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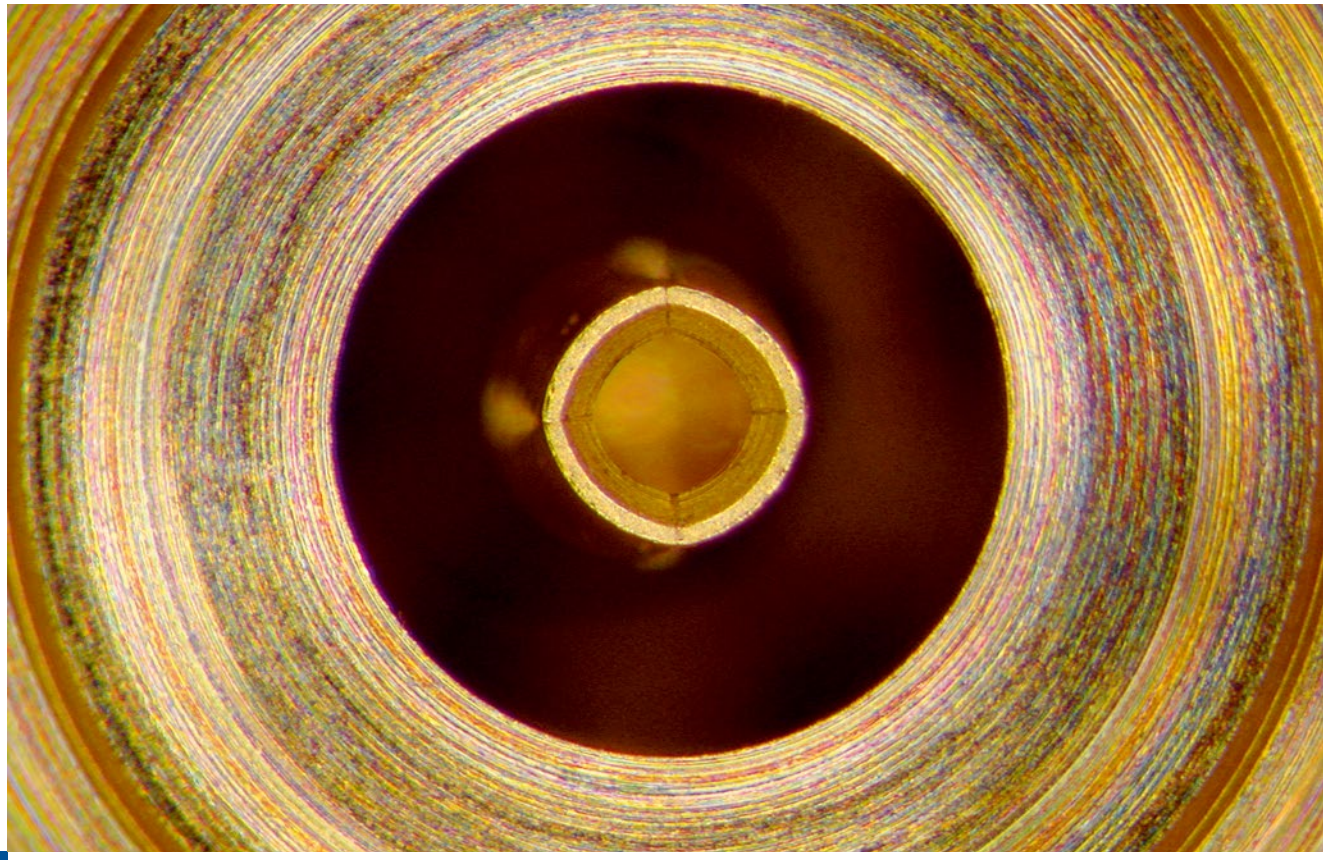
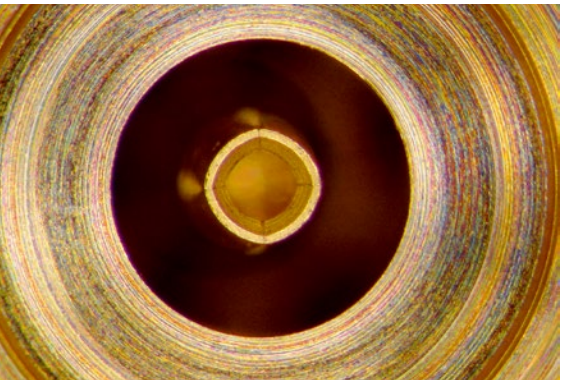
Federal Institute of Metrology METAS



METAS in 2018



Cover picture: A connector of highest precision as it is used in high-frequency metrology (see page 14).

Publisher's details

This report aims to provide an easily understandable overview of the activities of METAS in the reporting year. Further information can be gained from the Annual Report of METAS, the annual report on the implementation of the Metrology Act (both published on www.metas.ch), the Executive Pay Reporting (published on www.epa.admin.ch) and the short extracts of the Federal Council regarding the fulfilment of the strategic objectives of the independent units of the Confederation (published on www.efv.admin.ch).

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Change and constancy

There were a number of changes in the Institute Council over the past year. In February, Dr. Ursula Widmer joined the Council, providing welcome reinforcement with her expertise in the fields of informatics and law as well as information security. The previous President, Prof. Dr. Martina Hirayama, stepped down from the Institute Council at the end of the year following her appointment by the Federal Council as the new State Secretary for Education, Research and Innovation.

On 6 November 2018, the Federal Council elected me as President of the Institute Council for the remainder of the current term of office. I have been a member of the Institute Council since it was established. Now, in my new position, and together with my colleagues on the Institute Council and the Executive Board, I look forward to continuing to apply myself to the strategic orientation and entrepreneurial leadership of METAS.

As the first President of the METAS Institute Council, Ms. Hirayama was actively engaged in the preparations for the founding of the institute and the commencement of operations, and has made a lasting contribution to the strategic orientation and the research and development programme. I thank her wholeheartedly for her tremendous commitment to METAS.

The tasks of the Institute Council remain unchanged. They are first and foremost at the strategic level. Research and development are of central strategic importance for a national metrology institute. The Institute Council has accordingly deliberated on the orientation of the research and development undertaken at METAS. We took note of the successful results achieved with the initiation of activities approved in 2014 in three new areas in the fields of reference gas mixtures, dimensional measurement and optics. Moreover, we gave the go-ahead to a new development project, namely the laboratory medicine / nucleic acid metrology project.

Dr. Matthias Kaiserswerth
President of the Institute Council

> Research and development are of central strategic importance for a national metrology institute.

A milestone in the evolution of the International System of Units

Metrology is a long-term undertaking. This is demonstrated not least in the revision to the International System of Units adopted by the *26th Conférence générale des poids et mesures* (General Conference on Weights and Measures) in Versailles in November 2018 (see page 16).

The first experiments towards a redefinition of the kilogram based on physical natural constants in place of the prototype kilogram were conducted in the second half of the 1970s at the UK's National Metrology Institute. Max Planck had come up with the idea of using constants as, so to speak, natural measurement units as far back as 1900 when he was formulating his law on radiation. However, a change-over to a new definition of the kilogram would only become possible when the experiments to determine the Planck constant could provide traceable results with sufficient measurement uncertainty. Any transition from an existing to a revised system of units must be undertaken with appropriate care. A system of units must enable the comparability and stability of measurement results, because measurements should be comparable to one another over long periods of time.

Whereas the measurement principles are oriented towards the long term, technology continues to evolve. METAS renders services to the Swiss economy and makes its expertise available. Accordingly, like other national metrology institutes, METAS must diligently maintain the measurement principles and also remain at the forefront of technology.

Dr. Philippe Richard
Director

« Metrology is a long-term undertaking. »

Guiding METAS: the Institute Council and the Executive Board

At the head of METAS is the Institute Council. It is responsible for guiding the organisation. The operative management is the task of the Executive Board.

The regulatory requirements call for the Institute Council to be made up of five to seven expert members. In the reporting year, it comprised six members after the Federal Council had elected, on 12 February 2018, Dr. Ursula Widmer as a new member of the Institute Council for the current term of office until the end of 2019. The members of the Institute Council have extensive leadership experience, in both academic and entrepreneurial terms, and many years of diverse experience in research and development in both sciences and technology. The previous President of the Institute Council, Professor Dr. Martina Hirayama, stepped down from the Institute Council at the end of 2018 following her appointment by the Federal Council as the new State Secretary for Education, Research and Innovation (SERI). On 6 November 2018, the Federal Council elected Dr. Matthias Kaiserswerth as President of the METAS Institute Council for the remainder of the current term of office.

Defining the strategic orientation

The duties of the Institute Council are defined in the Institute Act. It applies to the Federal Council for the monies for services to be provided by the Federal Government and authorises the research and development programme. It exercises a supervisory role vis-à-vis the Executive Board and issues the personnel regulations.

Among the Institute Council's most important tasks is the definition of the strategic orientation of METAS, which it carries out in conjunction with the Executive Board. In so doing, it follows the Federal Council's guidelines set out in the strategic goals for METAS. The Federal Council expects METAS to provide industry, the scientific community and the public administration with an effective metrological infrastructure together with the necessary measurement principles and metrological services.

Executive Board

The Executive Board is responsible for the operative management of METAS. It represents METAS to the outside world and, in the reporting year, consisted of the Director, Dr. Philippe Richard, the Deputy Director, Dr. Gregor Dudle, and the Vice-Director, Dr. Bobjoseph Mathew.

The members of the Institute Council f.l.t.r.: Dr. Tony Kaiser, Member; Dr. Matthias Kaiserswerth, President; Dr. Ursula Widmer, Member; Prof. Dr. Thierry J.-L. Courvoisier, Member; Prof. Dr. Ulrich W. Suter, Vice President.

Dr. Matthias Kaiserswerth holds a doctorate in computer science. From 2006 to 2015, he served as Director of the IBM Research Laboratory in Zurich-Rüschlikon and Vice President of Global Systems Management and Compliance Area Strategy at IBM Research. Since 2015, he has been Managing Director of the Hasler Foundation. He was a member of the METAS Institute Council since it had been established in 2012, and took over the office of President of the Institute Council at the beginning of 2019.

Dr. Ursula Widmer is a lawyer. She specialises in informatics, Internet and telecommunications law and has founded a commercial law firm that practises in these areas. She is a lecturer in information security law at the Federal Institute of Technology in Zurich. She has served on a variety of expert commissions and think tanks and was president of ISSS and ITechlaw.

Measurement for industry and society: The role of METAS

Wabern, the place with the most accurate measurements in Switzerland. Here the Federal Institute of Metrology METAS is at home – the metrological reference centre of Switzerland.

METAS is the Swiss national metrology institute. It serves as the Federal centre of competence for all issues related to measurement and for measuring equipment and measuring procedures. Through its activities in research and development and its range of services, METAS is instrumental in ensuring that measurements can be performed in Switzerland at the level of accuracy demanded by industry, research, administration and society.

Authoritative reference standards

METAS realises the Swiss reference standards, ensures their international recognition and disseminates them with the requisite degree of accuracy in each case. In this way, it provides industry and society with a basic metrological infrastructure that is important wherever measurements are made.

METAS oversees the market launch process, use and control of measuring equipment in the retail trade, traffic, public safety, health and environmental protection. It makes sure that the measurements required for the protection of people and the environment can be carried out correctly and in the prescribed manner.

Metrology

Metrology is the science and technology of making measurements (from the Greek word *metron*, meaning "measure"). *Metrology* is frequently confused with *meteorology*. However, these two fields are clearly distinct. *Meteorology* is the study of weather phenomena (from the Greek word *meteoros*, meaning "raised from the ground").

Progress demands precision

Reliable manufacture and monitoring is only possible with the aid of accurate measuring systems. New scientific and technological developments are therefore dependent on constantly evolving metrological principles and processes. Important branches of the Swiss economy such as micro and medical technology or applications such as measuring and control procedures call for measuring methods with an accuracy that may lie in the order of millionths of a millimetre.

METAS keeps up with scientific and technological developments in order to maintain its place at the cutting edge. It is engaged in research and development with a view to improving measuring stations and metrological services. It regularly reviews its range of services and adapts it to market needs.

The place with the most accurate measurements in Switzerland: at METAS in Wabern.

Measurement projects: METAS research and development

METAS mainly conducts its research and development activities as part of the European metrology research and development programme EMPIR.

In the reporting year, METAS participated in 24 EMPIR projects. In parallel, 2018 saw the fifth project tender for the EMPIR programme. METAS submitted project proposals relating to the key topics "Health", "SI Broader Scope", "Pre-normative" and "Networks", and achieved an above-average success rate.

Measurement principles for improving air quality

After carbon dioxide, so-called black carbon is one of the most important influencing factors in climate change. "Black carbon" refers to aerosol particles consisting of pure carbon that are formed by incomplete combustion of fossil fuels or biofuels and released in soot. Aerosols not only affect the climate but also have a severe impact on human health. In 2011, around 430,000 premature deaths in the EU were attributed to fine particulates.

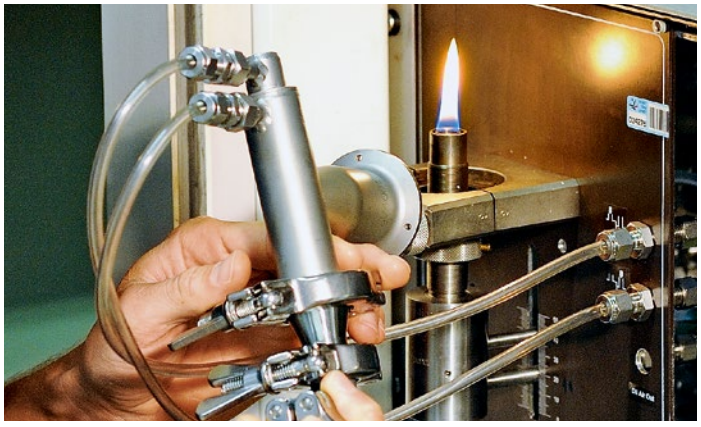
The measurement of black carbon particles in the air is important both for understanding their role in climate change and for determining the health implications of combustion products. Today, numerous measurements of this kind are being made, and compact, accurate and relatively inexpensive real-time instruments are available. The metric used is based on the light absorption properties of the airborne particles. While this is conceptually simple, full traceability to the SI is not yet assured, which has a negative effect on the comparability and interpretation of the data. A European research project in which METAS participates aims at finding a workable solution to this problem.

Reference particles

METAS's contribution concerns the production of reference particles that come as close as possible to the black carbon particles found in the atmosphere with regard to their chemical form, size distribution and optical properties. This permits the calibration of the measuring equipment used in the field. A machine to generate black carbon with the required characteristics has been developed and characterised in collaboration with the company Jing SA. It enables the prior enrichment of the combustion gas with air, which results in the production of particles with a higher proportion of elemental carbon. The chemical and optical properties of the particles can be adjusted independently of their size. Moreover, a method for mixing the soot particles produced with organic material and artificially ageing them using ultraviolet light (coating) was further developed in collaboration with the Univer-

sity of Applied Sciences and Arts Northwestern Switzerland. This accelerated ageing process assists in the emulation of naturally aged particles in the atmosphere.

The measurement methodology developed in the course of the project contributes to the uniform and reliable determination of airborne pollutants. The improved data situation makes it possible to improve climate models and support regulation in the field of air pollution control.



Production of reference particles.

Measurement in the service of product development: cooperation projects with industry

METAS is recognized as research partner by Innosuisse (former: Commission for Technology and Innovation CTI). Companies can thus make use of METAS's research and development expertise for their own innovations and developments and carry out projects in application-oriented research and development in conjunction with METAS.

The scientific and technical know-how accumulated by METAS may be used by industry not only in the form of calibration and measurement services but also directly for product and process development. This makes METAS an attractive potential collaboration partner in the most diverse areas. The collaboration with industry in the form of innovation projects continues to be expanded. Since 2013, twelve projects have been approved by Innosuisse (CTI).

New fields in impedance measurement

Alternating current resistance, also known as impedance, is one of the most important electrical parameters. Determining the impedance at multiple frequencies over a defined frequency range is referred to as impedance spectroscopy. It has a broad spectrum of applications, from the study of materials to the characterisation of batteries, fuel cells and corrosion processes, the characterisation of electrical and electronic components, all the way to the analysis of tissues and cell suspensions in medical applications. New developments have necessitated the expansion of the frequency range into the upper megahertz range.

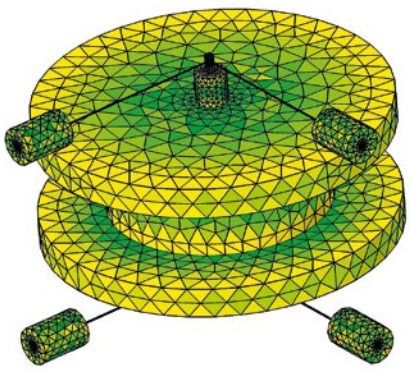
Resistance and capacitance standards

The Swiss company Zurich Instruments AG is one of the leading manufacturers of lock-in amplifiers for use in science and high-tech applications. On the basis of this core competency, the company develops impedance measuring instruments that operate with unmatched accuracy at frequencies of up to several hundred megahertz. In a collaboration project supported by Innosuisse, METAS is developing resistance and capacitance standards that are required to calibrate the new measuring instruments.

The particular challenge in this case is to cover the range from approx. 30 kHz to several hundred MHz. Here, the wave properties of the electrical signal can no longer be neglected; the wavelength, however, is still large compared to the dimensions of the electrical components. Accordingly, this is where the transition between two fundamentally different approaches in metrology takes place, which also manifests itself in a deterioration of the measurement uncertainties. The problem – also referred to as the "frequency gap" – has been overcome thanks to the development of standards that can be dependably employed over the entire fre-

quency range, by means of highly accurate measurements in the ranges below 30 kHz and above 100 MHz, as well as by modelling over the entire frequency range using modern software tools.

The project assists the industrial partner in the development of a new and innovative product and its introduction in a competitive market. At the same time, it enables METAS to significantly expand and improve its measuring capabilities in a previously only moderately covered area, and thus to define a new state of the art.



Development of resistance and capacitance standard.

Metrology for industry: measurement uncertainty at the push of a button

With its services, METAS helps numerous companies in various economic sectors in Switzerland to perform correct measurements. Thereby ensuring that they can satisfy the quality requirements that are imposed on their products.

METAS provides numerous calibration, measurement and test services for industry. In 2018, almost 5000 certificates and reports were produced. The most important customer segments are the engineering, electrical, metalworking and watchmaking industries, as well as medical and communications technologies.

High-frequency metrology

Vector network analysers (VNA) are used to measure the reflection and transmission behaviour of electrical components with respect to high-frequency signals. These are basic measurands in high-frequency metrology. In communication technology, for example, the quality of signal transmission is determined by means of VNA measurements.

A correct evaluation of measurement uncertainty is paramount for the dependability of the results. In the case of VNA measurements, however, this evaluation is difficult for several reasons: The measurand is complex (amplitude and phase are measured simultaneously), the measuring process involves a number of stages, and large quantities of measurement data are generated. This results in a computational burden that cannot be handled manually or using a spreadsheet program.

Efficient tools for determining measurement uncertainty

Against this background, the *RF & Microwave* laboratory has developed the *VNA Tools* metrology software. It runs on a PC and externally processes the raw measured values from the VNA. VNA Tools is under constant development and its capabilities now exceed those of many types of commercial VNA firmware. The software particularly stands out, though, for correctly determining the measurement uncertainties according to international guidelines. To this end, *VNA Tools* utilises *UncLib*, a software library for measurement uncertainty propagation that was also developed by the lab. *UncLib* is a stand-alone software package and can be used in other areas as well.

VNA Tools was originally developed for users at the level of national metrology institutes. Today, the almost 800 licensees also include universities as well as calibration and industrial laboratories. In order to fully exploit the potential of the software, it is advisable to attend a three-day course offered by the *RF & Microwave* laboratory. Nearly 200 users have benefited from this offer by now.

VNA Tools metrology software

The *VNA Tools* metrology software can be downloaded at *www.metas.ch/vnatools*. The *UncLib* software package, a software library for measurement uncertainty propagation, is available at *www.metas.ch/unclib*.

For industrial users, the Real Time Interface (RTI) – a defined interface for straightforward access to the functions of VNA Tools – is also of interest. Using the RTI, which must be licensed separately, it is possible to integrate *VNA Tools* into other systems. METAS provides *VNA Tools* and *UncLib* free of charge, thereby making an important contribution to the reliable evaluation of measurements.

Determining measurands in high-frequency metrology.

Natural constants instead of the prototype kilogram: new definitions for our measurement units

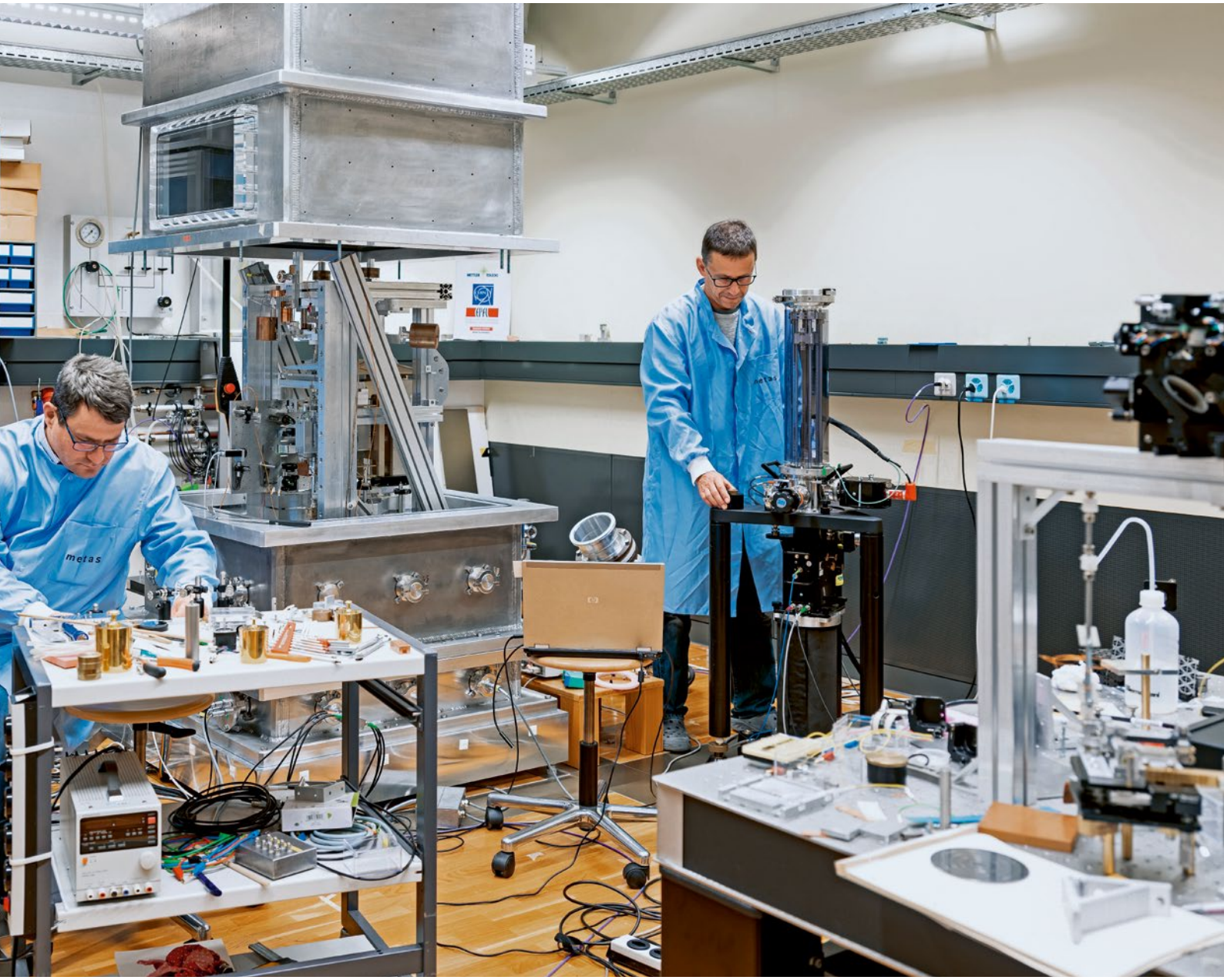
The units that we use in our measurements, such as kilogram or ampere, have been given new definitions. In the future, they will all be defined on the basis of natural constants – even the kilogram, which used to be defined by a material reference standard, the prototype kilogram in Paris. Not least, this change opens prospects for new technical applications.

One kilogram is one kilogram wherever you are – this is a matter of course today. But it was not always so straightforward. For thousands of years, countless measurement units and systems of units were used concurrently. For example, the unit 'foot' was common in many places but was far from denoting the same length everywhere. As a result, measurements were often made using different units of length and weight, which gave rise to problems for trade and later for the emerging industrial production as well.

An important step in overcoming the myriad of measurement units in use was the introduction of the metric system in France towards the end of the 18th century. The decisive step was the introduction of internationally recognised measurement units with the International Metre Convention of 1875. It forms the basis for the International System of Units (*Système international d'unités,* SI), which was introduced in 1960. The International System of Units (SI), with units such as kilogram, metre, second, ampere, kelvin, mole and candela, is the globally binding basis for measurement today.

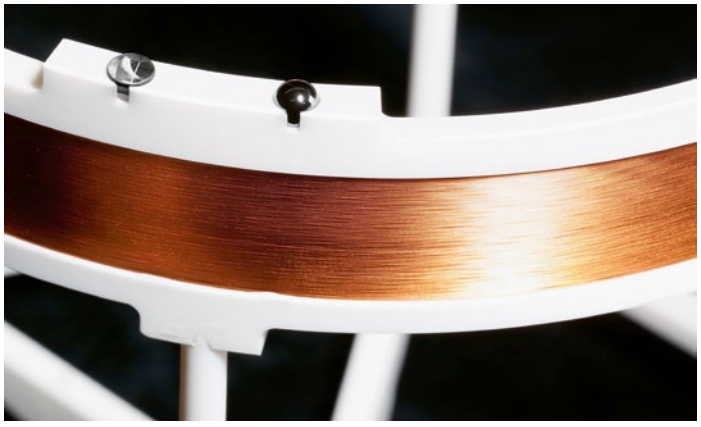
Internationally harmonised metrological infrastructure

The Metre Convention laid the foundations not only for the International System of Units (SI) but also for an internationally coordinated metrological infrastructure. The Metre Convention includes, among others, the *Conférence générale des poids et mesures* and the *Bureau International des poids et mesures* in Paris, the central office and research institution of the Metre Convention. In the individual countries, the national metrology institutes – METAS in the case of Switzerland – are at the cutting edge of measuring accuracy. The cooperation between METAS, other national metrology institutes and the bodies of the International Metre Convention ensures that the reference standards in Switzerland are internationally recognised and available with the requisite accuracy.



Natural constants as the measure of all things

Over time, scientific and technical developments may entail new requirements to which a system of units must be adapted. This applies both to the definition of the individual units and to the overall system of units. For example, the original 1889 definition of the metre was replaced in 1960 by a definition based on a wavelength, that is to say a physical phenomenon. This enabled the unit 'metre' to be realised with greater accuracy. The definition of the metre with reference to a natural constant, namely the speed of light, which came into effect in 1983, heralded an even higher level of accuracy.



Experiments for the realisation of measurement units.

In November 2018, the *26th Conférence générale des poids et mesures* in Versailles adopted a revision of the International System of Units (SI) that ushered in new definitions for various measurement units. In the future, all our measurement units will be based on physical natural constants. This also applies to the kilogram, which is no longer defined by the International Prototype Kilogram in Paris but by fundamental physical natural constants. The kilogram, as it is the case with other units, is thus no longer dependent on a local reference standard but is universally defined.

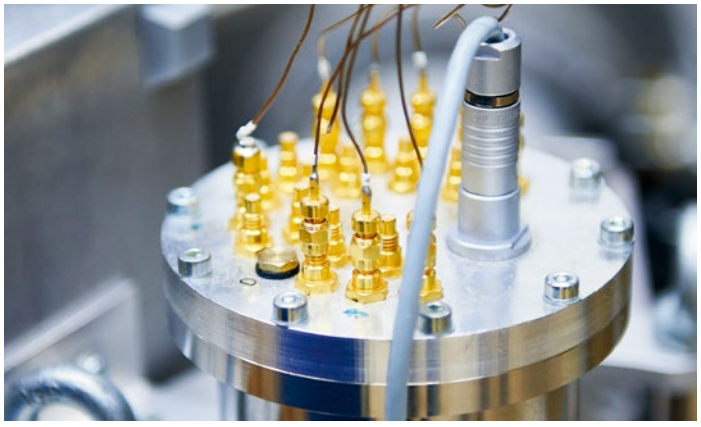
Using natural constants as a basis renders the units independent of material reference standards and precisely mandated instructions for realisation. In the future, new insights in the field of physics or new technologies will enable an even more accurate realisation of units without necessitating a change to the definitions. Better units allow for more accurate measurements and are thus a prerequisite for scientific and technological progress in a wide variety of areas. In this light, the revision that has now been adopted constitutes a fundamental change to the system of units. Of course, care was taken to ensure that the transition from the old system to the revised one would not have any impacts on everyday life – a kilogram remains a kilogram. The new definition of the kilogram will, however, shift the boundaries of what can be achieved because the unit will be significantly more stable and, in parallel with technical progress, the accuracy of mass determination will increase.

Strong impacts of advances in metrology

Conversely, too, technological advances call for even more accurate and dependable measurements. What we are unable to measure, we are unable to understand correctly. For this reason, advances in metrology have a strong impact on our capacity to understand and shape the world around us, helping us to meet current and future societal challenges and to fulfil the requirements of industry.

In the health sector, metrology can contribute to improving the quality and comparability of diagnostic results and therapeutic outcomes by providing recognised reference materials and new measurement methods. Checking the quality of foodstuffs and drinking water is dependent on traceable measurements. With regard to climate policy, it is vital that political measures aimed at reducing anthropogenic effects on the climate are based on sound science and reliable climate models. This makes it essential to pursue a holistic approach based on comparable data. Metrology also has important contributions to make in the storage and transportation of energy, for example: The decentralised and temporally fluctuating energy feed-in that results from using solar plants and wind turbines requires improved monitoring of electrical networks. Metrology is indispensable for the management and allocation of energy flows. The quality of fuels must be checked to ensure consumer protection.

It remains the responsibility of METAS and all other national metrology institutes to establish the foundations for the correct definition of measurands and reference values in areas as diverse as basic physical research and food safety, so that measurements can be undertaken with the requisite degree of accuracy.



Experiments for the realisation of measurement units.

Measurement across borders: international metrology organisations

METAS – and thus Switzerland – has a disproportionately high presence in international metrology organisations. METAS personnel are currently playing an active and formative role in a number of these organisations.

International collaboration is indispensable in the field of metrology. It has been vital in replacing the multitude of co-existing measurement units and regionally applicable systems of units with the globally applicable International System of Units (SI). The basis of the SI is the Metre Convention, an international treaty dating from 1875. In 2018, the high point of international cooperation in metrology was the *26th Conférence générale des poids et mesures,* at which the historic revision of the SI was adopted (see page 16). The conference took place from 13 to 16 November in Versailles; the Swiss delegation was headed by the director of METAS.

Great commitment at the international level

The commitment of METAS staff at the international level is considerable. METAS plays an active and formative role in EURAMET, the European Association of National Metrology Institutes. From June 2015 to June 2018, the Chief Science Officer of METAS chaired EURAMET. METAS also provides the chair of the *Metrology in Chemistry* Technical Committee. The head of the Optics laboratory has been elected President of the *Commission Internationale de l'Éclairage* (CIE), the international body for standards in the field of lighting technology and illumination. He will commence work in this position in June 2019. The Deputy Director of METAS has served as the chair of WELMEC, the European Cooperation in Legal Metrology, since 2017. The Director of METAS is a member of the *Comité international des poids et mesures* (CIPM).

Not least, these positions and other forms of involvement in international expert organisations demonstrate the high international regard for METAS and its personnel as competent and dependable partners.

26th Conférence générale des poids et mesures.
Versailles, 16 November 2018.

Regulating measurement: legislation concerning metrology

Participating in the preparation of enactments in the field of metrology is one of METAS's statutory duties. In 2018, it prepared a number of amendments to ordinances, some of which entered into force in that year. To ensure the uniform application of provisions, METAS also issued instructions to the enforcement bodies of the Metrology Act.

The following amendments to ordinances in the field of metrology entered into force in 2018:

- On 1 October: amendments to the ordinance on verification fees. In particular, the fees for measuring equipment for electrical energy and power have been revised to account for the increasing use of smart meters.
- On 1 December: amendments to the FDJP ordinance on exhaust gas measuring equipment for internal combustion engines. The requirements for such measuring equipment have been adapted in a number of respects.

In addition, further amendments to ordinances were prepared. For example, interested parties were consulted on amendments to the ordinance on indications of quantity for goods sold loose and in prepacks.

Measurement of fine particle emissions from construction machinery.

Instructions as an instrument of supervision

It is not always clear from laws and ordinances which rules apply. In such cases, instructions from the competent authority can help to ensure uniform application of the provisions. METAS supervises the implementation of metrological provisions and, in this function, can issue instructions to enforcement bodies of the Metrology Act.

New instructions from METAS regarding the FDJP ordinance on measuring equipment for electrical energy and power entered into force on 1 January 2018. They include improvements regarding technical details of the procedures for maintaining measurement stability.

Compliant market launch of measuring equipment: METAS-Cert

METAS-Cert is the recognised conformity assessment body for measuring equipment operated by METAS. METAS-Cert serves customers on several continents.

Anyone who wants to launch measuring equipment on the market must show that it fulfils the legally prescribed requirements. To this end, manufacturers require the services of an independent conformity assessment body that is specialised in metrology, such as METAS-Cert.

The conformity assessment body METAS-Cert, which was created in 2006, is the body designated by Switzerland and recognised by the EU for the conformity assessment of measuring equipment according to EU directives. METAS-Cert assists manufacturers in the conformity assessment procedure for launching their measuring equipment on the market, offering them all of the required testing facilities. METAS-Cert is listed on the NANDO database for EU conformity assessment bodies and is thus permitted to offer its services throughout the EU. Thanks to this recognition, a Swiss manufacturer can market its products directly in all EU countries if have been certified by METAS-Cert. This means reduced costs as well as time savings for Swiss companies.

There are different procedures for legally regulated measuring equipment. METAS-Cert offers both Swiss and EU conformity assessments and is a so-called VCAP auditor for the US market.

The international organisation in charge of legal metrology, the *Organisation Internationale de la Métrologie Légale* (OIML), runs the OIML-CS certification system, to which METAS-Cert also belongs in several measuring equipment categories.

Upon successful completion of a conformity assessment, an electronic certificate is issued for the type, equipment or organisation.

The challenge posed by smart meters

METAS-Cert is continually addressing new technical developments and their effects. In contrast to conventional meters, it is currently necessary to ensure that smart meters fulfil the data security requirements. There is a risk that the data on the user's power consumption that is recorded and transmitted by the smart meter is misused. METAS-Cert is now establishing a procedure to check whether the elements of smart meters meet the data security requirements.

Certification also for time and weather

Since 2013, METAS-Cert has also been inspecting automatic weather stations operated by MeteoSwiss and their data suppliers. This encompasses an assessment of environmental factors influencing the weather stations. Using this data, Meteo-

Swiss is able to determine the measurement uncertainty of each station and, if necessary, make on-site corrections at the place of measurement.

Since 2015, METAS-Cert has also certified mechanical watches. The watches are exposed to strong magnetic fields and must also show the precise time in different temperatures, positions and power reserves; besides, they must be waterproof to the specified depth. Watches that have passed the test are permitted to bear the designation “Master Chronometer” and receive a corresponding certificate.

Weather station checked by METAS-Cert.

Measurement as a career: METAS as a place of work

METAS is the metrological interface of science, industry and society. The work that it undertakes requires highly qualified personnel from a broad spectrum of scientific disciplines. As an employer, the ability to consider individual needs is what sets METAS apart.

On 1 January 2013, the former Federal Office of Metrology became the Federal Institute of Metrology (METAS) with its own budget and constituting a separate legal entity. METAS is an independent employer under the Federal Personnel Act. It is currently structured into three departments: The employees in the *Physics and Chemistry* department, the largest in terms of staff numbers, focus on the technical realisation of the units and conduct research and development. Those in the *Legal Metrology* department are responsible for enforcing legislation concerning measuring equipment. The *Resources* department combines internal services such as finances, IT and technology.

Working in the place with the most accurate measurements in Switzerland

As a place of work, METAS is characterised by a highly technical environment and a sophisticated laboratory infrastructure. This follows from METAS's mandate as the national metrology institute of Switzerland and the duties this entails. METAS unites professionals from all manner of technical backgrounds, often working in highly specialised fields, under one roof. The diversity of the scientific and technical disciplines found at METAS creates a stimulating and challenging work environment. As a place of work, METAS also stands out for providing opportunities to engage in research and development aimed at building up new measurement capabilities, or to work with partners at both national and international levels. Also worth mentioning are the close relationships with industry and the cooperation with other authorities. In addition, METAS participates in a number of exchange programmes. In the reporting year, for example, a female scientist from China temporarily worked at the *Mass, Force and Pressure* laboratory.

Flexible working hours models

It is important to METAS that it can accommodate the different needs of its personnel. To this end, it offers various working hours models with a view to ensuring that work is compatible with family life, and that personal interests may be pursued as well. Apart from the options of working at home and part-time, a portion of the salary can be drawn in the form of holiday time.

METAS as a place of work is characterised by a highly technical environment.

Taking individual needs into account as far as operationally possible, the outstanding working atmosphere, the low workforce fluctuation and the excellent reputation are some of the values that distinguish METAS as a place of work and employment, demonstrating that the guiding principle in the culture of METAS – "We are METAS" – is indeed put into practice.

METAS as a training centre

METAS is also committed to providing good vocational training for future professionals. It offers various apprenticeships in technical and scientific areas (physics laboratory technician, chemical laboratory technician, polymechanic, electronics technician, computer scientist), a commercial BMS internship as well as a range of university internships.

Finances

METAS ended the 2018 financial year with a profit of 4.3 million Swiss francs. Expenditures amounted to 46.1 million Swiss francs and revenues (including payments received) to 51.4 million Swiss francs.

METAS prepares its accounts in accordance with the principles of the International Public Sector Accounting Standards (IPSAS).

Balance sheet

(in thousand CHF)	31.12.2018	31.12.2017
Assets		
Cash	20202	19976
Trade receivables	3000	3007
Receivables for research projects	2778	3599
Other receivables	110	52
Prepaid expenses and accrued income	811	731
Working capital	**26901**	**27366**
Tangible fixed assets	20923	20446
Intangible fixed assets	2336	1931
Fixed assets	**23259**	**22377**
Total assets	**50160**	**49743**
Liabilities and equity		
Current liabilities on trade accounts payable	1322	1280
Liabilities in respect of research projects	3930	4387
Other liabilities	1466	1051
Accrued expenses and deferred income	155	244
Short-term provisions	1098	878
Short-term borrowed capital	**7971**	**7840**
Provisions for pension fund liabilities	49580	44032
Provisions for service awards	1467	1466
Long-term borrowed capital	**51047**	**45498**
Net loss	–17235	–19152
Cumulative actuarial profits/losses	663	10227
Reserves for fixed assets	3413	3413
Profit	4301	1917
Equity capital	**–8858**	**–3595**
Total liabilities and equity	**50160**	**49743**

Profit and loss account

(in thousand CHF)	2018 1.1.2018–31.12.2018	2017 1.1.2017–31.12.2017
Net revenue	**51 295**	**48 048**
Profit from sale of fixed assets	**13**	**6**
Expenditure on materials and third-party services	**–685**	**–805**
Personnel expenses	–31 699	–30 684
Other operating expenses	–10 993	–11 298
Depreciation	–3 575	–3 357
Operating expenses	**–46 267**	**–45 339**
Financial revenue	61	107
Financial expenses	–106	–70
Financial result	**–45**	**37**
Tax expenses	–10	–30
Profit	**4 301**	**1 917**

In the reporting year, METAS was able to finance 58.0 percent of its activities (preceding year: 50.9 percent) out of its own resources. The following means contributed to this self-financing level: fees, payments for taking over additional tasks and external funds.

The auditors have confirmed without reservation that the accounts were properly prepared.

The detailed, IPSAS-compliant annual accounts can be downloaded on the Internet at www.metas.ch or requested from METAS.

Telling the measurement story: METAS publications and papers

The research and development work is also reflected in publications and papers authored or presented to a live audience by METAS researchers.

In 2018, METAS personnel again presented the results of their research and development work at symposiums, conferences and in scientific publications. They collaborated in specialist organisations and committees at national and international levels, contributing their know-how and experience. They made metrology accessible to a wide audience, beyond the immediate specialist circles, and were actively involved in courses for students at universities.

Measurement as a topic

A summary of the publications released and papers presented by METAS personnel can be found at the end of this section. A series of lectures were also given in the course of events at METAS itself.

Six specialised conferences were held at METAS, and verification officer training modules were offered.

In 2018, METAS published two issues of "METinfo", the technical journal for metrology. The articles are, as a general rule, written by METAS personnel. Several "METinfo" articles were taken up by trade journals from different areas.

A taste of the laboratories

As in previous years, METAS took part in the "Mädchen – Technik – Los!" programme during National Future Day on 8 November 2018. It offered a group of girls a taste of the work and activities carried out in its laboratories.

Guided tours for groups of interested persons were again conducted in the reporting year. Around 30 groups totalling over 700 participants took the opportunity to glean a direct insight into the laboratories and the development of measuring equipment. Guided tours enable METAS to show visitors its tasks and activities and give them a better understanding.

Publications and papers

The list below provides an overview of the most important publications authored by METAS personnel and the papers presented by them. When giving the authors' names, those of the METAS employees are shown in bold.

Publications

B. Bircher, F. Meli, A. Küng, R. Thalmann: *Characterising the Positioning System of a Dimensional Computed Tomograph (CT).* PTB open access repository (2018) (8 pp.).

H. Bissig, M. Tschannen, M. de Huu: *Improving Process Quality by Means of Accurate and Traceable Calibration of Flow Devices with Process-oriented Liquids.* Chimia, 72 (2018), pp. 124-129.

A. Buchter, J. Hoffmann, A. Delvallée, E. Hapiuk, C. Licitra, K. Louarn, A. Arnoult, G. Almuneau, F. Piquemal, **M. Zeier,** F. Kienberger: *Scanning microwave microscopy applied to semiconducting GaAs structures.* Review of Scientific Instruments, 89, 023704 (2018), pp. 1-6.

N. Castagna, J. Morel et al.: *Traceable instruments for Encircled Angular Flux measurements.* Proc. SPIE, 10683 (2018) (6 pp.).

N. Castagna, J. Morel et al.: *Modelling of standard and specialty fibre-based systems using finite element methods.* Proc. SPIE, 10683 (2018) (6 pp.).

S. Dash, F. Pythoud et al.: *Method for traceable measurement of LTE signals.* Metrologia, 55 (2) (2018), pp. 284-293.

M. Ess, K. Vasilatou: *Characterization of a new miniCAST with diffusion flame and premixed flame options: Generation of particles with high EC content in the size range 30 nm to 200 nm.* Aerosol Science and Technology (2018), pp. 1-16.

M. Guillevic, M.K. Vollmer, S.A. Wyss, **D. Leuenberger,** A. Ackermann, **C. Pascale, B. Niederhauser** et al.: *Dynamic-gravimetric preparation of metrologically traceable primary calibration standards for halogenated greenhouse gases.* Atmos. Meas. Tech., 11 (2018), pp. 3351-3372.

M. K. Vollmer, D. Young, C. M. Trudinger, J. Mühle, S. Henne, M. Rigby, S. Park, S. Li, **M. Guillevic** et al.: *Atmospheric histories and emissions of chlorofluorocarbons CFC-13 ($CClF_3$), ΣCFC-114 ($C_2Cl_2F_4$), and CFC-115 (C_2ClF_5).* ACP Atmospheric Chemistry and Physics, 18 (2018), pp. 979-1002.

A. Jallageas, L. Devenoges, M. Petersen, **J. Morel, L. G. Bernier** et al.: *First uncertainty evaluation of the FoCS-2 primary frequency standard.* Metrologia, 55 (2018), pp. 366-385.

B. Jeckelmann: *A milestone in the further development of the International System of Units.* Swiss physical society SPS, 56 (2018), pp. 26-29.

T. S. Carzaniga, N. P. van der Meulen, R. Hasler, **C. Kottler, P. Peier** et al.: *Measurement of the ^{43}Sc production cross-section with a deuteron beam.* Elsevier (2018), pp. 205-208.

O. Vaittinen, M. Metsälä, L. Halonen, S. Persijn, **D. Leuenberger, B. Niederhauser:** *Effect of moisture on the adsorption of ammonia.* Springer-Verlag GmbH Germany, part of Springer Nature (2018), pp. 1-8.

C. Mester, J.-P. Braun, C. Ané: *Einführung in die rückführbare Messung von Power Quality.* Technisches Messen, Volume 85 (12) (2018), pp. 738-745.

A. Nicolet, F. Meli: *Traceable measurements of rounded cutting tool edges.* PTB open access repository (2018) (8 pp.).

P. J. Brewer, B. Gieseking, V. F. Ferracci, M. Ward, J. van Wijk, A. M. H. van der Veen, A. A. Lima, C. R. Augusto, S. H. Oh, B. M. Kim, S. Lee, L. A. Konopelko, Y. Kustikov, T. Shimosaka, **B. Niederhauser, M. Guillevic** et al.: *International Comparison CCQM-K116.* IOPscience Metrologia, 55 (2018), pp. 1-47.

A. Demichelis, **C. Pascale,** M. Lecuna, **B. Niederhauser** et al.: *Compact devices for generation of reference trace VOC mixtures: a new concept in assuring quality at chemical and biochemical laboratories.* PubMed (2018), pp. 2619-2628.

N. D. C. Allen, D. R. Worton, P. J. Brewer, **C. Pascale, B. Niederhauser:** *The importance of cylinder passivation for preparation and long-term stability of multi-component monoterpene primary reference materials.* Atmos. Meas. Tech., 11 (2018), pp. 6429-6438.

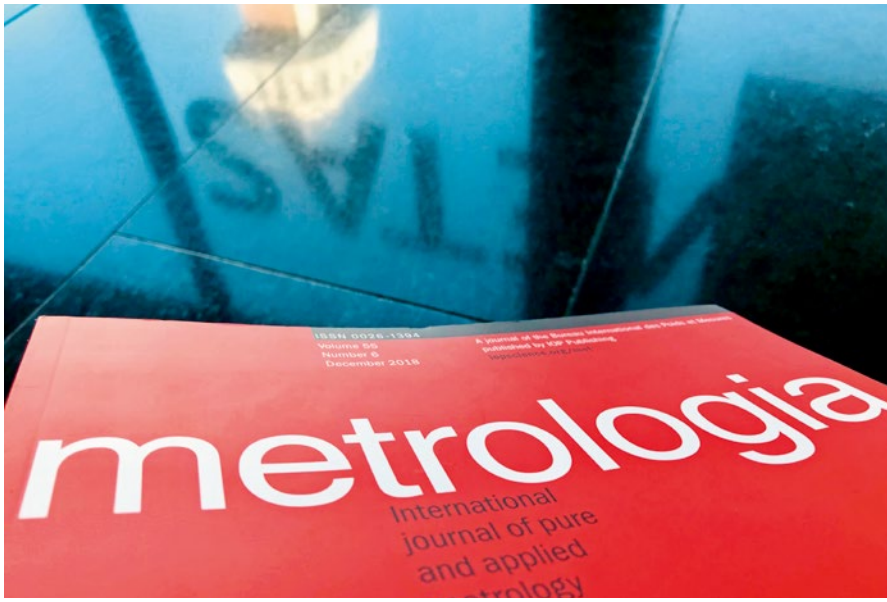
F. Pythoud: *Proficiency Testing in EMC Radiated Immunity.* IEEE Transactions on Electromagnetic compatibility, Volume PP/Issue 99 (2018), pp. 1-5.

M. J. van Camp, **P. Richard,** O. de Viron: Universal units reflect their earthly origins. EOS Earth & Space Science News, 99 (2018) (9 pp.).

Z. Jiang, V. Zhang, Y.-J. Huang, J. Achkar, D. Piester, S.-Y Lin, W. Wu, A. Naumov, S.-h. Yang, J. Nawrocki, I. Sesia, **C. Schlunegger** et al.: *Use of software-defined radio receivers in two-way satellite time and frequency transfers for UTC computation.* Metrologia, 55 (2018), pp. 685-698.

R. Thalmann et al.: *Angle comparison using an autocollimator – bilateral follow-up.* Metrologia, 55 (2018), pp. 1-11.

R. Geckeler, A. Just, V. Vasilev, E. Prieto, F. Dvoracek, S. Zelenika, J. Przybylska, A. Duta, I. Victorov, M. Pisani, F. Saraiva, J.-A. Salgado, S. Gao, T. Anusorn, S. L. Tan, P. Cox, T. Watanabe, A. Lewis, K P Chaudhary, **R. Thalmann** et al.: *Angle comparison using an autocollimator.* Metrologia, 55 (2018), pp. 1-57.



R. Thalmann, A. Küng, A. Nicolet, F. Meli et al.: *Versatile calibration artefact for optical micro-CMMs based on micro-spheres with engineered surface texture.* PTB open access repository (2018), pp. 1-6.
M. Zeier et al.: *Establishing traceability for the measurement of scattering parameters in coaxial line systems.* Metrologia, 55 (2018), pp. 23-36.

Conference contributions and papers

M.-O. André: *Challenges in metrology – From standard metre to immaterial references.* Digital Trust Conference / PriceWaterhouseCooper, Genève, 20.3.2018.
H. Andres: *Messunsicherheit & Konformitätsbewertung Atemalkoholmessmittel.* ZHAW Wädenswil, 4.12.2018.
C. Ané, J.-P. Braun, C. Mester: *Establishing traceability for Flickermeters.* First International Colloquium on Smart Grid Metrology (SmaGriMet), 2018, Split, 27.4.2018.
K. Auderset: *Calibration of optical particle counters.* Clean Zone Frankfurt, 23.10.2018.
K. Auderset, D. Schwaller: *Staubtrockene Fakten.* SVG-Tagung, 30.10.2018.
F. Assi: *Verifications and Simulation for Speed enforcement devices.* Chinese Institutes and Supplier Seminar of speed enforcement devices – NIM China, 13.12.2018.
L.-G. Bernier: *Operation of a time laboratory.* BIPM Capacity Building & Knowledge Transfer, 12–15.2.2018.
L.-G. Bernier: *Action to improve laboratory uncertainty.* BIPM Capacity Building & Knowledge Transfer, 12–15.2.2018.
L.-G. Bernier: *GNNS Time Transfer.* BIPM Capacity Building & Knowledge Transfer, 13–18.5.2018.
H. Bissig, M. Tschannen, M. de Huu: *Traceable response time characterization in fast changing flow rates.* 10th ISSFM, 21–23.3.2018, Queretaro, Mexico.
H. Bissig, M. Tschannen, M. de Huu: *High accuracy testing of drug delivery devices.* Workshop on Nano-Bio Surfaces and Interfaces, 8–9.5.2018, Lausanne.
H. Bissig: *Lowest traceable flow rates in micro fluidics and new measurement possibilities.* PTB Seminar: Metrology in Fluss, 8–9.11.2018, Brauschweig.
P. Blattner: *New CIE Color Fidelity Index.* International Scientific and Technical Conference "Light in Museum", 18.–20.4.2018, St. Petersburg.
P. Blattner: *Quantifying non-visual effects of lighting.* Integrative Lighting: SSLNet Conference 2018, Toronto, 2.6.2018.
P. Blattner: *CIE Research Strategy (in solid-state lighting).* NSVV national conference on LED solid-state lighting, Eindhoven, 12.6.2018.
P. Blattner: *Quantifying Light and Optical Radiation.* Joint CIE – IAU Discussion and Workshop on Light pollution, Wien, 24.8.2018.
P. Blattner: *On the revision of the SI- and its impact in photometry and radiometry.* Coomet-Workshop, Varadero, 4.9.2018.
P. Blattner: *International Standardization of Light and Lighting.* CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing, Moscow, 5.11.2018.
P. Blattner: *Practical Example of Measurement Uncertainty Analysis.* CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing, Moscow, 6.11.2018.
P. Blattner: *European regulations and standardization work in the field of light and lighting.* LED Forum, Moskau, 7.11.2018.
C. Blaser: *Kalibrierung von Strahlenschutzmessgeräten – Eine Zusammenarbeit mit dem Kernkraftwerk Mühleberg.* METAS Seminar, 23.5.2018.
J.-P. Braun: *Measure of the absolute phase angle of a power frequency sinewave with respect to UTC.* Conference on Precision Electromagnetic Measurements CPEM 2018, 8.–13.7.2018, Paris, 8.7.2018.
J.-P. Braun, C. Mester: *Metrology for Smart Grids.* First International Colloquium on Smart Grid Metrology SmaGriMet, 2018, Split, 27.4.2018.
A. Buchter: *Electrical Nanometrology at High Frequencies.* METAS Seminar, 17.10.2018.
N. Castagna, J. Morel et al.: *Modelling of standard ans specialty fibre-based systems using finite element methods.* SPIE Photonics Europe, 23.4.2018.
N. Castagna, J. Morel et al.: *Traceable instruments for encircled angular flux measurements.* SPIE Photonics Europe, 24.4.2018.
D. Corminboeuf: *Calibration of the absolute linearity of lock-in amplifiers.* Conference on Precision electromagnetic Measurements (2018).
M. Ess et al.: *Characterization of a New MiniCAST Generator (5201 Type BC) Including Diffusion and Premixed Flame Options.* Hyytiälä Summer School, 14.5.2018.
M. Ess et al.: *Characterization of a New MiniCAST Generator (5201 Type BC) Including Diffusion and Premixed Flame Options.* 22nd ETH Conference on combustion nanoparticles, 20.6.2018.
M. Ess et al.: *Characterization of a New MiniCAST Generator (5201 Type BC) Including Diffusion and Premixed Flame Options.* 10th International Aerosol Conference, 6.9.2018.
M. Guillevic et al.: *Metrologically traceable reference gas mixtures at trace levels from µmol/mol (10^{-6}) to pmol/mol (10^{-12}).* Exhalomics Workshop, Zürich, 27.2.2018.
M. Guillevic et al.: *A new method to produce SI-traceable, primary calibration standards for halogenated greenhouse gases.* EGU, Wien, 12.4.2018.
M. Guillevic et al.: *AGAGE58 – 13.f. Report on APRECON-GC-quadMS at METAS. AGAGE 58.* Meeting, 12.10.2018.
M. Enge, **C. Hof:** *Emerging alternative to the well-known LS2P microphones.* IMEKO XXII world congress, 3.-6.9.2018, Belfast, 3.9.2018.
C. Hof: *Metrologie im Bereich Vibration am METAS.* SPEKTRA-Kalibrierseminar, Dresden, 25.10.2018.
C. Hof: *Implementierung der Druckkalibrierung von Laborstandard-Mikrofonen durch die Reziprozitätsmethode am METAS.* SPEKTRA-Kalibrierseminar, Dresden, 26.10.2018.
C. Hof: *Zuverlässige Messungen dank Kalibrierung – auch mit dem Pendelfall-Hammer.* SGA-Herbsttagung, Sursee, 8.11.2018.
J. Hoffmann: *Open Innovation.* EMMT member meeting, Brussels, 11.6.2018.
J. Hoffmann: *Towards High Frequency Power Measurement Using the Electro-Optical Effect.* Conference on Precision Electromagnetic Measurements CPEM, 8.-13.7.2018, Paris, 9.7.2018.
S. Horender: *Investigation of the flow characteristics in an aerosol mixing facility.* Comsol Conference 2018, 23.10.2018.

S. Horender: *PM Sensor Kalibrierung mittels realitätsnaher Referenzaerosole – Stand und Ausblick.* Grimm Anwenderseminar, 29.10.2018.

M. de Huu et al.: *The European Research Project on Metrology for Hydrogen Vehicles – MetroHyVe.* 10th ISSFM, 21–23.3.2018, Queretaro, Mexico.

M. de Huu, M. Aeschbacher: *Performance testing of hydrometric current meters in a wind tunnel – feasibility tests.* 10th ISSFM, 21–23.3.2018, Queretaro, Mexico.

M. de Huu et al.: *The European Research Project on Metrology for Hydrogen Vehicles – MetroHyVe.* IMEKO XXII world congress, 3–6.9.2018, Belfast.

A. Jallageas, J. Morel et al.: *Wavelength calibration of high-performance spectrometers with a stabilized optical comb from an ultrafast semiconductor disk laser.* CLEO 2018, 15–17.5.2018.

B. Jeckelmann: *The revised International System of Units: A new foundation for all measures.* Plenary talk an der Jahrestagung der Schw. Physikalischen Gesellschaft, 28.–31.8.2018, Lausanne, 31.8.2018.

B. Jeckelmann: *Das revidierte SI: Hintergründe und wichtigste Änderungen.* METAS Seminar, 6.12.2018.

B. Jeckelmann: *Eine koordinierte metrologische Infrastruktur in Europa zum Nutzen von Industrie und Gesellschaft.* Technische Universität, Ilmenau, 12.12.2018.

K. Draxler, R. Styblíková, J. Hlavacek, G. Rietveld, H. E. van den Brom, M. Schnaitt, W. Waldmann, E. Dimitrov, T. Cincar-Vujovic, B. Pączek, G. Sadkowski, G. Crotti, R. Martín, F. Garnacho, I. Blanc, **R. Kämpfer, C. Mester** et al.: *Results of an International Comparison of Instrument Current Transformers up to 10 kA at 50 Hz Frequency.* Conference on Precision Electromagnetic Measurements CPEM, 3–18 July 2018, Paris.

C. Kottler: *Applied Radiometrology: Calibration of dose calibrators in nuclear medicine application.* Swiss Radiopharmacy Day (SGRRC – SSRCR), 15.3.2018.

A. Küng: *A geometry measurement system for a dimensional cone-beam CT.* 8th Conference on Industrial Computed Tomography iCT 2018, Wels, Austria, 8.2.2018.

A. Küng, B. A. Bircher, F. Meli, R. Thalmann: *Straightness and index sensor with sub-micron accuracy.* 18th International Conference & Exhibition, euspen 2018, Venice, Italy, 5.6.2018

D. Leuenberger, M. Guillevic et al.: *Concepts and challenges in the dynamic generation of SI-traceable nitrogen dioxide reference gas mixtures at ambient amount fractions.* EGU, Wien, 12.4.2018.

D. Lussi: *Regelung Hallwilersee.* GITHA, 27.09.2018.

D. Lussi: *IoT in der Umweltmesstechnik.* METAS Seminar, 7.11.2018.

S. Mallia: *Prozesskontaminanten in Lebensmitteln.* NRL Tagung PAK am METAS, 21.11.2018.

S. Mallia: METAS: *Referenzlabor für chemische Elemente.* ERFA Metalle, Amt für Verbraucherschutz Kt. Aargau, 28.8.2018.

A. Marti, S. Perrin, zusammen mit Agroscope: *The golden spirit.* Eurosense 2018, Verona, 2.9.2018.

K. Marti, M. Aeschbacher, S. Russi, C. Wüthrich: *Micro-force Measurements – a new instrument at METAS.* IMEKO XXII world congress, 3–6.9.2018, Belfast.

F. Meli, B. A. Bircher, S. Blankenberger, A. Küng and R. Thalmann: *A cone-beam CT geometry correction method based on intentional misalignments to render the projection images correctable.* 8th Conference on Industrial Computed Tomography iCT 2018, Wels, Austria, 7.2.2018.

C. Mester: *The role of national metrology institutes, the international system of units and the concept of traceability.* First International Colloquium on Smart Grid Metrology SmaGriMet, 2018, Split, 27.4.2018.

C. Mester, J.-P. Braun, C. Ané: *Messunsicherheit von Power Quality Analysern.* Sensoren und Messsysteme, 27.6.2018.

C. Mester et al.: *Sampling AC signals: Comparison of fitting algorithms and FFT.* Conference on Precision Electromagnetic Measurements CPEM, 8.–13.7.2018, Paris, 9.7.2018.

C. Mester: *Timestamping type 3458A multimeter samples.* Conference on Precision Electromagnetic Measurements CPEM, 8.-13.7.2018, Paris, 11.7.2018.

D. Giordano, P. Clarkson, F. Garnacho, H.E. van den Brom, L. Donadio, A. Fernandez-Cardador, C. Spalvieri, D. Gallo, D. Istrate, A. De Santiago Laporte, A. Mariscotti, **C. Mester** et al.: *Accurate Measurements of Energy, Efficiency and Power Quality in the Electric Railway System.* Conference on Precision Electromagnetic Measurements CPEM, 3.-13.7.2018, Paris.

B. Niederhauser: *Kleine Gasflüsse: Erstellen der Rückführbarkeit und deren Weitergabe.* Seminar «Messen, regeln, mischen und generieren von geringen Gasflüssen», Olten, 7.6.2018.

F. Overney: *Characterization of a Dual Josephson Impedance Bridge.* CPEM 2018, 8.–13.7.2018, Paris.

A. H. Pacheco: *Frequency dependence evaluation of CENAM calculable resistors.* Conference on Precision Electromagnetic Measurements CPEM 2018, 8.-13.7.2018, Paris.

F. Pythoud: *An overview of radiated EMC.* SwissT.net, Fachtagung EMV und Funk, Zürich, 18.1.2018.

F. Pythoud: *Einführung in die EMV / Introduction à la CEM.* Internationale Organisation für das Seilbahnwesen, Brunnen/Stoos, 20.3.2018.

F. Pythoud: *Proficiency Testing.* 53. Sitzung der PEGESS, Biel, 14.3.2018.

T. Le Quang: *Comsol Simulations for Scanning Microwave Microscopy.* Comsol Conference, Lausanne, 22.10.2018.

S. Reimann, **M. Guillevic** et al.: *Measurement of F-gases and OVOCs: a need for traceable, high-accuracy standards in climate and air pollution research.* Workshop call Environment, Paris, 24.10.2018.

M. Delaval, D. Egli, H.R. Jonsdottir, **P. Schüpfer,** N. Baumlin, M. Salathe, H. Burtscher, und M. Geiser: *Evaluating adverse effects of aerosols from different e-cigarettes to airway epithelia by realistic in vitro technologies.* ATS 2018, San Diego, 18.5.2018.

P. Schüpfer: *Analyse des HAP dans les revêtements de surface.* Tagung PAK am METAS, 20.11.2018.

D. Stalder: *Primary Noise Temperature Calibration Based on RF Power.* Keysight Metrology Workshop, Paris, 5.7.2018.

F. Stuker: *Messen und Beurteilen von gesundheitlichen Effekten von Displays.* Licht 2018, Davos, 11.09.2018.

F. Stuker: *Optische Messtechnik am METAS.* NTB Photonik Kolloquium, Buchs, 27.11.2018.

E. Tas, F. Pythoud, B. Mühlemann: *Design of a Reference Device for Surge Immunity Interlaboratory Comparison.* EMC EUROPE, 27.–30.8.2018, Amsterdam, The Netherland, 28.8.2018.

R. Thalmann: *Fundamental principles of dimensional metrology.* EURAMET training course, 12.–13.9.2018, Montenegro.

R. Thalmann: *Calibration of gauge blocks by mechanical comparison.* EURAMET training course, 12.–13.9.2018, Montenegro.

K. Thodkar: *Observation of high accuracy resistance quantization in CVD graphene.* Conference on Precision Electromagnetic Measurements CPEM 2018, 8.–13.7.2018, Paris.

M. Tschannen: *Messanlage zur Prüfung von Wasserstoff-Zapfsäulen.* METAS Seminar, 29.8.2018.

K. Vasilatou et al.: *Metrology for light absorption by atmospheric aerosols: the EMPIR Black Carbon project.* 22nd ETH Conference on combustion nanoparticles, 20.6.2018.

K. Vasilatou et al.: *Laboratory-generated coated soot aerosols with tunable physical, chemical and optical properties using a CAST generator and a portable Micro Smog Chamber.* 10th International Aerosol Conference, 6.9.2018.

M. Zeier: *Software zur Bestimmung der Messunsicherheit.* PTB-Seminar, Berechnung der Mussunsicherheit – Empfehlungen für die Praxis, Berlin, 16.3.2018.

M. Zeier: *Embedded Metrology Software.* VDI/VDE GMA FA1.11, Erlangen, 25.6.2018.

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