IT ALL STARTED OUT INNOCENTLY ENOUGH…

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to my wife Anna and all the friends from the former Division of Applied Science at Brookhaven National Laboratory

On 27th of November, 1984, together with my wife Ania, I set off on what was originally planned for just one yearbut proved the most exciting and eventful, triple longer journey of my life, both literally and figuratively: so started my scientific research adventure with matter disclosing its secrets when illuminated by energetic and unusually intense photon beams. Our destination, New York, was by no means easy for us to reach at that time: American answer to the martial law in Poland (1981 – 1983) included Polish aircraft being banned from landing at U.S. airports. A detour via Montreal happily ended at La Guardia Airport in New York. In the arrival hall we soon spotted a gentleman wearing the BNL (Brookhaven National Laboratory) badge on his uniform. If it were not for this badge we would have never guessed that the word *Kwitek* he uttered with an American accent was supposed to be my surname. He opened the door of a BNL Buick. "What a boat of a car", I thought, being used to the view of vehicles moving on Polish roads in mid-eighties. Another two hour drive down the Long Island Expressway (L.I.E. or I-495) and we called at the door of our fully equipped apartment with keys and ID cards in our hands. Tired after a long journey, we reclined in comfy armchairs and listened to the happy silence of our new home. Impressed by what we had just experienced we realized: America – a dreamland for generation of Poles was welcoming us so warmly. Was it for real? Or maybe a daydream?

Next day I went to the Laboratory to see my new boss, Dr. Keith Jones. Rather short gentleman dressed in a navy-blue sweater was engaged in a telephone conversation with somebody. After a while he replaced the handset, noticed me, greeted me warmly and invited me to his office. Little could I understand of the words he spoke to me for my ear was not at all tuned to the American pronunciation of English. I could at most nod from time to time. Fortunately, a friend of mine, Marian Cholewa, accompanied me and helped me out of deep water a couple of times. Somehow I managed to survive until 5 p.m. and rushed home. Half an hour walk towards the *Apartment Area* could not change the mood of dismay brought on by my first day at BNL. I rang the doorbell of our Apt. 41G.

Ania was almost done unpacking our four suitcases. "Let's pack up! We are going back right away! I can't make a single word out of what they are talking to me!". My dear Ania, she really knew how to pour oil on troubled waters. She was right: I felt better and better with each coming day. The laws of physics, fortunately, do not depend on the particular language you speak. I worked with the proton beam from a 3.5-MeV Van de Graaff (Figs.1 & 2) accelerator and took to it like a duck to water. I needed no help. I knew what to do. Soon I met Mati Meron, a chap who spoke Polish, and our secretary, Lore Barbier, a lady of German origin, every so often refreshing my, once quite good, command of her mother tongue. No longer did I feel adrift.

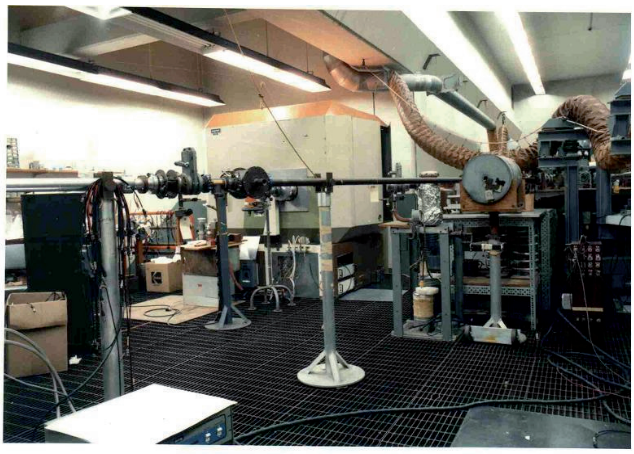

Figure 1. At the back there is VdG accelerator. On the left – PIXE line, on the right – microbeam line.

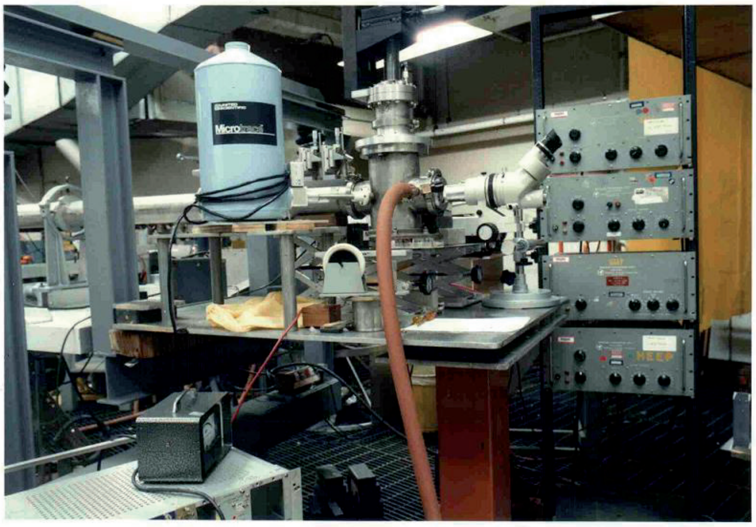

Figure 2. Microbeam experimental chamber with optical microscope clearly visible.

After a time I figured out that our group, named Division of Applied Science, was involved in building a beamline at Brookhaven's National Synchrotron Light Source (NSLS), whose X-ray ring had been just commissioned (1984). I realized that the X26A beamline under construction meant a unique chance for my scientific development. My Kosciuszko Foundation Scholarship would last another half a year and, despite a placement at a highly reputed research centre plus some further experience gained with the proton microbeam, I might be coming back home with few scientific achievements. A proton beam of 20 – 50 µm in diameter was proudly called *a microbeam* (now proton microbeams of cross section below 1 µm are commonly used for experiments). A manually operated manipulator allowed the sample to be positioned in X, Y, Z directions with a theoretical precision down to 5 µm. Collecting a 2-D scan took ages! Hardly anybody would now believe we really felt like doing all this by hand. Mind you, today my students would not even imagine their work without a fully-automatic sample positioning system; and the use of millimetre graphing paper to carry out spectrum energy calibration is for them like moving back to an ancient era. We are talking about the progress we have been witnessing over the period of twenty-five years!

I was lucky. In November 1985, during one of our weekly group meetings, Brant Johnson turned to Keith with an idea that I could join their team and participate in the construction of X26 at NSLS. Keith immediately approved and I eagerly took up the challenge, although it was absolutely obvious for me that a more-or-less experienced researcher on proton microbeams would have to turn into a newbie, fixing nuts and bolts. I did not object, though. Quite the contrary: I was proud to participate in this pioneering project of building a new instrument. Our group with Keith, Barry Gordon. Brant Johnson, Mark Rivers, Albert Hanson and Mati Meron were the great minds to listen to and learn from.

Computer networks, now considered a bloodstream of modern scientific work, information interchange, processing and storage, already at that time were of tremendous help to researchers. I was happy to master *DECnet,* then a ten-years-old network protocol developed by DEC company and widely used to build architectures of PDP, VAX and like machines.

February 1986 approached fast. Our group, plus Professor Joe Smith from Chicago University, the boss of Mark Rivers and Steve Sutton, gathered at the X26C beamline to celebrate the first opening of the beam shutter. "*Slits are open. Look at the wall*" — announced Mark Rivers with the sonorous voice of a herald. The wall of the experimental cabin, called *hutch* among the X-ray community, was lined with lead plates. A sheet of fluorescent paper, fixed to the lead lining, now lit up, illuminated by X-ray beam (Fig. 3). Not for nothing was NSLS named a Light Source.

With Champagne in plastic cups we looked at glowing luminescent paper illuminated with synchrotron radiation, and into the glowing future of our research. A new era began for the group (Fig. 4) and a new stage in my own research career, marked by a love affair with synchrotron radiation.

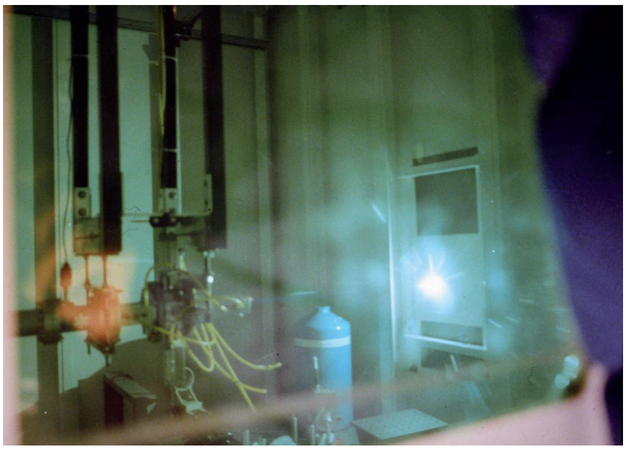

Figure 3. Glowing luminescent paper illuminated with synchrotron radiation.

Figure 4. At the X26C. Standing left to right: Albert L. Hanson, Keith W. Jones and Hu Bej-lai (both not visible behind Albert Hanson), George Schidlovsky, Józef Kajfosz, Joel Smith, Wojciech M. Kwiatek, Mati Meron, Steve Sutton, Mark Rivers, Brant Johnson, Per Spanne, Joel Pounds, Barry Gordon.

Joel Pounds, a toxicologist, joined our group, with the desire to apply the quickly developing synchrotron radiation techniques to biological problems. I liked the idea, as it agreed with my interest in interdisciplinary research. I had just completed a series of PIXE (Proton Induced X-ray Emission) measurements of trace elements in the hair of patients suffering from colon cancer and decided to write my first research proposal concerning SRIXE (Synchrotron Radiation Induced X-ray Emission) studies of cancer tissues. Everybody in our group was writing some proposals, for we had a new instrument: X26C (Fig. 5). In fact, Brant and Mati worked on the development of two X-ray instruments: "our" X26C and another one, X26A, dedicated to atomic spectroscopy (Fig. 6). The X-ray beam had to pass though the Brant's chamber before it entered X26C area. After years the hutches were separated, and the old X26C now became X26A.

Although my proposal was never submitted to NIH (National Institutes of Health), I received invaluable experience in writing research proposals. Now you cannot even dream of successful scientific activity without an ability to apply for funds. Moreover, Joel Pounds took interest in it and offered participation in his project. Soon Greg Long, his Ph.D. student, arrived and became my collaborator. Greg's work consisted in setting up a model experiment on the influence of a particular diet administered to rats on the elemental composition of various organs in these rodents [1]. My job, as a physicist, was to arrange and optimise the experimental setup on X26C for micro-SRIXE measurements.

Together with Albert Hanson and other group members, we embarked on this task. We studied the dependence of the MDL parameter (Minimum Detectable Limit) upon the position of the Si(Li) detector. We found that the signal-to-noise ratio (S/R) decreased whenever we departed from the plane of electron polarization in the storage ring. Similar worsening of S/R was observed when we changed detector orientation with respect to the direction perpendicular to the beam. All the effects we observed provided an experimental proof to theoretical calculations of the beam polarization components and of the Klein-Nishina distribution of scattered beam. The sample takes it optimum position in focal plane. The task to determine the latter proved most difficult, though. Until now, no better way exists than to achieve a sharp image of the sample surface, as viewed through an optical microscope arranged perpendicular to this surface. Consequently, the sample positioned at the intersection of three straight lines: the symmetry axis of the X-ray beam, optical axis of the microscope, and the symmetry axis of the Si(Li) detector, provided optimum quality spectra of X-ray characteristic radiation [2].

Results which I obtained during our work were fundamental for my Ph.D. thesis which I defended in Poland after completion of my three years stay at the BNL.

Figure 5. General view of the X26 line from the port (at the back) towards the hutch. The space, then quite empty, now is jam-packed with equipment.

Experiment control post of X26C (Fig. 7) was located next to the hutch, along the beam direction. Mark Rivers (Fig. 8) was responsible for all its software. This included remote manipulation of the instrument components, such as step motors, data acquisition and analysis. The system relied on VAX computers, and data analysis programs were written in IDL (Interface Description Language). DECnet made it possible for Mark to carry out remotely a vast part of software development work.

Engaged in fascinating work as it was, I saw the days go by very fast. One Saturday Ania and I were leaving for a dinner party in Passaic, New Jersey. My key just grated in the door lock when the phone rang. We were pretty short of time and I did not feel like opening the door but phone kept ringing insistently. A few more steps towards the car, and the ringtone seemed even louder. And what if something important happened? — I thought and returned home. It was Keith calling. Angry as hell at Keith I suspected bad news. Why on earth would he call Saturday afternoon? Sure it was not an invitation for dinner as at that time we still were not as close friends as we are now. My intuition did not fail me. "*Hi Wjiech, I have a good news for you. In two hours you will have beam time at X26C. I presume you are happy to come*" — I heard.

Figure 6. Setup for atomic physics experiments. Mark Rivers sitting at the back of the photo.

Figure 7. George Schidlovsky (left) and me at the measurements of lead concentration in bone tissue.

Figure 8. Mark Rivers, busy as usual, at the control post of X26C.

Many a reader of this tale may think: “sounds familiar”, recalling similar stories from the beginning of their own research careers, of being proposed in no uncertain terms to do something interesting, yet at odds with young family life. With my Ph.D. thesis in mind I realized how important it was to catch every minute of the beamtime that was getting more and more difficult to obtain. Yet I took my courage in both hands and decided to tell Keith the truth. "*Keith, it is fantastic to have beam time tonight but I am just about to leave for New Jersey for dinner with Ania.*" — I replied. — "*We are invited by Polish Teachers’ Association*". Keith knew that Ania taught at St. Isidore’s Polish Supplementary School in Riverhead, New York. "*So, could I have it tomorrow morning?*" Silence hung in the air and after a while I heard: "*O.K. You go with Ania and I will stay here with your samples until midnight.*"

We set off. On our way to New Jersey we agreed with Ania that we should be leaving by 10 p.m. in order to call at the Light Source around midnight. What a good time we had that night! Ania was greeted by the President of Polish Supplementary School Council of America, Mr. Jan Woźniak, Ms. Helena Ziółkowski, Editor-in-Chief of Polish teachers’ journal "Głos Nauczyciela" and the headmaster of Polish Supplementary School, Ms. Feliksa Sawicka. I stayed in the background as a mere accompanying person. However, Mrs. Diana Niewiarowski appeared out of the blue. She was a member of the Kosciuszko Foundation Council. Ania and I were introduced to Dede (Diana’s nick name). As soon as she learned that I was a grant holder of the Kościuszko Foundation, she invited us to the Athletic Club in New York, for the Debutante Branch and to the Debutante Ball to be held at the Waldorf-Astoria hotel in Manhattan. Was it all worth bargaining with Keith over returning to the beamline?

As it had been agreed , we left around 10 p.m. I took Ania home and called at our lab just before midnight, still in my evening suit. Keith was sitting in front of a computer monitor, supervising measurements for me, so glad to see I kept my word.

Days passed by, almost unnoticed, as I was more and more committed to my work. Well, hours do not strike for a happy man at a source of synchrotron radiation. Together with Greg we sought the best solutions for the target preparation. The biological part of his experiment was almost completed and the time came to start measurements of elemental composition of the tissues under study (Fig. 9). The first results taught me a lesson on how complex data analysis would be. With biological material in beam, one had to consider a handful of factors that might possibly affect the spectra. To start with, the particular substrate underlying the sample, left its footprint on the results. Next, the spectra appeared dependent upon sample thickness, an effect easy to foresee but difficult to account for. Unlike most solid state samples, a biological specimen is often non-uniform, hence a need to identify precisely the area illuminated by X-ray beam. Despite the use of an optical microscope, such identification proved very difficult. It took some time until we learned how to dye a sister specimen and then to orient the tissue with respect to the microbeam. So far, only being able to vary the diaphragms (slits size), we had been working with a "white" beam [3].

The need for a monochromator and a beam focusing optics became evident. The use of diaphragms meant an obvious waste of photons and did not allow to decrease the MDL parameter. Efforts to obtain the necessary funds started forthwith. I also enjoyed studying the field of physics I was not very familiar with so far, that the foundation of X-ray optics.. Future use of the X-26A beam line was based on the use of an ellipsoidal 8:1 platinum-coated mirror machined from an aluminum block.

With this equipment installed our measurements gained tremendously in quality. We were able to determine even small concentrations of elements we were interested in [4]. With the use of visualisation software that Mark wrote, spatial distributions of concentrations under study could be easily seen (Fig. 10). I looked at my work with satisfaction: not only was it extremely interesting but also had practical applications.

In the meantime Per Spanne was setting up tomography experiments. He placed a sample on the path of an intense, well collimated beam, an intensity monitoring detector right behind the sample (Fig. 11). The intensity of the incoming X-rays was measured by means of an ionisation chamber. In this way absorption of radiation by the sample could be determined accurately. The sample orientation with respect to the beam could then be varied and, by measuring the absorption coefficient as a function of sample orientation, a cross section of the inner structure of the sample could be reconstructed.

Per did this measurements in one plane but already it was apparent that the imaging capabilities of synchrotron beams would reach far beyond that achievement. Nowadays high resolution 3-D X-ray imaging is a routine measurement. Per illustrated his experiments by reconstructing a cross section of a pencil (Fig. 12).

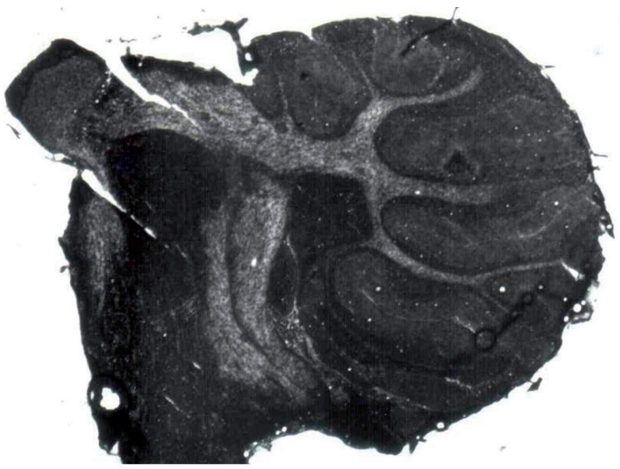

Figure 9. Sample of rat *cerebellum* tissue we analysed.

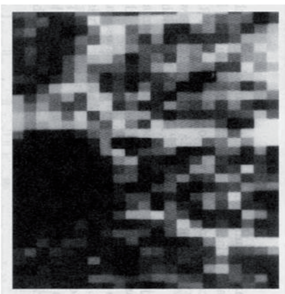

Figure 10. Iron distribution in a selected area of tissue section shown in Fig. 9. The brighter the pixel the higher Fe concentration.

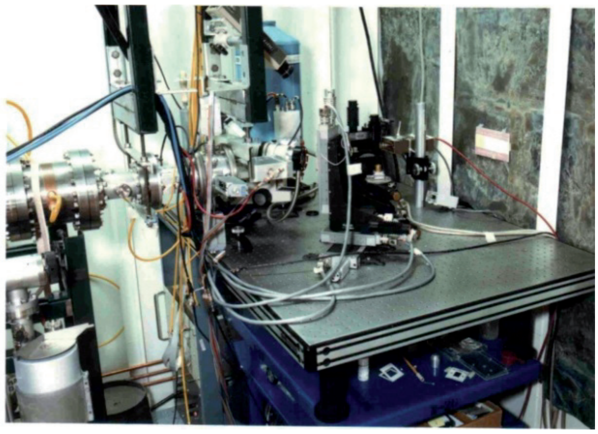

Figure 11. One of the first experimental set-ups for X-ray tomography.

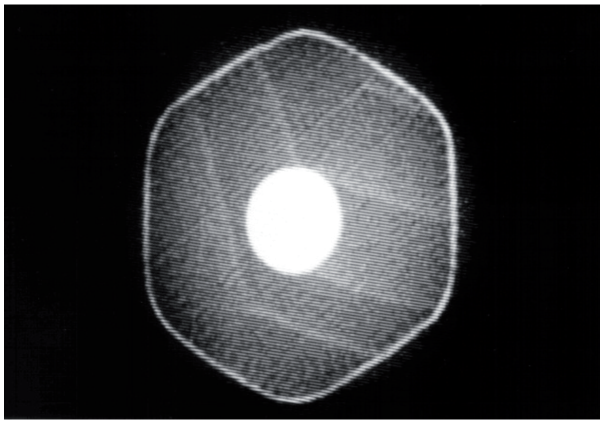

Figure 12. Tomography image of a cross section of an office pencil.

One day in January 1987 I was busy doing measurements. Suddenly an announcement was broadcast: following a decision of the Lab Director, the working day would end at noon, due to an approaching snowstorm. Were they joking? — I thought. Only a few moments ago I walked from our building 901A to NSLS in full sunlight, under clear skies, without a trace of snow anywhere. Suddenly Al turned up. I hardly recognised him. He wore a hat covered with a thick layer of snow. I looked at him, amazed by the accuracy of the weather forecast. That very day Ania visited our friends at their place near the end of the Island. I rang them up only to learn that she had left an hour earlier. I was worried in earnest: how was she going to make it through such a blizzard, a driving license holder for half a year only. Another two hours of waiting and I could tell her at the doorstep how proud I was of her. There were many vehicles abandoned on L.I.E., with only one lane open for traffic. A couple of days later, with that snowstorm and my wife's courage still in mind, I was again busy measuring on a Light Source. Suddenly the telephone rang. I answered with usual: "*X26. Wojtek is speaking*". The voice on the other side said: "*Good morning Mr. Kwiatek. This is Dr. Halfen. I'm so glad to tell you: your* *wife is pregnant*". I was speechless for a good while with teardrops of happiness around my eyes. Dr. Abraham Halfen was Ania's gynaecologist. Everything had changed since then. We were awaiting the joy of our life. Neither of us wanted to know the baby's gender in advance, although we were offered such information a couple of times during medical examination. There was something of a miraculous mystery in this uncertainty. On September 22, 1987 our daughter Joanna (Joasia) was born. Today she is a student at Jagiellonian University, exploring the mysteries of biophysics. She already took part in a few experiments on synchrotron beams in Frascati and Hamburg. It looks like Dr. Halfen's phone call came at right time in a right place. I am very proud of Joasia and sure Ania would also be… Or, rather, she IS.

Until the end of my stay at Brookhaven I was occupied not only with newborn Joasia but also with collecting results for the Ph.D. thesis. The days, one by one, were "growing tense" with more and more new ideas, measurements, possible interpretations. Together with my Ph.D. supervisor, professor A.Z. Hrynkiewicz, we agreed as to the main contents of the thesis. It would discuss optimum experimental conditions for experiments on the elemental composition of biological tissues. The thesis entitled "Trace element analysis using synchrotron radiation" was completed in English, while still at BNL. I am deeply thankful to Al Hanson, with whom we made friends, for the revision of this work.

My stay at the BNL was originally planned for one year. I owe it to Dr. Keith W. Jones, who believed in me and who recognized my capabilities, that I spent there three most fascinating years of my life.

All three of us returned to Poland on November 27, 1987 with my Ph.D. thesis ready to submit. The adventure that began with an innocent group meeting at the BNL lasts until now. The adventure with synchrotron radiation.

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References

[1] J.G. Pounds, G.J. Long, W.M. Kwiatek, K.R. Reuhl, A.L. Hanson, B.M. Gordon, K.W. Jones, "Application of synchrotron radiation-induced x-ray fluorescence to trace element toxicology", *Toxicologist* **6**, 1 (1986) 208.

[2] A.L. Hanson, W.M. Kwiatek, K.W. Jones, "The use of a SiTek position sensitive detector for synchrotron radiation beam monitoring and alignment", *Nucl. Instrum. Meth. Phys. Res. A* **260** (1987) 529-533.

[3] A.L. Hanson, K.W. Jones, B.M. Gordon, J.G. Pounds, W.M. Kwiatek, G.J. Long, M.L. Rivers, S.R. Sutton, "Trace element measurements using white synchrotron radiation", *Nucl. Instrum Meth. Phys. Res. B* **24/25** (1987) 400-404.

[4] W.M. Kwiatek, G.L. Long, K.R. Reuhl, A.L. Hanson, K.W. Jones, J.G. Pounds, "Distribution of Fe, Cu, Zn, and Hg in the mouse cerebellum", *Toxicologist* **7**, 1 (1987) 302a.