Czech Republic and Switzerland.

The development department improved the products based on the experience from the market in order to facilitate the entry to a distribution network. In early 2015, *Visaris* signed the first distribution contract for USA, as well as an agreement with the company *Swissray*, pioneer of digital radiography, on the sale of *Visaris*' advanced devices under the brand of this company. During 2015, the first orders for new *Vision C* devices came from Czech Republic and United Kingdom.

Vision V – Swissray, Visaris' best-selling digital device (so far)

Vision C device in *Bienville Orthopedics*, Mississippi, USA

Presentation of movement of the *Vision Air* device a the Congress of Radiologists in Chicago, December 2019



In early 2016, an approval given by the US Food and Drug Administration opened the greatest world market to *Visaris.* In the summer of 2016, *Bienville Orthopedics Specialists Group* from Mississippi began using *Visaris'* device, while Radiology Centre *Tampa Radiology*, Florida, began using it under the brand *Swissray ddR Aura*.

In 2017 and 2018, high performances of the devices, together with reasonable prices, opened the markets of Australia, Germany, Taiwan, Slovenia and other countries. The devices got a uniform and recognizable look and there was also a plan to return of platforms with double ceiling robot for a new generation of devices. In late 2017, a serious malfunction on a device in Czech Republic impacted the work on improvement of safety and reliability of devices.

2020–2021

Years of Challenges and Opportunities

In 2020, Covid-19 epidemic halted the global economy and presented a huge challenge for health systems around the world. It turned out that it is necessary to secure special X-ray machines for Covid patients. In a situation in which the manufacturers in the world were not able to redirect devices from their markets to Serbia, *Visaris* began producing cheap, mobile X-ray machines and by the end of the year, they produced over 120 devices for the Serbian market. Every day, several thousands of X-ray images of lungs are taken using *Visaris*' devices in health centres and hospitals in Serbia.

Since April 2020, the Faculty of Technical Sciences in Novi Sad and *Visaris* have been part of a consortium consisting of 30 partners on a project called *Horizon 2020 INCISIVE*, directed towards the development of artificial intelligence (AI) in the process of diagnosing, predicting and monitoring pathological changes in oncological patients.

Vision M — A device developed for the needs of Covid patients' diagnostics

Already in 2021, the first algorithms for analysis of mammographic and radiographic images began being tested in Novi Sad and Belgrade.

With its program of development and creation of solutions in the field of digital radiology and medical imaging, in 2021, headed by its general manager Marko Petrović, *Visaris* positioned itself highly on the territory of South-East Europe. The team, which consists of 90 employees, has secured export of over 1,700 devices in more than 30 countries.

Visaris strives towards the following goal in the future of roentgenology—development of universal devices that enable multiple radiological methods and significantly increase diagnostic capabilities. Mastering the technology of X-ray imaging in three dimensions is a long-term vision of the *Visaris.*

Vision Air — Universal device with radiolucent carbon fibre table

CIP - Каталогизација у публикацији - Народна библиотека Србије, Београд

535-34(497.11)(091)(083.824)

JOVANOVIĆ Simić, Jelena, 1967-

Development and Application of X-ray Technology in Serbs : from Tesla and Pupin to modern times / [authors of the catalogue Jelena Jovanović Simić, Aleksandar Vl. Marković, Vladimir Petrović ; photographs Miloš Jurišić ; translation Katarina Spasić]. - Belgrade : Museum of Science and Technology : Visaris, 2021 (Zemun : Birograf Comp). - 92 str. : ilustr. ;

24 cm

Prevod dela: Развој и примена рендгенске технологије код Срба. - Podaci o autorima preuzeti iz kolofona. - Tiraž 300. - Napomene i bibliografske reference uz tekst.

ISBN 978-86-82977-90-2 (MNT)

1. Marković, Aleksandar, 1973- [аутор] 2. Petrović, Vladimir, 1975- [аутор]

а) Рендгенски зраци - Србија - Историја - Изложбени каталози

COBISS.SR-ID 47347721