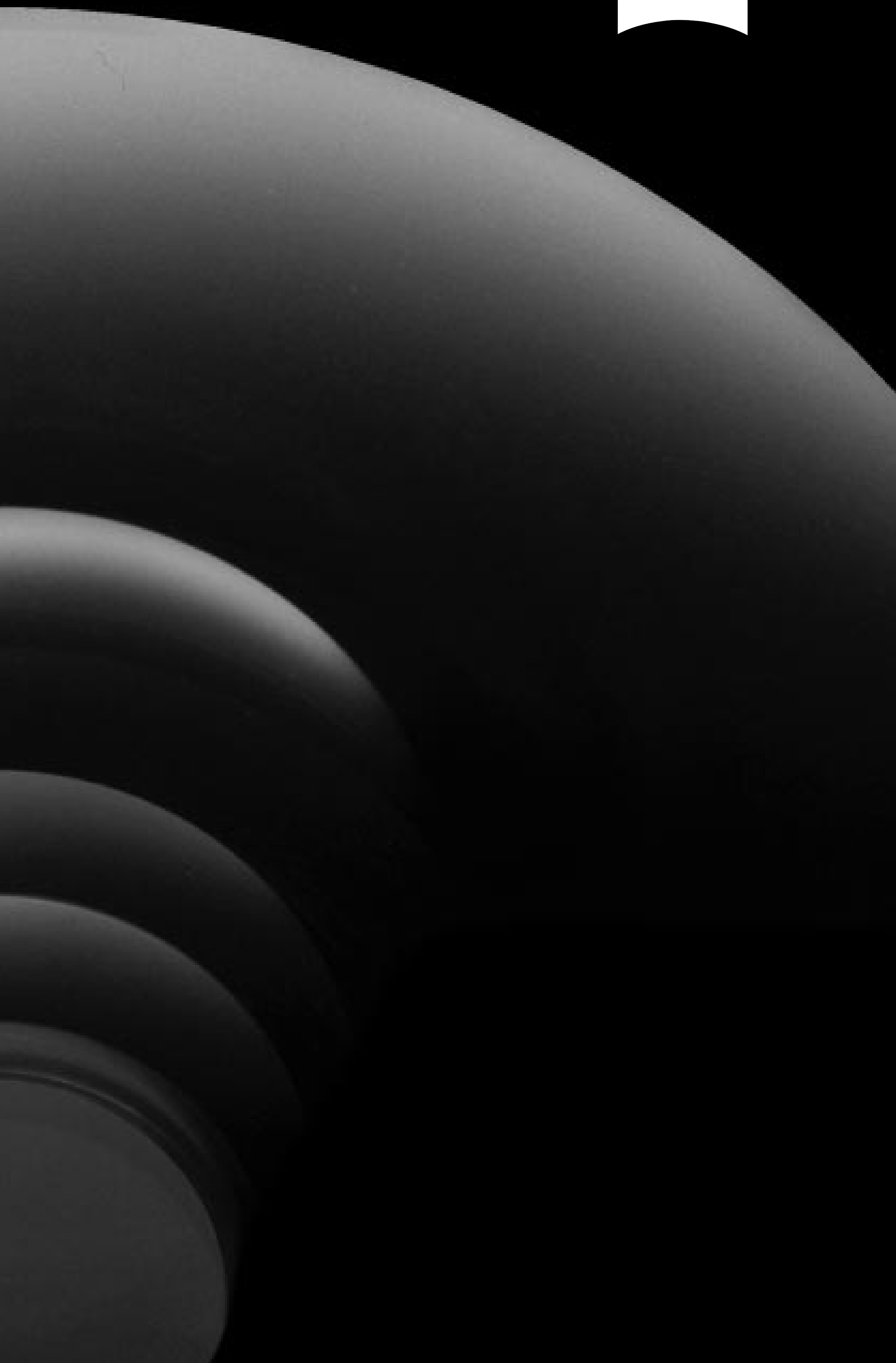
CARL ZEISS JENA

ZEISS

ZEISS

many



Anticipating the Future

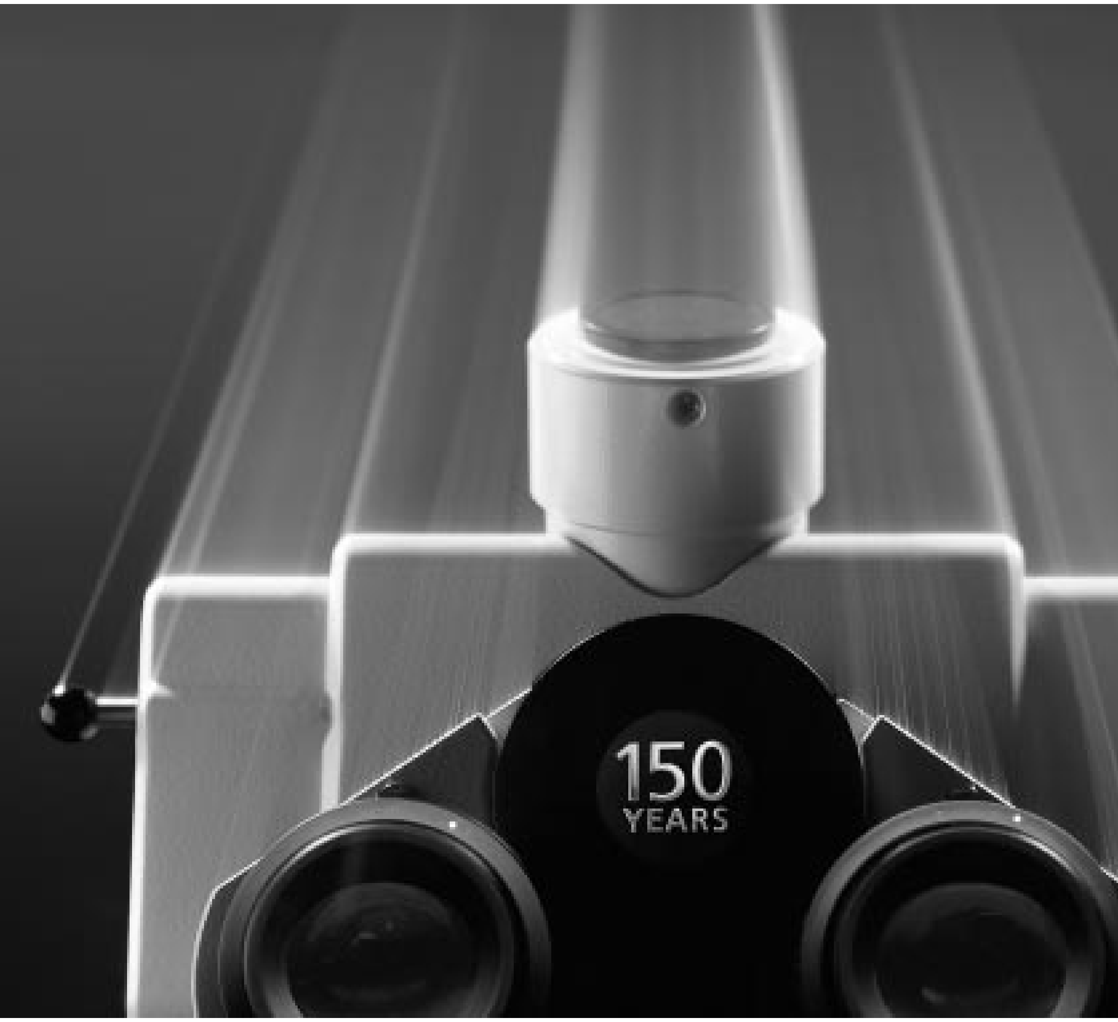
“Anticipating the Future”
is the title of this portrait, which covers,
in words and pictures,
the 150 years’ history of Zeiss microscopes.

“Anticipating the Future”
might also be the motto of the worldwide
community of Carl Zeiss microscope users,
whose demands for quality have given birth
and constant stimulus to progress
in microscope design.

A man of skill,
experience ...

... and foresight

150 years, and the legend keeps growing



Questions like these may be pointless, but they are nevertheless intriguing: Is a glass of champagne (to suit the occasion), with half of its contents sipped, half empty or half full? And does a 150th anniversary make its subject 150 years old or 150 years young?

Well, it is all a matter of how you look at it. To be sure, with all the tradition, handed-down values and sound standards of quality involved, the 150-year-old cannot be denied a distinct maturity. On the other hand, there is an undiminished, youthful vitality and an inexhaustible urge for permanent innovation and improvement.

Surprising? Not quite. After all, the innovative power, the future-anticipating spirit of progress are part of the tradition. They have been there from the very onset.

Whether considered old or young, Carl Zeiss is a legend. But a legend that is very much alive. No matter in which part of the world: wherever someone mentions Carl Zeiss, the name invokes microscopes. And, reportedly, it has caused the normally matter-of-fact face of many a scientist to mirror enthusiasm.

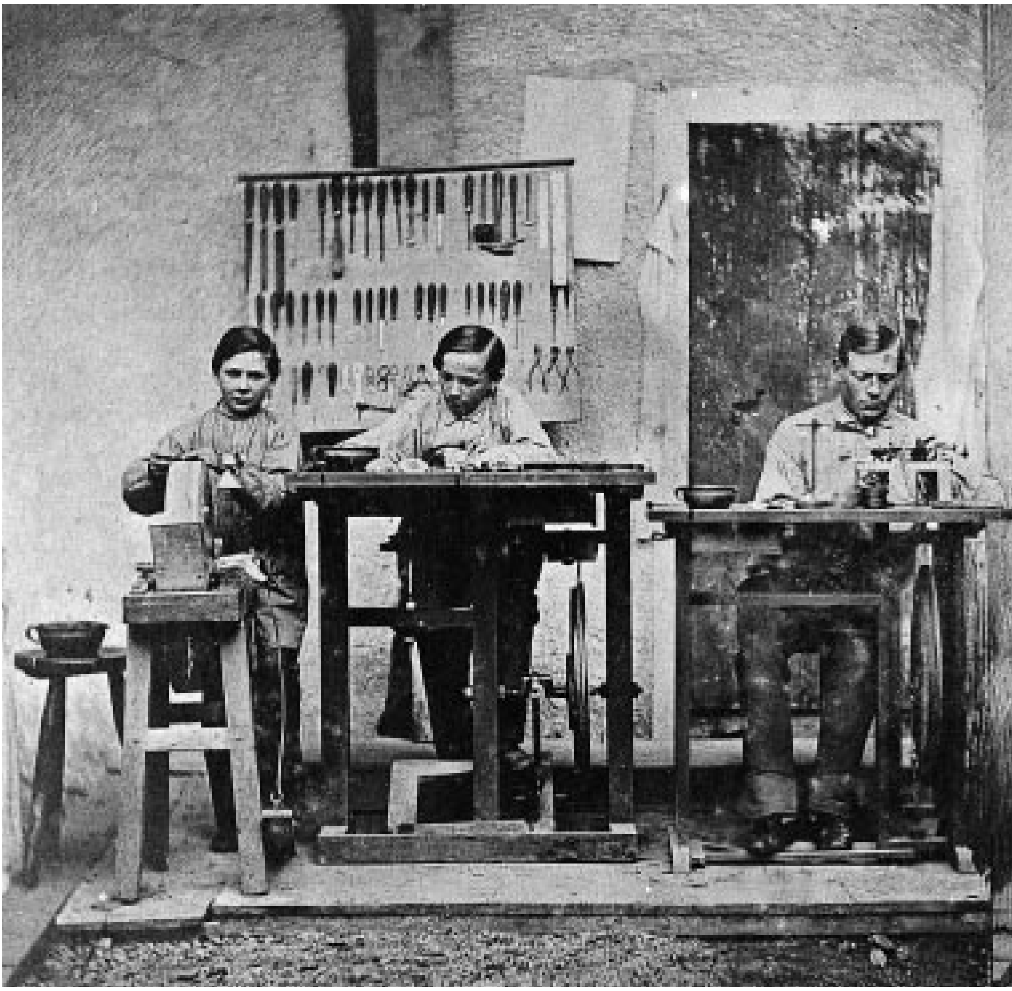
Like Rome, a reputation like that was not built in a day. To trace it back to its roots, there is hardly a fitter occasion than this 150th anniversary. Well then, let's stroll back into the history of Carl Zeiss, to find out

how everything started.

Microscopes from Zeiss

May 10, 1846. A certain Carl Zeiss submits an application to the state authorities in Weimar, asking for permission to establish a mechanic's workshop. To the Grand-Ducal government this is a matter for run-of-the-mill bureaucracy and not to be handled with undue speed (there has not been much change since, it seems). Anyhow, a deed is issued on November 19, permitting the applicant to set up a workshop in Jena and to make and sell mechanical and optical instruments.

Carl Zeiss does not dither about. The fact that the workshop has actually been opened two days earlier, on the 17th, speaks of the young mechanic's ambition. Some people say he started with a borrowed sum of 100 thalers. First address: Jena, Neugasse 7. Carl Zeiss? Who's that? Your particulars, please, Sir! Zeiss, Carl Friedrich, born in Weimar in 1816, grammar school, apprenticeship with Dr. Friedrich Körner, mechanic and supplier to the court (who has been

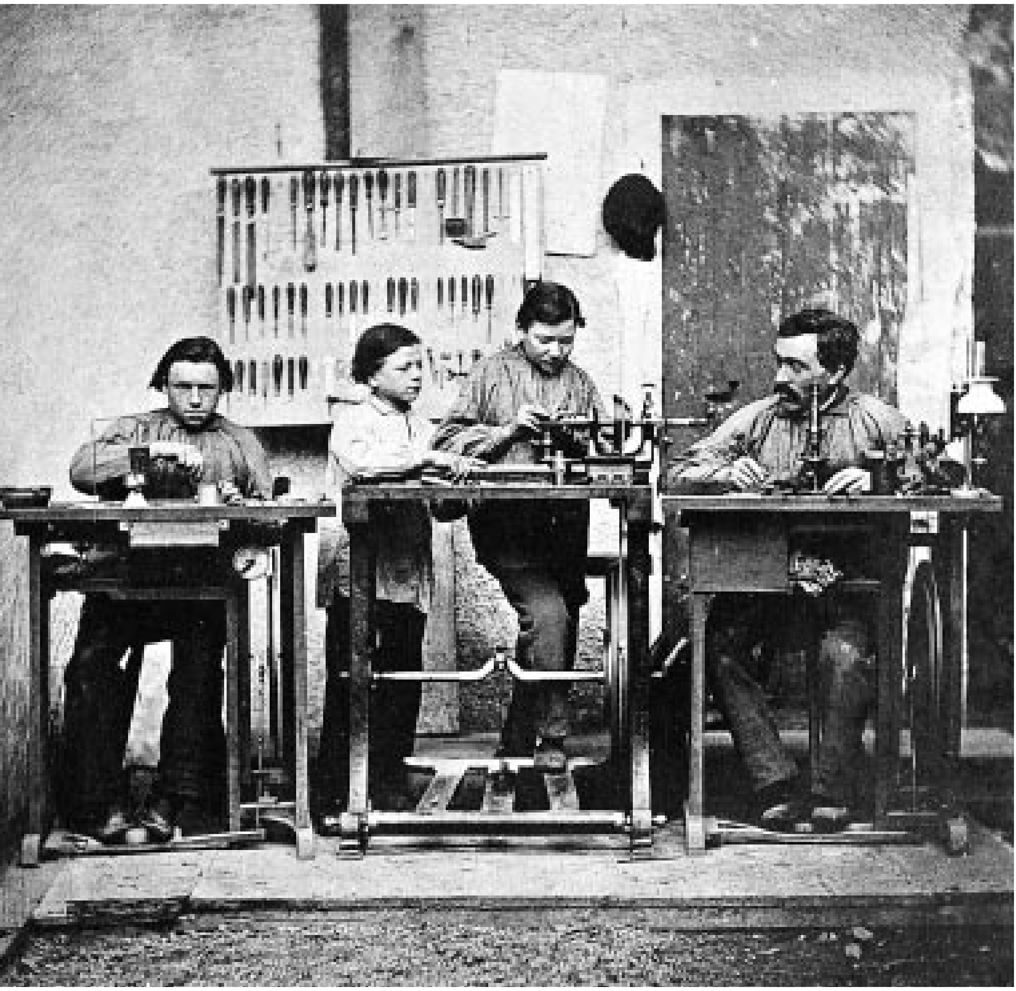


1846: First workshop
Neugasse 7

1847: New premises
Wagnergasse 32

making simple microscopes since the early forties); attendance of lectures at the Jena University (mathematics, experimental physics, anthropology, mineralogy, optics); journeyman's travels for several years; practicals at Professor Schleiden's physiological institute in Jena.

And now: new-made owner of a one-man business. With little money, just the most essential tools, working all on his own in the dim light of an oil-lamp, but, what is more important, full of ideas, energy and determination. He sells eyeglasses, magnifiers and balances, builds and repairs physical and chemical apparatus for the university. The business gets going. In 1847 Zeiss moves his workshop to a bigger site and employs his first apprentice. The same year sees the death of his former master, Dr. Körner, and Zeiss now turns to the subject that has fascinated him ever since his own apprentice years: the making of microscopes.

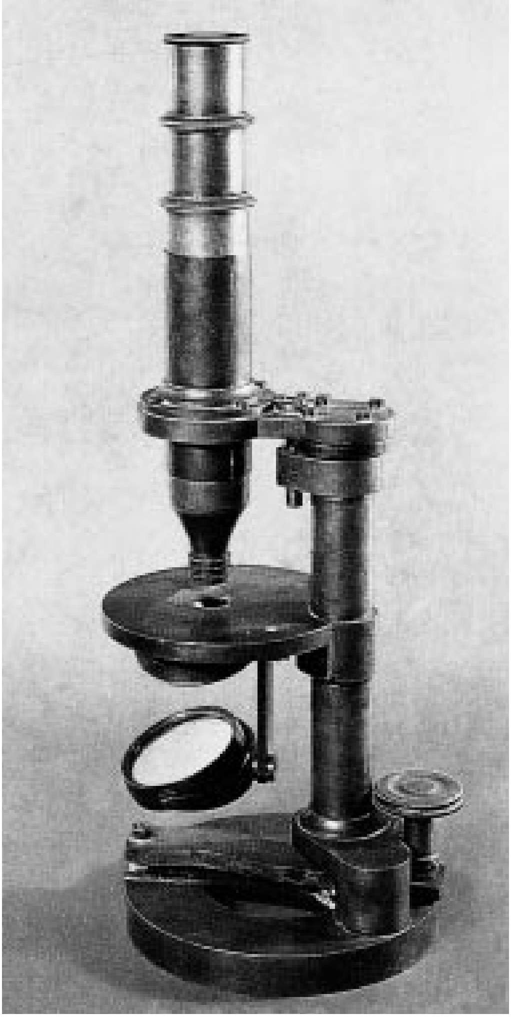


1864: In the courtyard of the third workshop site, Johannisplatz 10

Simple …

1847: The first simple microscope / Das erste Mikroskop

compound …



1857: Stand I, the first compound microscope

Microscopes: A Long Story of Success

September 1847: With skill, experience, vigor, and ideas of his own, Carl Zeiss starts making microscopes on his new premises at Wagnergasse 32. These are simple microscopes, consisting of one lens only and intended mainly for dissecting work. During the first year, Zeiss sells as many as 23 of them, an indication that they do well in comparison with other makes. Nevertheless, they undergo many improvements during the following years.

Encouraged by this early success, Carl Zeiss soon sets about a more demanding task – the production of compound microscopes. These consist of two optical elements: an objective and an eyepiece. The first unit of the "Stand I" model goes on sale in 1857.

… excellence from the start

1995: Axiophot 2, the first computer-controlled photomicroscope

Modifications of this, as well as new designs follow. In 1861 Carl Zeiss is awarded a gold medal at the Thuringian Industrial Exhibition, because his compound microscopes are ranked *"among the most excellent instruments made in Germany".* In 1863 Carl Zeiss is appointed supplier to the Grand-Ducal court. Now, after not quite two decades, the flourishing business employs about 20 people.

The success of those years is all the more worthy of note as it has been achieved merely by skill and experience, applied to a trial-and-error method of manufacturing instruments whose designs lack a theoretical foundation.

As a man of foresight, Zeiss is well aware of this lack. And he finds something ought to be done about it.

No More Trial and Error

1866: The 1000th microscope leaves the Zeiss workshop. Despite all due pride, the principal is preoccupied, has been so for quite some time. He has realized, as nobody before him, that trial and error is insufficient in microscope making. He is convinced that even the most skilled craftsmanship reaches its limits where the perfect form of an optical system has to be found by experimentation rather than by computation. In Zeiss' own words: *"The only remaining function of the working hand should be that of precisely implementing the forms and dimensions of all construction elements as determined by the design computation."*

Optics of calculable, predetermined performance: a demanding task. For some time, Zeiss tries to tackle it himself, in vain. But he does not give up. Then he meets Dr. Ernst Abbe, a physicist and mathematician, 26 years of age, lecturer at Jena's university. Carl Zeiss engages him as a free-lance research worker. Two matching minds join to make possible what nobody has thought of before.

Ernst Abbe

$$d = \frac{\lambda}{2n \sin \alpha}$$

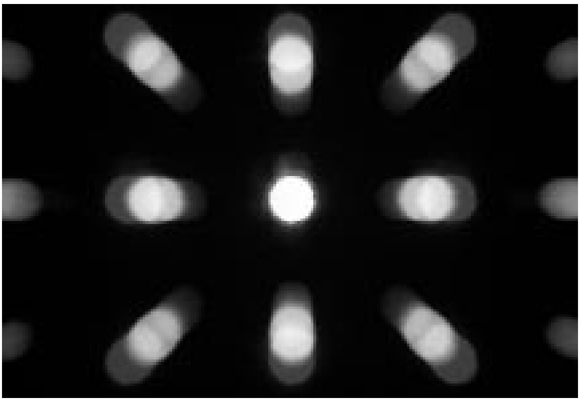
The Formula One of Microscopy

During the ensuing six years, Zeiss and Abbe work intensively to lay the scientific foundations for the design and fabrication of optical systems. The path is arduous, and not without setbacks. A vast scope of theoretical studies and experiments have to be made, testing methods and equipment to be devised. In 1869, a new "illumination apparatus" is designed for use in the studies *("with all parts assembled according to purely theoretical considerations"),* which soon comes into widespread use.

And finally, the breakthrough. In 1872, Ernst Abbe formulates his wave theory of microscopic imaging, and defines what becomes known as the Abbe sine condition. A great year in the history of Zeiss, and in the history of the microscope. Now, for the first time, Zeiss offers a range of 17 microscope objectives (three of them being of the immersion type) designed on the basis of optical research and mathematical operations. In Abbe's words, *"Based on a precise study of the materials used, the designs concerned are specified by computation to the last detail – every curvature, every thickness, every aperture of a lens – so that any groping around"* (Abbe might also have said, any trial and error approach) *"is excluded."*

Abbe's discoveries mark a revolution in microscope design. The new microscopes built in Jena gain the name of Zeiss a worldwide reputation for quality and innovation.

By the way, as far as quality is concerned, Carl Zeiss is a man of principle: With a hammer in his own hands, he smashes many a microscope made in his workshop that fails to satisfy his critical inspection – rather a striking method of quality assurance.



Diffraction experiment

Visible Quality Based on Science

1994: Water-immersion C-apochromat 40x/1.2 with correction collar, mainly for confocal imaging

Abbe's findings are nothing less than the theoretical principles on which microscope objectives can be designed to predetermined performance specifications. They are nothing more either. In many respects, the theory does not materialize – due to lack of proper materials. As demands of microscope users on image quality increase, further progress is impeded because the glass available for lens making just does not have the desired dispersion properties to match improved lens designs. So Zeiss and Abbe, now business partners, face another challenge: the development of new kinds of optical glass satisfying Abbe's specifications. Another challenge, another trailblazing success.

Ingenious Theory, Visionary Practice

Otto Schott (about 1890)

The Glass

January 4th, 1881: Ernst Abbe meets Otto Schott, a glass chemist aged under 30, who gained a doctorate in Jena in 1875. Abbe urges Schott to collaborate in the development of optical glasses with special properties. A few months later, in his native town of Witten, Schott makes the first melting experiments. In the following year he moves to Jena to work in a glass-making laboratory specially set up for him (the nucleus of what later is to become the Jena glassworks of Schott & Genossen).

The series of experiments consumes lots of effort, time and money. The success more than justifies every bit of it. A vision becomes true when Zeiss, in 1886, markets the first lot of an entirely new type of microscope objectives: apochromates. Made in different varieties as dry, water immersion and homogeneous immersion objectives, and used together with so-called compensating eyepieces, they provide images free from color distortions throughout the image field, *"without their design having to be more intricate".* This even applies to apochromates of relatively high aperture.

Together with Abbe's wave theory and sine condition, the new glass types provide the basis for practically any modern high-performance optics.

A note on the enterprise in between: In 1886, the year of the glass breakthrough, Zeiss employs 250 workmen and turns out the 10,000th microscope.

During this period of breakthrough and upswing, the founder and prime mover of the enterprise leaves his comrades-in-arms: Carl Zeiss dies on December 3, 1888.

The Light

August Köhler

The scientific theory is there, and so are proper glasses. But there is yet another factor to be mastered before best results can be achieved in microscopy: Illumination.

Enter Professor August Köhler. In 1893, at the age of 27, he reports on an illumination method he has devised for photomicrography. Known as Köhler illumination, this elaborate method makes it possible for microscopists to use the full resolving power of Abbe's objectives.

It cannot be a mere coincidence: Köhler joins Zeiss, contributes his illumination system, and later is put in charge of microscope development.

To this very day, no other illumination method beats Köhler for optimum results in microscopy.

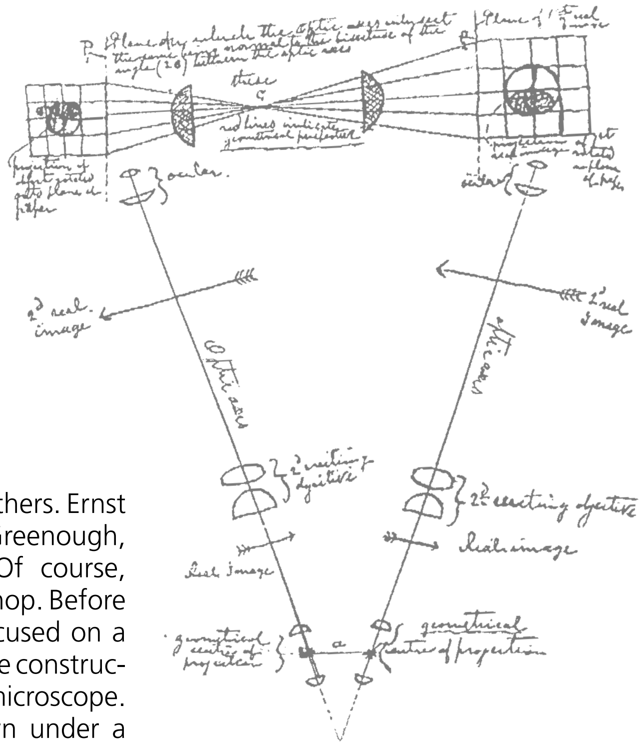
The Goal

1996: Metaphase chromosomes, double fluorescence, laser scan microscope LSM 410 invert

The death of Carl Zeiss is a grievous loss. In honor of the name of his friend and partner, Ernst Abbe in 1889 establishes the Carl Zeiss Foundation, and in 1891 transfers to it his shares in the Optical Workshop and the Schott Glass-works, together with those of Roderich, son of Carl Zeiss, and co-partner since 1881.

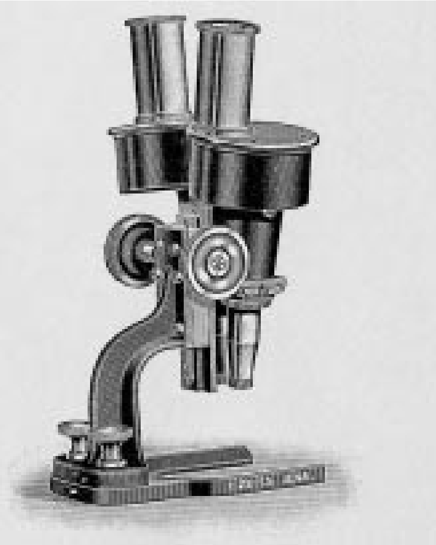
Onwards Forever

As much as they miss Carl Zeiss, both as an initiator and a friend, his collaborators carry on the business in his spirit. The last decade of the 19th century is paved with milestones – inventions and design innovations that already look forward past the turn of the century: Metallographic microscopes, anastigmatic photolenses, binocular microscopes with image-reversing prisms, to name but a few. And then a push forward that is out of the ordinary, even for an enterprise as extraordinary as Zeiss.



The Third Dimension

1896 is not a year as others. Ernst Abbe meets Horatio S. Greenough, an American biologist. Of course, they cannot help talking shop. Before long, the discussion is focused on a seemingly utopian idea: the construction of a stereoscopic microscope. Utopian? The idea is born under a lucky star. The American visitor draws a promising sketch on a sheet of paper. That's it. Around the turn of the year, Greenough's invention has taken shape as a Zeiss product: the first stereomicroscope ever.

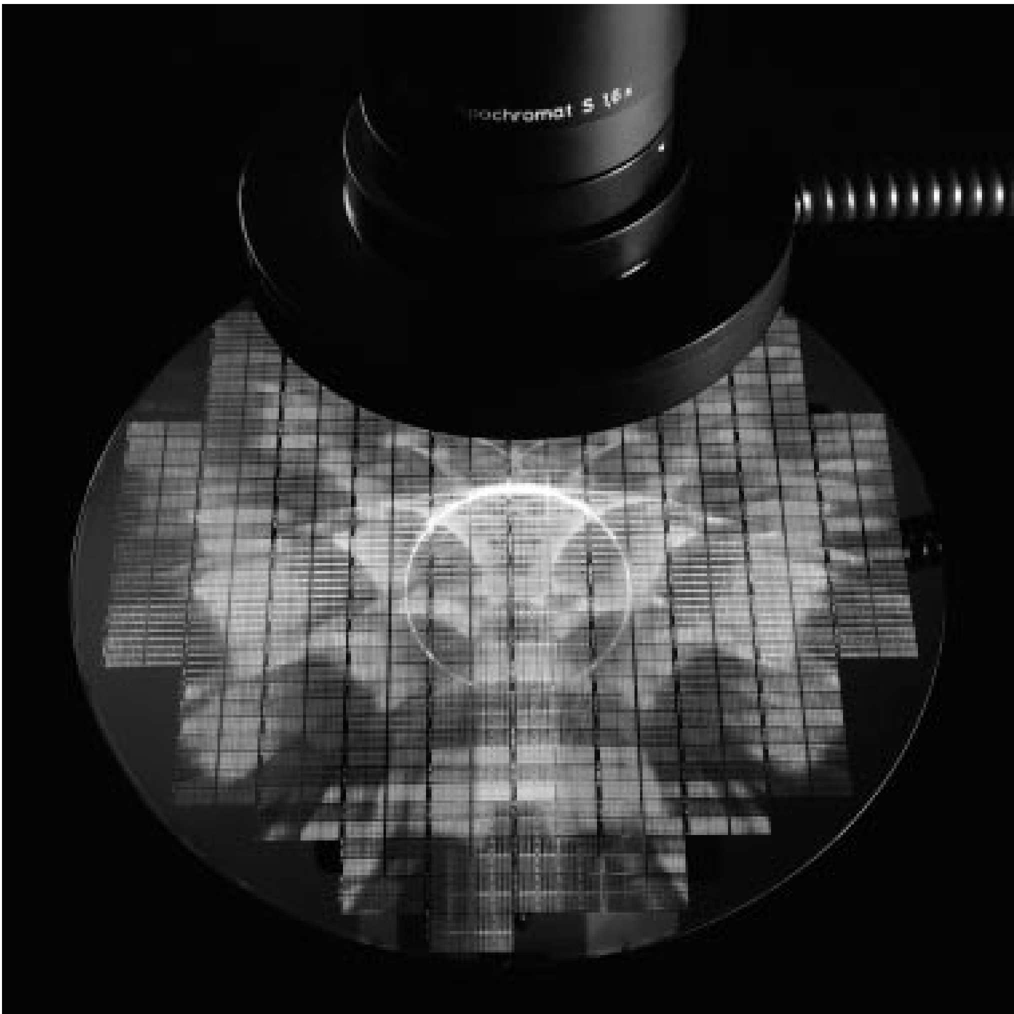


1897: Greenough stereomicroscope

Success in 3D

And More To Come ...

1993: Stemi 2000



1995: Stemi SV 11 Apo

First Half of 20
but No Half M

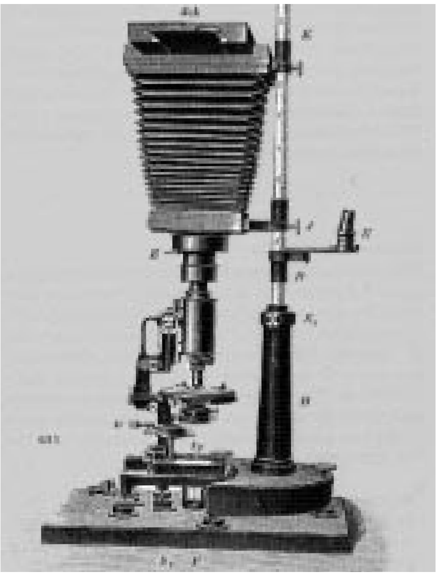
The first year starting with 19 sees the Carl Zeiss company employing no less than 1070 people, and there is no end of growth. While activities over the first fifty years were exclusively devoted to microscopes, the enterprise now gets busy in more and more other lines of optical instruments.

Still, the history of Zeiss is primarily a history of microscopes. So let us stick to the subject in this tribute to Carl Zeiss, the more so as there is no lack of sensational development, inventions and innovations during the first decades of the century. Their mere enumeration would go beyond the scope of this brochure. At least the most essential ones deserve mentioning, though.

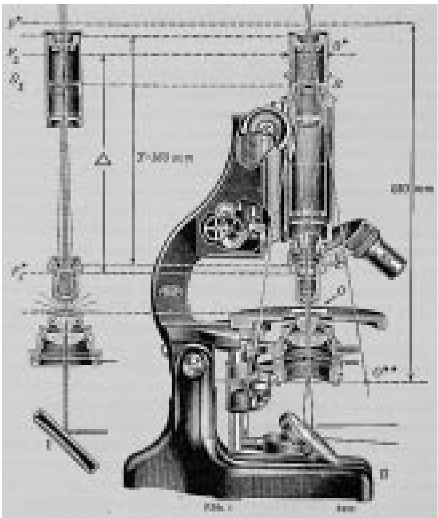
In 1903 Ernst Abbe retires from the management, handicapped by severe health problems. He lives to see in this year the limits of classical microscopy finally exceeded by the ultramicroscope, an invention by Henry Siedentopf and Richard Zsigmondy, which makes submicroscopical colloids visible. He lives to welcome August Köhler's study reports about the ultraviolet microscope in 1904 (which is followed by the luminescence microscope in 1913). On January 14, 1905, the man who jointly with Carl Zeiss wrote a decisive chapter of the history of microscope making dies, deeply mourned by all Zeiss employees.

The ultramicroscope, the UV microscope and the luminescence microscope exemplify the inventive genius of those years and reflect three goals of microscopy, which have remained topical to date: Making ever smaller dimensions accessible to observation; observing living objects without damaging them; and finding methods to contrast the substances in such objects.

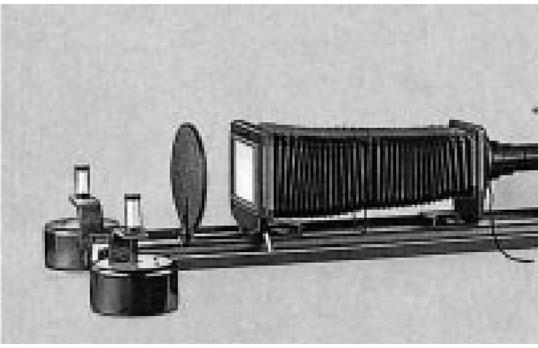
In 1911, Zeiss implements Köhler's idea of parfocalizing all objectives used on a microscope, which means that the image remains in focus when the observer exchanges one objective for another. In 1920,



1904: Ultraviolet microscope



1924: Path of rays in a microscope



1934: NEOPHOT, a large epi-microscope with camera

th Century,
easures

the comparison eyepiece is introduced, which allows simultaneous observation of two specimens under two microscopes.

1924 sees the world's first lot production of infinity-corrected objectives for the Large Metallograph of the LeChatelier type.

Let us jump to 1931 to see the development of the first electron microscope, devised by Max Knoll and Ernst Ruska. Two years later, Zeiss once more revolutionizes microscope design with its legendary L stand. Curved tube arm, inclined viewing head, invariably horizontal stage and low-positioned controls – features that are enthusiastically welcomed by users for the operating convenience they provide.

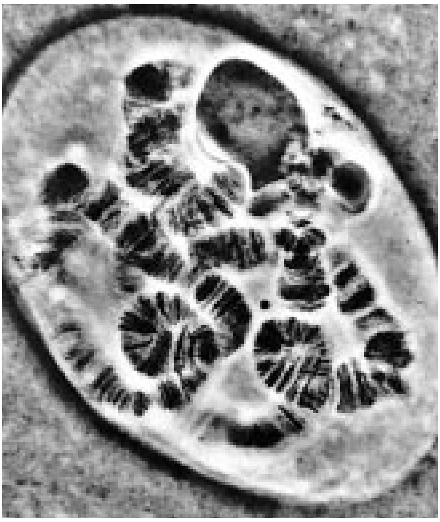
Photomicroscopes follow – the Neophot in 1934, and the Ultraphot in 1937. In 1938, Zeiss presents another “first”: After long and tedious experimentation, Hans Boegehold succeeds in flattening the image field of objectives, so that the company can market the first planachromats. Upon a suggestion by Frits Zernike, Zeiss in 1936 creates the prototype of the phase microscope.

During World War II, microscope development has to be soft-pedaled, on government order. Nevertheless, the microscope development laboratory designs and builds a cine-micrographic apparatus and in 1943 shoots the first cine record of a cell division through a phase microscope – an examination method that opens up a new era of cell research.

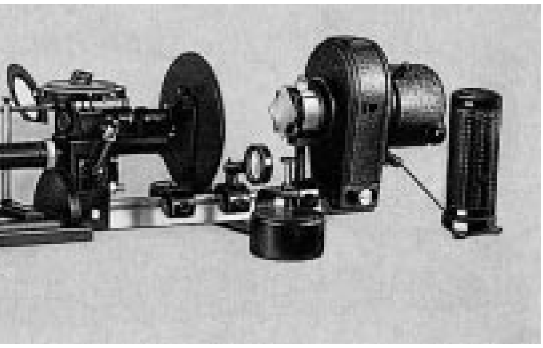
This may suffice as a fast glimpse of the near-half century of Zeiss since 1900. The grief over Abbe's death, enormous technical progress, successful business, setbacks: all considered, a great time.

Now imagine, in striking contrast, the drastic consequences of the war and its aftermath.

1936: The L stand, prototype of a phase microscope



1941: First photograph of a living cell nucleus



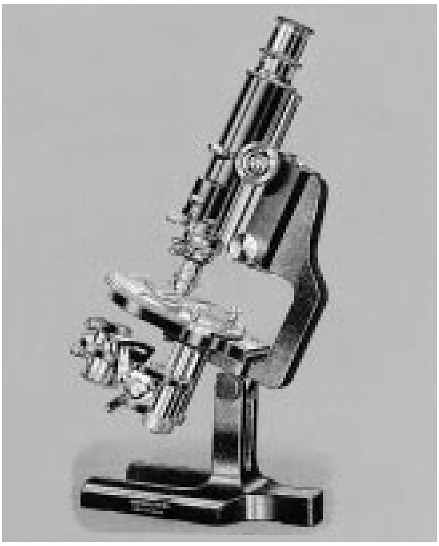
Jena – Göttingen – Oberkochen – Jena

1945: The disastrous war has ended with Germany's (and Europe's) political and ideological division. As a bitter consequence, Zeiss is forcibly cut in two.

Zeiss managers and many scientists are evacuated to the American zone, many more scientists, designers, engineers and foremen taken to Russia. By 1947, all production facilities in Jena, save for a rest of 6%, have been dismantled and shipped abroad.

In the first years after the war, Carl Zeiss once again demonstrates the significance of a future-oriented attitude. Reconstruction in Jena starts with a workforce of about 4500.

A new start is also made by 250 people at Oberkochen, Württemberg. Despite adverse conditions, the old Carl Zeiss spirit refuses to give up. Splitting, in this case, means doubling.


1926: Ore microscope III M for teaching and routine

Göttingen
A Flashback

Back to the year 1857. Rudolf Winkel sets up a mechanic's workshop in Göttingen. Guess what he makes? Right – microscopes. Simple ones at first, compound ones later. Good ones throughout. He is successful, exports a lot, expands the business, and has his sons enter it. Ernst Abbe first visits Winkel in 1894. In 1911, Carl Zeiss becomes the principal shareholder of the company, which continues to grow.

After 1945, Jena's traditional microscope manufacture is continued in Göttingen. In 1957, the firm of R. Winkel GmbH is taken over by the Carl Zeiss Foundation.

Stages of a Chronicle

1955: Automatic photomicroscope

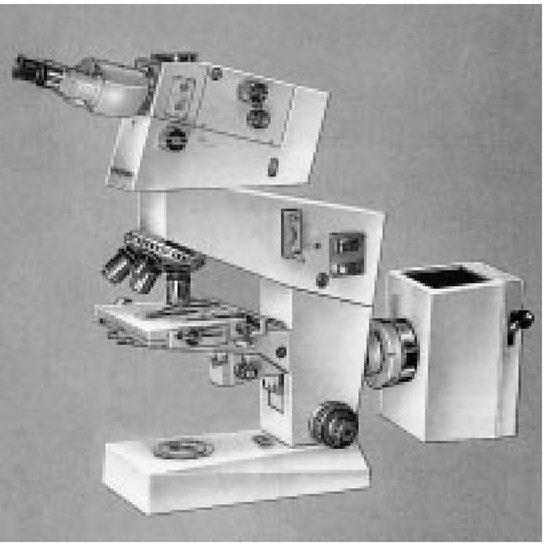
Today, the company which has contributed many improvements to microscope design, still makes about 80% of all Zeiss microscopes and employs about 750 people. They simply have deserved this brief flashback

For four decades, the Zeiss plants in eastern and western Germany operate separately and independently of one another. Achievements are made on both sides. There is no point in separately counting the points made by either side. Let us rather count the points made by Carl Zeiss at large. There are many of them in the chronicle of Zeiss microscope making in the years after 1945.

Take 1949, for example: The intensive development efforts in transmission electron microscopy bears fruit. Or 1950: The first member of the Standard family of microscopes sees the light of day. It ushers in a modular, highly flexible system, which becomes one of the most successful developments in the history of microscopes. In the same year, Zeiss applies for a patent on the invention of a magnification changer known by the name of Optovar. 1955: Launching of an all-new photomicroscope with integrated camera and automatic exposure control. 1959: The year of Ultrafluar. Zeiss succeeds in making dioptric objectives suitable for both ultraviolet and visible light. A big step ahead in microspectrophotometry.

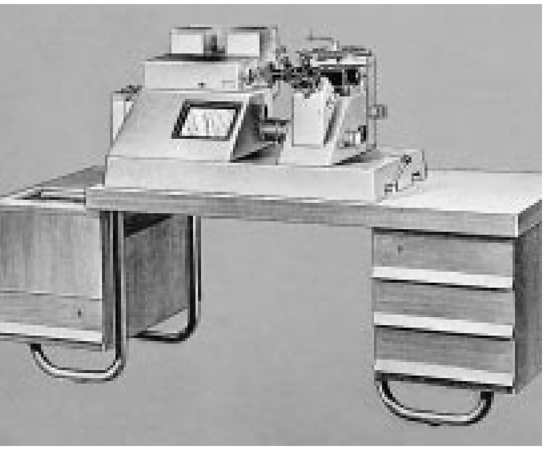
In 1965, materials researchers, doctors and biologists are happy with the new interference phase contrast (Interphako) technique for measuring object thicknesses in the nanometer range and refractive indices of tiniest substance volumes. In 1966 the Mikroval series of microscopes is ▷

◁ STANDARD, a microscope family with many members

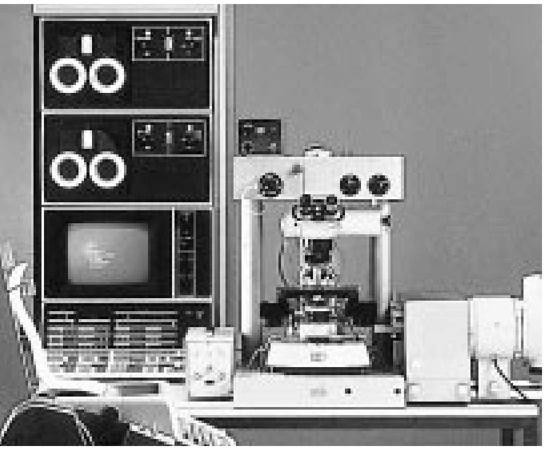


1971: EPIVAL interphako

1973: Axiomat NDC



1965: NEOPHOT 2



1969: Scanning microscope photometer

started. The Ultraphot and Neophot, photomicroscopes of good repute, are upgraded into #2 versions and continue on their triumphant progress around the world. A scanning microscope photometer for the automatic photometry of microscopic specimens follows in 1969. Zeiss is always likely to turn out some innovation or other.

1986: JENAMED 2

1973 sees another instant: Zeiss presents the Axiomat microscope system, a modular system with zoom optics providing unparalleled stability and imaging performance. In the same year, Epiquant makes its debut, a fully automatic digital petrofabric analyzer. In 1975 follow the Plan-Neofluar multi-immersion objectives, in 1976 the inverted IM 35 and ICM 405 microscopes in a design that sets new standards.

1987: Axioskop

1982: Zeiss creates the prototype of a laser scanning microscope. Another sensation in the same year: the JENA MICROSCOPES 250-CF with new, fully color-corrected and infinity-corrected objectives, available at last for daily routine in medicine and biology. 1986: ICS optics, an optical highlight that still causes experts to go into raptures; the SI (System Integration) design, the Axioplan and Axiophot universal microscopes, the Axiotron inspection microscope for the semiconductor industry. 1987: Axioskop, a high-grade routine microscope. 1988: Axiovert inverted microscopes ... where to begin, where to end?

1990: A great year. And, just this once, not because of microscopes. The Berlin wall comes down, and so does the wall between the two concerns bearing a common name. The agreement made between them to go together from now on seems to release extra thrust and to open up a new dimension – without borders or other limits.

There always seems to have existed some affinity between Carl Zeiss and top-flight scientists. People with bold ideas have sought to get in touch with Zeiss, where many of the tools and methods for their research have come from, while Zeiss has always entertained close relations with universities and other research institutes. No wonder that quite a number of Nobel laureates have either, in their research, used Zeiss microscopes, or made discoveries or inventions that went into them. Our applause is due to all of these celebrities, even though we can only mention a few here.

Nobel Prizes for Noble Minds

Robert Koch, Nobel Prize for Medicine, 1905.
Koch is considered the founder of modern bacteriology. In the eighteen-eighties, the country doctor discovered the bacilli that caused tuberculosis and cholera. In a letter to Carl Zeiss he wrote, *"A large part of my success I owe to your excellent microscopes".* In 1904, he received the 10,000th Zeiss objective, a homogeneous immersion system, as a present.

Richard Zsigmondy, Nobel Prize for Chemistry, 1925.
As a professor at Göttingen, Zsigmondy conducted pioneering research in colloid chemistry. He invented the ultramicroscope in 1903, and two types of membrane filters in 1918 and 1922. Ultramicroscopy after Siedentopf and Zsigmondy makes visible submicroscopic particles whose linear extension is below the microscope's resolution limit.

Frits Zernike, Nobel Prize for Physics, 1953.
The Dutch physicist, when experimenting with reflection gratings in 1930, discovered that he could observe the phase position of each ray, and sought to utilize the effect for microscopy. Together with Zeiss he developed the first phase-contrast microscope, the prototype of which was made in 1936. It allowed the examination of living cells without harmful chemical staining.

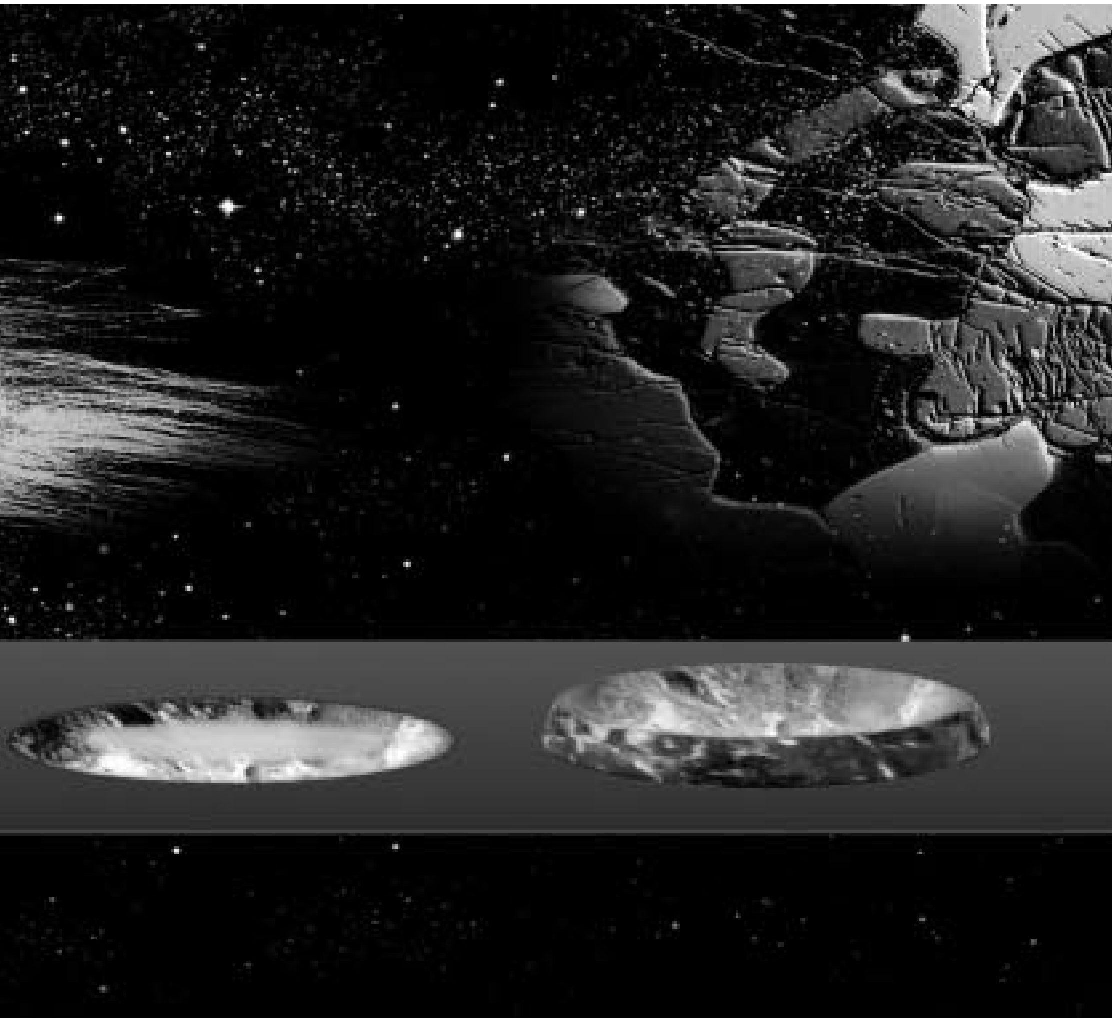
The Nobel Tradition Continues

Manfred Eigen, Nobel Prize for Chemistry, 1967.
The molecular biologist and director of the Max Planck Institute in Göttingen developed a method of keeping track of extremely fast chemical and biochemical processes. In a joint effort, Eigen, his Swedish colleague Rudolf Riegler and Carl Zeiss succeeded in 1993 to create ConfoCor, the first commercial fluorescence correlation spectrometer.

Bert Sakman (photo) and **Erwin Neher,** Nobel Prize for Medicine, 1991.
The two scientists of the Max Planck Institute conducted epoch-making investigations of living cells. All microscopes they used were custom-designed Zeiss products specially made for this application.

Edward B. Lewis, Christiane Nüsslein-Volhard (photo) and **Eric Wieschaus,** Nobel Price for Medicine, 1995.
Two Americans and one German studied the hereditary factors of the fruit fly (Drosophila) to explore the development of complex organisms from an egg cell and the mechanisms of morphogenesis. The epoch-making discoveries might, in the long run, throw light on the causes of deformities, the Nobel committee declared. For their experiments, the three scientists extensively used Zeiss microscopes, among them the Stemi 2000 stereomicroscope.

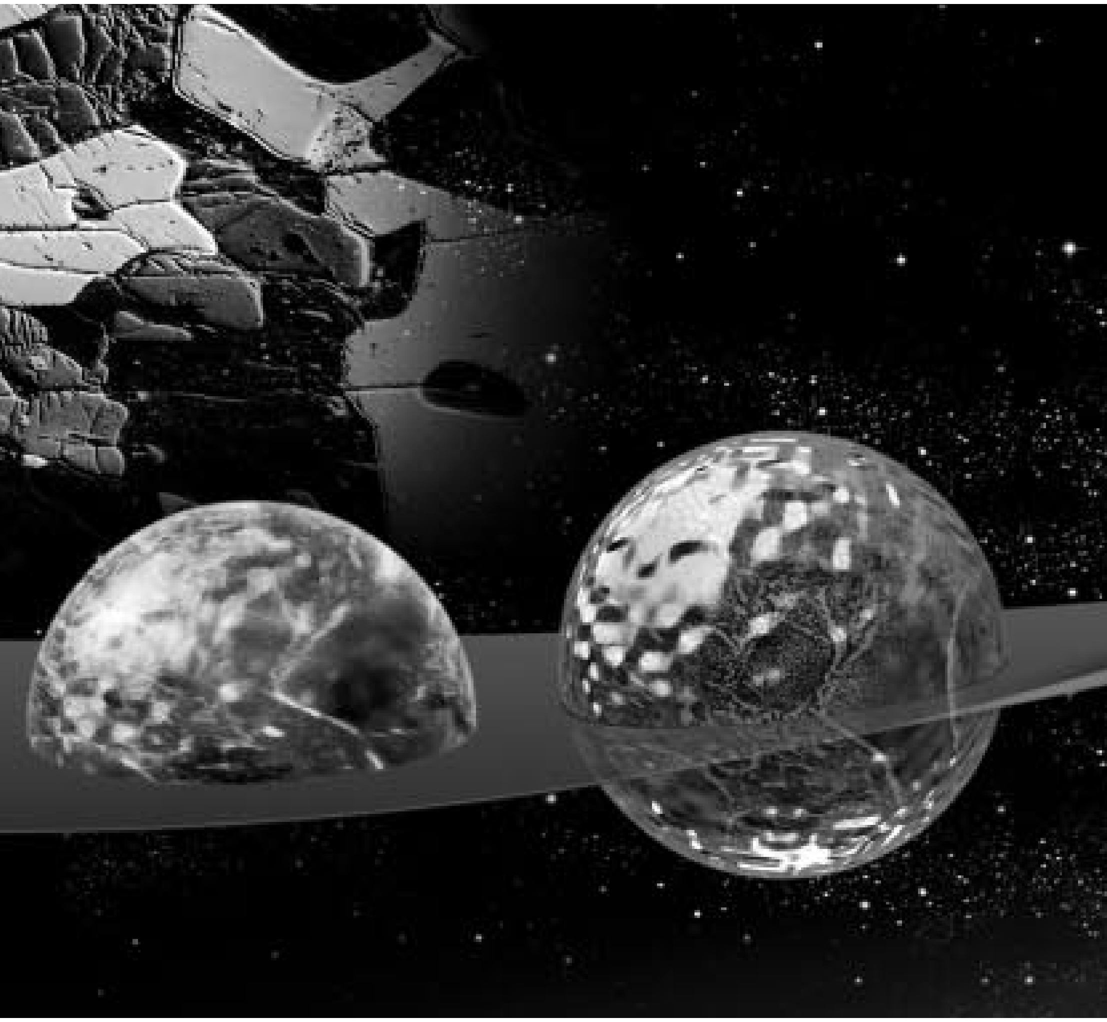
If That Is What the Future Looks Like …



Borders are disappearing, limits are being exceeded and frontiers shifted. New dimensions open up which would have been considered science fiction years ago. The potential of what is technically possible in microscopy is far from exhausted yet.

Telemicroscopy around the globe. Digial communication at light velocity. Series of high-resolution, high-contrast, real-time 3D microimages...

All this, and more, is in the offing. Carl Zeiss, as ever, anticipates the future.



... Super!

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