The Reference.

Switzerland's metrology magazine

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METAS

Editorial

Dear readers,

Even the very first civilisations used measurements to regulate trade. Modern metrology – in other words, the science of measurement and how it is applied – traces its roots back to the French Revolution. Today, it is so far advanced that our measurements are based on the fundamental constants of the universe and new applications are always possible.

In the past 40 to 50 years, we have seen a marked increase in the use of quantum principles. These applications will transform the world in the fields of communication, computers and sensor technology.

Legal notice

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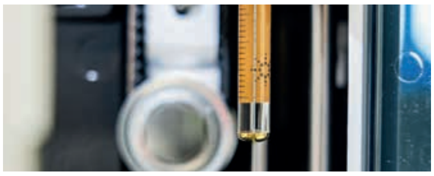

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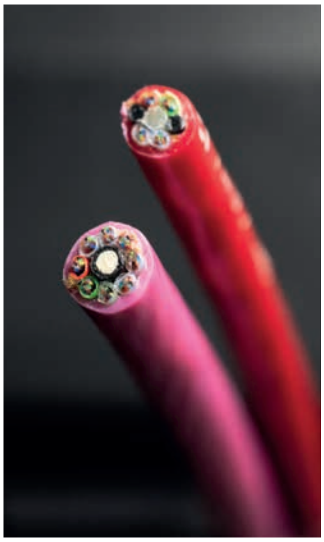

The first impacts are already being felt, and this is something that we as a national institute for metrology have to be prepared for. This is why we want to establish a centre of competence for quantum metrology (see page 14).

In parallel to quantum measurements, other fields of metrology are also being developed further. In chemistry, a reliable control marker has been introduced across Europe that requires a new analytical approach (see page 4). In the field of food safety, the National Reference Laboratories for Genetically Modified Organisms in Food and for Food-Borne Viruses have to be familiar with the latest analysis and detection methods and apply them in order to be able to verify adherence with legal regulations (see page 30).

I hope you find the articles in this issue interesting and wish you an enjoyable read.

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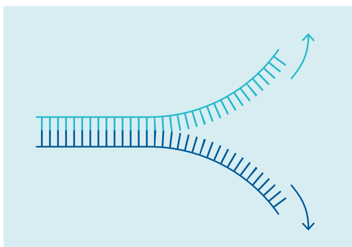


Service

New fiscal marker for heating oil comes into force

A fiscal marker is added to heating oil to distinguish it from fuels such as diesel, which is subject to a higher rate of duty. Since 2024 in Switzerland and 2022 across wider Europe, the fiscal marker used previously – Solvent Yellow 124 (SY124) – has gradually been replaced by a new marker compound that is more resistant to fuel fraud, which causes considerable tax losses. The introduction of this new marker also gives rise to the need for a new analytical approach to make sure that checks are carried out effectively.

Dr Patrick Schüpfer

Heating oil and diesel have the same properties, but they are not taxed in the same way. The tax imposed on mineral oils varies depending on the products concerned and their use (different types of fuel, technical uses). Based on this system, tax reductions apply to (extra-light) heating oil, which – in Switzerland – is taxed at a rate of CHF 3.00 per 1000 litres, while the rate for diesel is CHF 795.70. This makes it very tempting for fraudsters to try to use heating oil as motor fuel. This kind of fraud can result in significant shortfalls for the Swiss Confederation (in 2022, tax on mineral oil accounted for 7.6% of the Confederation's income), which is why heating oil is specifically distinguished by adding a dye and a marker. The dye used leaves a lasting trace in engines and exhaust pipes that is clearly identifiable, making it easier to spot cases of fraudulent fuel use. The marker makes it possible to check whether motor fuel contains heating oil, which would be illegal.

New marker introduced in the European Union

Solvent Yellow 124 (SY124 for short) is a registered trademark of BASF and was adopted as the standard marker within the European Union (EU) – also known as the Euromarker – in August 2002. It is a yellow azo dye with the chemical name N-Ethyl-N-

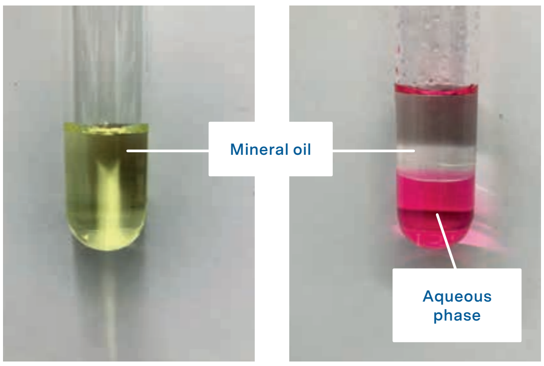


Figure 1. Treatment of a mineral oil marked with Solvent Yellow 124 (SY124), left, and with an aqueous hydrochloric acid solution, right.

[2-[1-(2-methylpropoxy)ethoxy]ethyl]-4-phenyldiazenylaniline. When it is present in a mineral oil, it can be extracted using an aqueous hydrochloric acid solution (HClaq.): the soluble yellow neutral molecule in the mineral oil turns into a bright red soluble product in the aqueous phase (see Figure 1).[1]

This particular property of SY124 offers the advantage of making it possible to carry out a quick and simple visual test by using HClaq. to extract a small quantity of mineral oil (additives in concentrations as weak as 2% to 3% can be detected in this way). However, this same procedure can also be exploited by fraudsters to remove the fiscal marker SY124 from heating oil so they can then use it as motor fuel.

Fuel fraud is responsible for an estimated EUR 7 to 10 billion a year in tax losses in the European Union.[2] In 2015, the EU therefore launched a public call for tenders aimed at replacing SY124 with a new Euromarker that would be more reliable and more resistant to illegal extraction. Following an intensive testing process involving four candidates,[3] the option chosen was *ACCUTRACE™ Plus Fuel Marker*, manufactured by Dow (United States), which contains 76% butoxybenzene (marker compound) in a solvent (petroleum distillates). On 14 February 2022, the European Commission named *ACCUTRACE™ Plus* as the new Euromarker and set a 24-month transition period that would end on 18 January 2024. During this transition period, both the old Euromarker and the new one were authorised for use. As of 18 January 2024, only *ACCUTRACE™ Plus* may be used to mark heating oil at concentrations between 12.5 g and 18.75 g per 1000 litres (equivalent to a marking level of 9.5 g to 14.25 g of butoxybenzene per 1000 litres).[4]

Dye and marker used in Switzerland

The dye and marker for Switzerland are specified in Chapter 7 Article 90 of the Swiss Mineral Oil Tax Ordinance (MinOTO).[5] Up to the end of 2023, extra-light heating oil was allowed to contain only SY124 as a marker at a level between 6 g and 9 g per 1000 litres and at a temperature of 15 °C.

In light of the introduction of the new Euromarker *ACCUTRACE™ Plus* in the EU, the Federal Council decreed in a decision dated 25 October 2023 that Switzerland would also adopt butoxybenzene as its fiscal marker for extra-light heating oil from 2024. However, SY124 will continue to be authorised in Switzerland until further notice so that existing compulsory stocks of extra-light heating oil can still be used. As a result, the version of MinOTO revised as of 1 January 2024 now states that it is also possible to use butoxybenzene at concentrations between 9.5 g and 14.25 g per 1000 litres at 15 °C.

Analysis

SY124 is detected and quantified using a technique known as high performance liquid chromatography (HPLC). This analytical method is ideal for substances with low volatility like SY124, with an estimated boiling point of around 591 °C. Unfortunately, however, it is not so easy to make it work for the new marker compound (butoxybenzene). A more advanced technique is required for detecting and quantifying this particular marker in mineral oils, which are highly complex matrices made up of hundreds of molecules.

A method developed by Agilent Technologies in partnership with Dow Chemical uses two-dimensional gas chromatography (2D-GC) paired with a mass selective detector (MSD) and Agilent's 'Capillary Flow Technology' (CFT) for flow control set to measure specific ions in the butoxybenzene (mass 94 and mass 150). This technique offers the advantages of better chromatographic peak resolution and improved sensitivity and specificity. Another significant bonus is that there is no need to prepare the sample beforehand.

The equipment required consists of an oven with a variable temperature, containing two gas chromatography capillary columns (GC columns) – one polar and one non-polar. This setup makes it possible to separate hydrocarbons from the oil mixture and the marker compound. The flow configuration across the GC columns can be adjusted with the aid of an electronic pressure control (EPC) module known as a pneumatic switching device (PSD).

In terms of the technical process involved, the sample (1 microlitre) is introduced into the injector directly, without any advance preparation. The injector is kept at a higher temperature (250 °C) to allow the sample to evaporate. Now in a gaseous form, the sample is then pushed along the first (non-polar) GC column by a stream of carrier gas, applying a pressure of 14 psi in the injector. The temperature of the oven is gradually increased to heat up the column ready to perform an initial separation of the mixture components. The instrumental analysis is then carried out in four stages:

Stage 1:
First of all, the system is set to the C1 configuration (see Figure 2): keeping the PSD pressure at 9 psi and the position of the Dean switch to "no cut" make it possible to direct the flow towards the flame ionisation detector (FID) via a restrictor. This restrictor consists of an inert column with a small internal diameter (0.1 mm) and is designed to restrict the flow of gas. In the C1 configuration, the components separated as they pass into the first (non-polar) column are picked up by the FID in the form of chromatographic peaks (see Figure 3).

Stage 2:
When the butoxybenzene (marker compound) exits the first column, the Dean switch is positioned to "cut" (see Figure 4, configuration C2): The flow from the injector (green arrows) is then diverted to a second column (this is known as a "heart-cut") to carry out an additional separation process.

The butoxybenzene is thus detected by the MSD, resulting in a very clear signal in the chromatogram indicating its presence (see Figure 5). The quantification process is therefore fairly straightforward and involves injecting standard solutions containing known concentrations of butoxybenzene. If no flow reaches the FID, this is shown by a flat line in the FID chromatogram (see Figure 3).

Stage 3:
The system is put back in the C1 configuration (see Figure 2), making it possible to see the heavier components exiting the first column following the heart-cut.

Stage 4:
Before the high-boiling (heavy) components of the sample exit the first column, the pressure of the carrier gas in the injector is reduced from 14 psi to 1 psi,

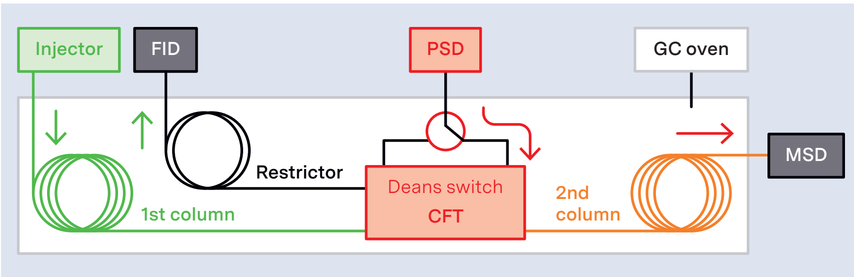


Figure 2. C1 flow configuration: the entire flow is directed towards the flame ionisation detector (FID).

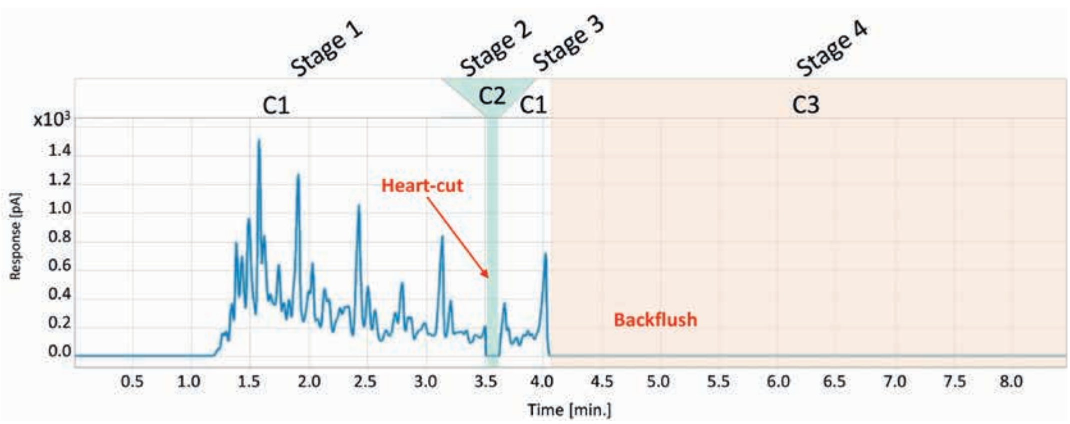


Figure 3. Chromatographic signal recorded by the FID over the course of the four stages. During stages 2 and 4, the outgoing flow from the first column is channelled either into the MS detector (C2) or back into the first column (backflush, C3), so there are no peaks in the chromatogram.

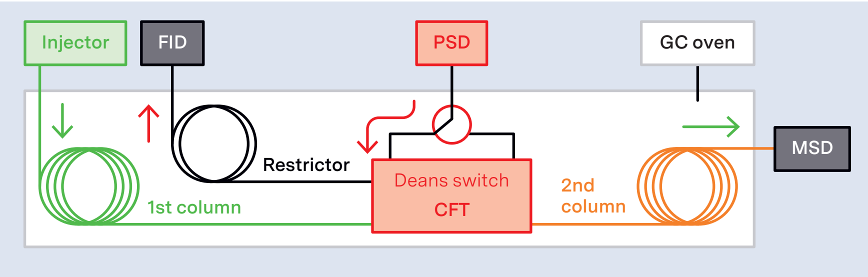


Figure 4. C2 flow configuration: the flow is directed towards the MSD.

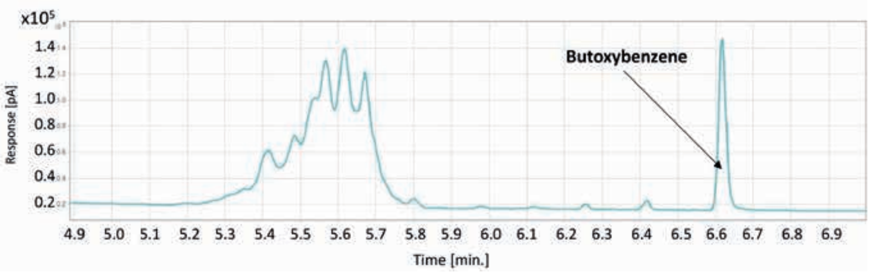


Figure 5. Chromatographic signal picked up by the MSD (ion current measured for mass 94 and mass 150). Thanks to the additional separation along the second column, it is possible to record a very clear chromatographic peak for the butoxybenzene.

METAS plays a part in supporting customs

Customs duties and taxes fall under the remit of the Federal Office for Customs and Border Security (FOCBS). As a tax authority, the FOCBS has the power to collect mineral oil samples for checking and monitoring. METAS' "Chemical tests and consultancy" technical field performs analyses for customs purposes in Switzerland. In particular, it analyses collected mineral oil samples to check for the fiscal marker. Since the end of April 2023, the laboratory has had its own GCxGC-MS (Agilent) system for analysing the new marker compound (butoxybenzene) in mineral oil.

while a pressure of 9 psi is maintained in the PSD so that these heavy components are pushed back towards the injector (see Figure 6), thus preventing them from reaching the second (polar) column and the MSD. This helps stop the system from clogging up and minimises the number of maintenance interventions required.

Validating the method of analysis

In the summer of 2023, the Customs Laboratories European Network (CLEN) organised an interlaboratory test comprising 11 samples, with marking levels ranging from 1 % to 150 % and different matrices (B0 diesel, B7 diesel, B10 diesel, HVO diesel, kerosene, designer fuel), and involving 55 laboratories from all over Europe – including the "Chemical tests and consultancy" technical field at the Federal Institute of Metrology (METAS). This interlaboratory test produced excellent results, demonstrating a good command of the technology involved and validating the method of analysis developed for quantifying the new Euromarker. The validation of this new method of analysis and its implementation by METAS and other European metrology institutes pave the way for curbing fiscal fraud in relation to mineral oils and fair taxation of these products.

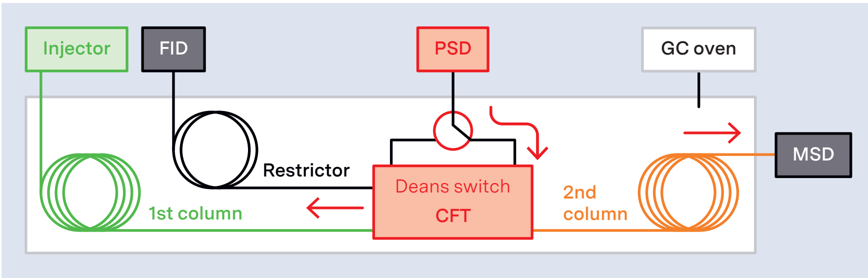
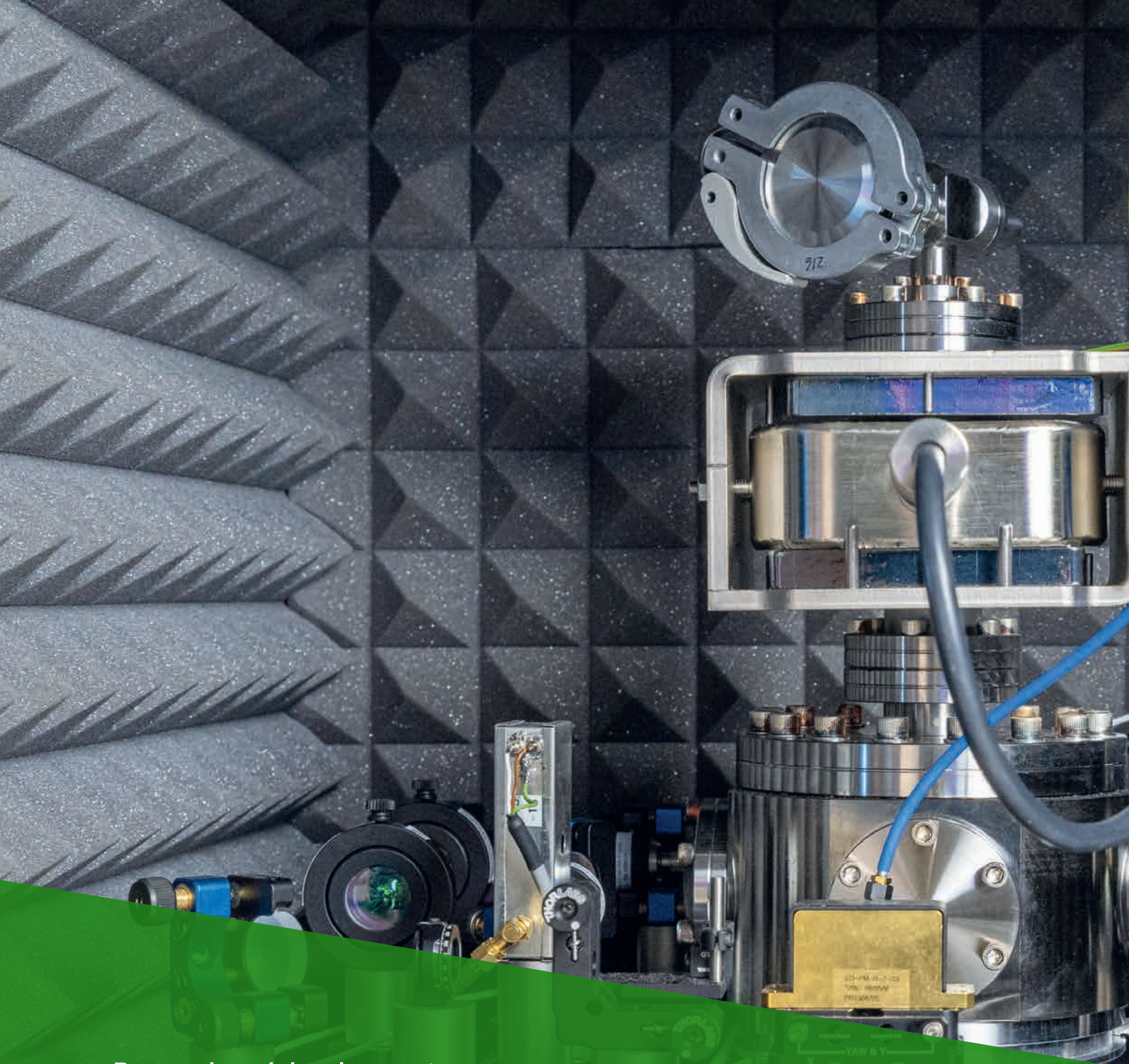


Figure 6. C3 flow configuration: the flow is pushed back into the first column towards the injector (backflush), reducing the injector pressure from 14 psi to 1 psi.

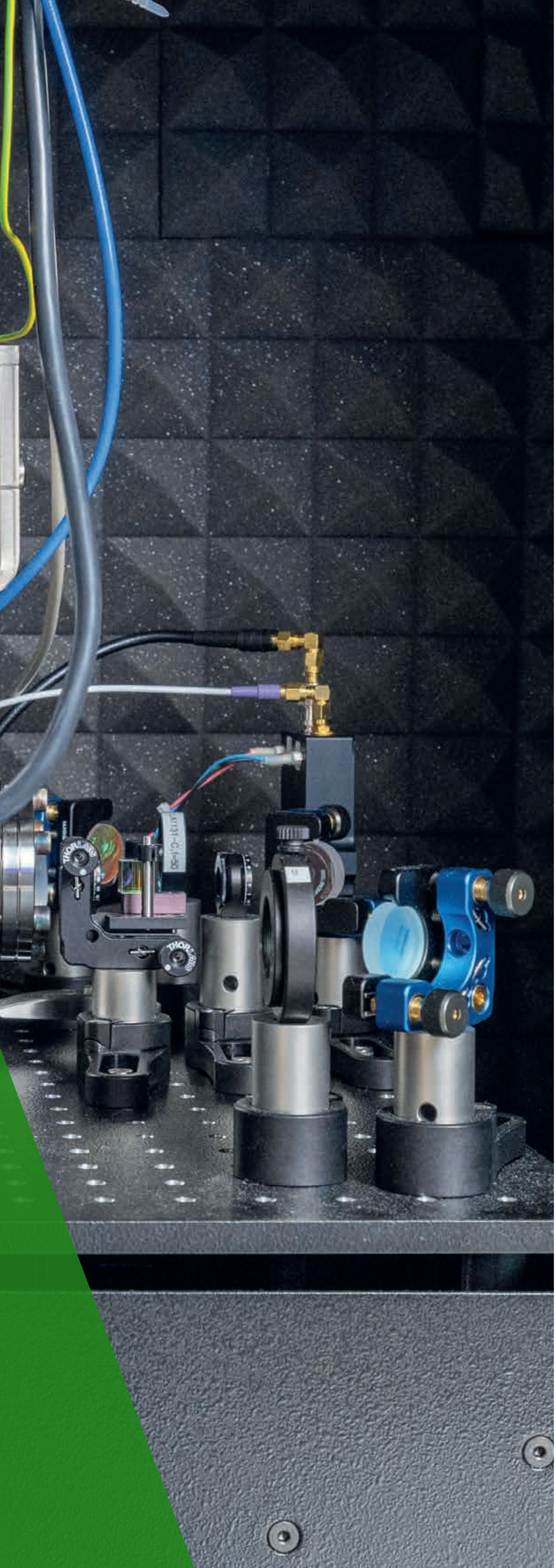
1 Grzegorz Zadora, «Laundering of ‹Illegal› Fuels – a Forensic Chemistry Perspective», Acta Chim. Slov. 2007, 54, 110–113.
2 Ecorys (2019): Study on the estimated economic implications of fuel laundering & wider fuel fraud in the EU.
3 European Commission «Evaluation of the Performance of the Short-Listed Candidate Markers Regarding the Technical Requirements» JRC Technical Reports, Public Version, 2017.
4 Commission Implementing Decision (EU) 2022/197 of 17 January 2022, notified under document C (2022) 74, Official Journal of the European Union.
5 641.611 Mineral Oil Tax Ordinance (MinOTO).



Research and development

Optical frequency distribution for earthquake research

The spread of reference frequencies over the fibre-optic network can provide positive surprises. By suppressing the noise of the optical signals, the fibre-optic network can perform a second function to detect earthquakes. This experience was gained by the Laboratory Photonics, Time and Frequency of METAS together with a research group of ETH Zurich.



Dr Dominik Husmann, Dr Jacques Morel

A core task of the Laboratory Photonics, Time and Frequency is the realisation and dissemination of ultra-precise and stable reference frequencies and time signals. This is done with the help of an ensemble of atomic clocks, which are continuously compared with each other, both nationally and internationally. Based on these comparisons, METAS implements the official Swiss time UTC(CH) and contributes to the realisation of Coordinated Universal Time (UTC).

Thanks to this arrangement, METAS has SI-traceable time and frequency signals. These are important for a wide range of users, including manufacturers of time and frequency measuring instruments, the watchmaking industry, operators of navigation systems, the stock exchange, and also basic research using precision spectroscopy. A major challenge is how to bring the ultra-precise and stable signals from the laboratories at METAS to the users – especially without impacting the precision as a result of dissemination.

Methods of frequency dissemination

The traditional method is that users bring their equipment to the METAS laboratories to reference them locally at METAS against our time and frequency scales. The opposite approach is also already being practised: METAS brings a mobile atomic clock to the user and carries out the measurement comparisons locally. This is sufficient for many applications, but of course only allows selective – not continuous – comparisons. Satellite technology-based comparisons (GNSS) allow continuous comparisons, but are sensitive to signal degradation due to interference on the transmission path, such as natural weather-related fluctuations in the atmosphere or even deliberate interference from interfering signals, which is called spoofing.

These methods are therefore insufficient for state-of-the-art reference frequencies – such as those used in precision spectroscopy in research laboratories. In recent years, a new method of dissemination based on optical frequencies has become established in fibre-optic networks. To that end, the reference frequencies of the atomic clocks at METAS are converted into optical frequencies using a frequency comb – a special laser technology. These optical signals are then fed into a traditional fibre-optic network and sent to the user. Today, such a frequency fibre-optic network connects METAS with the University of Basel and ETH Zurich. The fibre-optic infrastructure used for this purpose is provided by the company SWITCH.

Optical fibres are sensitive sensors

As with satellites, the transmission path of the optical fibres is a source of interference. This is because optical fibres are formidable universal sensors and sensitive to external influences such as temperature fluctuations and vibrations. Such disturbances are directly influenced by the signals propagating in them. For frequency metrology, this is a problem because it affects the accuracy of the frequency and requires complex noise suppression. In a complex optical design, the ambient noise in the optical fibres is measured and compensated by generating counteractive "anti-noise". This is conceptually comparable to the noise cancellation in modern headphones.

Now it turns out that this anti-noise contains valuable information about various ambient effects: variations in ambient temperature, man-made vibrations and seismic events lead to measurable deformations of the optical fibres. This was the case, for example, on 10 September 2022 when a magnitude 3.9 earthquake had occurred in the Mulhouse region. This earthquake was detected on a 123 km stretch of optical fibre between METAS in Wabern and the University of Basel (see Figure 1). The individual seismic waves are visible in Figure 2 as significant deflections of the resting position of the noise baseline.

This observation was the starting point for collaboration with Prof. Andreas Fichtner from ETH Zurich and his research group for seismology and wave physics. Prof. Andreas Fichtner and his team specialise in calculating and modelling the effect of seismic waves on the Earth's surface.

Interpretation and modelling of the signal

Interpreting and modelling this recorded signal in a meaningful way poses a major challenge. This is difficult because the nature of the measurement causes the recorded signal to be added up over the length of the entire optical fibre. Spatial resolution, such as that which is present in other optical fibre-

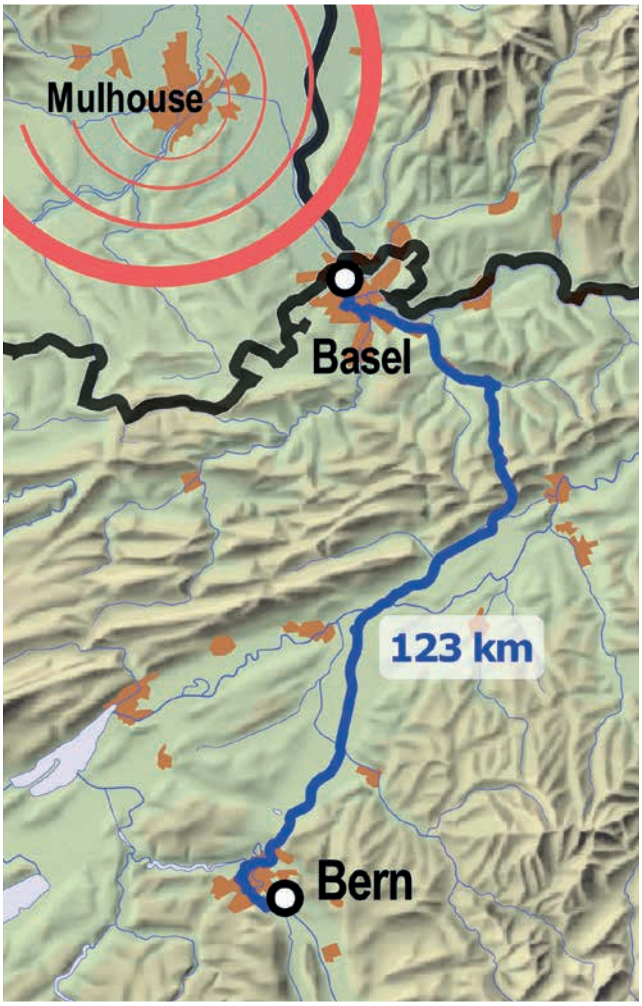


Figure 1. Route of the fibre-optic connection between METAS in Wabern and the University of Basel as well as the approximate epicentre of the earthquake in Mulhouse.

based methods such as distributed acoustic sensing (DAS), is not present here. For example, a section of the optical fibre can be stretched at a certain time, while another section is compressed at the same time. The two effects can cancel each other out to a net zero sum. In order to understand the net effect of seismic waves on the observed signal in the optical fibre and compare it with the observation, the deflection along the entire length of the optical fibre must be added up.

As part of the collaboration between METAS and ETH, it has been possible to model the observation of the earthquake on the fibre-optic network with astonishing consistency. To that end, the seismologists used known data to model the propagation of seismic waves in the geographical region of our optical fibre. Data from conventional seismic measurement stations were used as a reference to verify

Optical fibres enable precise and accurate transmission of frequencies over distances of hundreds of kilometres.

the model. The next step involved dividing the fibre-optic connection into many short segments, and for each segment, the deformation caused by the seismic waves was calculated individually. Subsequently, all contributions from the individual segments were added up to obtain the net signal of the optical fibre. This was then compared with the measurement on the optical fibre. The result showed a high level of correlation both in the arrival time of the seismic waves and in the amplitude of the observed deformation. This demonstration of quantitative model-observation correlation qualifies our frequency dissemination system as an unconventional seismometer with the potential to provide findings complementary to conventional seismic methods.

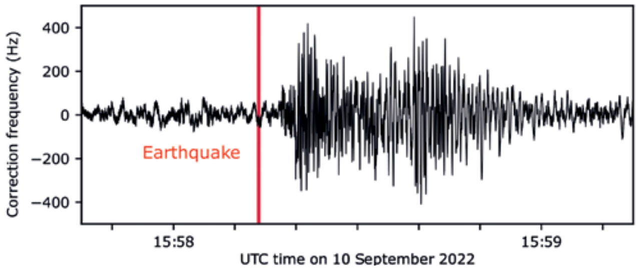


Figure 2. Signal of the earthquake, detected along the fibre-optic connection. A few seconds after the event, the first waves hit the optical fibre.

Fibre-optic networks can be used as seismic sensors

The exact detection of earthquakes, as well as the associated characterisation and early warning, requires large-scale geographical coverage of seismic sensors which is as dense as possible. This is costly and can be difficult to implement depending on environmental characteristics. Collaboration between the Laboratory Photonics, Time and Frequency and the Seismology and Wave Physics group at ETH Zurich has now demonstrated how fibre-optic networks for ultra-precise frequency dissemination commonly used in metrology can also be used as seismic sensors. This allows new information to be obtained in addition to existing sensor networks, which in turn can help to improve earth models.

The results of this collaboration have been published in the scientific journal “Scientific Reports”[1] and promise to deliver new perspectives on the use of fibre-optic networks in the field of seismology.

1 S. Noe, D. Husmann, N. Müller, J. Morel and A. Fichtner, «Long-range fiber-optic earthquake sensing by active phase noise cancellation», Scientific Reports, 13, Article Number 13983, (2023).

METAS employee honoured as a dedicated international expert

Dr Volker Zeuner, an expert in data security testing at METAS, was awarded the IEC 1906 Award in 2023 for bringing his experience in cyber-security to the standardisation of measuring instruments for performance and power quality measurements, data collection and analysis. Every year, the International Electrotechnical Commission (IEC) honours only 160 of its 20,000 global standards experts with this award.

METAS joins European Metrology Network

METAS has joined the European Metrology Network (EMN) for Energy Gases, which provides measurement science expertise to society and industry to support the energy transition towards renewable gaseous fuels. METAS is particularly actively involved in hydrogen flow rate measurement, and joining the EMN will give it an opportunity to raise its profile at European level.

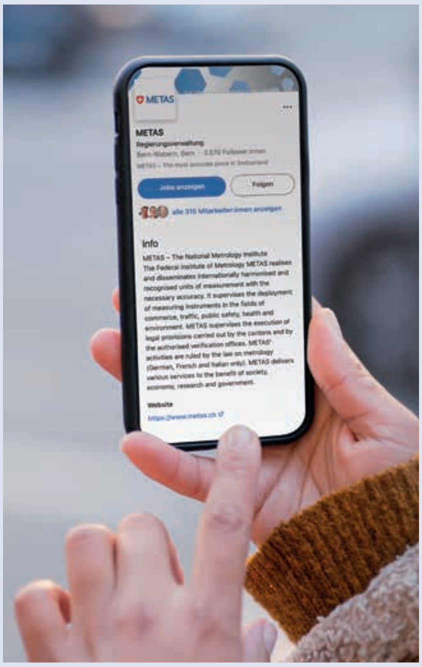
Renovation of the integrating sphere

The Optics laboratory at METAS is equipped with an integrating sphere that was built in 1965 and has a diameter of four metres. This allows for a uniform diffuse reflection of the light in the sphere, and is used for measuring the luminous flux, spectral distribution and colour values. In order to ensure that these measurements can continue at the required high level, the sphere had to be renovated. This renovation involved a new coating of the inner surface with barium sulphate paint in order to achieve a very high degree of reflection (>90 %). Additionally, the latest measuring instruments and a fisheye camera were installed. Moreover, the new software control on the measuring station allows for the automatic generation of measurement reports.

World Metrology Day 2024

The year 2024 marks the first official recognition by UNESCO of 20 May each year as a UNESCO International Day. This year's World Metrology Day has the motto "We measure today for a sustainable tomorrow". METAS is making an active contribution with various projects aimed at increasing sustainability in society and business. Examples of this include projects for determining peat in plant soil, recycling phosphorous from waste-water sludge, and also the detection and determination of halogenated volatile organic compounds (VOCs) in the atmosphere.

Find out more on our website.



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Federal councillor Beat Jans visited METAS

On 25 March 2024, the new head of the Federal Department of Justice and Police, Federal Councillor Beat Jans, visited METAS. The programme included an introduction to the activities of the institute and visits to various laboratories. The head of the department was able to familiarise himself with the activities of METAS in the following areas: legal metrology, reference gases for measurements of air pollution and climate protection, measurement of particulate matter and measurements with computed tomography. At the end, he had the opportunity to hold a short welcoming speech for all METAS employees and to engage in dialogue with some of them.

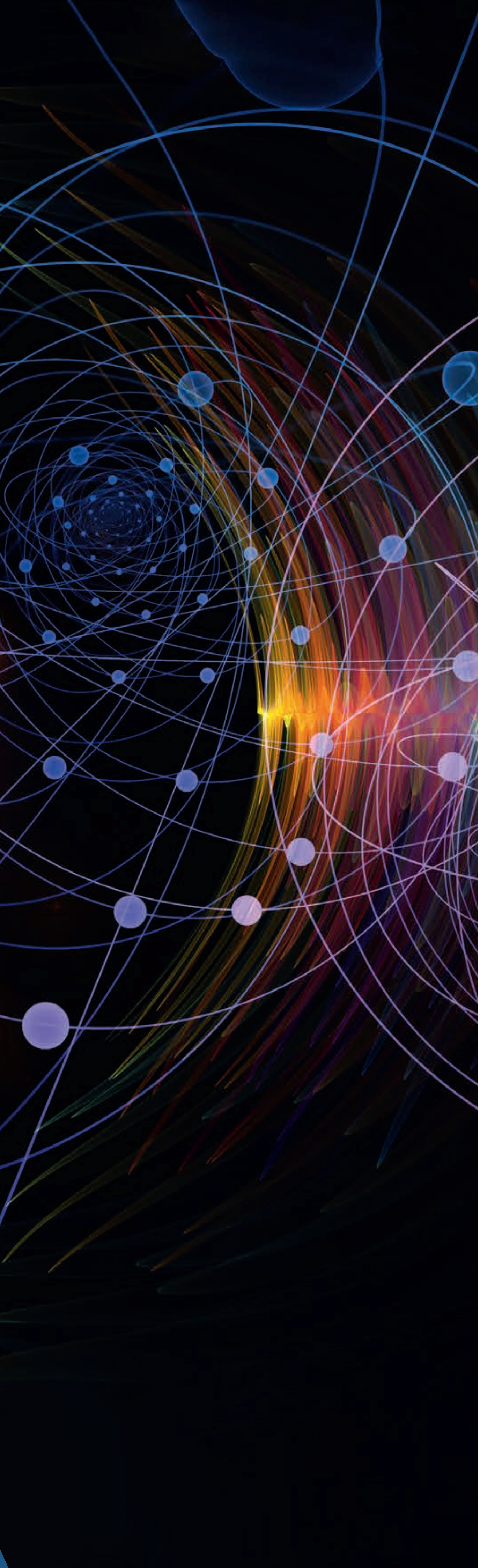
Successful monitoring of the STS 0119 test laboratory

The Swiss Accreditation Service (SAS) has finished monitoring the METAS STS 0119 test laboratory. SAS has thus confirmed that METAS is authorised to carry out chemical, physical, biological and sensory tests in accordance with ISO standard 17025. This monitoring also confirmed that the former testing laboratory for biological testing of food and feed of the Federal Food Safety and Veterinary Office (FSVO) has been successfully integrated into METAS. The scope of our accreditation, extended to include the molecular biological detection and determination methods of GMOs and viruses, has been approved and published on the SAS website.

About METAS

Metrology for the second quantum revolution

The second quantum revolution is in full swing. It will change our lives and lead to applications that are currently unknown. Both metrology and industry must prepare for this development. That is why METAS wants to set up a centre of competence for quantum metrology.



Dr Hugo Lehmann

By the end of the 19th century, the understanding of physical laws was already well advanced. When Max Planck, as a young student in about 1870, enquired about the prospects of studying physics, he was told that physics was an almost-completed science and therefore no more groundbreaking findings could be expected.[1] It is an ironic turn in history that it was exactly the same Max Planck who, at the turn of the 20th century, provided the impetus for the first quantum revolution in physics with his explanation of black-body radiation by quantified energy states.

In the 1920s, a group of physicists, including Erwin Schrödinger, Werner Heisenberg, Paul Dirac and Wolfgang Pauli, formulated the fundamentals of quantum mechanics. This theory made it possible to better understand the natural phenomena on a very small scale. Over the decades that followed, this new type of mechanics was developed to the point where the properties of atoms, molecules, solids and radiation could be described in detail.

The fact that the models of quantum physics are sometimes counter-intuitive and that the nature of the infinitely small exhibits behaviour that differs from our daily experience even troubled renowned physicists. For instance, until the end of his life, Albert Einstein struggled with the significance of quantum mechanical knowledge. It was not only the stochastic behaviour, but also the spooky action at a distance (or entanglement in technical jargon) that caused him problems. It was only the experiments of Alain Aspect, who was awarded the Nobel Prize[2] for this in 2022, that were able to clearly prove that while this entanglement[3] is difficult to understand, it is actually a reality.

While the first quantum revolution led to an understanding of matter in its smallest dimensions as well as to indirect technical applications – for example in semiconductor technology – the physicists and engineers learned over time to control the quantum properties better and to take advantage of them by making use of technology.

For example, quantum cryptography was developed, which makes it possible to develop a method that is in principle tap-proof. By using quantum-based random number generators and light quanta detected by single-photon detectors, it can be ensured that the transmission channel has not been eavesdropped due to the quantum properties. Combined with classical encryption methods, high transmission rates can be achieved and data can be transmitted in a quantum-encrypted manner. The long-term goal is the quantum Internet, which is supposed to give us a completely secure Internet. This will not improve the quality of the information transmitted, but that is a completely different topic.

Another new application of quantum systems is the measurement of electromagnetic fields. To that end, atoms in a certain excited state are used, for example, atoms whose outermost electrons are further away from the centre than in the ground state, so-called Rydberg atoms. These atoms are particularly sensitive to external fields, which leads to changes in their energy state that can be measured.[4] This allows for more accurate and sensitive measurements in certain frequency ranges than with traditional methods. These are just two of many other applications that are being developed.

This direct use of quantum systems in technology is also referred to as the second quantum revolution. It will lead to unprecedented technological opportunities and will open up both significant scientific advances and new business opportunities. As a result, global investments in quantum technology are large, both in academic and in industrial environments. In addition, the national quantum technology scenes are very dynamic, especially in Switzerland. In addition to the well-positioned higher education institutions, some Swiss SMEs are also well positioned on the global market and several start-ups are waiting in the wings.[5]

A Swiss centre of competence for quantum metrology

However, the new technologies and methods that use quantum effects must also be characterised and calibrated and traceable to the International System of Units (SI). This creates the conditions for successful standardisation of quantum-based systems and will also strengthen confidence in quantum technologies. Moreover, well-characterised quantum devices could give Swiss companies a competitive advantage on the global market. This would also allow the properties of precision and high quality, often associated with "Swiss", to be brought into the quantum era.

So it must be ensured that the Swiss quantum technology scene has access to suitable metrology infrastructure. The need for metrology infrastructure for quantum technology has also been recognised by the European Commission[6] and initial activities have already been launched.

For all these reasons, METAS wants to further develop its expertise in quantum technologies. In metrology, quantum systems have been used as references for almost 30 years. Such systems are based on natural constants and represent irrevocable standards for different units. In this way, for example, the unit ohm for the electrical resistance via the quantum Hall effect[7] or the volt via the Josephson effect[8] are realised. Quantum effects have also long been used for the definition of the second. Atomic clocks, such as the "Fontaine Continue Suisse 2" (FoCs2) at METAS, which define the international time scale, use the ground state transition of laser-cooled caesium atoms to determine the frequency with quantum accuracy (almost a kind of pendulum at the atomic level).[9] In the future, optical clocks will be even more accurate by a factor of 100[10] and will be used as a second reference. The higher precision achieved by this will trigger many further scientific and technical developments. METAS is therefore well positioned to build and maintain quantum metrology infrastructure, as well as to provide research capabilities and relevant services. On the other hand, as a Swiss metrology Institute, thanks to its extensive network and established role within European metrology, it is well positioned to encourage the coordination of Swiss and European efforts and to help Swiss industry to be compatible with developments in the European market.

The infrastructure which is being planned in order to meet the new requirements of quantum technology can be divided into the following three subject areas:

- quantum communication
- quantum computers
- quantum sensing

In the first two subject areas, METAS plans to create calibration and characterisation capacities for key components of quantum communication technology, such as quantum cryptography devices for the distribution of quantum keys, single-photon detectors or qubits.

In the third area, METAS will also explore ways of using the new quantum sensor methods for measuring electromagnetic fields (e.g. Rydberg atoms or NV centres[11]) for metrological applications. The use of these technologies should also enable METAS to characterise such devices and ensure metrological traceability for quantum sensor applications. Supplemented with the classical quantum standards, the planned centre of competence for quantum metrology at METAS provides an overview illustrated in Figure 1.

Where are we today and where should the journey lead?

The concept for quantum metrology at METAS was developed in 2023. In 2021, however, initial clarifications into the possibilities of quantum sensing had already been made. These were deepened in 2022 in cooperation with the University of Basel's Quantum Center[12]. The plan is to continue this cooperation. First, the competencies and technologies for electrical field measurements will be explored and then ultimately transferred to METAS. In a project launched in 2024 as part of the European Partnership on Metrology research and development programme, it is planned to try to use Rydberg atoms as electric field sensors. The advantages of these sensors are higher accuracy, higher speed and higher measurement frequencies, which can be of interest in industrial manufacturing.

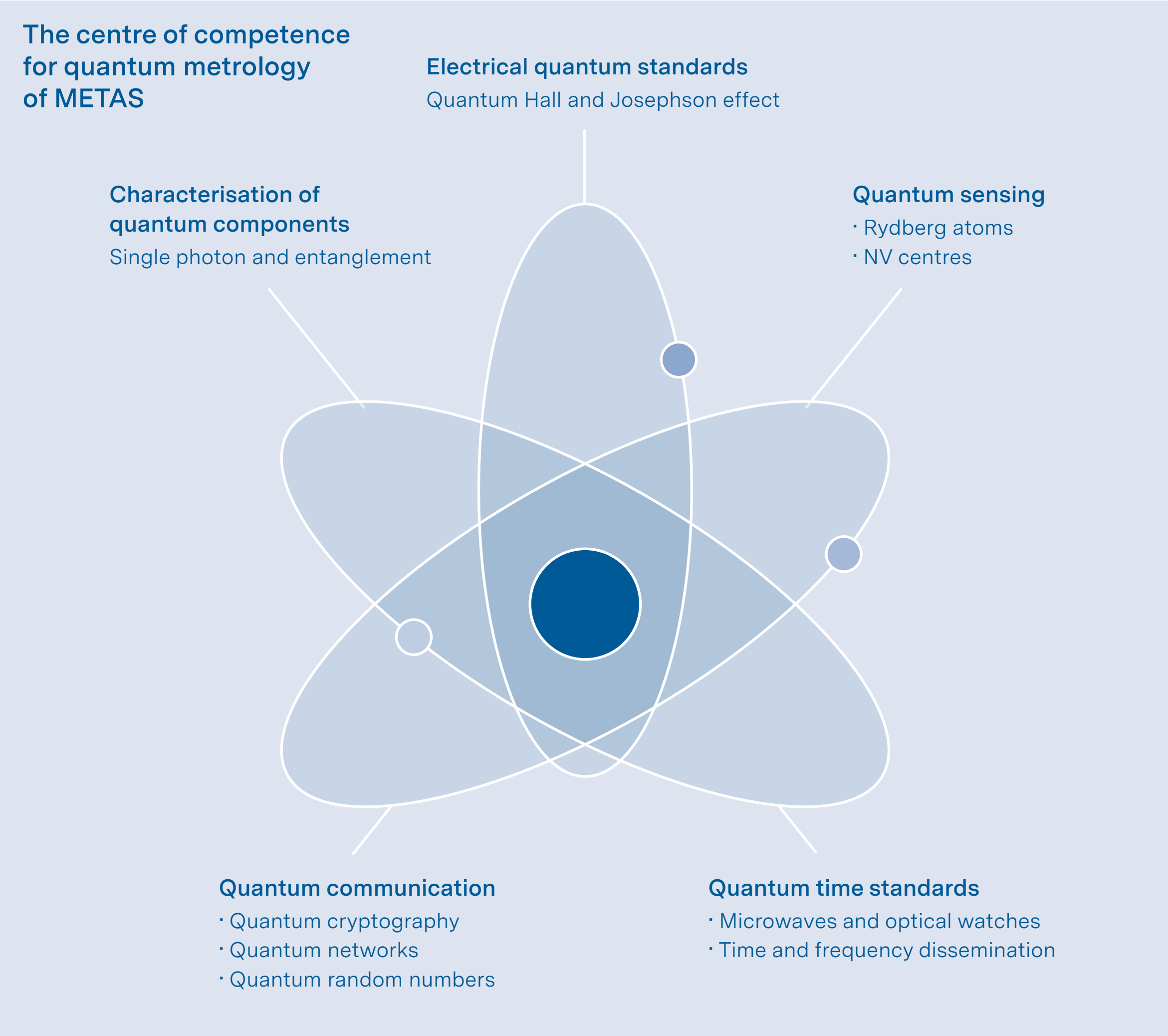
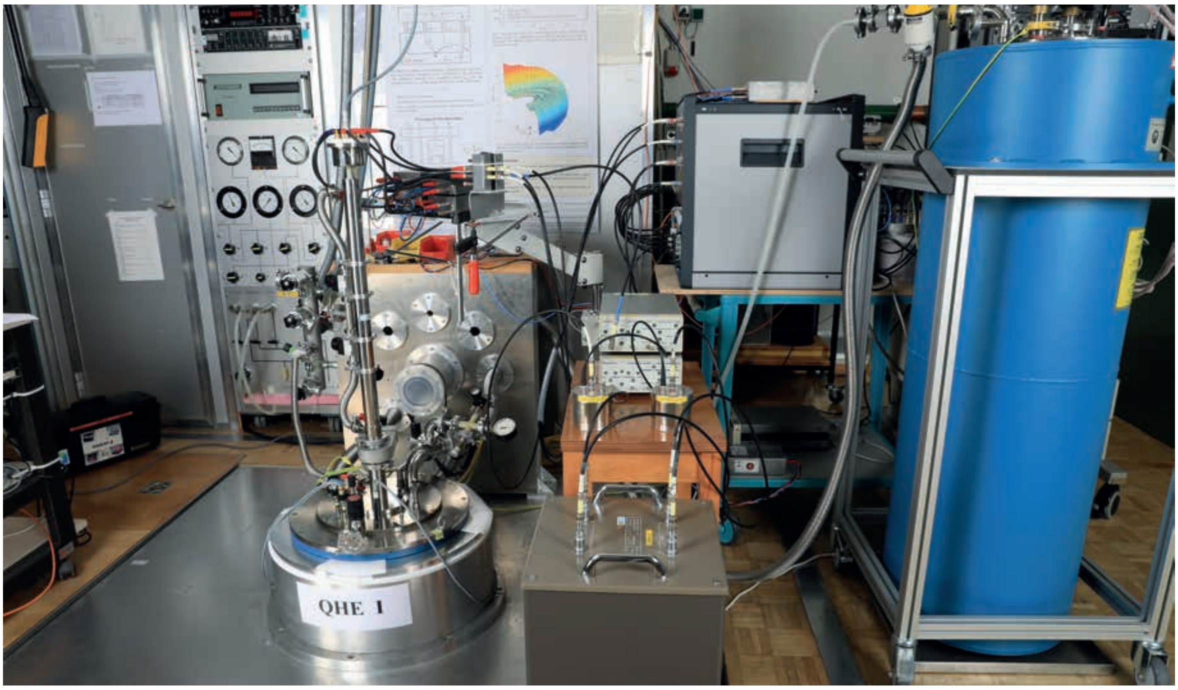


Figure 1. The subject areas of the centre of competence for quantum metrology of METAS.



Example of an impedance comparison with the Josephson impedance bridge at METAS based on the reference resistance of the quantum Hall effect.

Opportunities for cooperation within the dynamic Swiss quantum technology scene are also being sought for the other subject areas. Quantum metrology is to be built up gradually so that all quantum technologies relevant for Switzerland can be covered in the future. This guarantees that METAS will successfully exploit the benefits of the second quantum revolution and that the necessary metrological foundations are available to industry and research.

Quantum mechanics

Quantum mechanics is the set of physical laws that describe the behaviour of the world at the level of atoms and molecules. The laws of traditional mechanics, which we experience on the scale of our usual dimensions, cannot aptly describe all phenomena on the atomic level. From a certain order of magnitude, quantum mechanics is transferred to traditional mechanics. This correspondence principle connects the two theories.

1 Max Planck: *Vorträge Reden Erinnerungen (Lectures Speeches Memories).* Publishers: Hans Roos, Armin Herrmann. Springer, Berlin, Heidelberg 2001, *Vom Relativen zum Absoluten (From the Relative to the Absolute),* doi:10.1007/978-3-642-56594-6_11
2 Alain Aspect – Facts – 2022. NobelPrize.org. Nobel Prize Outreach AB 2024. Mon. 5 Feb 2024. https://www.nobelprize.org/prizes/physics/2022/aspect/facts/
3 He was able to show that two quantum-mechanically entangled particles or photons exhibit this action at a distance or also non-locality, i.e. that when measuring one of the particles, the second one immediately knows about this intervention.
4 See for example: A. Osterwalder and F. Merkt. Using high Rydberg states as electric field sensors, 1999, Phys. Rev. Lett., 82, 1831–1834.
5 Switzerland: A hub for quanta, November 2023, Swissnex https://swissnex.org/app/uploads/sites/8/2023/11/Switzerland-A-Hub-for-Quantum-latest.pdf
6 Testing and Evaluation Infrastructure for European Quantum Communication Infrastructure (EuroQCI), July 2023, European Commission, https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci
7 B. Jeckelmann and B. Jeanneret, The quantum Hall effect as an electrical resistance standard, 2001, Rep. Prog. Phys. 64, 1603–1655.
8 B. Jeanneret and S. Benz, Application of the Josephson effect in electrical metrology, 2009, Eur. Phys. J. Spec. Top. 172, 181–206.
9 A. Jallageas, L. Devenoges, M. Petersen, J. Morel, L. G. Bernier, D. Schenker, P. Thomann and T. Südmeyer, First uncertainty evaluation of the FoCS-2 primary frequency standard, 2018, Metrologia 55, 366–385.
10 B. Bloom, T. Nicholson, J. Williams, et al. An optical lattice clock with accuracy and stability at the 10-18 level, 2014, Nature 506, 71–75.
11 NV centres are nitrogen vacancies in diamonds. They provide an excellent way to control the state of a quantum system in a coherent manner, thus measuring magnetic or electric fields.
12 See https://www.quantum.unibas.ch/

Object

Precisely manufactured connectors as central elements in high-frequency metrology

Coaxial connectors are essential in metrology to establish a signal connection between different components. They therefore also play an important role in accurate high-frequency measurements and in the calibration of measuring equipment. Precise manufacturing and high-quality workmanship are essential to ensure reliable and defined signal transmission. Coaxial connectors exist in different sizes and forms for different frequency ranges. The latest generation, which METAS is currently working on, will enable measurements up to 220 GHz and thus play a role in the development of the upcoming mobile communications standard 6G.

Interview

"I want to focus on sustainability."

In mid-October 2023, Dr Bobjoseph Mathew – Deputy Director and Head of the Department of Legal Metrology at METAS – took office as President of the International Committee of Legal Metrology. In this interview, he explains the importance of the International Organization of Legal Metrology and legal metrology on an international level.

Dr Bobjoseph Mathew, Vice Director and Head of the Legal Metrology Division at METAS and President of the International Committee of Legal Metrology.

Dr Bobjoseph Mathew, before we go into more detail, can you explain what legal metrology is and why it is so important for society and industry?

Legal metrology defines the requirements for measuring instruments, their testing and inspecting how they are used. The application of legal requirements for measurements and measuring instruments is aimed at the fields of trade, health, environmental protection and public safety. The objective is to prevent incorrect measurements that result in negative impacts on society, the environment or end consumers.

You are now President of the CIML, which is the committee for legal metrology and part of the OIML – the highest international body in the field. What is the mission of the OIML?

The mission of the OIML is to support the individual countries in maintaining an infrastructure for legal metrology. The objective is to establish the basic standards and requirements for the different measuring instruments on an international level and achieve mutual recognition. These regulations make trade easier, increase mutual trust and promote a high level of consumer protection around the world.

The OIML works with several governments, international organisations and those in industry to establish this infrastructure through standards and processes, for example. How does the OIML cooperate with all of these partners?

The OIML is an organisation based on a multilateral international treaty. The members of the OIML are 120 different countries. These members send government officials who represent metrology in their country at the OIML, and also the OIML in their country. They have a dual role.

Cooperation with international organisations takes place on one hand via a Memorandum of Understanding (MOU), where the framework for cooperation is defined. Agreements like this are in place with the International Organization for Standardization (ISO), International Electrotechnical Commission (IEC) or the International Laboratory Accreditation Cooperation (ILAC), for example.

We also work together with international organisations as part of working groups, such as with the World Trade Organization (WTO), or as part of projects, such as with the United Nations Industrial Development Organization (UNIDO).

What about cooperation with Switzerland? You are the Swiss representative in the OIML, after all.

The main contact partner is METAS, who represents Switzerland on this committee. I am the METAS delegate. METAS is involved on various levels, including in several working groups and at a management level, either through our experts or myself. METAS also organises seminars and meetings of the working groups at its main site in Wabern.

How can the OIML influence the legislation of the member states in order to ensure consumer protection and easier trade worldwide in terms of measuring instruments?

The majority of the work carried out by the OIML involves drawing up recommendations. Some countries adopt these word for word, while others refer to the principles or certain definitions. Nonetheless, a certain degree of global harmonisation in legal metrology can be reached in this way.

Furthermore, the OIML Certification System (OIML-CS) also contributes to simplifying the launch of measuring instruments on the market. This is a system that allows for the mutual recognition of test reports for measuring instruments. As a result, various administrative hurdles in approval and assessing conformity no longer have to be overcome.

Let's now take a look at your new role as President of the CIML. How did you end up in the position? Did you have to start an election campaign or win over voters?

In the past few years, I worked on various projects within the OIML on a range of topics and I started to become interested in taking on a leading role. The former President supported me and encouraged me to join the Presidential Council. I stood for the position of Vice President when it became vacant in 2019. There was actually an election campaign between me and four other candidates, and I emerged as the victor.

A few years later, the President announced their resignation. One other candidate was also interested in the position, so a vote was taken between us. It was important to gain a certain level of support from all regions during the election. But it wasn't an election campaign in the true sense of the word.

What are your most important duties as President of the CIML?

As President, I have a strategic role, a supervisory role, a representative role and a decision-making role. Firstly, I have to define the strategic guidelines for the coming years together with the Presidential Council. Secondly, I have to ensure that the management team – the International Bureau of Legal Metrology (BIML) – performs its duties and carries out its management roles and everyday business efficiently. Thirdly, I represent the OIML at various national and international events where the OIML is invited. Finally, I have to make decisions that relate to the organisation together with the Presidential Council, such as the prioritisation of future projects or the definition and implementation of the work programme.

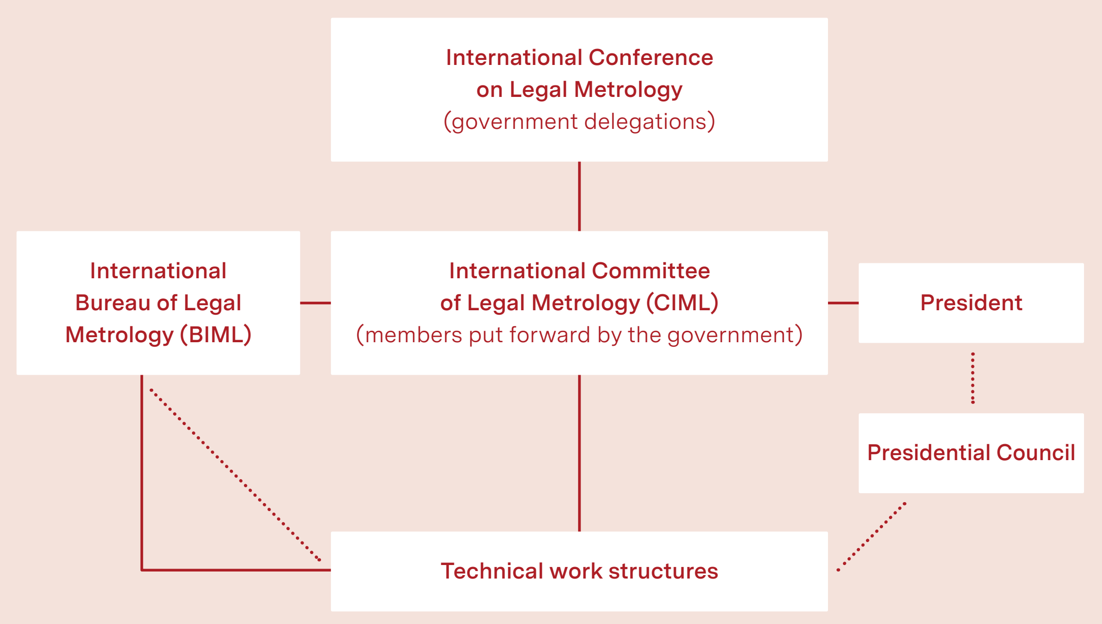
I am also responsible for heading up conferences and meetings. A meeting takes place annually and a conference every four years, which I have to prepare for with the BIML.

What skills and knowledge do you have to have in this role?

Great interest in the role and in legal metrology is essential. I would even say you have to have a passion for it. Diplomatic skills are indispensable, and patience is a real virtue. You have to be open to everything and listen to all sides of the story. You also have to have political awareness, particularly now where the global political situation is not so easy.

> **"Diplomatic skill is essential and patience is an indispensable virtue."**

Structure of the OIML



The OIML has a range of bodies. One of these is the International Committee of Legal Metrology (CIML).

The members of the CIML at the last CIML meeting in Chiang Mai, Thailand.

Knowing multiple languages and having an affinity for different cultures also help to better understand the various global regions.

We live in an increasingly digitalised world. What are the impacts of digitalisation on legal metrology globally?

The properties and use of measuring instruments are set to change. Requirements in terms of certificates and their processing capabilities will undergo a transformation. As a result, digital calibration certificates (DCC) will become increasingly important. The challenge for the OIML is to keep pace with these developments with its recommendations.

Is digitalisation in legal metrology dealt with the same way around the world?

That's exactly the challenge we are facing! Digitalisation is treated differently depending on the region. There are regions that are more technologically advanced than others, meaning the challenges are also different. For example, when looking at artificial intelligence (AI) in Europe, the debate is different to that seen in other regions. Here, the goal is to establish technical measuring instruments or digitalise the processes that are already further advanced in Europe. Questions relating to data protection and data security are dealt with differently in the various regions. As things stand, a uniform way of dealing with these issues still appears to be a long way off.

What is the OIML doing to bring all its members to the same level?

We launched a working group – the digitalisation task group – where the joint requirements and concerns of the member states were collected and assessed. Based on this, a work programme will be developed that has to be backed by the majority and where focal points are set.

While it may sound strange, e-learning will be a very important element as the OIML plays a decisive role in exchanging knowledge. It is an ideal way to do this without the representatives having to fly around the world. A range of courses are planned. An exchange platform will also be included, where we invite experts to participate or discuss specific questions. E-learning includes the entire spectrum of learning resources.

Which new or future developments in legal metrology could have an impact on companies and consumers worldwide?

In addition to the advance of digitalisation, I think that food safety, the environment and health will have an increasing impact. Legal metrology can take on an active role here – either as regulator or legislator – in order to check that requirements are being met. However, this depends on the political decisions made in each country.

What do you want to achieve at the OIML during your term as President?

I want our core activities – such as drawing up recommendations – to be perceived as being efficient and tailored to the needs of the member states. I also want to focus on sustainability. The OIML should align its objectives more towards sustainability. To start with, we no longer carry out all meetings in person – online meetings are also encouraged. However, there should also be an increasing focus on recommendations that have an impact on sustainability, such as in EV charging or health.

International Committee of Legal Metrology (CIML)

The CIML is the functional decision-making body of the OIML.

The committee meets every year.
In general, the committee's decisions relate to the following:

- approval of the OIML strategy and the annual BIML work plan,
- the election of the president and vice presidents,
- approval of the financial reports submitted by the BIML Director,
- appointment of the BIML Director and Assistant Directors,
- adoption of various statutes, regulations, internal procedures, etc.,
- approval of changes to the OIML's technical work programme and
- adoption of OIML recommendations, documents and other publications.

LinkedIn profile of
Dr Bobjoseph Mathew

Service

Determining speeds based on video recordings

With the help of suitable video recordings, breaches and violations of the Road Traffic Act can be proven. Proper analysis of video footage requires expertise that METAS can use to support law enforcement agencies. An important aspect of such time/distance analyses are the uncertainties of the determined speeds.

Dr Daniel Sprecher, Dr Christian Mester and Dr Sören Fricke

On the one hand, they can sometimes be perceived as paternalistic; on the other hand, other drivers are firmly expected to stick to them: many of us have an ambivalent relationship with them. This refers to the indicated and general maximum speeds, hereinafter referred to as speed limits.

Regulatory authorities often detect speed limit violations when measuring speed. These are usually minor violations which have no further consequences apart from a fine. However, violations are sometimes also found to be so high that they are considered serious offences in which both the Office of the Public Prosecutor (for criminal proceedings) and the driver and vehicle licensing office must take action (for the purpose of revoking the driving licence). In non-urban areas, where a speed limit of 80 km/h applies and most fatal traffic accidents occur, net speeds (measured speed minus the legally defined tolerance deduction) of between 110 km/h and 139 km/h are considered a violation of the Road Traffic Act. Even higher net speeds are a crime (dangerous driving offence) which is punishable by a fine and results in a revocation of the driving licence for a period of at least two years and a sentence (often suspended) of at least one year.

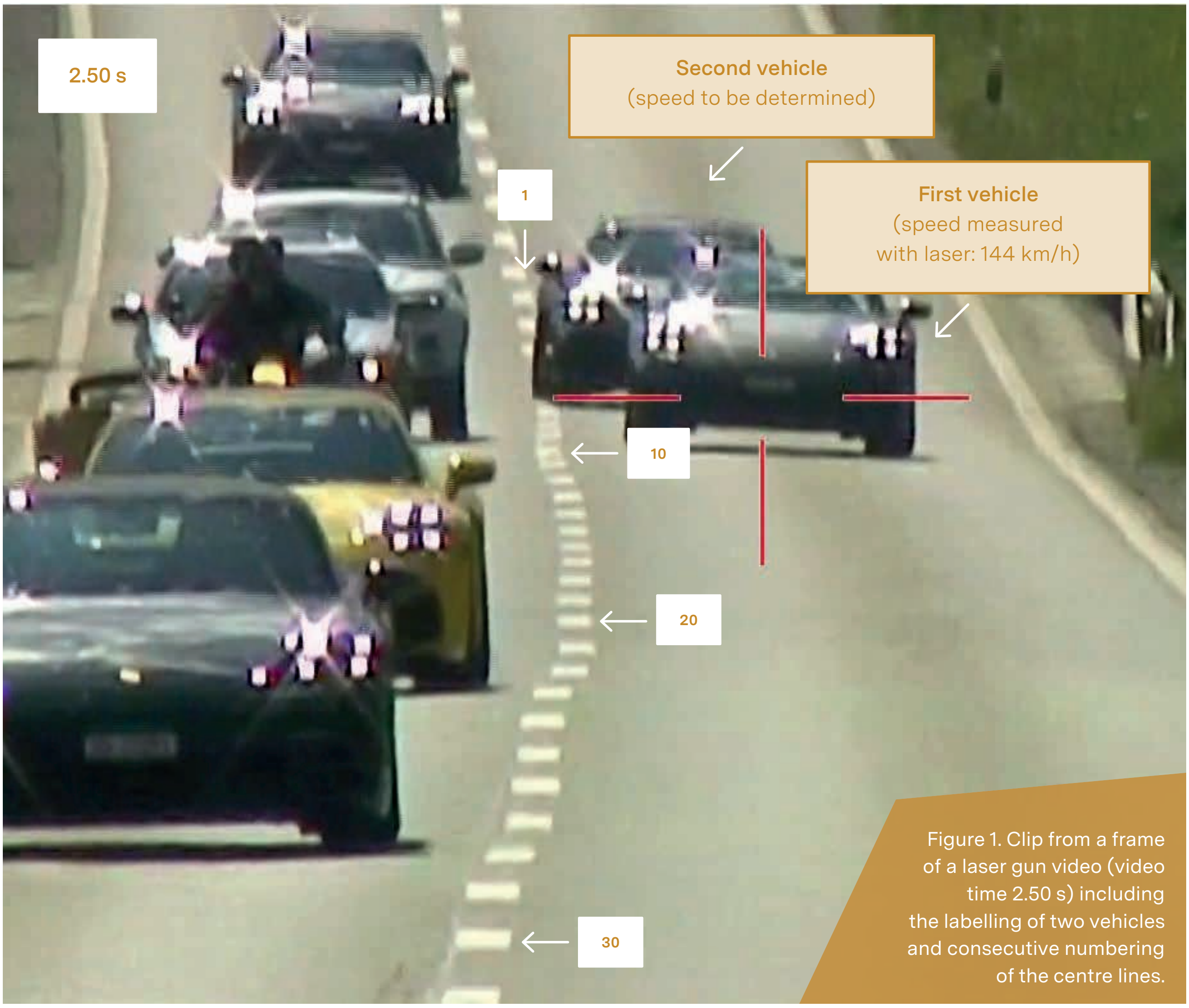


Figure 1. Clip from a frame of a laser gun video (video time 2.50 s) including the labelling of two vehicles and consecutive numbering of the centre lines.

Establishment of a dangerous driving offence by means of an official laser measurement

In order to detect speeding violations, the police primarily use radar measuring devices, laser measuring devices and threshold detectors, which METAS has previously checked, approved and verified annually. A laser measurement, which was carried out in a non-urban area on a mountain pass, is considered in this article in the context of a case study. The approved laser gun detected a measured value of 144 km/h and recorded a video sequence in this context (see Figure 1). The measured value applies to the car referred to as the “first vehicle” and the net speed is thus 140 km/h when the applicable tolerance deduction of 4 km/h is applied. This violation is therefore on the verge of constituting a dangerous driving offence.

In view of the serious impact that such a measurement has, the measuring equipment used must work totally reliably. However, even in the case of minor violations, the statutory error limits must be demonstrably observed. As a testing and certification body, METAS, together with the manufacturers and users, is responsible for ensuring reliable speed measurements during official speed checks.

Other methods of detecting dangerous driving offences

The activities of METAS are focused on measurements with approved measuring equipment. However, there are other ways in which speeding violations can be established. This article focuses on one of these possibilities. In the video recording of the case study, it could be observed that a second vehicle was following closely behind the first vehicle (see Figure 1). Thus, it was indicated that the speeding violation of the second vehicle was also within the range of a felony or misdemeanour. However, no official measurement was available for this vehicle.

So there are situations where law enforcement authorities come across evidence of a felony or misdemeanour without an official measurement being carried out on this vehicle. In such cases, the authorities are obliged to initiate investigations in order to

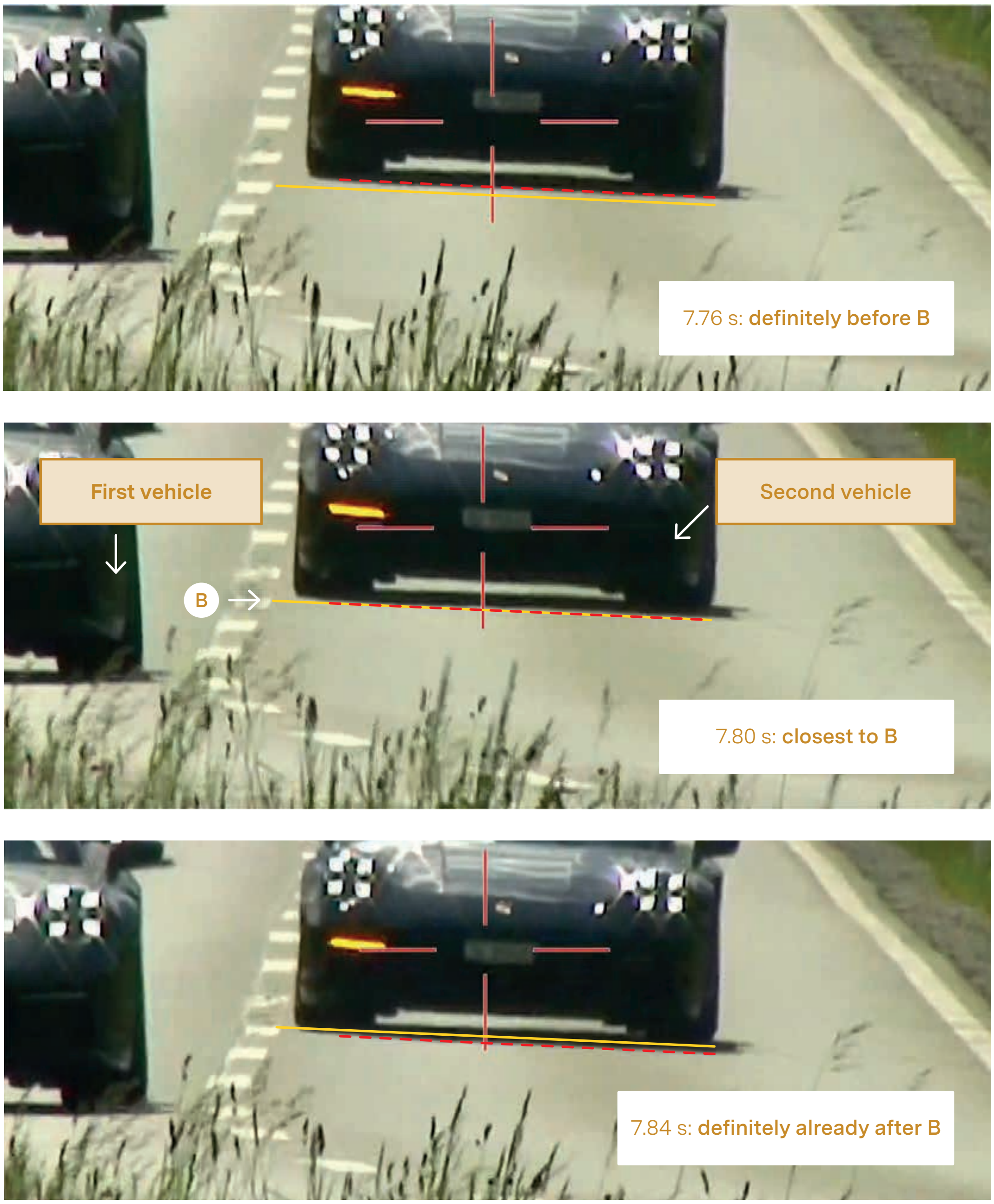


Figure 2. Clips from three additional frames of the laser gun video with specified video times, labels and guides.

substantiate or invalidate the indications. Possible sources of information may be visible traces of the accident, digital traces in the vehicle or confiscated video recordings. In this context, the services of METAS focus on investigations based on video recordings, such as those which may exist in the following situations:

- An accident or the conscious acceptance of a serious risk to the safety of other road users has been recorded by a camera (e.g. a road safety camera);
- One person filmed their own driving style with their mobile phone, for example, and shared the recording on social media, or the police found this recording elsewhere;
- In the context of an official speed check, a vehicle was recorded by the video camera of the measuring device without a valid measurement able to be performed on this vehicle (like the second vehicle in Figure 1).

If the video recording has been classified by the law enforcement authorities as admissible evidence, experts will be commissioned to quantify the minimum speed at which the vehicle was being driven. The following section illustrates a possible analysis method for the second vehicle in Figure 1.

Time/distance analysis of the case study

The time/distance analysis uses at least two fixed reference positions which determine the vehicle's passage times. In this case study, the starting points of centre lines No. 6 and No. 30 (see Figure 1) were chosen as the two reference positions A and B.

Figure 2 shows clips of three consecutive frames. In the first frame (video time 7.76 s), the front wheels of the second vehicle (marked in red) are certainly still ahead of reference position B (marked in yellow). In the third frame (video time 7.84 s), the front wheels have certainly already passed reference position B. It follows that the passage time is 7.80 s ± 0.04 s. The uncertainty of 0.04 s specified here limits a value range within which the true value lies.

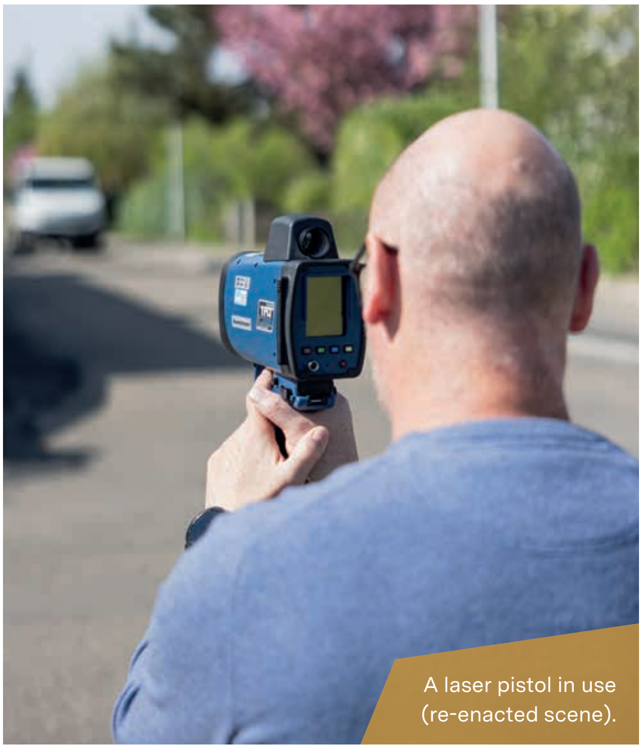
Analogously, the passage time at reference position A was determined to be 2.28 s ± 0.08 s. The duration of the journey from A to B can be determined as 5.52 s ± 0.12 s from the two determined passage times.

Since the video recording contains only information about time but not length, it is not possible to determine speeds solely on the basis of video recordings. It is imperative that another independent source containing metric information is provided. Distance lengths can be measured retrospectively on site using technical aids such as measuring tapes, measuring wheels, laser scanners or measuring vehicles. In this case, the distance from A to B was determined to be 231.7 m ± 1.3 m in Swisstopo's orthoimage, which is available online.

The calculation of the speed from the duration and the distance travelled is shown in the box at the top right. The question of the Office of the Public Prosecutor ("What was the minimum speed at which the second vehicle was being driven?") can thus be answered as follows: the speed of the second vehicle as determined in this analysis was *at least 147 km/h.* The uncertainty relating to the investigation was taken into account in favour of the accused.

Not every video recording is suitable for investigation purposes

The analysis demonstrated here shows that it is possible to derive quantitative and reliable statements about the speed driven from video recordings. The sources of the analysis are the registered imaging time points, the image contents and the



A laser pistol in use (re-enacted scene).

Two results are calculated for the speed:
Gross speed = most likely result
= 231.7 m / 5.52 s = 42.0 m/s = 151.1 km/h;

Net speed = smallest result consistent with the data
= (231.7 m – 1.3 m) / (5.52 s + 0.12 s) = 40.8 m/s = 147.0 km/h;

Summary and rounded description: 151 km/h ± 4 km/h.

separate distance measurements. During the analysis, the uncertainty of the investigation for this particular case was inferred and deducted in favour of the accused. A flat-rate deduction as is often made with official measurements is not applicable and would not be sensible because uncertainty depends on many factors, such as the distance travelled, quality and perspective.

The video recording of the laser gun was chosen as an illustration in this article because it contains the two fundamentally different methods of determining speeds. In the case of measurements (as on the first vehicle), the measuring instrument and its method are subject to the Measuring Instruments Ordinance and must be checked, approved and verified in advance. In case of investigations, however, the principle of freedom of evidence applies, i.e. the evidence available in individual cases is analysed afterwards. It should be noted that not every video recording is suitable for an investigation; the technical usability must be assessed in individual cases by a specialist. The analysis methods used are also selected on a case-by-case basis, depending on the evidence available.

It should be emphasised that investigations are only possible if there are indications of serious offences. Measurements, on the other hand, can be carried out independently of suspicion and in large numbers. For a more detailed discussion of the topic and a description of further analysis methods, the article *"Weg-Zeit-Analysen von Videoaufnahmen"* (time/distance analyses of video recordings) can be read in the *Jahrbuch zum Strassenverkehrsrecht* (yearbook on road traffic law) (Zurich 2024, in print).

METAS services

Related to investigations based on video recordings:

- Video reports on offences involving speeding and drivers not keeping their distance (only on behalf of public prosecutors and courts).
- Courses on time/distance analyses of video recordings (see info box)

Relating to approved speed measuring devices:

- Tests and approval of types
- Verification of individual measuring devices
- Measuring device report on individual speed measurements (only on behalf of public prosecutors and courts).

Basic course on time/distance analyses

Since 2021, METAS has conducted an annual German-language course on the method of analysing video recordings described here. The course has already been conducted once in French and once in Italian. The course is aimed primarily at employees of police authorities and institutes, but is open to everyone. Appropriate software tools are introduced and the participants learn to use them based on demonstrations and numerous practical examples.

Further information:

www.metas.ch › Services › Course offerings

The National Reference Laboratories for Genetically Modified Organisms in Food and for Food-Borne Viruses

Food safety is ensured by multiple players, be that at the production, processing, marketing or control level. The National Reference Laboratories for Genetically Modified Organisms in Food and for Food-Borne Viruses play a key role in the control process. They help ensure that the enforcement laboratories apply universal analysis methods.

Foods consumed raw or only slightly heated can transmit pathogenic viruses to humans. This also applies to this delicious ice cream cake as the strawberries were contaminated with hepatitis A viruses.

Dr Dominik Moor

In Switzerland, a basic principle applies whereby food that is sold on the market may not endanger the health of consumers. In order to guarantee that products pose no harm and to prevent any deceit, food and also utility articles are subject to mandatory examinations. For example, genetically modified organisms GMOs in food are not accepted by the majority of the Swiss population, which is why regular market checks are carried out and compliance with legal requirements is reviewed. These duties are predominantly carried out by the official Swiss enforcement laboratories (cantonal laboratories and consumer protection offices). The two METAS National Reference Laboratories NRLs for Genetically Modified Organisms in Food and for Food-Borne Viruses ensure that the enforcement laboratories apply universal analysis methods, amongst other things. Through the consistent deployment of validated analysis procedures, pathogens like viruses in food can be reliably detected, minimising the risk of serious diseases.

The legal bases regarding appointing and specifying the duties of NRLs are stipulated in the Foodstuffs Act (Art. 43 FSA) and the Ordinance on the Implementation of Foodstuffs Legislation (Art. 59–61 FLIO). The federal government, or rather the Federal Food Safety and Veterinary Office (FSVO) appoints the National Reference Laboratories. It may charge laboratories operated by the federal government or private laboratories with the relevant duties. There is a total of 15 NRLs in Switzerland, all of which are entrusted with a special analytical field. Four METAS laboratories perform this role; the two mentioned above along with the NRL for Chemical Elements and Nitrogen Compounds in Foodstuffs and the NRL for Process Contaminants in Foodstuffs.

Roles and duties

The NRLs fulfil various duties in their role. They work with the European Union Reference Laboratories (EURLs) and maintain a dialogue with the network of Member-State NRLs at the European level. As well as this, they coordinate the activities of the enforcement laboratories, promote the harmonisation of internationally recognised analysis methods and organise an annual event designed to allow the enforcement laboratories to share their experiences. Thanks to their often extensive experience in their area, the NRLs form an analytical competence centre and provide the enforcement laboratories with technical and scientific support. For example, the NRLs can carry out confirmation analyses for the enforcement laboratories, validate new detection methods and organise lab comparison tests or suitability tests for the official laboratories. The NRLs can also carry out investigative campaigns on behalf of the FSVO.

Measurement campaigns and market controls on behalf of the FSVO

The two METAS NRLs for Genetically Modified Organisms in Food (GMO NRL) and for Food-Borne Viruses (viruses NRL) advise the FSVO with regard to the risk to consumers from human-pathogenic viruses in food or the presence of GMOs in food on the Swiss market. If viruses or GMOs are suspected in food, or if there is an increased occurrence, for example based on reports in the European rapid alert system RASFF (Rapid Alert System for Food and Feed), market controls on imported foods can be requested, which the FSVO commissions the METAS GMO NRL or viruses NRL to carry out. For these measurement campaigns, samples are mostly taken at Swiss customs authorities or airports. The relevant enforcement laboratory is responsible for any potential enforcement duties that arise as a result of positive findings.

The viruses NRL has previously already carried out a wide range of measurement campaigns, for example the investigation into frozen berries in 2014, vegetables and herbs of Asian origin in 2015 and raw sausages and liver meat paste in 2016. During the 2017/2018 mussel season, oysters, mussels, clams, etc. were examined and, from 2019 to 2021, a range of campaigns focusing on the hepatitis E virus in meat products were carried out.

In the spring of 2021, the Federal Office of Public Health (FOPH) recorded an increased number of hepatitis E virus infections across Switzerland based on doctors' reports. Some 104 people were affected, 29 of whom had to be hospitalised, while two patients died as a result of the infection. The people affected were asked about their food consumption, which did not result in a clear allocation to a particular source of infection. However, all individuals stated that they had consumed pork products. The FSVO therefore decided to carry out monitoring on hepatitis E viruses in meat and meat products. The cantonal food control authorities from Switzerland and

EU Reference Laboratories

- Developing and validating test methods
- Carrying out arbitration analyses
- Advising the European Commission
- Supporting the National Reference Laboratories
- They promote the harmonisation of the laboratories' capabilities and, in doing so, help prevent market distortions within the European Single Market

↓

Swiss National Reference Laboratories

- Maintain dialogue with the network of Member-State National Reference Laboratories at the European level
- Coordinate the activities of the enforcement laboratories
- Promote the harmonisation of internationally recognised analysis methods
- Organise an annual event to allow the enforcement laboratories to share their experiences

↓

Official Swiss enforcement laboratories

- Implement the Federal Act on Foodstuffs and Utility Articles and the cantonal requirements regarding the Foodstuffs Act
- Responsible for controls of foodstuffs and food processing facilities, utility articles like crockery, cosmetics and toys, bath and drinking water
- Implementing the Major Accidents Ordinance, the Dangerous Goods Risk Prevention Officer Ordinance and the ordinances on biological safety, chemicals and radon control and refrigeration system authorisation

the Principality of Liechtenstein collected 199 samples from various facilities. From the 47 fresh-meat samples, two pork livers tested positive for hepatitis E and, from 152 sausage products, three were positive. These results revealed that meat products in Switzerland can be contaminated with hepatitis E viruses, thus making it possible for humans to become infected when consuming such products.

Investigation methods

In order to detect and quantify GMOs and viruses in food, both National Reference Laboratories use molecular biological methods. The detection of GMOs as well as human-pathogenic viruses is carried out using the nucleic acids extracted from the food matrix/genetic material. In GMO samples, this consists of deoxyribonucleic acid (DNA), while in the relevant viruses it is mostly ribonucleic acid (RNA). Nucleic acids are detected via a polymerase chain reaction (PCR; see text box).

Real-time PCR

With a real-time PCR, also called a quantitative PCR, a fluorescently labelled probe is added to the reaction mixture. The increase in the PCR product is measured using this probe at the end of each PCR cycle. During this process, the nucleic activity of the DNA polymerase causes the probe's fluorescent colouring to detach, which is detected by the real-time PCR thermocycler. The number of PCR cycles for which the measured fluorescent signal exceeds a pre-defined threshold provides the Cq (quantification cycle) value. The more target DNA is added to the PCR reaction, the fewer PCR cycles are required to reach the threshold value. This enables the DNA content of unknown samples to be determined. To quantify the target DNA in a sample, the sample's Cq value is compared with the Cq of a standard (or standard curve). This allows the percentage of GMOs in a food product to be determined, for example Roundup Ready soya in a tofu sample.

The digital PCR method

A second, more precise method is used for the quantitative analysis of GMOs and viruses: the so-called digital PCR. This process involves dividing the target DNA into a large number of individual reaction tubes (water-in-oil droplets or nanoplate cavities) that have a defined volume in the nanolitre range. The DNA in the cavities is then amplified in a PCR with a fluorescently labelled probe (as with the real-time PCR). The droplets are subsequently read out in the digital PCR reader; each droplet provides a digital result: amplification signal yes/no. In counting a large number of droplets – around 20000 per reaction – a statistical significance is achieved. The number of droplets with successful amplification is proportional to the amount of target DNA used, which is used to quantify the GMO proportion or virus concentration in a sample. Unlike a real-time PCR, with a digital PCR the signal is not assessed by the reader after every PCR cycle, but only after the DNA sequence has been amplified (end-point PCR). Here, the amplification efficiency plays only a small role, which is why the digital PCR is less sensitive to inhibitors than a real-time PCR. This is a big advantage when it comes to analysing food samples which quite often contain inhibitive ingredients.

GMO analytics process

When examining foodstuffs for GMO content, the first step is to extract the DNA from the sample material. The GMO NRL has six different extraction procedures, which are used depending on the nature of the food matrix in question. After this, general search procedures (screening) are used to examine the sample DNA for genetic elements that are contained in the transgenic DNA of many GMOs. Most of the time, these are genetic regulatory elements, such as promoter or terminator sequences, for example. In the event of a positive finding, so-called construct or event-specific methods are used, enabling the GMO to be identified. Multiplex PCR methods allow multiple genetic elements to be detected in one PCR reaction at the same time, which can speed up investigations and reduce costs.

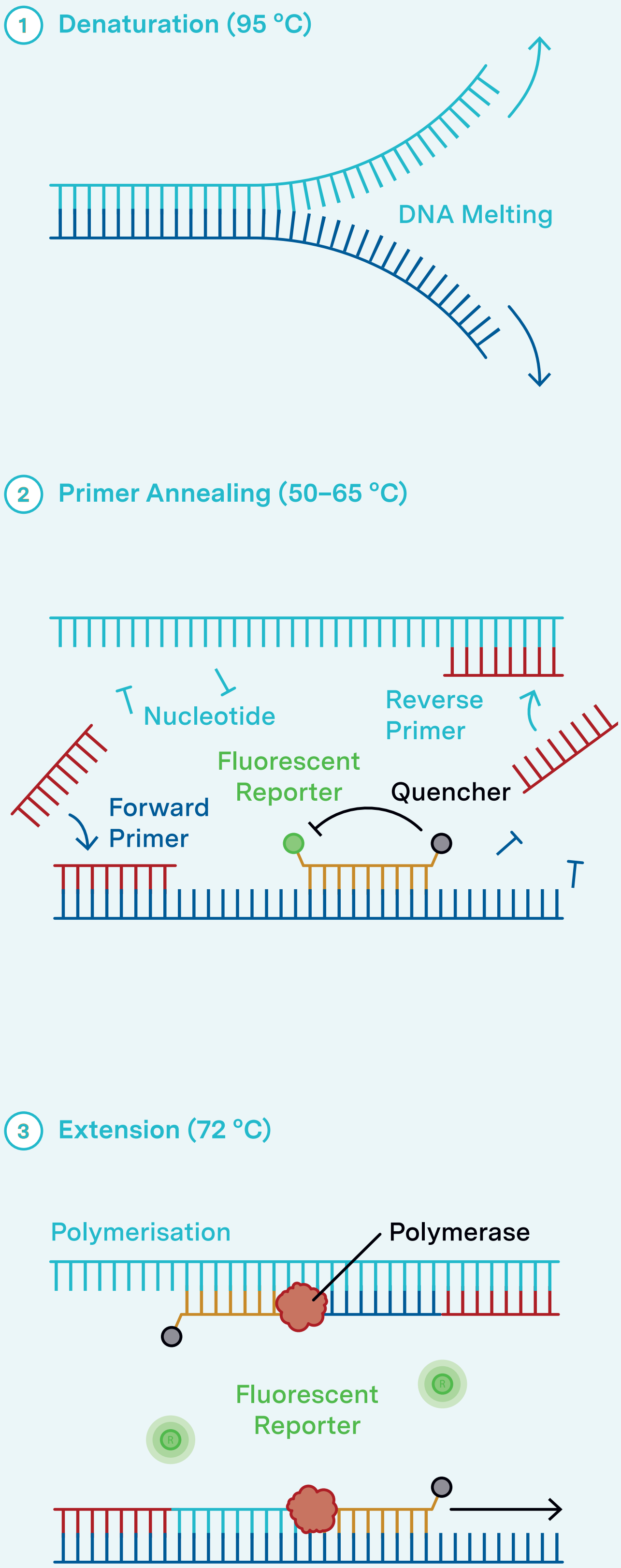
In Switzerland, genetically modified organisms in foods, such as these grains of maize and soya beans, may only be placed on the market with the approval of the FSVO. At the METAS NRL-GMOs, checks are carried out to determine whether the legal requirements with regard to GMOs in food are met.

The polymerase chain reaction (PCR)

The polymerase chain reaction (PCR) is a molecular biological method used for the exponential amplification of DNA in vitro. The PCR enables the quick and selective reproduction of specific DNA sections. Target DNA, primers, DNA building blocks (nucleotides symbolised in the graphic by the T) and a heat-resistant DNA polymerase enzyme are added to a PCR mix. The PCR cycle comprises three main steps: denaturing, annealing and extension.

During denaturing, the DNA double helix is separated through heating at 95 °C; annealing refers to the process by which the primers attach to the target DNA at around 50–65 °C; extending is when the DNA polymerase extends the primers at 72 °C by binding the nucleotides to form a new DNA strand, whereby the nucleotide sequence of the target DNA serves as a template and is read by the DNA polymerase. This synthesises two new DNA strands that in turn serve as templates for the next PCR cycle.

The DNA fragments are reproduced exponentially through multiple cycles (typically 35–45). For real-time PCR, a fluorescently labelled probe is added to the reaction mix. This is broken down by the activity of the DNA polymerase, setting off a fluorescent signal that is measured by the real-time PCR device after each PCR cycle.



For analysis mandates from an enforcement laboratory, the GMO NRL most often receives samples that have already returned a positive result during GMO screening. The GMO NRL then attempts to identify the GMO event contained using multiplex qPCR methods developed in-house. If successful, the identified GMO event is quantified using digital PCR, whereby the event-specific reference methods validated by the EURL are used. However, in heavily processed foods, such as popcorn, tofu, ketchup, corn starch, etc., the DNA is often severely degraded or only present in small traces, which makes molecular biological analysis difficult or even impossible.

Virus analytics procedure

For virus analytics, the enforcement laboratories often take samples in the event of a suspicion of a food-related outbreak of a disease. On the basis of the foodstuffs consumed and the symptoms of the people affected, suspicions regarding the causative virus can be raised before being confirmed through an analytical investigation of the food in the viruses NRL.

Development of measuring techniques for biological measurements

The main objective of both NRLs is to develop new measuring techniques for biological measurements, make measurements comparable and to be able to use measurement methods that have previously been primarily qualitative in a quantitative manner. Most recently, the viruses NRL has developed reference materials for detecting vibrios (bacteria found in seawater and seafood) and hopes to develop more soon.

Genome editing (CRISPR-Cas system) is increasingly being used in the research and development of GMO plants, whereby only the smallest sequence segments, or even just individual base pairs, are changed in the plant genome. Reliably verifying and quantifying these modifications using the established PCR technology is a big challenge. One of the GMO NRL objectives is to develop and validate new measuring techniques based on genome sequencing in order to prepare biological measuring procedures for future analytical challenges.

GMO approval

Genetically modified organisms (GMOs) in food can only be brought into circulation in Switzerland with authorisation from the Federal Food Safety and Veterinary Office (FSVO). Four genetically modified plant lines are approved: three maize lines and one soya line (Roundup Ready soya). A comprehensive labelling obligation is in place for food and additives that originate from these approved GMOs. There is a tolerance policy for 55 further GMO plant lines (maize, soya, cotton, rapeseed).

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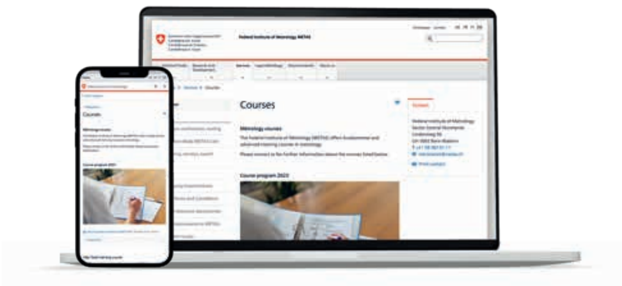

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