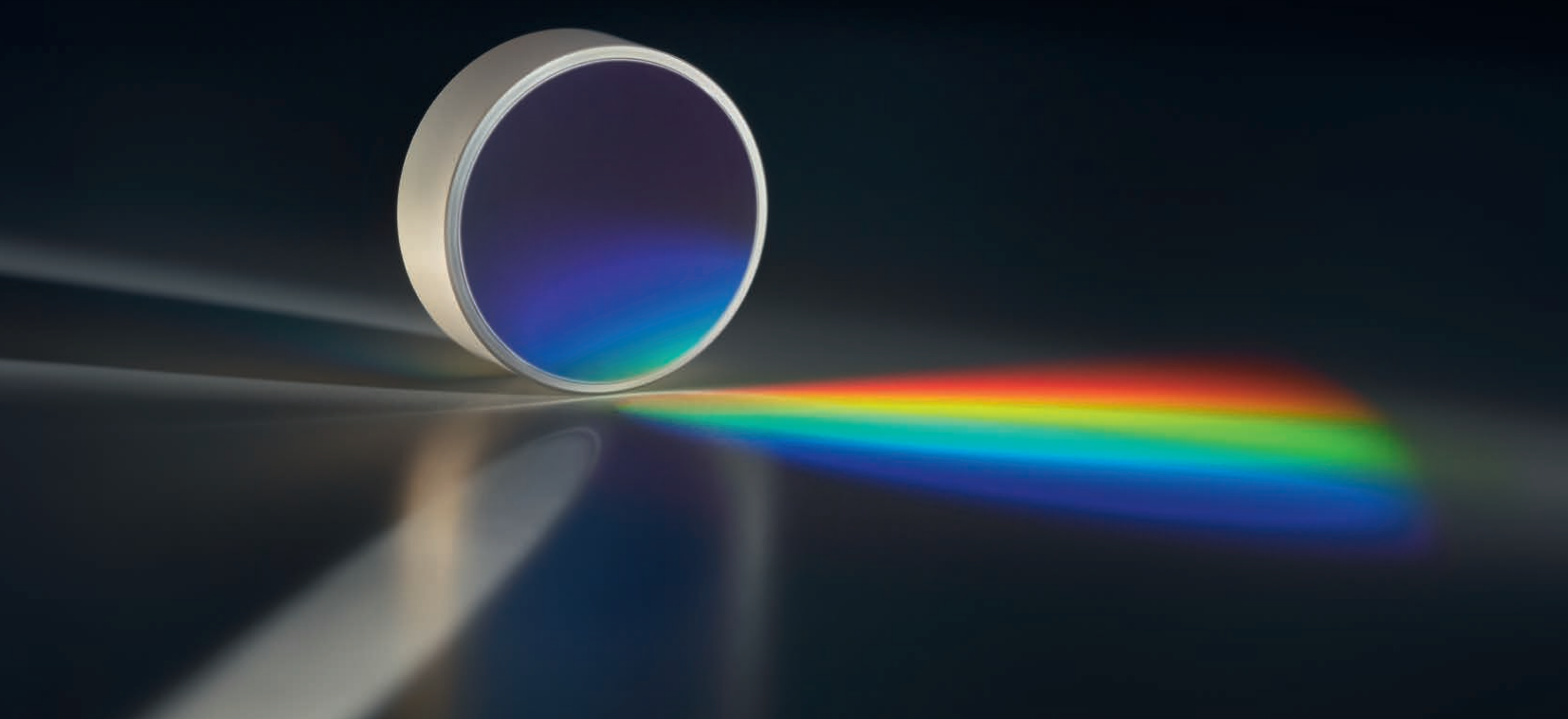
A Legacy of Light

ZEISS

Seeing beyond



150 YEARS
ZEISS SPECTROSCOPY

Reflecting on 150 years
of spectroscopy at ZEISS

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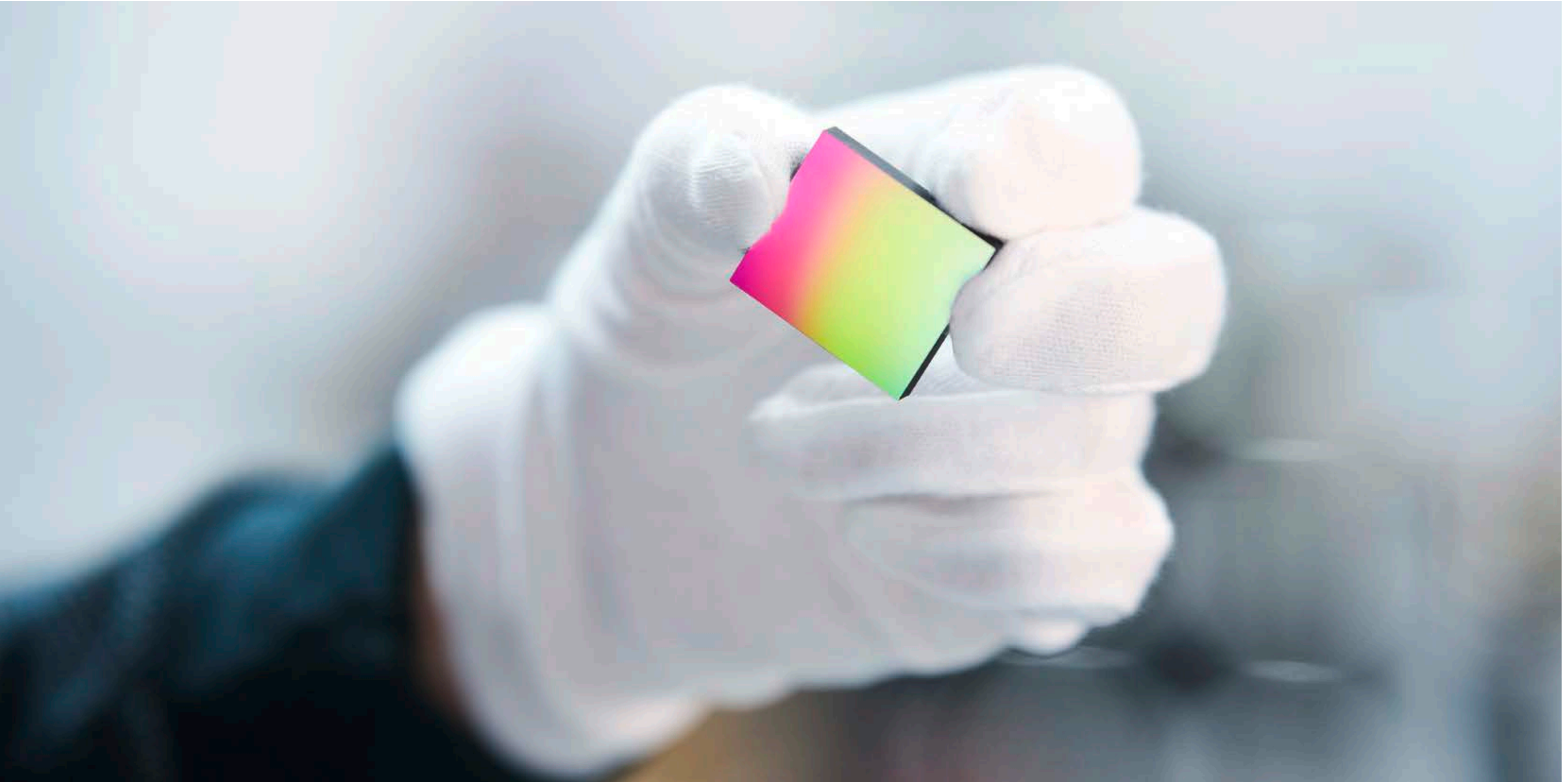
As a pioneer in scientific optics, ZEISS has been pushing the boundaries of imagination for nearly 180 years. The long history of spectroscopy has played a crucial role in shaping our innovative strength, which continues to define us today. Driven by the highest standards and our globally recognized expertise in optics, we develop solutions that set new benchmarks, turn ideas into reality and foster mutual success. At the same time, we motivate and guide people, while our passion for excellence creates value for our customers and inspires the world to see things differently. These visions propel us forward every day, driving us towards a better future.

Dr. Karl Lamprecht, President and CEO of the ZEISS Group



A foundation for innovation

ZEISS Spectroscopy as an enabler of scientific progress

From aspirin and automobiles, computer chips and milk, to butter and biofuels, much of modern life relies on quality and production control with optical spectroscopy. It involves analyzing how light interacts with matter to reveal detailed information about the composition and properties of substances.

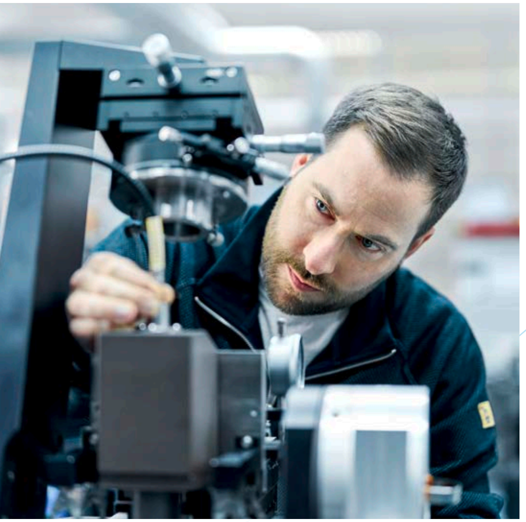
When light is shone onto a sample, it can be absorbed, transmitted, reflected, or scattered, depending on the material's unique characteristics. By measuring these interactions, spectroscopy provides valuable data that can identify chemical compositions, physical properties and monitor changes in molecular structures.

This versatility and precision make optical spectroscopy an indispensable tool in advancing technology, improving product safety and enhancing our understanding of the natural world. By shedding light on the molecular intricacies of various materials, spectroscopy continues to drive innovation and ensure the quality and safety of countless products and processes essential to modern life.

For 150 years, ZEISS has been at the forefront of this technology, continuously refining and developing spectroscopic instruments to meet the evolving needs of various industries. Our commitment to precision and innovation has made us a leader in optical spectroscopy, providing state-of-the-art solutions that illuminate the hidden details of our world.

Illuminating innovation for 150 years

For the last century and a half, ZEISS Spectroscopy has been at the forefront of technological breakthroughs, consistently pushing the boundaries of scientific and industrial progress.



From Ernst Abbe's prism spectrometer in 1874, which transformed the analysis of glass, to the first array spectrometers in the 1980s, ZEISS has consistently advanced the field of optics and spectroscopy.

Today, there are new developments in portability and connectivity, delivering lab-quality field measurements and real-time data access. ZEISS Spectroscopy continues to innovate, ensuring precision in automotive and architectural applications while maintaining leadership in spectroscopic technology.

Throughout its history, ZEISS Spectroscopy has consistently turned challenges into opportunities, advancing the frontiers of science and industry. As we celebrate these milestones, we look forward to a future where our legacy of light and innovation continues to inspire and drive excellence in the field of optics and beyond.

© German Optical Museum

1874 The Foundation of Spectroscopy at ZEISS

A prism for progress: the first step in industrial spectroscopy

Renowned scientist Ernst Abbe (1840 – 1905) designed his first prism spectrometer in 1874, enabling the reproducible investigation of the dispersion and refractive index of glass. This marked the beginning of the industrial production of analytical instruments at ZEISS. Ernst Abbe joined ZEISS in 1866, bringing a theoretical and scientific approach to microscope design, which was revolutionary at the time. The collaboration between Ernst Abbe and Carl Zeiss (1816 – 1888) was pivotal in the advancement of optical technology.

Abbe's innovations and his work on defining the diffraction limit of resolution, were instrumental in establishing ZEISS as a leader in the optical industry. This partnership not only improved the quality and functionality of microscopes but also laid the foundation for future advancements in optical instrumentation and industrial precision.

Applications: Precise analysis of glass properties, essential for optical instruments. Advanced material science and quality control in glass production. This development allowed for better understanding of light dispersion and refractive indices, vital for advancements in both optical research and the manufacturing of precise optical devices, such as ZEISS microscopes and telescopes, as well as other essential tools in scientific research and medical diagnostics today.

The Color Measurement Revolution
Pulfrich’s Palette: measuring the spectrum of color

Carl Pulfrich (1858 – 1927) was a German physicist who joined Carl Zeiss in 1890 and made significant contributions to the development of optical instruments. He’s best known for his eponymous photometer for color measurement in 1899, laying the foundation for global advancements in photometry and later spectrophotometry.

1924

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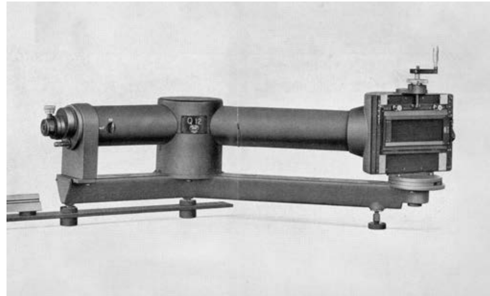
Applications: Essential for industries requiring accurate color measurement, including textiles, paints and chemicals. It also set the stage for modern colorimetry and spectrophotometry. This development was fundamental in quality control and the manufacturing process of products where color precision is critical. Today, similar principles are used in colorimeters for quality control in various industries, such as architectural glass, textiles and many more.



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First UV Quartz Spectrograph Q 24
Illuminating the unseen secrets of metals: the power of UV light

1933

The Q 24 spectrograph used quartz optics, which allowed for the analysis of metals in the ultraviolet range down to 200 nm, becoming a standard tool in the metal-producing and processing industries.

Applications: Critical for the steel industry to analyze metal compositions, enhancing quality control and material properties and extending the capabilities of spectroscopic analysis into the UV range. This allowed for improved detection of impurities and better control over the metallurgical processes.

Development of the GTM
From vision to precision: mastering optical gratings

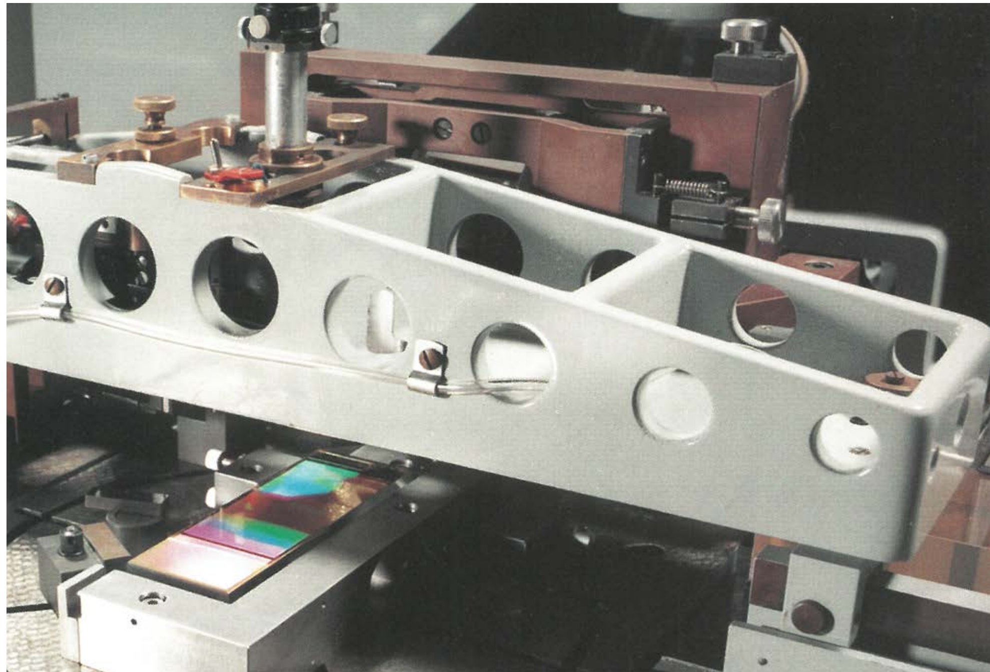
In the early 1930s, ZEISS was already working on the development of a diffraction grating machine (Gitterteilmaschine – or ‘GTM’), a precision instrument for the production of diffraction gratings. However, it never went into production and was eventually sent to the USSR as reparations after WWII, where it was not used again.

After the war, the development of a new GTM was initiated by Horst Lucas. Despite significant challenges, including bombed facilities and lack of resources, the new GTM was completed in 1951. It underwent several years of optimization and by 1955, it produced gratings of sufficient quality for spectrography, leading to its use in the first post-war Zeiss-Jena spectrograph PGS 2 from 1959.

This innovation made it possible to produce spectrometers with in-house optical gratings, advancing spectrometry technology.

Applications: Improvement of the accuracy and efficiency of spectrometers, supporting advancements in both scientific research and industrial applications such as chemical analysis and pharmaceuticals. The development of in-house optical gratings enhanced the precision and reliability of spectrometric measurements.

1950

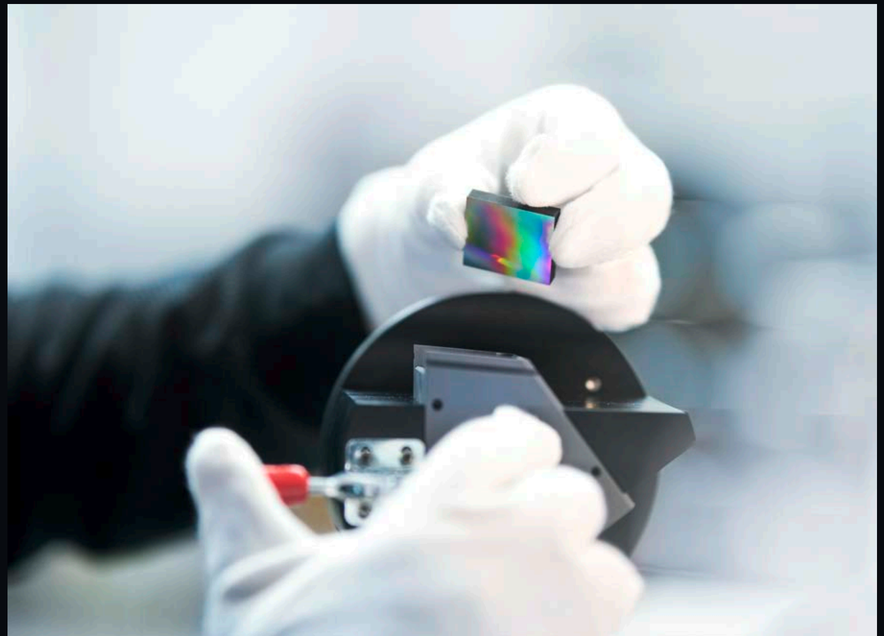


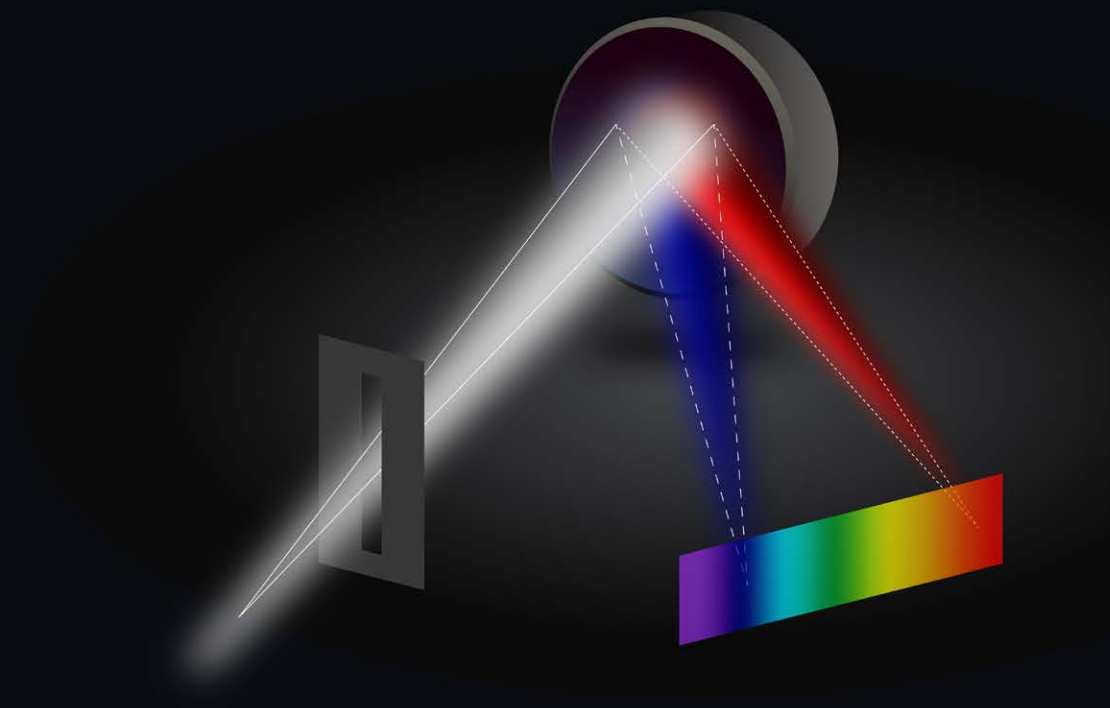
Gratings: The heart of spectroscopy

Optical gratings are the heart of the modern spectrometer, serving as the key component that disperses light into its constituent wavelengths.

This dispersion is crucial for analyzing the spectral composition of light, which allows scientists and engineers to identify and quantify various materials with unparalleled precision. While prisms laid the foundation for early spectrometry, the role of gratings has evolved, reflecting advancements in technology and the growing demands for more accurate and versatile instruments.

These optical components are now at the core of cutting-edge spectrometric techniques, allowing for detailed and accurate spectral analysis across a wide range of scientific disciplines.





How do gratings work?

Gratings work with diffraction, where a series of closely spaced lines or grooves on a reflective or transmissive surface cause incoming light to spread out into a spectrum. The angle at which light is diffracted depends on its wavelength, allowing different wavelengths to be separated and analyzed individually. This process is fundamental to a wide range of applications, identifying chemical compositions and physical properties in a non-destructive way.

The ZEISS advantage

ZEISS gratings are mechanically ruled or holographically recorded with interferometrical set-ups. Our holographic gratings ensure exceptional accuracy and minimal stray light. This results in clearer, more precise spectral data, which is vital for the widest variety of hi-tech applications.

Types of ZEISS gratings

Our gratings cover the entire wavelength range:

1. Plane gratings
2. Rowland circle gratings
3. Mono- and polychromator gratings
4. Laser gratings
5. Offner gratings
6. Grisms

SPECORD UV-VIS
Dual beams, singular precision: the SPECORD UV-VIS Era

The PGS-2 is a single beam spectrometer released in 1959 and was the first instrument to be mass produced after the war in Jena. The SPECORD UV-VIS introduced dual-beam spectrophotometry, setting a new standard for laboratory spectrometers by enhancing measurement accuracy and reliability. This innovation has been a game-changer in various scientific fields, providing researchers with unparalleled precision.

Applications: Enhanced accuracy in laboratory spectrophotometry, which is crucial for research in chemistry, biology and environmental science. It facilitated precise measurements of absorbance and transmittance of samples, essential for studying reaction kinetics, enzyme activities and environmental pollutants.

Ongoing advancement by Analytik Jena
In the early 1990s, ZEISS transferred its laboratory instruments business to Analytik Jena. Since then, Analytik Jena has continued to develop and enhance SPECORD technology, building on 60 years of continuous innovation.

1968

Simultaneous Spectrometry
Speed of light: capturing spectra in milliseconds

1984

The Simultaneous Spectrometer was the first to be equipped with photo-array detectors. It was recognized as one of the 100 most significant developments of 1984, earning the prestigious American IR-100 Award and the 1985 Innovation Award from the German Economic Association.

The Simultaneous Spectrometer was driven by two key developments: affordable photodiode arrays and image-corrected gratings that project the spectrum without distortion. This allowed the simultaneous capture of a complete spectrum in fractions of a second, eliminating the need for moving parts. It also led to the ZEISS spectrometer module family, such as today's Multi-Channel Spectrometer (MCS), which focuses on a minimalist optical-mechanical design with the fewest components possible. This lays the foundation for transitioning from laboratory measurements to process solutions, as it enables real-time measurement of a sample (like on the production line, for example). This technology is the basis for spectrometer modules and systems, which are now produced for process applications at ZEISS Spectroscopy.

Applications: High-speed industrial processes, enabling real-time monitoring and quality control in manufacturing, pharmaceuticals and environmental testing. The ability to capture complete spectra quickly improved efficiency and accuracy in various analytical applications, ensuring product quality and consistency, reducing waste and increasing efficiency in production lines.

OPTOPLEX® P+Q Systems
Inline insight: OPTOPLEX® systems transform coating quality

These systems provided inline process control for coating properties and automated quality control of architectural glass. This significantly reduced produc-

1990

tion costs for high-quality thermal insulation glass, as well as color consistency and accuracy, which are key factors in the design of glass buildings.

Applications: Real-time, automated quality control in the architectural glass and coating industries reduces production costs and improves product quality. This system enhances the manufacturing of high-quality thermal insulation glass and coatings, meeting strict performance standards essential for energy-efficient buildings.

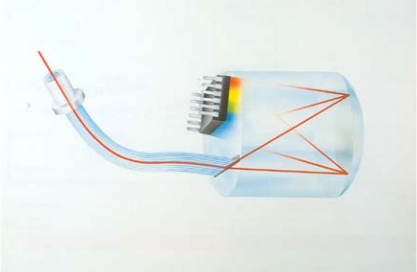
OPTOPLEX® is a registered trademark of Applied Materials GmbH & Co. KG

MMS1 Monolithic Miniature Spectrometer
Compact clarity: the power of miniature spectrometry

The first spectrometer with a glass body, offering compactness and permanence of adjustment, ideal for precise measurements in various environments.

1994

Applications: Portable, precise spectroscopic analysis for various applications, from fieldwork in agriculture to on-site industrial quality control. The compact design allowed for greater flexibility and application in different environments. This technology was vital for farmers to monitor nutrient levels and optimize crop yields.



MMS NIR
Seeing more: MMS NIR expands the spectral horizon

The first compact spectrometer for near-infrared wavelengths, using Infrasil quartz glass for transparency up to 2500 nm, expanding the range of spectroscopic

1997

applications. Near-infrared wavelength measurement makes it possible to analyze multiple ingredients and constituent parts, which is integral to the agricultural and food production industries.

Applications: Extended spectroscopic analysis to near-infrared, vital for agriculture, food quality control, and pharmaceuticals. This advancement enables more detailed and accurate analysis, such as checking fat, protein, and moisture levels in the food industry to ensure product quality.

CORONA® 45 NIR
Harvesting results: NIR spectroscopy on the go

1999

This NIR diode-array spectrometer was integrated into harvesters for real-time agricultural measurements, demonstrating robustness and high-speed analysis in the field.

NIR technology helps improve plant breeding and crop quality measurement. By enabling on-site, rapid and non-destructive analysis of crop components such as water, protein, oil and carbohydrates, mobile NIR spectrometers increase efficiency and support precision farming.

Applications: Real-time analysis of crops, enhancing agricultural research and optimizing harvest quality and efficiency. The integration of NIR spectroscopy into harvesters facilitated better monitoring and quality control directly in the field. It is particularly beneficial for monitoring parameters like moisture content in grains and ensuring optimal harvest conditions. On top of that, CORONA® 45 NIR is very robust and reliable in the toughest conditions: it is temperature-stable, compact and completely resistant to vibrations, while delivering the same precision as conventional laboratory devices.

Plastic Gratings and Housings

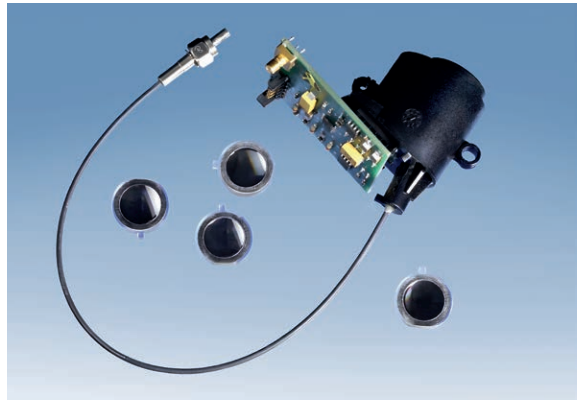
Plastic fantastic: spectroscopy for the masses

2000

ZEISS introduced the first spectrometer with plastic gratings and housings, enabling large-scale production and accessibility to broader markets.

ZEISS Spectroscopy developed a cost-effective method to produce optical plastic gratings using a nickel tool insert from a holographically produced master. This process allows for the mass production of spectrometers, which has expanded our offerings and led to the production of hundreds of thousands of modules.

Applications: The use of plastic gratings made spectrometry more affordable and available to consumer applications for color measurement (like printing applications, for example).



MCS 600 Diode Array Spectrometer

Modular Mastery: customizable spectrometry for every need

With advanced electronic principles, this spectrometer allowed software-controlled settings and monitoring, providing wide-ranging combinations of lamps and spectrometer modules.

Applications: Modular spectrometric solutions offer flexibility and adaptability for customized analytical setups in research and industry.

2004

2015

ThinProcess®

Revolutionizing large surface coating: laboratory precision on the production line

ThinProcess® is the latest innovation from the OPTOPLEX® family, providing a comprehensive solution for monitoring large surface coating processes with laboratory precision. It supports both horizontal and vertical glass coating, as well as roll-to-roll film coating in either vacuum or atmospheric conditions. The ThinProcess® family includes several variants like ThinProcess® Q, WEB, P and R. These are all backed by ThinProcess® software for displaying spectral properties and calculating coating parameters. It also includes the compact spectrometer MCS 700 developed in 2014, which integrates spectrometric analysis directly into production lines.

Applications: In-line monitoring for large surface coatings, ensuring high-quality standards in industries such as architectural glass, thin-film photovoltaics, electrochromic glass and automotive glass. Real-time measurement of spectral reflectance, transmittance, color values and coating thickness in various environments.

Portable Spectrometer
Accuracy on-the-go: portable spectrometry in the palm of your hand

2015

A full-feature spectrometer for both laboratory and field use, offering laboratory-quality measurements and integrated computer capabilities for on-site quality control.

Applications: High-quality spectrometric analysis in remote locations, crucial for environmental monitoring and field research. The portability and accuracy of this spectrometer made it an invaluable tool for on-site analysis

Connected Spectroscopy
Joined-up insights: real-time spectroscopy in the digital age

2019

The first connected spectrometer with real-time data access, facilitating precise product quality definition and embracing the era of digitalization. This was a groundbreaking innovation and made even greater gains in efficiency possible. Especially when combined with dedicated software developed in-house.

Applications: Remote monitoring and data analysis, improving efficiency in quality control, process monitoring and research collaborations. The connectivity feature facilitated better data management and real-time decision-making.

2020

OFR A10c
Self-sufficient spectroscopy: unbounded precision

A self-referencing measuring probe for absolute transmission and reflection measurements, designed for in-situ analysis in vacuum applications, which is critical for the automotive and architectural glass industries.

The OFR A10c is the world's first inline-capable measuring head that can measure spectral reflectivity without needing an external calibration standard.

OFR A10c is a cost-effective and reliable solution for real-time optical property measurements in various industries, providing lab-like precision without the need for expensive reference materials. Its high-frequency measurements of spectral reflectance and transmittance (360 nm to 1,050 nm, with the option of up to 1,650 nm) allow for detailed analysis, while self-referencing technology ensures long-term accuracy and ease of calibration.

Applications: Essential for high-precision applications in vacuum environments, such as semiconductor manufacturing, advanced coatings and high-tech material analysis. This innovation ensured accurate and reliable measurements in critical applications.

OFR 160
Driving innovation: screens by spectrometers

An absolute measuring head for the automotive industry, enabling precise measurement of windscreen optical properties and facilitating the mass-market adoption of head-up displays.

Applications: Facilitated the development of advanced head-up displays in automobiles, enhancing driver safety and information accessibility with precise optical measurements. This technology plays a crucial role in the automotive industry by improving the quality and functionality of windshields.

2024

Shaping the spectrum
The evolution and future of spectroscopy

Dr. Christian Korth,
Managing Director
ZEISS Spectroscopy

What significant developments do you personally consider to be key milestones in the history of spectroscopy?

In my view, two pivotal milestones stand out in the recent history of spectroscopy. The first is the development of the diode-array spectrometer in 1984. This innovation remains the technological foundation for our entire range of spectrometer modules and systems to this day. The second crucial milestone is the integration of the first NIR system into a Haldrup agricultural machine. This achievement paved the way for ZEISS to become a leading provider of NIR sensor technology in agricultural machinery, in close collaboration with renowned manufacturers.

How does spectroscopy contribute to addressing challenges in science, industry, or healthcare today?

Spectroscopy plays a vital role in various sectors, including water analysis, the semiconductor industry and in the measurement of ingredients with agricultural machinery. It is also instrumental in the characterisation of thin films on architectural glass, display glass and solar panels. Our technology empowers customers to optimize the way they use resources while ensuring the quality of their products at the same time. This contributes significantly to their business success and addresses global challenges.

Are there still advancements being made in spectroscopy and where is the field headed?

We are continuously working on advancing our technology to make it useful for new applications and areas. Our goal is to develop solutions that tackle the most pressing problems and challenges, while succeeding together with our customers at the same time. One exciting area is the use of NIR sensor technology in agriculture and the food industry, for example. We see a wide range of new potential applications there in the future if we succeed in making the technology much easier to access and use than it is today.

How spectroscopy makes our world a better place

Making outcomes brighter
Whether it’s identifying biomolecules or proteins present in biological samples or analyzing blood, spectroscopy enables accurate diagnostics and effective treatments, contributing to excellent patient care.

Fueling a greener future
Ensuring the quality and sustainability of biofuels and alternative energy sources, our solutions make tomorrow's energy possible.

Perfecting pharmaceuticals
Our technology ensures drug quality and effectiveness, safeguarding health with every dose.

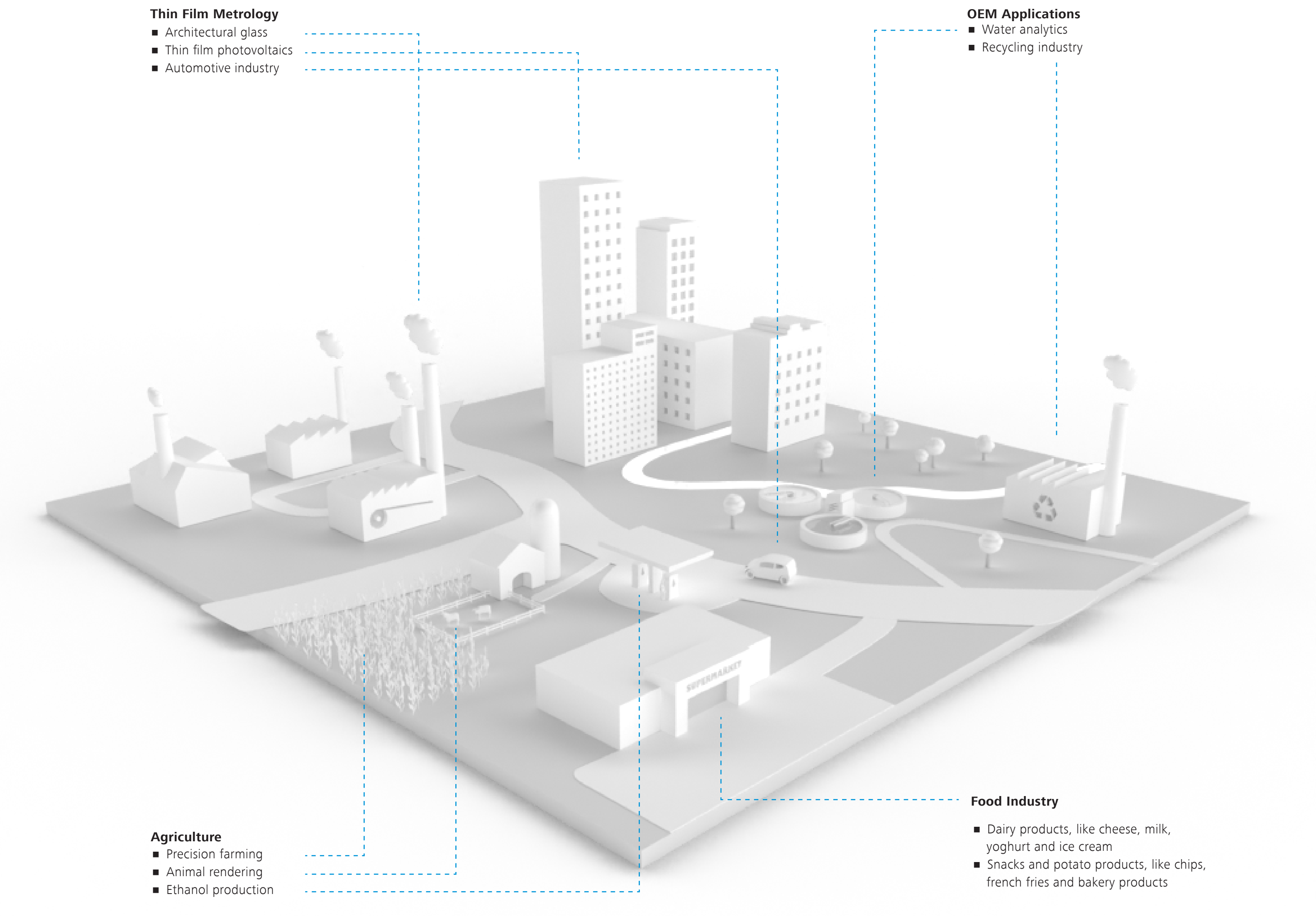
Tasting the difference
Ensuring the purity of milk, the quality of beer and the safety of food, our solutions make a difference in every bite and sip.

Revving up innovation
From paint quality to material durability, we make advancements in automotive performance possible.

Mastering material science
Enhancing material science, we provide insights that drive innovation and quality in manufacturing processes.

Keeping an eye on the environment
Our advanced measurement solutions make precise environmental monitoring possible, like monitoring air quality using satellites equipped with ZEISS gratings, for example.

Making tomorrow’s technology available today
Providing process control for the manufacturing of microchips, our technology helps shape the future of information and communication technology.



ZEISS Spectroscopy and the future of innovation

Reflecting on our journey, it's clear that a commitment to progress and innovation has been a guiding light. From the early days of the prism spectrometer to the advent of connected spectroscopy, we have consistently advanced the frontiers of optical technology.

As digitalization and new technological developments continue to transform industries, ZEISS Spectroscopy remains dedicated to pushing boundaries and exploring new horizons. Our focus on precision, quality and innovation means we can respond to the evolving needs of our partners in science and industry. While challenges are inevitable, they also present opportunities for growth and discovery. ZEISS Spectroscopy will continue its legacy of contributing advancements that drive progress and enhance our understanding of the world.

The path forward is bright and we are committed to maintaining our role as a pioneer in the field. By building on our history and embracing future possibilities, we will continue to illuminate the way for spectroscopy.

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