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REMEMBRANCES OF THINGS PAST

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Franz Fankhauser: The Father of the Automated Perimeter

Balder P. Gloor, MD

Zürich, Switzerland

Abstract. Franz Fankhauser is known as the father of automated perimetry and of the q-switched Nd:YAG laser knife. His 15-year journey to computerize perimetry started in 1958 with unsuccessful attempts to automate kinetic perimetry. The switch to using static perimetry resulted in a breakthrough in 1973, and in 1975 the OCTOPUS perimeter came on the market. At the same time Fankhauser was working on the use of light sources for the treatment of ocular tissues. During his career, Fankhauser worked in very close collaboration with mathematicians, physicists, engineers. One of the most astonishing characteristics of Fankhauser was his ability to find and to motivate young scientists to work as a cohesive group for his projects. (**Surv Ophthalmol 54**:417–425, 2009. © 2009 Elsevier Inc. All rights reserved.)

Key words. automated perimetry • Bebie, Hans • Cibis, Paul • Departement of Ophthalmology Berne • Department of Ophthalmology St. Louis • Fankhauser, Franz • Goldmann, Hans • history of ophthalmology • laser iridotomy • light sense • Nd:YAG laser • OCTOPUS primeter • photocoagulation • sensory physiology • Spahr, Jürg

There are the three ophthalmologists from the German-speaking part of Switzerland who have changed the face of ophthalmology worldwide in the last century: Alfred Vogt, Hans Goldmann, and Franz Fankhauser.[30,31] Fankhauser's extraordinary flair for mathematics, physics, and for basic research into the physiology of vision led to his development of high powered, sophisticated technical apparatuses (Fig. 1). He was the first to develop the automated perimeter and thereafter more and more sophisticated instruments that made use of light: from coagulation by heat to the photodisruptive laser. This was a step from knife to light.

Career

Fankhauser was born on September 7, 1924, in Thun, near Berne, Switzerland. He received his MD from the medical faculty of Berne in 1950. To earn pocket money he worked for the Swedish shipping company, The Johnson Line, for a few months, as many recently graduated doctors did in those days. After some years of training in internal medicine and general surgery, he completed a residency in ophthalmology under Hans Goldmann at the University Eye Hospital in Berne from 1954 to 1958.

To wait and sit still was incompatible with Fankhauser's character. When he felt that good surgical training was beyond his reach in Berne, he took the position as chairman of the department of ophthalmology at the Medical College in Ludhiana, East Punjab, India, where he spent two formative years exposed to the realities of a then underdeveloped country. Fankhauser then resumed work for Professor Goldmann, which was followed by an

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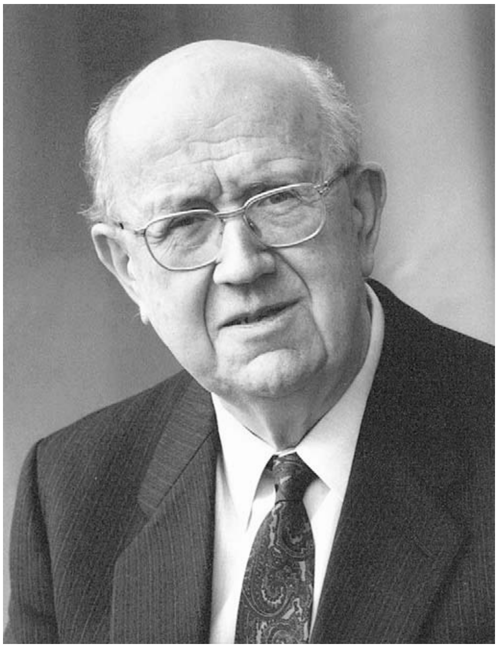

Fig. 1. Portrait of Franz Fankhauser.

important year as a research fellow at the Department of Ophthalmology, Washington University, School of Medicine in St. Louis, Missouri, under the umbrella of the so-called "Swiss Grant" of the National Institute of Health. The chief of the Department of Ophthalmology was Bernard Becker, a pupil of the famous Jonas Friedenwald.

In St. Louis, Fankhauser worked together with Paul Cibis, a top retinal and vitreous surgeon and a sensory physiologist, and with Jay Enoch, also a sensory physiologist. Sixteen years later I was told by Robert Moses, who at that time was an associate professor in their department, that "the Swiss had left an excellent record!" He was referring to Fankhauser and especially his wife Verena who had worked as a technician at the department. Department staff wondered how Fankhauser kept pace with Paul Cibis. Cibis repaired one retinal detachment after the other during the day and then, after 10 p.m., he met with Fankhauser, who had to report and discuss on what he had done during the day. Papers on receptor orientation and on the effects of blur upon perimetric thresholds resulted from these after-hours discussions.[12,13] When Fankhauser returned to Berne, he worked again for and with Goldmann. At this time Professor Hans König, a friend of Hans Goldmann, was chief of the Swiss National Institute of Standards in Berne, previously the working place of Albert Einstein. König was extremely generous, giving Fankhauser unlimited facilities to make use of instruments in the early stages of their development.

When Rudolf Witmer, then consultant in Berne, became chairman and Professor of Ophthalmology in Zürich in 1965, Fankhauser obtained his position as consultant and took over his office in town. This combination gave him freedom to achieve his extraordinary advances without being encumbered by administration. For the rest of his life, remembering the formative year with Paul Cibis, he didn't know what "limitation of working hours" meant. He could never understand that not everybody shared his attitude. He remained faithful to Berne despite being offered jobs elsewhere, and he retired in 1994. Fankhauser finished his private practice in January 2007, but he continues to perform intensive research work.

Physiology of Vision and Development of the Automated Perimeter

Fankhauser's path of trial and tribulation regarding the automated perimeter started as early as 1956 when Jean Marie Parel became his closest collaborator and tried to automate the original Goldmann manual perimeter. This turned out to be difficult to accomplish and ended when the research grant for Parel was running out. Fankhauser then recommended Parel to Gerard W. Crock in Melbourne. What made Parel famous was not his work on perimetry, but his invention of the first vitrectomy instrument while he was in Melbourne. This is the instrument that he brought to Miami when he was hired by Ed Norton, and it was developed further with Robert Machemer.

Fankhauser's work on physiology of vision related to perimetry started in Berne when Goldmann wanted to know more precisely the relation between the size of a target and its luminance (spatial summation expressed by an index): how is the visual system stimulated when either the luminance or the size of the perimetric target are manipulated? Fankhauser and Schmidt answered this in their investigation on spatial summation using static and kinetic targets.[22,23]

When Fankhauser returned to Berne from St. Louis, he was ready to advance sensory physiology in collaboration with the many other scientists working in this field, such as Henke, Röhler, Wallmann,[21,38] and Giger.[14,27,28] The investigations together with Röhler ("The physical stimulus, the quality of the retinal image and foveal brightness discrimination in one amblyopic and two normal eyes"[21]) brought about some intense and controversial discussions with Goldmann. Goldmann's criticism, to revise some of his own hypotheses,[33] was instrumental, as it finally led to the successful development of an automated perimeter by Fankhauser and his coworkers Spahr, Bebie, Koch, Giger, Roulier.[4–6,14–16,27,28,41,50–52]

After the theoretical background for the automatization of perimetry was established,[14,21–23,27,28]

Fig. 2. A prototype of the Octopus 201.

Fankhauser, Bebie, and other physicists and engineers still had a tough time solving the technical problems associated with actually making a working automated perimter (Fig. 2). It was at this time that I shared with Fankhauser a 3 × 3 m room at the University Eye Hospital in Berne. Fankhauser and I sat opposite each other at our own desks, and Franz once said in despair to me "As soon the automated perimeter will be realized, I shall stop doing research!" I bet a Magnum of champagne that he would not, and I won this bottle.

Shortly after this Fankhauser hired a new physicist, Jürg Spahr, to replace Alfred Rouiller. In the first weeks Franz claimed loudly:"How awful is it with this Spahr, he does not start in the morning before 9 a.m. and he leaves again at 5 p.m. If after my work with patients I invite him to discuss the research done during the day with me around 10 p.m., he refuses. What kind of attitude to work is this?" But with time Franz stopped complaining and the day came when he announced: "Listen, Spahr made it!"[50–52] What had been decisive? Until then all endeavors were focused on automatization of kinetic perimetry. Spahr, coming from outside and not burdened by history and Bernese traditions, checked all the instruments built for static perimetry, such as the Tübinger perimeter, and then, he had an inspiration: the way to go is automatization of static perimetry[4–6,8,50–52] and to forget kinetic. With this discovery, progress came fast. In 1974 the Octopus 201[51,52] (Figs. 2, 3, and 4) was on the market (Figs. 3 and 4).

Two different working philosophies had clashed: the one of working until exhaustion as exemplified by Cibis and Fankhauser, and the other by working "refracta dosi" and enjoying leisure time in between like Spahr. Both may bring achievements. It should be mentioned that Schiefer[48,49] and his group eventually found a way to computerize kinetic perimetry with special programs for the OCTOPUS 201 almost 30 years after introduction of the original instrument.

Fig. 3. The first commercially available fully automated perimeter to determine differential light sensitivity threshold, the Octopus 201. The instrument needed a lot of space.

Fankhauser and coworkers were not the only ones who worked on the development of automated

Fig. 4. The inside of the Octopus 201.

perimeters. Semi-automated machines preceded the fully automated ones.[7,29]

There were also some relatively crude instruments, for example, the Friedman Visual Field Analyzer Mark I (1966)[26] and Mark II (1979). Crude in the sense that they worked with suprathreshold stimuli, whereas Fankhauser and his group aimed from the beginning at determination of the differential light sensitivity threshold. This was an absolute requirement, if an instrument were to be useful in long-term glaucoma control.

In 1975 Krakau and Heijl presented the "Competer," which relied also on a real threshold determination algorithm.[37] Lengthy discussions took place at some of the first meetings of the International Perimetric Society as to which of these two automated perimeters would be the better, but because not many users knew both instruments, these discussions had a somewhat scholastic tone.The possibilities of the Competer were restricted both regarding the extent of the field and its software even if it focused only on glaucoma questions. Nevertheless, there was great intellectual input and technical competence behind the Competer by Krakau and Heijl;[37] however, it couldn't survive. It was at this stage that Humphrey and later Zeiss entered the market when all the work with the test algorithms was done.[5,6,15,16,50–52] The new machine was sold for much less than the OCTOPUS; and it became the leader in the market for quite a long time.

It should be noted that the OCTOPUS had to pass several additional trials:

1. There were difficulties and impediments in the progress of OCTOPUS from the very earliest stages of conception—for instance, the long delays in publication of scientific papers. Such delay weighed heavily on companies such as INTERZEAG, which had put all its money in the projects for OCTOPUS.
2. At that time, perimetric technicians employed in departments in Canada or in the U.S., who did manual perimetry with Goldmann or Tubingen perimeters, saw the automated perimeter as a terrible threat to their jobs. Rumor circulated that manipulations were done during the night to prove that the "the Swiss monster" did not work.
3. Many ophthalmologists not only had doubts about the usefulness of a machine that may replace human skills, but also feared that perimetry would be driven out of their office toward big clinical centers, as such instruments seemed too expensive for an individual ophthalmologist's office. This instrument sounded the bell for a new era of high technology instruments at a price level never reached before in this speciality, not even for ceiling-mounted surgical microscopes.
4. The fourth hurdle to overcome was the clash with the free market as practiced in the U.S. The first OCTOPUS was confiscated at the custom house in New York, when Zühlke brought it over the Atlantic to be shown at the meeting of the American Academy of Ophthalmology and then to be delivered to the Baylor College of Medicine in Houston. A group had lodged a complaint against violation of patents. They had patented their ideas of how to computerize perimetry in order to have priority on every manufactured instrument. Whether this was after they had read the papers of the group around Fankhauser or not[8,15,16,41,50] is open to question. A week of day and night work together with a lawyer from New York, flown to Berne, was necessary to knock out this patent and to release the OCTOPUS for the Academy meeting and Houston.
5. Finally, it had to pass the test of time in practice. The feedback, achieved in the last 30 years, has been provided by clinical investigations, which have been essential for the progress in computerized perimetry. They have led to improvement of the software,[25,29,32,53,54] including statistical tests and prediction of prognoses. By reducing the size of the automated machines (Figs. 3 and 4) and the price, the instruments have found their way into the offices of the ophthalmologist—and manual perimetry with the Goldmann apparatus is falling into oblivion, unjustly, indeed.

Ophthalmic Surgery with Light

The first apparatus for photocoagulation of retinal lesions developed by Fankhauser and Lotmar[20] took advantage of the xenon lamp of the photocoagulator of Meyer-Schwickerath. They replaced the direct ophthalmoscope, which had many disadvantages (remember the backaches we got from bending over the patient!), by superimposing the ray of the xenon arc lamp upon the illumination beam of the Haag-Streit-slit-lamp. By using the 60-diopter three-mirror contact lens the conditions for observation and photocoagulation could be improved considerably. This optical concept was extended when Fankhauser first got a ruby laser to work with Dr. Röss in Münich. Soon afterwards he was able to share the 200-watt argon laser developed at the Federal Institute of Standards in Berne,

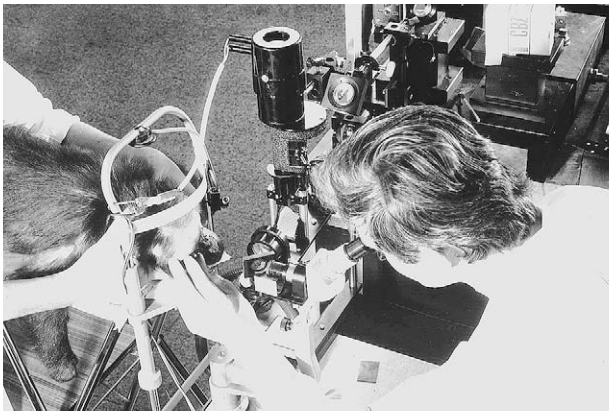

Fig. 5. Photocoagulation of the retina of a dog with a section of a 200 W Argonlaser-beam. Optics built by Lotmar to deflect a part of the beam in a slitlamp system.

originally built to be targeted toward the moon. Lotmar built the optics to bring a part of this light through the slit-lamp to treat diabetic retinopathy (Fig. 5).

The appearance of new of lasers was breathtakingly fast in those days. Fankhauser remembers his encounter with the q(uality)-switched and the mode-locked lasers, also named gigantic pulse lasers, as follows: “I watched Rockwell and Goldman from Cincinnati, when they focused the aiming beam of the ultrashort pulse configuration of the ruby laser on a Kaposi sarcoma on the lower leg of a patient. When they triggered the laser, there was a bang, the sarcoma was blown away, and a deep crater was left. This was the beginning of laser surgery of the human body. It became immediately clear that such lasers working with explosive energy would become, when used at the correct size, extremely useful for microsurgery in the closed eye.” The only available gigantic pulse laser in Switzerland was then at the research laboratories of Asean Brown Bovery (ABB) in Dättwil, 120 km from Berne. Professor René Dändliker, chief of these laboratories, allowed him to use this laser for research over the weekends. In fact, the first photodisruptive laser-iridectomy was done with the laser in Dättwil on a woman who had lost her first eye from a malignant glaucoma. She refused eye-opening surgery, but agreed to have “surgery” on the unopened eye. Investigations on laser effects on tissue of the eye in monkeys (Macaca speciosa) by Van der Zypen et al[24,55–57] were the base for the development of a q-switched Nd:YAG laser together with P. Roussel, Walter Lotmar, J. Marshall, and H. Bebie at the LASAG Medical Company[24,55–57] (Fig. 6).

The primary application of the q-switched Nd:YAG laser (Fig. 6) was surgery of the iris (Figs. 7 and 8), of the chamber angle, and of the vitreous. However, it was the switch from intracapsular to extracapsular cataract extraction and capsular fixation of the artificial lens that opened almost over night a huge market for this type of laser, because it was the ideal instrument to disrupt the central region of the posterior capsule (Fig. 9).

Fig. 6. The first commercially available q-switched Nd-Yag Laser, the Microruptor I.

Although Aron Rosa et al are credited as being the first to publish on interventions with a disruptive Nd:YAG laser in humans (1980),[1,2] before Fankhauser, Roussel, and Steffen (1981),[24] it should be remembered, that Fankhauser et al’s paper had already been submitted in 1980. Rosa et al had never reported on experiments done with animals, whereas Van der Zypen and Fankhauser published in 1977 the fundamental research on the effect of the q-switched Nd:YAG laser[55–57] in animals. Aron Rosa et al had chosen a mode-locked Nd:YAG laser. Fankhauser Steffen, and Roussel saw much more potential in the less costly q-switched version. They were right. The mode-locked version soon disap-

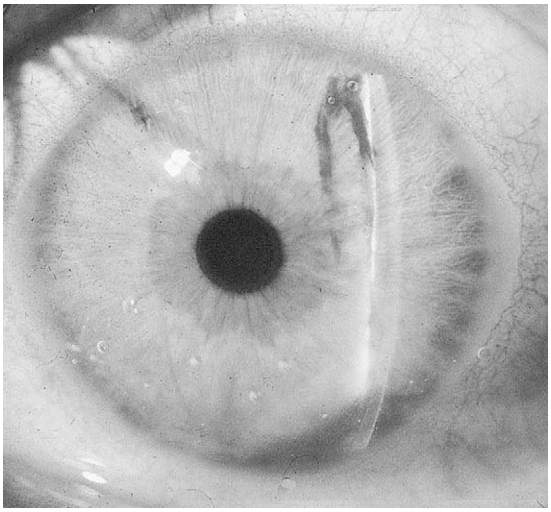

Fig. 7. Nd:YAG laser iridotomy, one small hole without, the other, larger one with bleeding into the anterior chamber.

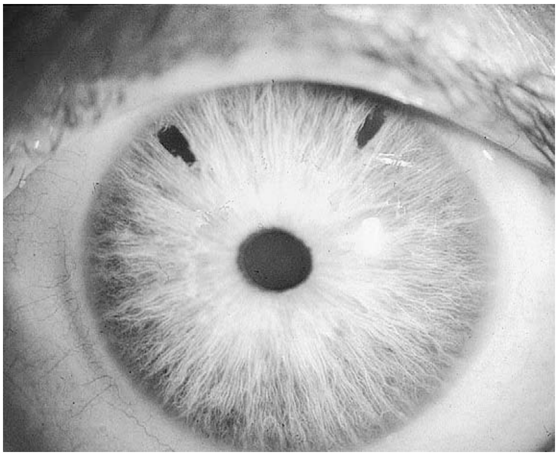

Fig. 8. Two peripheral iridotomies created by an Nd:YAG laser.

peared, and the q-switched version was copied almost immediately and has stood the test of time.

Looking out for other applications for the Nd:YAG laser resulted in the construction of the contact-laser for cyclodestruction.[18,19] Further work was done together with Josef Bille (Heidelberg), Stewart Brown (La Jolla, California), and at the University Eye Hospital in Zürich with a Nd:YLF picosecond laser[39] in 1992. This was the timid beginning of intracorneal photodisruptive refractive surgery.

The introduction of the Nd:YAG laser called for calculation of new contact lenses ground from high-quality glass to obtain the excellent optical quality needed for image formation. This has resulted in lenses,[44,47] such as the outstanding wide-angle contact lens for examination of the retina devised by Pascal Ro,[45,46] and the goniolens CGA 1 of the LASAG company (Fig. 10), which allows a view of the chamber angle of a quality not known until that time.[40]

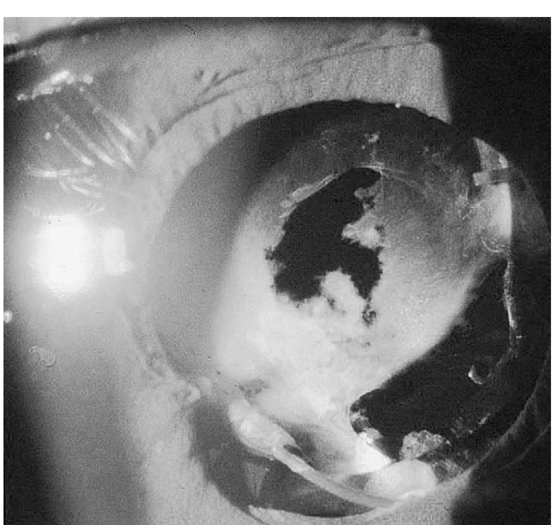

Fig. 9. Producing a pupil in a secondary cataract in the times of beginning ECCE, with implantation of posterior chamber lenses.

Who's Who

Fankhauser, looking beyond the limits of his field, had a vision for developments in physics and techniques that promised to become useful in ophthalmology. He had the skill—he called it luck—to find the right people working in natural sciences and to focus them on common goals. From these connections with physicists, mathematicians, engineers, micro-morphologists, and doctors of any speciality emerged not only the numerous apparatus for diagnostics and therapy, but also friendships. Many became directors of university institutes, research workers, industrialists, even generals. These people, through their exemplary interdisciplinary work, have contributed enormously to ophthalmology. In an attempt to recognize those who contributed to these important advances, they are listed in the following Who's Who.

Hans Bebie, PhD, professor of theoretical physics, director of the Institute of Theoretical Physics of the University of Berne 1983 1999. He created and continues to create the software for the OCTOPUS. He invented substitution devices for the visually handicapped and the blind,[11] such as the Makrolektor and the worldwide first talking calculating machine.[3]

Josef Bille, professor of physics, chairman of the Institute of Applied Physics of the university of Heidelberg, developed the Nd:YFL femtosecond laser for use in ophthalmology.

René Dändliker, PhD, professor of physics, Director of Research of the Swiss company Asean Brown Bovery (ABB), later chairman of the Laboratories of Microtechnology of the University of Neuchâtel and the Institute of Technology in Lausanne (EPFL), provided the access to the first gigantopulse laser in Switzerland.

U. Dürr, PhD, physicist, laser specialist, working with Meridian, now a branch of Haag-Streit, designed, together with Dr. Pierre Henchoz, the laser apparatus Microruptor 1, 2, and 3 (Fig. 6). Now he works at Laser Technical in Thun.

Hans Giger, a mathematical genius, worked together with Hans Goldmann and Franz Fankhauser on mechanisms of vision, on glaucoma, and on dynamics of intraocular fluids. Had he been a little more diplomatic he may have achieved a splendid academic career.

Pierre Koch, PhD, professor of physics, successor of Professor H. König as director of the Institute of Standards of Switzerland in Berne. He was one of the first to design models of automated perimeters.

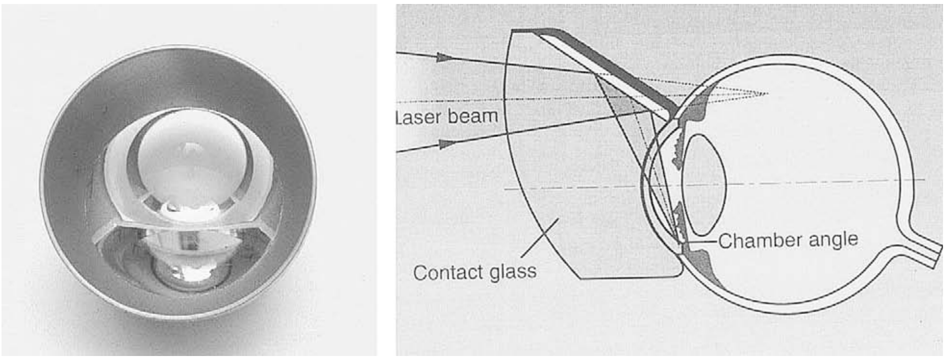

Fig. 10. The CGA 1 Goniolens of superior optical quality.

Sylvia Kwasniewska, MD, stateboard in Warshaw, thesis with Hans Goldmann, second wife of Franz Fankhauser.

Walter Lotmar, PhD, physicist, specialized in geometric optics, worked with the optical firm Kern in Aarau, Switzerland (remember the famous Alpa-Reflex-Camera), later with the National Institute of Standard. Constructed laser related optical systems. After retirement he worked with Professor Goldmann on stereochronoscopy[31,34–36] and developed an apparatus to determine retinal visual acuity by Moiré-fringes with Haag-Streit.[42,43]

John Marshall, PhD, Frost Professor of Ophthalmology, Head Department of Ophthalmology, St. Thomas Hospital, London, was a steady companion in laser research.

Klaus Meyer, PhD, professor of physics, former director of the Institute of Applied Physics, University of Berne. Many of laser physicists listed here are his pupils, the so-called "Meyer-boys". He founded LASAG, a world-renowned foundation for laser material processing.

Jean Marie Parel, engineer, research professor of ophthalmology, Director, Ophthalmic Biophysics Center, Bascom Palmer Eye Institute, Miami, tried to automate the Goldmann perimeter in 1956, engineered the first instrument for vitrectomy together with G.W. Crock at the Department of Ophthalmology in Melbourne and later in Miami with R. Machemer.

Didier Riquin, PhD, graduate of the Institut d'Optique, Paris. Engineered contact lenses, worked for LASAG. He died on the Mont Blanc.

Pascal Rol, PhD, graduate of the Institut d'Optique, Paris. Outstanding physicist, developed various optical system for laser use. Died in an air crash of Crossair Airlines at Nassenwil in 2000.

Rainer Röhler, PhD, was professor at the Institute for Medical Optics of Technical University, Münich, Germany, when Fankhauser did essential work in sensory physiology with him.

Dieter Röss, PhD, professor of physics, chief of the research department of Siemens and Halske, Münich, Germany.

Alfred Roulier, PhD, worked on the first programs for automation of perimetry, then on the development of lasers for ophthalmology. Later he choose a military career and became a two-star general and commander of the 3rd Infantry division of the Swiss Army.

Philippe Roussel, PhD, physicist, graduate of the Institut d'Optique. Pioneered the Nd:YAG q-switch laser. He is now in a leading position at the European Space Agency (ESA).

Jürg Spahr, PhD, was instrumental in bringing the automated perimeter to life. He went the head of the Institute to enhance technology in Berne.

Hermann Stich, Dr. h.c. (Doctor honoris causa) is an assistant at the Institute of Dentistry. He knows almost everything and is a genius when it comes to finding pragmatic solutions.

Heinz Weber, PhD, followed Professor Meyer as professor and director of the Institute of Applied Physics. He provided Franz Fankhauser the essential support of this institute.

Eugen Van der Zypen, MD, professor of anatomy and ultramicroscopy at the University of Berne, did pioneering work on laser tissue effects at the eye and on outflow systems.

Gerhard (Gerry) Zühlke, manufacturer of the automated perimeter. Without his entre-preneurial courage and endurance the OCTOPUS could never have been realized.

Then as a mainstay **Verena Fankhauser**, his first wife, who helped in numerous experiments and worked tirelessly for him, but who died much too early, and later his second wife **Sylvia Kwasniewska** who still helps in numerous experiments.

The research across the borders in the fields of science demanded from Franz Fankhauser sometimes extremely adventurous trips (with and without patients, sometimes with rebelling monkeys) from the Eye Hospital or the Lindenhof-Hospital in the Institute of Standards. When collaborating with Dr. Röss during weekends he would travel from Berne to Münich, or, for first interventions with an Nd:YAG laser on humans, from Berne to the research laboratories of ABB in Dättwil. These journeys on twisting mountain roads were done in an alarmingly tilting Citroen 2 CV and later in a faster Opel or Saab—always under enormous pressure of time.

National and International Recognition

Fankhauser's research is reported in almost 300 publications. Invitations for named lectures were numerous. These lectures were spicy and mixed with irony. When he started free associating and the flow of words continued after his assigned time, the audience enjoyed it, but the chairmen of the sessions became quite embarrassed.

He was honored with many awards. To mention a few: the 1983 Marcel Benoist Price(the highest award the Swiss government can give for achievements in research), the 1988 Helmholtz Medal of the European Ophthalmological Society, and the 1996 Graefe Medal of the German Ophthalmological Society.

The numerous awards can't hide the fact that Fankhauser was weighed down by many worries. On a personal level, Fankhauser was greatly disturbed by the untimely death of his first wife Verena, but he is now greatly aided by his second wife Sylvia.

Final Remarks

Fankhauser built bridges between natural sciences and ophthalmology in a way that nobody else has done since Hans Goldmann, making use of ongoing research in physics for the diagnosis and therapy of eye diseases. A flair for physical sciences, creativity, curiosity, strength of mind, and perseverance are behind his accomplishments. It was astonishing how many scientists and institutes he could mobilize to realize his ideas. But the times have changed since Goldmann, who together with Haag-Streit, could provide the ophthalmological world with instruments for daily use almost unchallenged for over 50 years. To get the newly developed high-tech instruments Fankhauser and his coworkers had to move from the protected surrounding of the university into the stormy sea of the free market and to face much more aggressive competition, takeovers, and the destruction of the firms which had done the original work. They had to recognize that the devoted researcher is no longer the determining force when big business is involved, but simply a pawn in the battle for share-holder values. This still disappoints him at the end of his life.

Throughout his life, Fankhauser remained a sought after practicing eye doctor. As was common at the time, he worked over the whole spectrum of surgery. Patients always came first, making what he achieved in research all the more astonishing, as it was it being done mainly at night.

Despite the hectic pace, Fankhauser has tried, especially in his later years, to lean back, to think, and to order the more recent results of sensory physiology[10] and biology, and by so doing has produced articles summarizing wound healing, light sensitivity, super-vision,[17] and the newest imaging techniques with extremely short pulse lasers. He dealt with epistemology by looking back to the phenomenon of Hans Goldmann.[9] Fankhauser believes that ethics and morality should be an interior standard. Franz Fankhauser is a man who is modest in his behavior, but not in what he achieved. He is self-critical, full of humor, ironic, sometimes sarcastic, and he has a great gift for friendship—that is the Franz Fankhauser I know.

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