MIKES

FINNISH NATIONAL STANDARDS LABORATORIES

ANNUAL REPORT 2002

Contents

Introduction 2

Reports of the NSLs 11

Mass 12

Thermometry 28

Ionising radiation 34

Length 38

Time and frequency 53

Photometry and radiometry 56

Electricity and magnetism 65

Acoustics 76

Chemistry 78

Contact information 80

Centre for Metrology and Accreditation

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Editorial board: Jaana Järvinen, Martti Heinonen and Antti Lassila

Helsinki 2003

Preface

The year 2002 was a period of establishing a base for metrology both nationally and internationally. The former refers to the new building project, which was – and still is – in an active planning stage. The building process is almost on schedule; the blasting work began in March 2003. The start fixes the moving date to the end of 2004. The new location is on the Otaniemi science campus, about 10 km from Helsinki. The international review group recommended the area because it offers the best opportunities for co-operation in research. The new building also means a step towards a more centralised metrology organisation in Finland. In other words, the existing MIKES-metrology activities will be gathered under one roof. Internationally, the Mutual Recognition Arrangement (MRA) is expected to lower the barriers to trade. Almost 90 % of Finland's trade is with countries that have signed the MRA. The *measured once accepted everywhere* principle seems to have a bright future. Achieving it in full scale requires the end users to be well informed. It is a cost reducing opportunity after all. All the countries that have signed the MRA need to take an active role. To fulfil the MRA requirements MIKES has actively participated in (key)comparisons and the CMC-process. For a small national institute this is a hard task. The number of personnel at MIKES Metrology is 36, which is quite small compared to the average of 184* in institutes that have signed MRA. In Finland the combination of national and international work needs to be wisely prioritised.

This annual review summarises the activities of the Finnish National Standards Laboratories and Contract Laboratories in 2002. I hope you will find this information useful.

Helsinki 2003

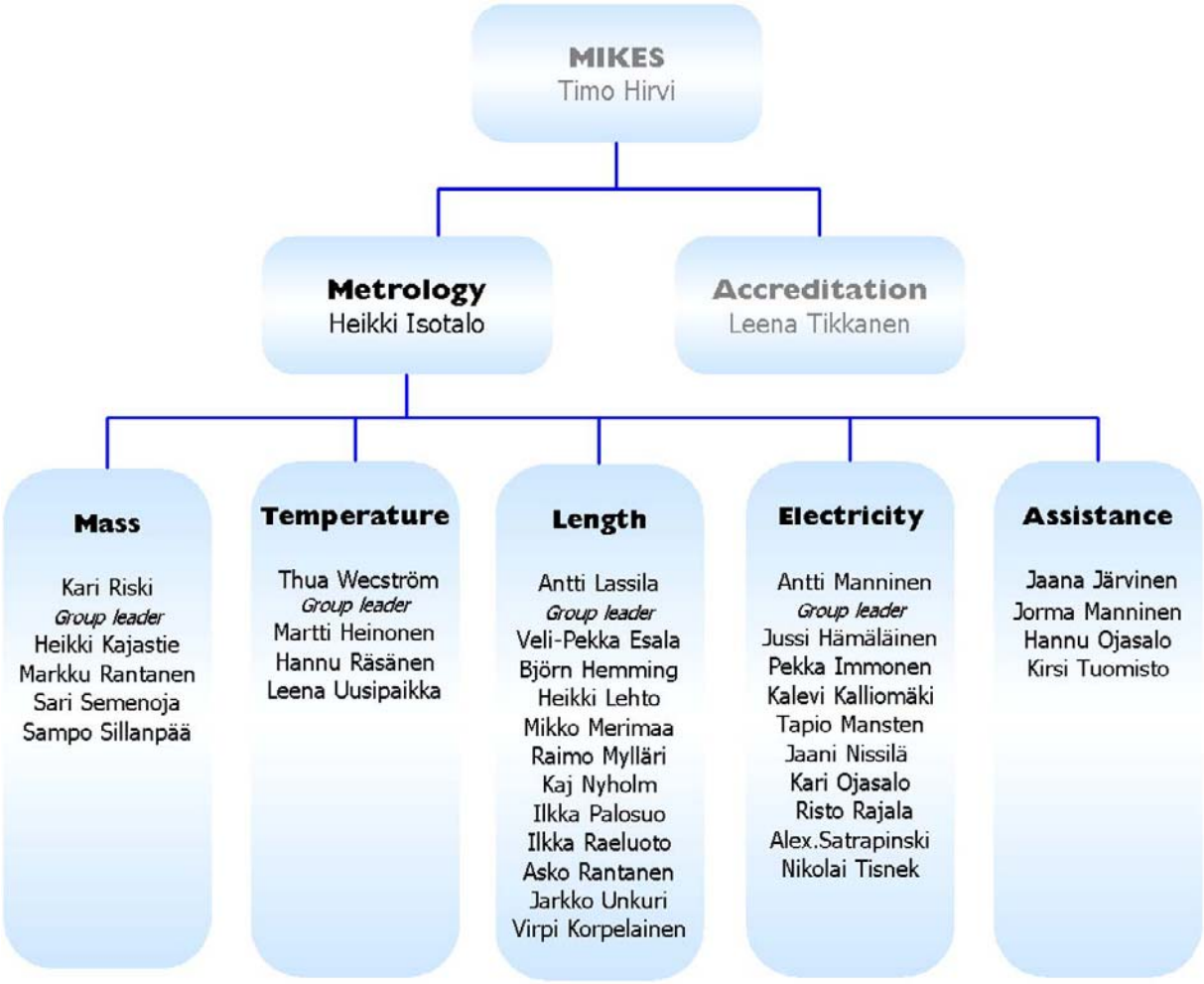
Heikki Isotalo
Head of Metrology

KANSALLINEN MITTANORMAALILABORATORIO
SUOMI FINLAND
MIKES

* Potential Economic Impact of the CIPM Mutual Recognition Arrangement, Study carried out by KPMG for the BIPM April 2002.

Mission of MIKES Metrology

In Finland the Centre for Metrology and Accreditation (MIKES) is responsible for the implementation and development of the national measurement standards system. MIKES also participates actively in international co-operation and ensures that Finnish metrology is up to international requirements.



Today Finland has a slightly decentralised organisation of its national standards laboratories. MIKES itself acts as the National Metrology Institute (NMI) of Finland, designating the National Standards Laboratories and financing the maintenance, research and development of the national measurement standards. Some of the activities are delegated to Contract Laboratories. International co-operation is also channelled through MIKES. The personnel of the department of metrology numbers 36 and is divided into four metrology groups – mass, temperature, length, electricity – supported by assisting activities.

MIKES is responsible for the following main areas:

MIKES participates in European and international research programmes and in scientific and technical activities promoted by European and international bodies in metrology, such as EUROMET, CGPM/CIPM/BIPM, EA, OIML, NORDTEST etc.

MIKES organises various training courses and seminars in several sub-fields of metrology. In addition experts from MIKES give lectures in courses and seminars organised by others.

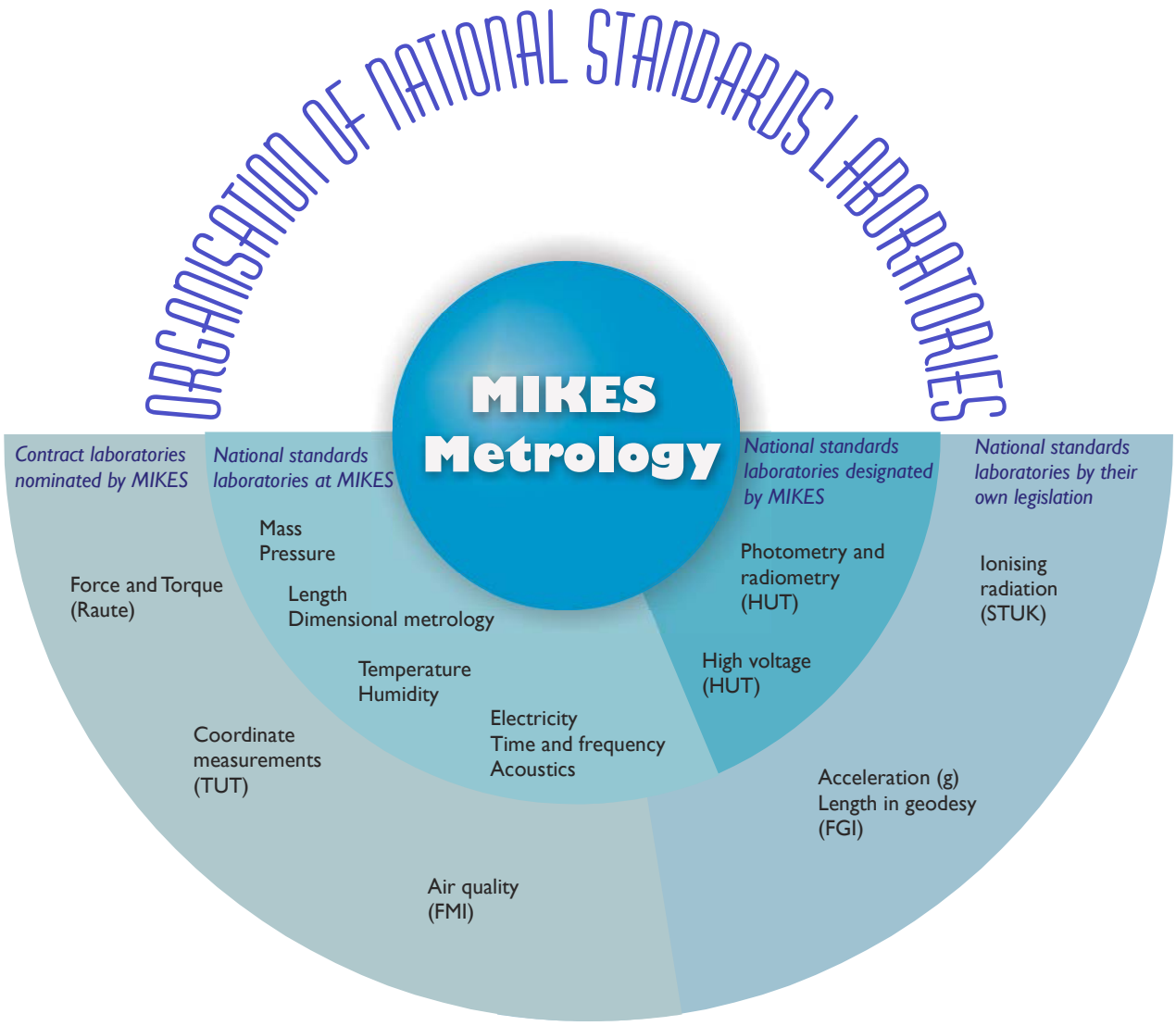
Research on the realisation methods of SI units, measurement standards and methods is carried out in various research projects often in co-operation with other research institutes and universities. In these projects several young scientists are carrying out their practical training and master's and doctoral thesis work.

MIKES Metrology works together with industry and various institutes. This type of national co-operation in the field of metrology is increasing in Finland

The laboratories of MIKES Metrology offer a calibration service to establish the traceability of reference standards at the accredited laboratories. The calibration service is also offered directly to end-users, mostly when the scope of accredited laboratories is not sufficient for the customer.

The national standards for mass, length, temperature, pressure, electrical quantities, time, frequency, humidity, acoustics and dimensional quantities are maintained and developed at MIKES to fulfil the needs of consumers and the society in Finland. The duties of the national standards laboratories for photometry and radiometry, high voltage, length in geodesy, acceleration of free fall and ionising radiation have been delegated to other institutes outside MIKES. In addition the traceability, international relations and expert services in the field of force, torque, coordinate measurements and air quality measurements have been organised through Contract Laboratories.

Within MIKES, the Metrology Department is responsible for tasks relating to the maintenance and supervision of the national measurement standards system. Below is the organisation of the National Standards Laboratories in Finland.



MIKES = Centre for Metrology and Accreditation, HUT = Helsinki University of Technology, TUT = Tampere University of Technology, FMI = Finnish Meteorological Institute, FGI = Finnish Geodetic Institute, Raute = Raute Precision Oy, STUK = Radiation and Nuclear Safety Authority

2002 in figures

Various research projects carried out in 2002 reflect the increasing efforts in metrological research at the National Standards Laboratories. Valuable results were obtained e.g. with

- *determination of the refractive index of air by measuring group velocity of ultrasound over the same distance that is measured with a length interferometer*
- *research on chilled mirror hygrometers*
- *effect of density gradients on hydrometers*
- *applications of microelectromechanics (MEMS) in electrical metrology*
- *applying an xy-scanning method with a tunable Ti:Sapphire laser to determine the spectral irradiance responsivity of filter radiometers that are used for radiation temperature measurements*
- *characterisation of the spectral irradiance responsivity of low-sensitivity UV meters with a monochromator-based system.*

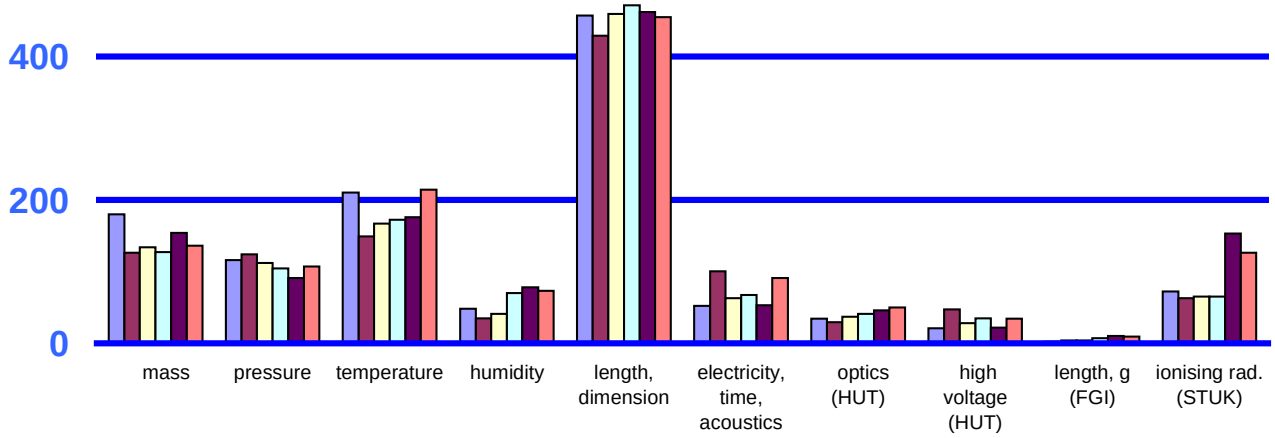
New techniques and measurement methods are being developed in projects on:

- *a Josephson AC standard*
- *an optical frequency comb*
- *a new definition of mass based on the superconducting magnetic levitation method.*

New types of service were developed e.g. for calibration of small gas flow meters and determining the thermal expansion of gauge blocks. Many other research and development projects were carried out to improve the facilities and level of service at MIKES. The results are published in scientific conferences and journals, enabling a free flow of information with other scientists and sharpening our competitive edge.

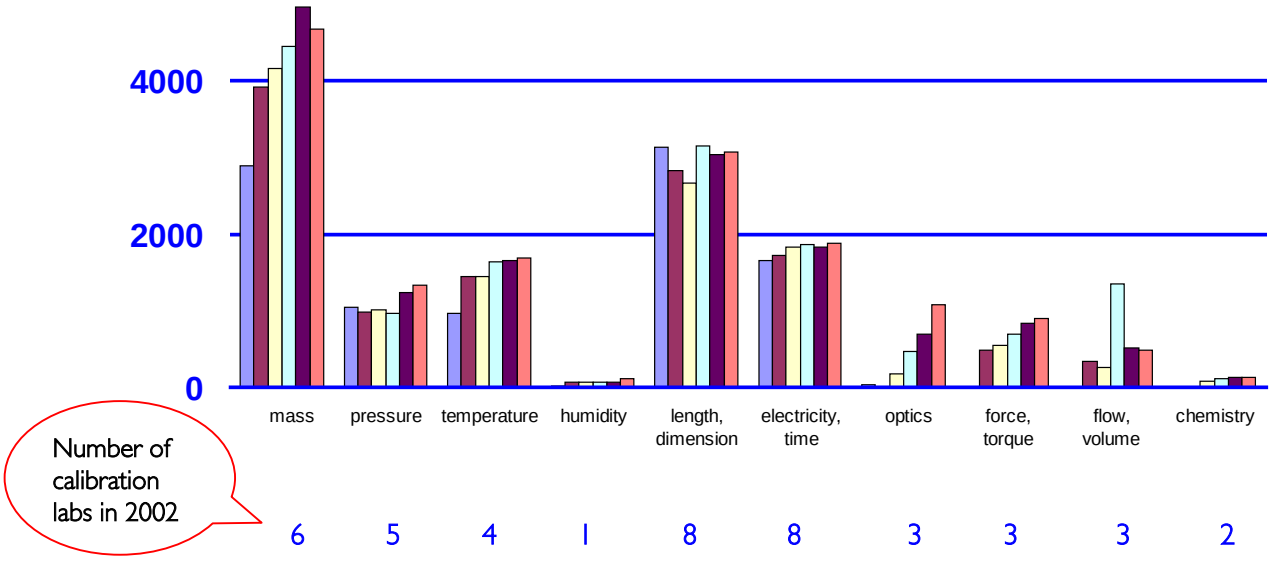
The results and know-how obtained in these projects will enable MIKES to provide the expert and calibration services needed by Finnish industry in the future. For example, a new National Standards Laboratory was designated in acoustics and the NTP (National Network Time Protocol Servers for the Government and Communities) system was put into operation.

Number of calibrations 1997-2002
NSLs

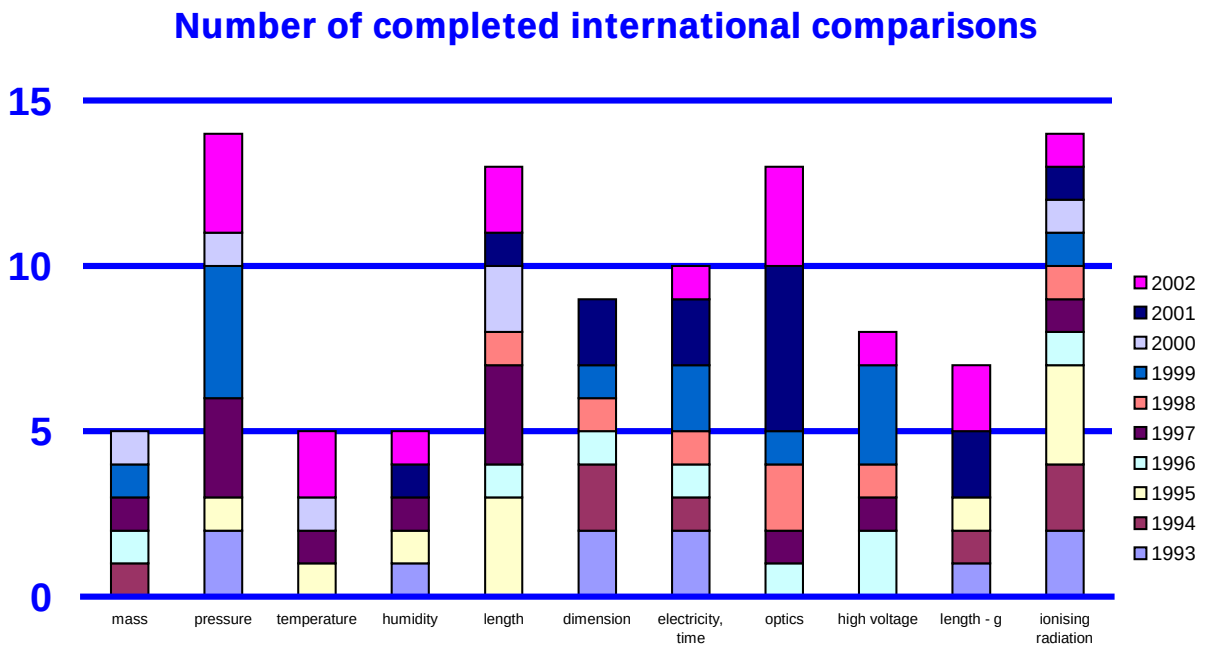


The volume of the calibration service in Finnish NSLs was roughly the same as in previous years. In the future Nordic and European (EUROMET) co-operation will update standards to a higher level for the future needs of industry. Attempts in this direction are e.g. EUROMET initiated MERA (Metrology Research Area) projects.

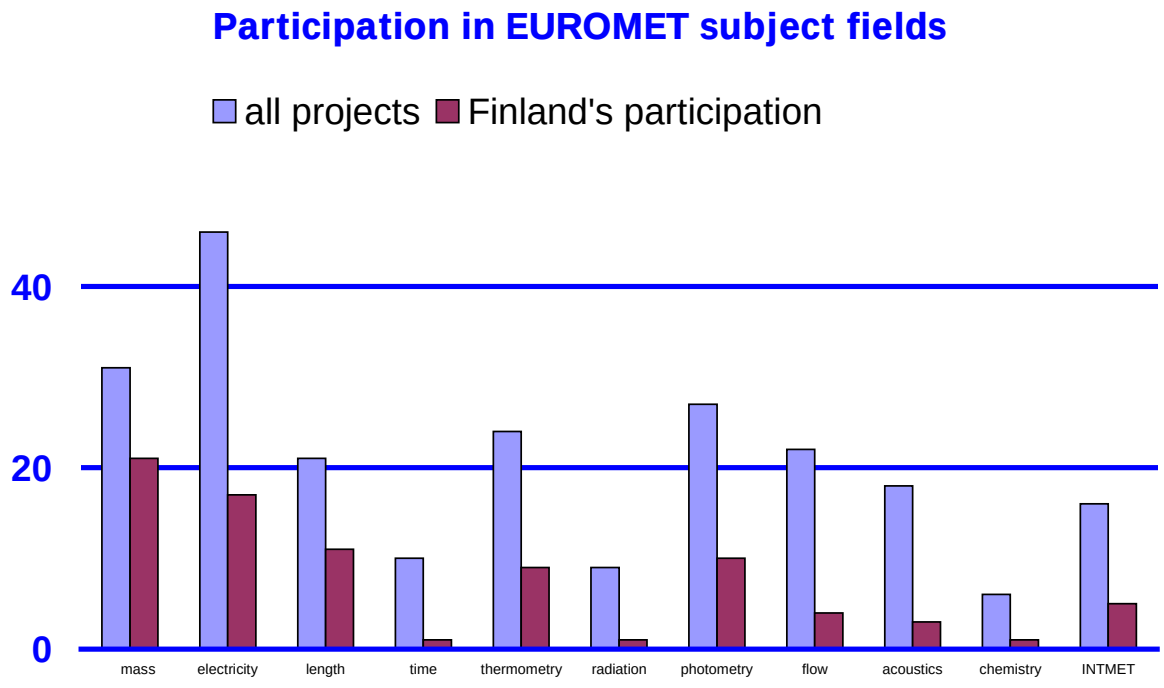
Number of calibrations 1997-2002
Accredited calibration laboratories

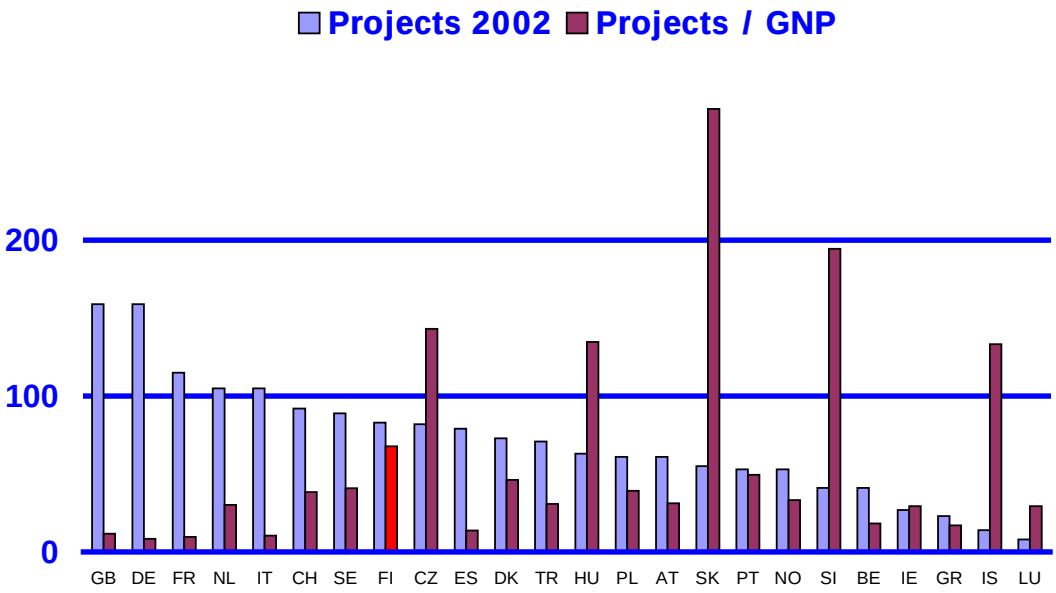


In accredited calibration laboratories the volume of calibrations is tenfold compared to the NSLs.

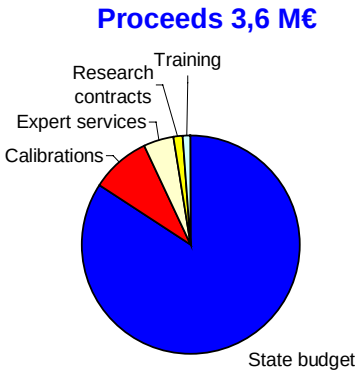


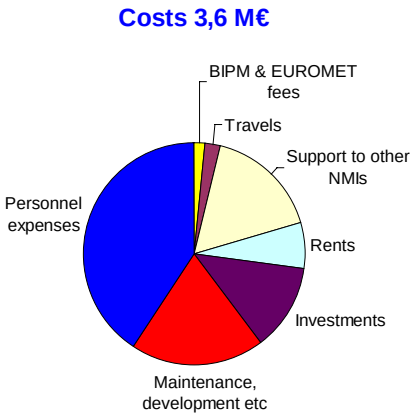
International comparisons are essential in showing competitive strength.





International co-operation plays a significant role in the metrological activities of MIKES. Experts from the institute therefore participated in meetings of various expert groups and conferences and maintained personal contacts with their colleagues abroad. One measure of the institute's activity is its participation in EUROMET projects.

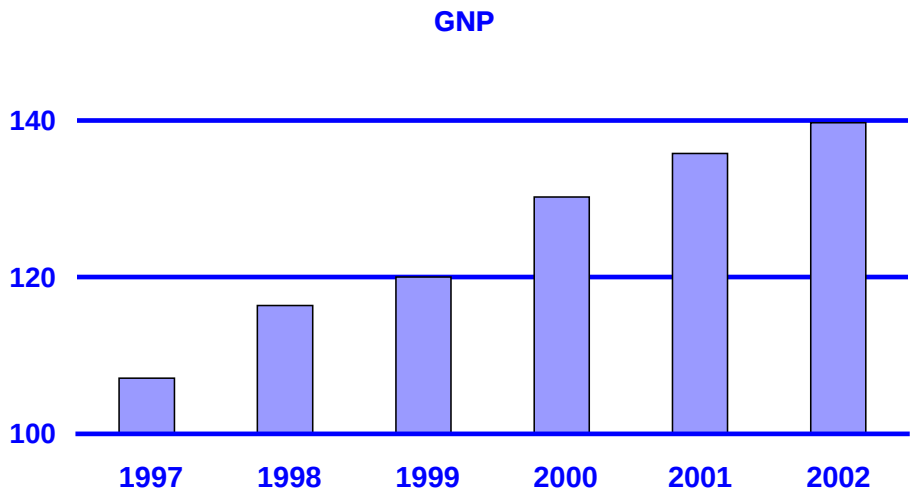




Proceeds and costs of MIKES-metrology were 3.6 MEUR in 2002. The administration and Accreditation departments in MIKES have their own budgets.

The impact of metrology

In Europe today we measure and weigh at a cost equivalent to 6 % of our combined GNP! Metrology has become a natural part of our everyday lives. Planks of wood, and coffee are both bought by size and weight. The consumption of water and electricity is measured. We feel the effects of these measurements in our pocket books. Some times measurements cause us anxiety, like in the case of getting a very large electric bill or even a speeding ticket, for example. We all want to be sure that the measurements that affect our lives are accurate. Lives hang in the balance when the quantities of active substances in medicine are measured, blood samples are analysed and laser surgeries are performed. We find it almost impossible to describe anything without referring to weights and measures: Hours of sunshine, alcohol percentages, weights of letters, room temperatures, tyre pressures and so on. Just for fun, try having a conversation without using words that refer to weights or measures.*



Gross National Product of Finland in 10^9 EUR. Source: Statistics Finland (Tilastokeskus).

* Text taken from **Metrology in short, Focus on Finland**, based on EUROMET project no. 595, October 2002.

Reports of the National Standards Laboratories

Mass

Mass • Density

Kari Riski	Senior Research Scientist, Head of Laboratory, Group Leader
Martti Heinonen	Senior Research Scientist
Heikki Kajastie	Research Scientist
Jorma Manninen	Laboratory Engineer
Hannu Räsänen	Research Assistant
Sari Semenoja	Research Scientist
Sampo Sillanpää	Trainee

Realisation, traceability

Maintenance

The national standard of mass is the Pt-Ir prototype kilogram No 23. The national standard was calibrated at BIPM in 2001. Secondary stainless steel kilograms are calibrated periodically against the national standard. Weights with other nominal masses are calibrated against secondary kilograms by the subdivision method.

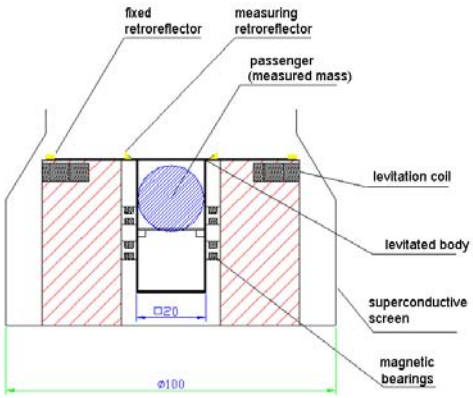
The traceability of density is obtained either from the density of pure water or from the density of silicon. Also traceable mass, temperature, pressure and humidity measurements are needed. Solid density standards are calibrated by hydrostatic weighing in water.

The four secondary kilograms were calibrated against the national Pt-Ir prototype kilogram in August 2002. The changes in the masses of the kilograms from a previous comparison in 2001 were of the order of 5 µg. The changes are too small to predict any instability of the national standard kilogram or the secondary kilograms. Reference mass standards from 1 mg to 10 kg and working mass standards up to 50 kg have been calibrated. Hydrostatic weighing instruments have been checked with silicon density standards.

Development

Realisation of the kilogram

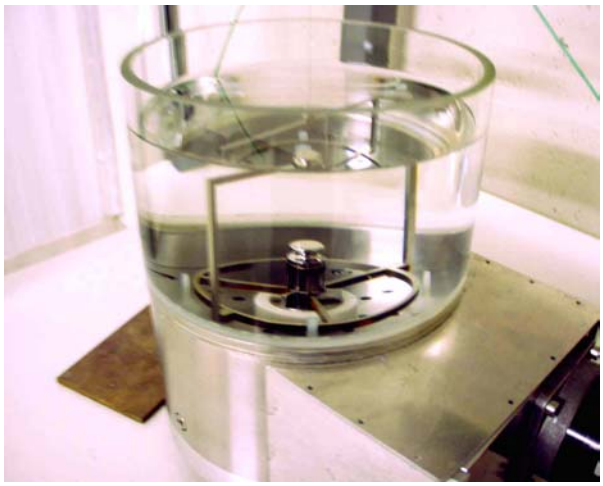
The purpose of the project is to define the unit of mass (kilogram) in terms of other quantities (length, time, current, voltage) using the superconducting magnetic levitation method. In 2002 the construction of an interferometer for measurement of the displacement of the levitating body was begun. The resolution and accuracy of the interferometer will be better than 1 nm. Designing of the superconducting magnetic levitation system has been continued. The cryogenic calorimeter which measures energy losses in superconducting materials is still under construction. Test measurements with the calorimeter should start in 2003. The project has been carried out in co-operation with VNIIM (Russia), VTT Information Technology and the University of Jyväskylä.



Schematic design of the magnetic levitation system.

Density measurements

A new instrument for measurement of the density of small weights (1 g - 100 g) has been constructed, tested and taken into use. The weight immersed in water is placed on (and off) the balance hanger by a step motor-operated weight-lifting device. The uncertainty of the instrument is still under investigation.



Determination of the density of a 20 g weight.

Effect of density gradients on hydrometer calibration results

In the MIKES Hydrometer Calibration System, temperature non-uniformity in the calibration liquid is maintained by evaporation and heat transfer between the liquid and ambient air. In this work, the effect of the density gradient induced by vertical temperature gradients was investigated theoretically and experimentally. A method to compensate the effect was developed and tested.

A calibration system for gas flow meters

A new calibration facility for small gas flow meters has been developed. A gas flow standard based on dynamic weighing was constructed and tested. According to the results obtained so far, the relative standard uncertainty of this apparatus is between 0.1 % and 0.6 %. The maximum uncertainty will be reduced by improving the connection of the gas vessel to the pressure controller. The results will be reported in a Master's Thesis (Sampo Sillanpää) and at the FLOMEKO 2003 Conference.

Overview of the MIKES calibration system for small gas flow meters.

International comparisons

EUROMET 445: **"**Comparison of mass standards in multiples and sub-multiples of the kilogram". Regional key comparison. Participants: almost all Euromet members. Several parallel comparisons, started in 2002. Measurement at MIKES in January and February 2003.

EUROMET 510: "Comparison of mass standards of the kilogram (stainless steel)", Regional key comparison. Participants: BE, CH, CZ, DE, DK, ES, FI, FR, GB, HU, IE, IS, IT, NL, NO, PT, SI, TR. Measurements at MIKES in September 2002.

EUROMET 509: "Intercomparison of Pt-Ir kilogram standards". Participants: BE, CH, CZ, DE, DK, ES, FI, FR, GB, HU, IT, NO, PL, SE, SI, SK. Measurements at MIKES in September 2002.

EUROMET 627: "Comparison of density determination of liquid samples". Supplementary comparison. Densities of water, dodecane and viscose oil at three different temperatures were compared. Participants: DE, FI, FR, HU, IT, PL, ZA. The measurements were performed in 2001. Results have been distributed to the participants. For MIKES the results were not very good. The uncertainties were large (compared with most laboratories) and in many cases the E_n values were close to 1. The results show that the hydrometer calibration instrument is not very good for liquid density calibrations.

"Comparison of measurement standards for small gas flow meters", bilateral comparison with NMi/VSL (NL). Measurements at MIKES in January and February 2003.

Publications

M. Heinonen, S. Sillanpää, The effect of density gradients on hydrometers, submitted to *Measurement Science and Technology*.

Conferences

H. Kajastie, J. Manninen, K. Riski, Density calibrations at MIKES, *Proceedings of the international Conference on Force, Mass, Torque, Hardness and Civil Engineering Metrology in the age of globalization, IMEKO TC3/TC5/TC20,* 24-26 Sept. 2002, Celle, Germany, VDI-Berichte 1685, pp. 279-284, 2002.

H. Kajastie, J. Manninen, K.K. Nummila, K. Riski, and A. Satrapinski, Calorimetric measurements on losses in superconducting materials, *International Conference on Precision Electromagnetic measurements,* 17-20 June 2002, Ottava, Canada.

Lectures

Heikki Kajastie: Density calibrations at MIKES, IMEKO TC3, Celle, 26 September 2002.

Kari Riski: Akkreditoinnin vaatimukset mittaustulosten luotettavuudelle; Mittausepävarmuus, analyysimittaukset, AEL, 23 March 2002 (in Finnish).

Kari Riski: Punnukset, vaa'at ja dimensiomittaukset, Laboratoriolaitteiden kalibrointi ja laadussapito; AEL, 3 October 2002 (in Finnish).

Kari Riski: Kilogram and its realization now and in future, Åbo Akademi, Turku, 1 March 2002.

Kari Riski: Kilogramma ja sen realisointi nyt ja tulevaisuudessa, TTKK, Tampere, 7 November 2002 (in Finnish).

Visits

Kari Riski participated in EUROMET Mass TC meeting and Mass and Density project meetings, 18-22 February 2002 at SMU, Bratislava, Slovakia.

Heikki Kajastie visited PTB, Germany, 27 September 2002.

Visitors

V.M. Khavinson, VNIIM, Russia, 5-30 March 2002, (Realisation of the kilogram project).

Memberships

Kari Riski and Heikki Kajastie, Expert Group for Mass Quantities, Advisory Commission for Metrology.

Kari Riski, EUROMET Contact person for mass.

Martti Heinonen, Secretary of the Expert Group on Flow Measurements, Advisory Commission for Metrology.

Sampo Sillanpää, Expert Group on Flow Measurements, Advisory Commission for Metrology.

Martti Heinonen, The planning committee of the AEL-INSKO training course on flow measurements.

Pressure

Markku Rantanen — Senior Research Scientist, Head of Laboratory
Sari Semenoja — Research Scientist

In the range from 5 kPa to 500 MPa the unit of pressure is realised using a set of pressure balances. The effective areas are traceable to BNM-LNE, France. The BNM-LNE results are supported with dimensional measurements by MIKES Length laboratory on two 35 mm diameter piston cylinder units.

The reference standard for pressure in the range from 20 Pa to 15 kPa is a digital piston manometer. The effective area is traceable to the conventional pressure balances of MIKES.

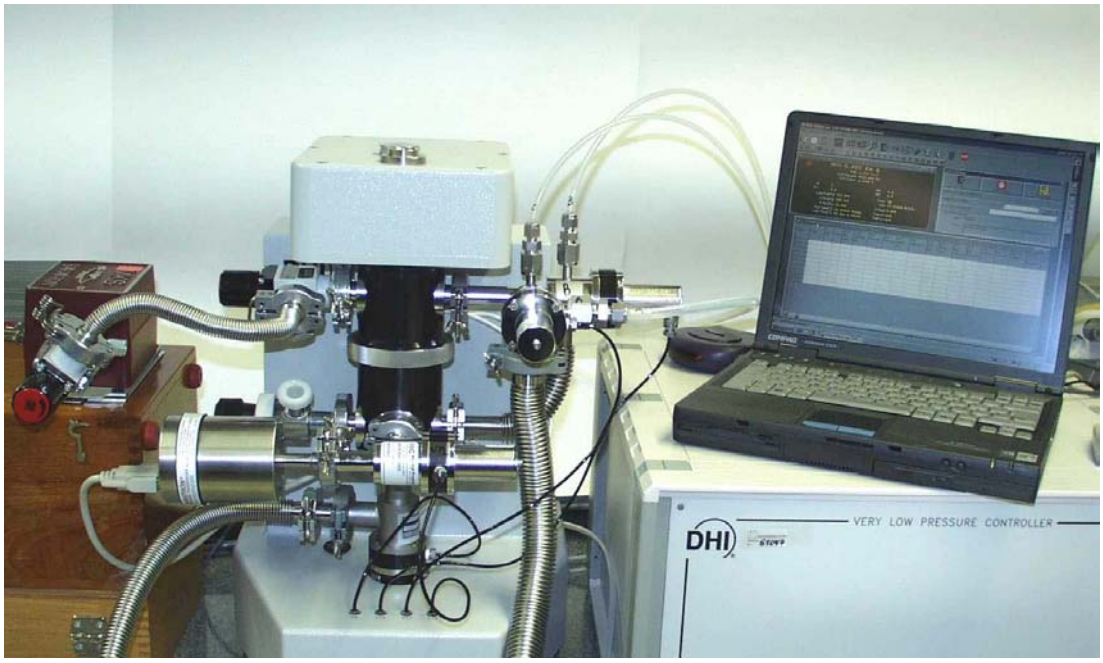
In the range from 0.2 Pa to 20 Pa the reference standard is a capacitance diaphragm gauge, traceable to PTB, Germany.

In the range from $5{\cdot}10^{-4}$ Pa to 0.2 Pa absolute pressure the reference standard is a spinning rotor gauge, traceable to NPL, Great Britain.

In 2002, the Length laboratory of MIKES made dimensional measurements on one 35 mm diameter piston cylinder unit.

The capacitance diaphragm gauge used as the reference standard for the range from 0.2 Pa to 20 Pa was calibrated in PTB, Berlin.

In 2002 the absolute pressure range was expanded down to $5{\cdot}10^{-4}$ Pa and the uncertainties were decreased in the range 0.2 Pa to 10 kPa. The development was facilitated by two spinning gauges and a novel type of digital piston manometer. The digital piston manometer for absolute and gauge pressures from about 3 Pa to 15 kPa, received in 2001, was upgraded in 2002 for better measurement capability and pressure control.



The DHI digital piston manometer was upgraded by the manufacturer to improve the pressure control and the reference vacuum measurement. The resolution of the pressure display is now 0.001 Pa.

International comparisons

The MIKES measurements in the EUROMET key comparison for absolute pressure range from 0.1 Pa to 1000 Pa (project #442) were performed in August and September 1999. Another EUROMET key comparison (project #439) in the gauge pressure range 0.08 MPa to 7 MPa was participated in during September and October 2000. The draft reports of these comparisons are due to be published in 2003.

MIKES, SP/Sweden and Vaisala Oy made in 2001–2002 a comparison of their spinning rotor gauges in the range from $5 \cdot 10^{-4}$ Pa to 5 Pa absolute pressure (see *Reports*). The agreement of the results was good; the maximum absolute value of the normalised errors E_n was 0.82.

MIKES and BNM-LNE arranged a bilateral comparison (Euromet #650) in the pressure ranges from 0 to 13 kPa (differential mode) and from 0.1 Pa to 13 kPa (absolute mode). The aims of the project are to compare the standards and the methods used in both laboratories in these ranges and to evaluate the performances of the capacitance diaphragm gauges. The two laboratories circulated their three differential CDGs so that their own CDGs were calibrated before and after the calibration in the other laboratory. The report will be completed in 2003.

In June 2002, the digital piston manometer of MIKES was compared to the mercury column manometer of PTB, Braunschweig, in the absolute pressure range from 1 kPa to 15 kPa. The report is still under preparation but the preliminary results show good agreement.

In August a comparison between MIKES and NMi-VSL, the Netherlands, was arranged in the gauge pressure ranges from 5 kPa to 13 kPa and from 20 kPa to 180 kPa. The report will come out in 2003.

Further, MIKES participated as an auxiliary laboratory in a Dutch national comparison in the gauge pressure range 0–10 kPa. The results of MIKES were in good agreement with the results of the pilot laboratory NMi-VSL (see *Reports*).

In September-October 2002, a 130 Pa capacitance diaphragm vacuum gauge (CDG) was calibrated in three laboratories: first at MKS Instruments Deutschland, then at Physikalisch-Technische Bundesanstalt (PTB) and finally at MIKES. Here, too, the agreement of the results was good; the maximum absolute value of the normalised errors E_n was 0.76 (see *Reports*).

Intercomparison reports

Jos C. G. A. Verbeek: RvA/NKO comparison NKO-P0101: Gauge pressure 0–10 kPa. RvA 2002.

V. König, A. Pitkäkoski, M. Rantanen & S. Semenoja: Comparison of spinning rotor vacuum gauges between MIKES, SP and Vaisala Oyj. Publication J5/2002, MIKES.

M. Rantanen & S. Semenoja: Calibration of a 130 Pa CDG: Comparison of the results from MIKES, PTB and MKS Deutschland. Publication J6/2002, MIKES.

Lectures

Markku Rantanen: Painemittareiden kalibrointi. AEL-INSKO, Kalibrointi – tarve ja suoritus käytännössä. 30 January 2002 Helsinki.

Markku Rantanen: Paineen yksikön realisointi. MIKESin painelaboratorion esittely TTKK:ssa. 7 November 2002 Tampere.

Visits

Sari Semenoja participated in the EUROMET Mass Contact Persons Meeting and the pressure project meetings in Bratislava 19–22 February 2002.

Sari Semenoja and Markku Rantanen visited the pressure laboratory of PTB, Braunschweig, 3-13 June 2002 and the vacuum laboratory of PTB, Berlin, 7 June 2002.

Sari Semenoja participated in a course on Advanced Pressure Metrology Using Piston Gauges, arranged in Phoenix, USA by DH Instruments Inc, 29 April - 3 May, 2002.

Markku Rantanen participated in the Theme Day on Pressure Measurements in the Swedish industry, arranged in Stockholm, Sweden, by SP, 1 October 2002.

Sari Semenoja participated in PRESSMET Special Interest Meeting: Working with pressure balances, NPL, UK, 9 October 2002.

Visitors

Fredrik Arrhén, SP, Sweden, 6-7 February 2002.

Luc Dargent, DH-Budenberg, France, 8 May 2002.

Jos C. G. A. Verbeek, NMi, the Netherlands, 19-23 August 2002.

Memberships

Sari Semenoja: Secretary of Expert group for mass quantities, Advisory Commission for Metrology.

Markku Rantanen: Expert group for mass quantities, Advisory Commission for Metrology.

Force and Torque

Force • Torque

Raute Precision Oy is nominated by MIKES to act as the Contract Laboratory for force and torque.

Aimo Pusa	Head of Laboratory
Mikko Mäntylä	Supervisor
Rami Lehto	Technician

Realisation, traceability

Force

The force scale is realised in the range 1 N .... 100 kN by a dead weight standard machine. The range over 100 kN up to 1.1 MN is realised by a hydraulic amplified machine, with the 100 kN dead weight standard machine as the reference machine. Realisation is based on the formula

$$F = m \cdot g_l \, [\, 1 - (\rho_a / \rho_m)\,].$$

The traceability of masses leads to the Centre for Metrology and Accreditation (MIKES) in Finland and to PTB (Physikalisch-Technische Bundesanstalt, Germany). The gravity constant is determined by the Finnish Geodetic Institute.

Torque

The torque is realised by force and length,

$$M = F \cdot l.$$

The traceability of forces is described above. The traceability in length leads to MIKES, which is the national laboratory for length.

Maintenance

Regular internal comparison measurements have been carried out. Internal cross-check and routine testing has indicated normal condition of standards during the year.

Development

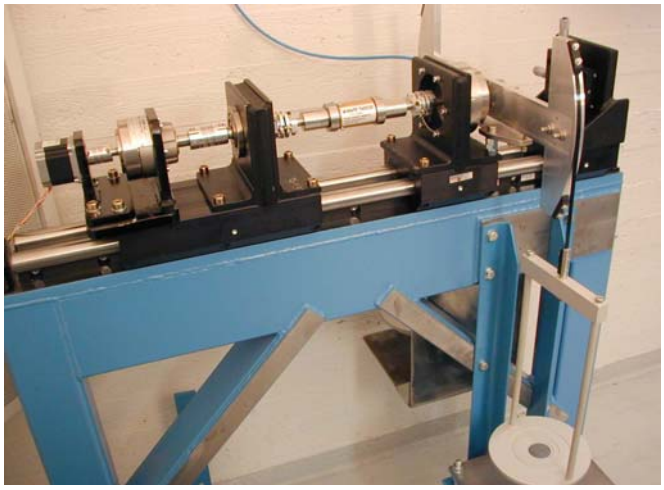
Traceability of torque up to 20 kN·m

The laboratory has started to construct a new torque reference standard machine for the range up to 20 kN·m. As reference, torque transducers will be used with a nominal range of 5 kN·m, 10 kN·m and 20 kN·m. The transducers will be calibrated by PTB. The machine will be ready for tests in the second quarter of 2003.

All the torque measurement devices have been checked and partially reconstructed for better capability. Some of the constructions will be ready in early 2003.

Research on new types of force and torque transducers

To be able to understand the function and principle of the transducer, the laboratory carries out investigations on new types of transducers which are sent for calibration. Manufacturers are producing transducers with less material, which affects the measurement capability, and this increases the influence of parasitic factors. For torque calibration, investigations were carried out for dynamic calibration between different types of calibration devices.



10 N·m torque standard machine. The accredited uncertainty is currently $2 \cdot 10^{-4}$ but the measured uncertainty shows a value of $5 \cdot 10^{-5}$, which is the next target once longer experience has been gained with device.

50 N·m reference calibration device for calibration of measurement instruments with lower accuracy.

International comparisons

A proposal report on Key Comparison CCM.F-K1.a (range 5 kN and 10 kN) and CCM.F.K1.b (5 kN) has been prepared for discussion. The final approval is awaited in 2003.

The regional comparison forming the continuation of the CCM Key Comparison started in January. So far eight laboratories have carried out measurements. The remaining laboratories will perform their measurements in early 2003.

Preliminary intercomparison with Estonia for 50 kN.

Regular comparisons with PTB for force and torque were made at the end of May. The measurement capabilities were confirmed at the level given for CMC tables.

EA-T2 for torque is still open; according to the information from PTB the final report should be ready in 2003.

International (EA or other) intercomparisons for accredited calibration laboratories

Participation in the EA-F3 force comparison in December. The comparison will end in 2003.

Preliminary force intercomparison with Estonia.

Publications

Traceability of the Calibration of Test Car for Roll Brake Tester, IMEKO TC-3 Conference, 23-27 September, 2002, Celle, Germany.

Conferences

IMEKO TC-3 Conference, 23-27 September 2002, Celle, Germany.

Reports

Realisation of the traceability for calibration car (renewed construction) of roll brake tester, measuring range 20 kNm.

Metrosert A/S voimakoneen mittausraportti**.**

Lectures

For AEL 5 lectures, subject calibration technology and uncertainty of calibration.

"Measurement Uncertainty", IIR Seminar, Helsinki.

"Calibration and conformity methods for measurement", The Finnish Vehicle Administration AKE, Helsinki.

Other activities

EUROMET mass contact persons meeting, February, Bratislava.

EA-AD-hoc expert group for uncertainty guide of non-automatic weighing instruments.

IMEKO, Finnish delegate in GC, member of the TB (technical board), which had meetings in Dubrovnik in November.

IMEKO, Technical Secretary of Technical Committee 3, Force, Mass and Torque (TC-3).

Member of the VAT (development of the education in the metrology) measurement group for AEL (Centre for Technical Training).

Standardisation

Member of the translating group for force measurement standards (MET).

Visits

PTB, Germany, April, May and September.

TÜV, Düsseldorf, May.

Visitors

SP, Sweden, Håkan Källgren, February.

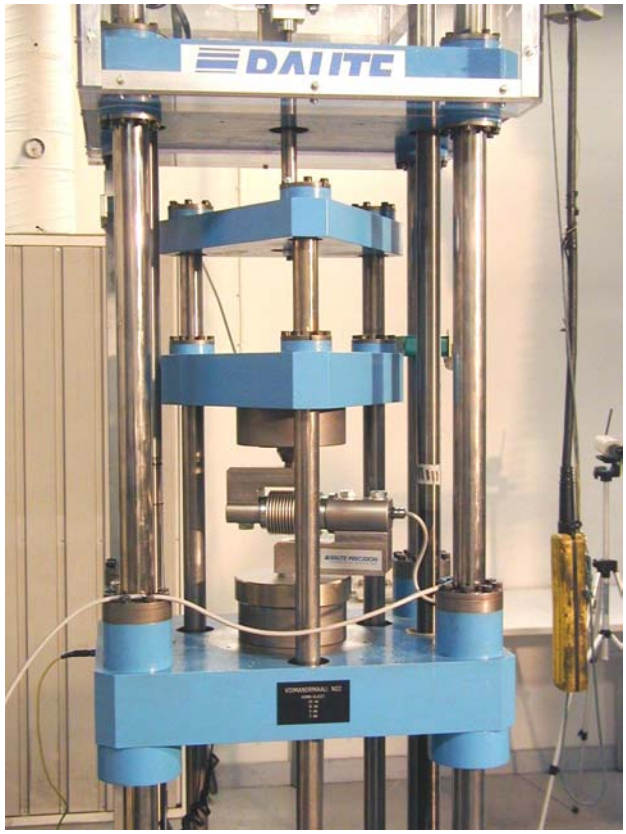
SP, Sweden, head of the section Mass, Force and Pressure, Jan Hjelmgren, March.

NMi, The Netherlands, Jose Verbeek, August.

SMERI, China, Shanghai, expert group of torque, head of the group prof. Weilu Shang, September.

NMI, China, Bejing, expert group of torque, head of the group, prof. B. Pan, Director General of National Institute of Metrology, October.

Metrosert, Estonia, Lauri Lillepea, October.



20 kN force standard machine, the master tool for CCM.F-K1.a and b key comparison.

Acceleration of free fall

Acceleration of free fall

Markku Poutanen	Head of Department of Geodesy and Geodynamics, Quality Manager
Jaakko Mäkinen	Senior Research Scientist, Head of Laboratory
Hannu Ruotsalainen	Research Scientist, Deputy Head of Laboratory
Heikki Virtanen	Research Scientist

Finnish Geodetic Institute is the National Standards Laboratory for acceleration of free fall.

Realisation, traceability

The Finnish Geodetic Institute has two absolute gravity meters, JILAg-1 and JILAg-5. They track the free fall of a corner cube retroreflector in a vacuum chamber. Distance is measured by a laser interferometer and time is based on a rubidium standard. Traceability of length and time is described below.

Maintenance

The absolute gravimeter JILAg-5 was used at the national reference station Metsähovi on 8–12 July, 16–17 July, 18–20 July, 27– 29 July, 7–9 October and 15–19 November. In the last five measurements the interferometer of the JILAg-1 were used. In the last four measurements it was fitted with an iodine stabilised laser (Winters WEO model 100, s/n 142).

The iodine laser locks automatically to an absorption line chosen by the user, and recovers lock if lost. However, the true line is not always the same as the nominal line. New code for the data acquisition software of the gravimeter was written to recognise lines automatically and to prevent dropping while the laser is unlocked. The laser has a non-saturated iodine cell and does not constitute a primary standard. However, comparisons with metre lasers are needed less frequently than with the two-mode lasers used earlier. The most recent comparison was done at the Kumpula accelerator laboratory of Helsinki University on November 11, 2001.

At present, the two-mode lasers (Laseangle RB-1 No. 18 of JILAg-5, and Laseangle RB-1 No. 19 of JILAg-1) are used for backup only. After the extinction of their plasma tubes in 2001, new tubes were installed at the Kumpula accelerator laboratory of Helsinki University. The frequency of the renovated laser No. 18 was compared with the metre laser of the laboratory on 13 December 2001 and on 19 December 2002. The frequency of the renovated laser No. 19 was compared with the metre laser on 3 January and 31 December.

The rubidium frequency standards of the JILAg-5 and JILAg-1 (Efratom FRK-L numbers 8533 and 8514, respectively) were compared with the hydrogen maser oscillator of Helsinki University of Technology on 10 July and 10 October. They were also compared with each other at every absolute measurement in Metsähovi.

Absolute gravity measurement with the JILAg-5 in Panevéžys, Lithuania.

Absolute-gravity measurements were performed with the JILAg-5 at three stations in Lithuania:

Station	Dates (2002)
Vilnius	4–5 August
Klaipéda	7–9 August
Panevéžys	11–13 August

The work was done in cooperation with the National Service of Geodesy and Cartography of Lithuania and with the Vilnius Gediminas Technical University. The three absolute stations form the basis of the Lithuanian gravimetric network. They had previously been measured in 1994. The apparent changes in gravity in 1994–2002 do not exceed the uncertainty of the measurements. However, they are consistently negative, -0.06 μm s^{-2} on average. This might be due to variation in subsurface water storage, as the summer of 2002 was very dry. This is being investigated more closely.

The performance and calibration of the relative gravimeters LaCoste&Romberg (LCR) No. G-55 and No. G-600 have been monitored on the Masala-Vihti calibration line.

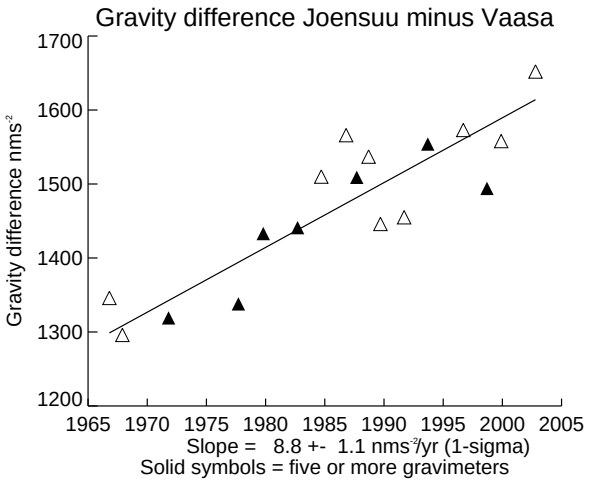
The superconducting gravimeter GWR T020 recorded variations in gravity at the Metsähovi national reference station all year. Research centred on the effects of environmental parameters on gravity (see "Development").

The national 5×5 km^2 gravity network was densified by 137 stations. Different methods of GPS positioning of the stations were tested.

A new absolute gravimeter (FG5) was ordered. Delivery is expected in early 2003.

A new quality system conforming to the ISO/IEC 17025 standard was implemented jointly with the NSL for length at the FGI.

In cooperation with the Royal Observatory of Belgium, electrostatic feedback ("maximum voltage retroaction" principle MVR, developed by M. van Ruymbeke) was installed in the LaCoste&Romberg No. G-600. It improves the accuracy in measuring small gravity differences, and also makes it possible to use the G-600 as a recording gravimeter.

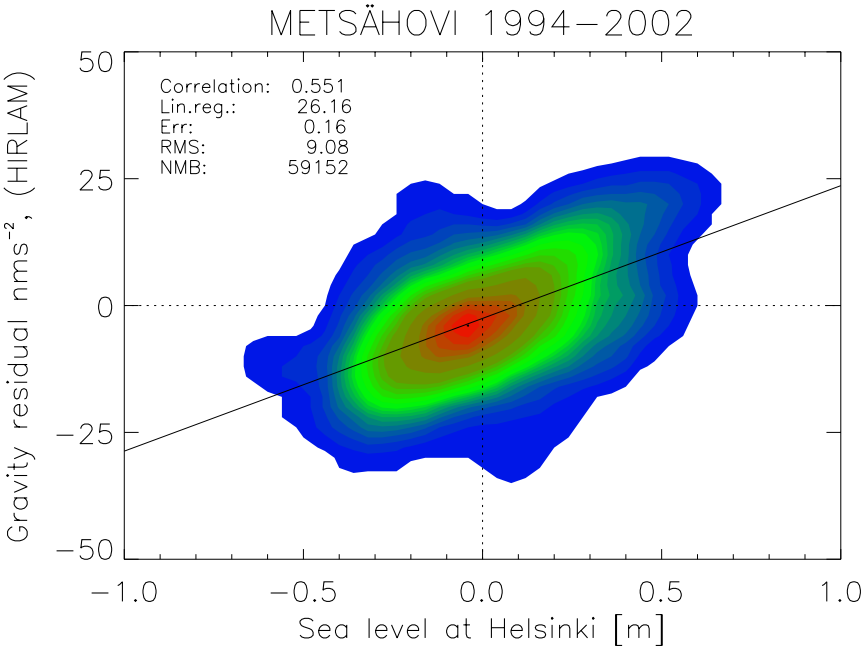


Change in the gravity difference between sites on the land uplift gravity line 63°N according to relative measurements in 1966–2002. In the plot, the gravity in Joensuu is increasing relative to Vaasa; in fact the gravity is decreasing at both sites, but more so in Vaasa where land uplift is about 5 mm/yr greater than in Joensuu.

The G-600 with MVR was successfully used in the measurement of the Finnish section of the land uplift gravity line along the latitude 63°N from Vaasa to Joensuu. The purpose of the work is to investigate the variation in gravity due to the Fennoscandian postglacial rebound, and the time series goes back to 1966. The measurements in 2002 were performed in cooperation with the Estonian Land Board. In addition to the G-600, the LCR gravimeters G-55, G-113 and G-115 were used.

Research into the influence of local water storage on gravity at Metsähovi was continued, using the observations of the superconducting gravimeter. The work being done in cooperation with Helsinki University of Technology (HUT; Department of Rock Engineering), the Finnish Environment Institute (FEI), and the Geological Survey of Finland. The Academy of Finland is financing a 3-year project, "Modelling and monitoring local hydrological effects in gravity". The responsible scientist is Professor Markku Peltoniemi (HUT). In 2002 HUT tested the use of GPR (Ground Penetrating Radar) to map sediments and rock fractures. FEI installed an array of TDR (Time Domain Reflectometer) sensors for soil moisture.

Modelling of the influence of atmospheric masses and Baltic sea level on gravity at Metsähovi continued in cooperation with the Finnish Meteorological Institute (FMI) and the Finnish Institute of Marine Research (FIMR). FIMR provided tide gauge data and FMI provided the detailed regional air pressure grid from the HIRLAM (HIgh Resolution Limited Area Model). Two methods of modelling gravity were analysed: (1) Integration of the attraction and of the deformation effect using air pressure and sea level grids, taking into account the elastic properties of the Earth. (2) Single coefficients for the admittance of local barometer and sea level readings into gravity, derived from regression and/or grid integration. In terms of root-mean-square reduction in the gravity residual of the superconducting gravimeter, single coefficients are nearly as effective as the grid integration, but shortcomings appear in extreme situations like the passage of a cyclone.



Regression of the 59152 hourly gravity residuals of the superconducting gravimeter at Metsähovi on the sea level record at the Helsinki tide gauge (1994–2002). The point distribution is shown as colour-coded density (red is highest). Prior to plotting, instrumental drift and the following physical effects were removed from the gravity record: Earth and ocean tides, atmospheric attraction and loading, groundwater attraction, polar motion, postglacial rebound. The spread on the vertical axis shows that the models for these effects are able to predict the temporal variation in the acceleration of free fall to better than 50 nms^{-2}, i.e. 5×10^{-9}.

International comparisons

ICAG-2001

The final report of the Sixth International Comparison of Absolute Gravimeters (ICAG-2001) that took place at the BIPM in Sèvres in June–August 2001 was published in *Metrologia*. FGI participated with the JILAg-5. After measurements on two sites (B1 and B) its laser failed and measurements on the remaining A and A2 were performed with a hybrid device: the JILAg-5 with the interferometer of JILAg-1. In the evaluation they are treated as two different instruments, JILAg-5 and JILAg-5/1.

Two different reference values are used in the report: (1) the unweighted mean of all 17 participating instruments, and (2) a weighted mean, where in addition four instruments are eliminated, among them those of the FGI and the IMGC. The reason for the rejection of FGI and IMGC from the second reference value is that neither institute (due to their data acquisition hard- and software) was able to provide the raw interferometric data.

A remarkable feature of the ICAG-2001 is that the uncertainty of the mean of all gravimeters was much larger (55 nm s^{-2} after the rejection and the weighting) than during the previous comparison ICAG-97 when it was 28 nm s^{-2}. This is due to increased inter-instrument scatter. The reason for this is not understood. Some fairly large intra-instrument discrepancies were also noted.

The difference of the two measurements with the JILAg-5/1 was 18 nm s^{-2} and with the JILAg-5 only 3 nm s^{-2}, both among the smallest of the participating instruments. The offset of the JILAg-5/1 relative to the unweighted reference value was

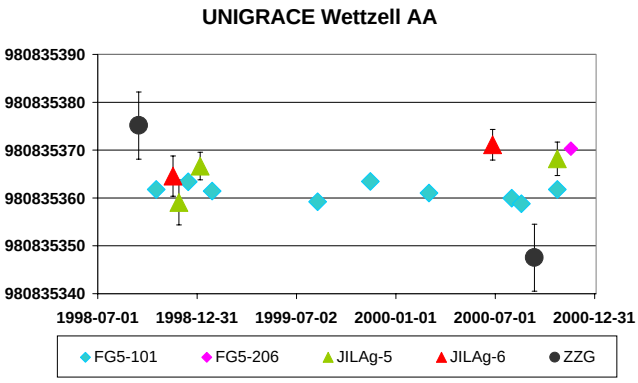
+57 nm s^{-2}, which is satisfactory. The offset of the JILAg-5 was, however, quite large, +144 nm s^{-2}. The reason for this is not known but it could be related to the impending laser failure. Offsets relative to the weighted value are 27 nm s^{-2} less.

The estimation of uncertainty for absolute gravimeters remains a difficult question and was not directly tackled in the comparison. The participants were not asked to provide uncertainty estimates to gauge their offsets against. The final report uses uncertainties estimated from intra-instrument discrepancies but only for drawing error bars in plots. The performance of the FGI instruments can, however, be gauged against the self-declared uncertainty of 200 nm s^{-2} (k=2) in the unofficial CMC tables, and against the self-declared statistical uncertainty of 50 nm s^{-2} (k=1).

UNIGRACE

Altogether 12 countries participated in the UNIGRACE (Unification of Gravity Systems of Central and East European Countries) project. Absolute gravimeters were provided by Germany, Austria, Poland, Finland, and France. A total of 19 stations were measured in Austria, Bulgaria, Croatia, the Czech Republic, Germany, Finland, Hungary, Italy, Poland, Romania, the Slovak Republic, and Slovenia. Of them, 16 were observed by at least two absolute meters. The first field campaign was performed in 1998–1999 and the second in 2000–2001. Reference sites Jozefoslaw (Poland) and Wettzell (Germany) were measured by all absolute meters in both campaigns.

The final results of the UNIGRACE measurements became available in 2001. They showed that gravity variations of the order of 100 nm s^{-2} during the project cannot be excluded, not even at the reference sites. It was hoped that they could be described by "station uncertainty", distinct from measurement uncertainty. In order to better separate the two in the final evaluation, it was decided to await the results of ICAG-2001.



Results at the UNIGRACE reference site Wettzell, point AA, with 5 different absolute gravimeters. The plot is adapted from the project final report. The unit on the vertical scale is 10 nm s^{-2}. Error bars are single-set standard deviations. Groundwater effects of more than 100 nm s^{-2} peak-to-peak have been corrected for.

The final UNIGRACE report was submitted in 2002. An evaluation of UNIGRACE instruments in ICAG-97, ICAG-2001, and in UNIGRACE itself was made using the FG5 No. 101 of BKG (Bundesamt für Kartographie und Geodäsie) as a reference. However, only the results of JILAg-5 of the FGI were consistent enough to motivate the determination of an offset (+44 nm s^{-2} with standard deviation 16 nm s^{-2}).

In view of this, the final UNIGRACE results were compiled as unweighted means of the instruments used at each station, lumping variation in gravity and measurement errors. The combined statistical uncertainty is at most sites well below 50 nm s^{-2} (k=1).

Publications

H. Virtanen and J. Mäkinen (2002): The effect of the Baltic sea level on gravity at the Metsähovi station. *J. Geodynamics*, in press.

L. Vitushkin, M. Becker, Z. Jiang, O. Francis, T. M. van Dam, J. Faller, J.-M. Chartier, M. Amalvict, S. Bonvalot, N. Debeglia, S. Desogus, M. Diament, F. Dupont, R. Falk, G. Gabalda, C. G. L. Gagnon, T. Gattacceca, A. Germak, J. Hinderer, O. Jamet, G. Jeffries, R. Käker, A. Kopaev, J. Liard, A. Lindau, L. Longuevergne, B. Luck, E. N. Maderal, J. Mäkinen, B. Meurers, S. Mizushima, J. Mrlina, D. Newell, C. Origlia, E. R. Pujol, A. Reinhold, Ph. Richard, I. A. Robinson, D. Ruess, S. Thies, M. Van Camp, M. Van Ruymbeke, M. F. de Villalta Compagni, S. Williams (2002): Results of the Sixth International Comparison of Absolute Gravimeters ICAG-2001. *Metrologia* 39, 407–424.

Conferences

J. Mäkinen (2002): Absolute gravity measurements at the Finnish Antarctic base Aboa in 1994 and 2001. Third Meeting of the International Gravity and Geoid Commission, Gravity and Geoid 2002 – GG2002. Thessaloniki, Greece, August 26–30, 2002. Book of Abstracts, p. 108 (Abstract).

J. Mäkinen (2002): Postglacial rebound from absolute-gravity records in Finland. Third Meeting of the International Gravity and Geoid Commission, Gravity and Geoid 2002 – GG2002. Thessaloniki, Greece, August 26–30, 2002. Book of Abstracts, p. 109 (Abstract).

J. Mäkinen (2002): The standardization of gravity. Workshop IMG-2002. "Instrumentation and Metrology in Gravimetry". October 28–30, 2002, Münsbach Castle, Luxembourg. Program and Abstracts, p. 19 (Abstract).

H. Ruotsalainen (2002): The Fennoscandian land uplift gravity lines—a tool for the Nordic geodynamical studies. In: M. Poutanen, H. Suurmäki (eds), *Proceedings of the 14th General Meeting of the Nordic Geodetic Commission, Espoo, Finland, October 1–5, 2002*. Finnish Geodetic Institute, pp. 107–110.

H. Virtanen and J. Mäkinen (2002): Air pressure and Baltic Sea loading corrections to gravity data at Metsähovi. In: M. Poutanen, H. Suurmäki (eds), *Proceedings of the 14th General Meeting of the Nordic Geodetic Commission, Espoo, Finland, October 1–5, 2002*. Finnish Geodetic Institute, pp. 148–153.

H. Virtanen, J. Mäkinen, M. Bilker, M. Poutanen, S. Haarala and K. Kahma (2002): Loading effects from the Baltic Sea and atmosphere in Metsähovi, Finland, EGS XXVII General Assembly, Nice, 21–26 April, 2002. Geophysical Research Abstracts, vol. 4 (Abstract).

Reports

J. Mäkinen (2002): UNIGRACE Copernicus Programme, contract No. ERBIC15CT970805. Finnish Geodetic Institute, Partner Final Report, 8 p.

H. Virtanen (2002): Summary of observations in Metsähovi 1994–2001 with T020. *Bull. Inf. Marées Terrestres* 135, 10605–10606.

Intercomparison reports

Unification of Gravity Systems in Central and Eastern Europe (UNIGRACE). Final report. Contract Number ERBIC15CT970805. Submitted to the European Commission, 32 p.

Lectures

J. Mäkinen: The treatment of long-term gravity change in the United European Gravimetric Reference Network UEGN2002. The Fennoscandian postglacial rebound. Workshop on UEGN2002 preparations and coordination of absolute gravimetric activities in Europe. Vienna, 13–14 May, 2002.

H. Ruotsalainen: Maannousulinjat pohjoismaissa. Mittaus- ja kartoitustekniikan sekä geoinformatiikan tutkijakoulu, Espoo, 25–28 November 2002.

H. Virtanen: Itämeren ja ilmakehän aiheuttama kuormitus maankuoreen. GPS-meteorologia-seminaari, 27 November 2002. Ilmatieteen laitos.

Other activities

T. Oja (Estonian Land Board) visited FGI for relative gravity work, 19 to 27 September. He calibrated LaCoste&Romberg gravimeters G-4, G-113 and G-115 on the Masala–Vihti line, and

participated in the measurements on the land uplift gravity line 63°N with the gravimeters G-113 and G-115.

Jaakko Mäkinen is a substitute member of the Advisory Commission for Metrology (ACM) and a member of the expert group for mass and derived quantities within ACM.

Jaakko Mäkinen is the national representative of Finland in the International Gravity and Geoid Commission (IGGC) of the International Association of Geodesy. He is also a member of Working Group 6 "Comparison of Absolute Gravimeters" of the IGGC.

Jaakko Mäkinen is a member of the CCM Working Group on Gravimetry.

Temperature

Temperature

Thua Weckström	Senior Research Scientist, Head of Laboratory, Group Leader
Leena Uusipaikka	Research Scientist
Hannu Räsänen	Research Assistant

Realisation, traceability

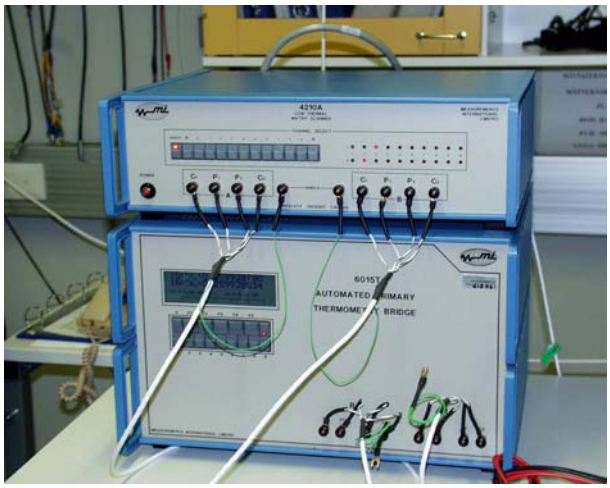
Realisation of the International Temperature Scale of 1990 (ITS-90) between the Argon point (-189.3442 °C) and the Silver point (961.78 °C).

Maintenance

Some of the digital multimeters and the standard resistors were calibrated, and the linearity of the ASL F18 bridge was checked. The reference pyrometer was calibrated at the Silver point.

The list of instructions for calibration in the laboratory was expanded after the visit from the technical assessor from SWEDAC.

The power source in the scanner for the ASLF18 AC bridge has been replaced. The new MI 6015T DC bridge (see Fig.) has been compared to the AC bridge. The difference is within the specifications. The DC bridge seems to pick up much less electrical noise than the AC bridge. The software for the MI bridge and scanner needs some corrections.



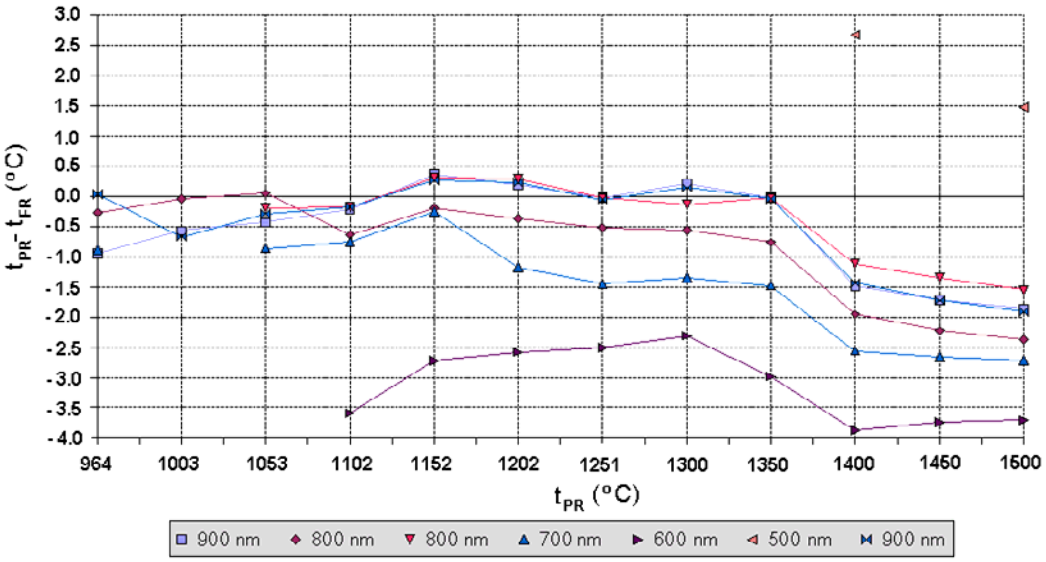
New DC bridge and scanner.

Development

Temperature measurements with a filter radiometer and a pyrometer

In this project the thermometry laboratory and the HUT Metrology Research Institute are working together to compare the International Temperature Scale of 1990 to filter radiometer techniques. The temperature of a blackbody radiator is measured using the reference pyrometer of the thermometry laboratory and a filter radiometer from the HUT Metrology Research Institute. When using the reference pyrometer the temperature is determined according to ITS-90, i.e. by comparing the signal from a source with known temperature to the signal from the source with unknown temperature. With the filter radiometer the temperature is determined from the spectral

radiance, which is calculated from the spectral irradiance measured at known distance from an aperture of known area. The two methods are therefore fundamentally different. In 2002 measurements were made in the temperature range 960 °C to 1500 °C. Alignment techniques were improved and the effect of the alignment and measuring distance on the filter radiometer was investigated. The new blackbody furnace of the thermometry laboratory was used for the measurements. The differences between the temperatures measured using the filter radiometer and the temperatures measured according to ITS-90 are shown in Figure. The difference depends on the temperature of the blackbody and the measurement wavelength.



Differences between temperatures measured using the MIKES reference pyrometer (t_{PR}) and the HUT filter radiometer (t_{FR}). The notations under the figure denote the different filters used.

International comparisons

In 2000, the laboratory took part in the TRIRAT measurements within the EU Framework IV. The results were published in 2002. The MIKES results for the temperature range between 400 °C and 900 °C were unsatisfactory due to problems with the laboratory's blackbody furnace. The furnace has now been replaced with a new one.

In 1998, the laboratory also participated in EUROMET project 391 (Intercomparison of Indium Cells). The results will be published for the conference report of the 8th Symposium on Temperature, Its Measurement and Control in Science and Industry, Chicago, October 2002.

The measurements for EUROMET project 412 (key-comparison of calibration lamps) were completed at the start of 2001. The results were not yet evaluated in 2002.

In 2001, the laboratory took part in EUROMET projects 549, Intercomparison of Water Triple Point Cells and 502, Intercomparison of Argon Triple Point Cells. No results are yet available.

In 2002, the laboratory took part in EUROMET project 635, in which two surface thermometers were calibrated. The results should have been ready in the summer of 2002, but evaluation of the results has been more troublesome than anticipated.

The laboratory is currently taking part in EUROMET project 552, which is an RMO comparison corresponding to the key comparison KC-3. The task is the calibration of an SPRT at all fixed points between Argon (-189.3442 °C) and Zinc (419.527 °C).

The European projects in Thermometry in which MIKES has participated usually have 15-20 participants.

International intercomparisons for accredited calibration laboratories

Two laboratories took part in the EA comparison Th-10, in which type K and type S thermocouples were calibrated. The thermocouples were also calibrated at MIKES. The results for the type S thermocouple were excellent, but the type K thermocouples (one per laboratory) gave a larger spread in the results.

Conferences

Convection effects in a small portable blackbody, T. Weckström and T. Hirvonen, Proceedings of the 8th Symposium on Temperature and Thermal Measurements in Industry and Science, p. 185.

Intercomparison of local temperature scales with transfer radiation thermometers between –50 °C and 300 °C, E.W.M. van der Ham, M. Battuello, P. Bloembergen, R. Bosma, S. Clausen, O. Enouf, E. Filipe, J. Fischer, B. Gutschwager, T. Hirvonen, J.U. Holtoug, J. Ivarsson, G. Machin, H. McEvoy, J. Pérez, T. Ricolfi, P. Ridoux, M. Sadli, V. Schmidt, C. Staniewicz, O. Struss and T. Weckström, Proceedings of the 8th Symposium on Temperature and Thermal Measurements in Industry and Science, p. 831.

L. Uusipaikka gave a presentation on the water triple point cells in Finland at the 8th Symposium on Temperature, Its Measurement and Control in Science and Industry, Chicago, October 2002.

Reports

Lämpötilan mittaus, MIKES julkaisu J1/2002.

Lectures

T. Weckström gave a presentation of the ITS-90 temperature scale and thermometry in Finland at Åbo Akademi and at the Technical University in Tampere.

Other activities

T. Weckström participated in the EUROMET meeting of contact persons for Thermometry at GUM in Warsaw.

T. Weckström is a member of the expert group on Temperature and Derived quantities of the Advisory Commission for Metrology in Finland. L. Uusipaikka is the secretary of this group.

T. Weckström has worked as a technical assessor for the Finnish Accreditation Service.

L. Uusipaikka attended a course on Infrared Thermometry at NIST.

L. Uusipaikka participated in the CCT workshop: "Towards the ITS-XX" in Chicago 25 October 2002.

T. Weckström participated in the International Workshop: Data Analysis of Interlaboratory Comparisons in Berlin 5–6 December 2002.

T. Weckström also participated in the MERA workshop (MERA = Metrology in the European Research Area) in Rotterdam 16-17 December 2002.

Humidity

Dew-point temperature • Relative humidity

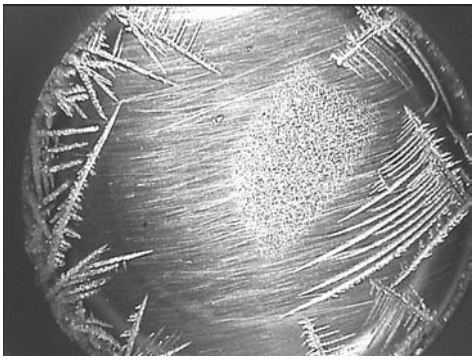
Martti Heinonen — Senior Research Scientist, Head of Laboratory
Hannu Räsänen — Research Assistant

The dew-point temperature and relative humidity scales were realised with two-temperature generator systems.

The thermometer of the MSPG generator was replaced by an ASL F700B resistance bridge with a switching unit for eight PRT sensors. A new test chamber system was constructed for calibrations of capacitive dew-point hygrometers.

Development of comparison methods for humidity

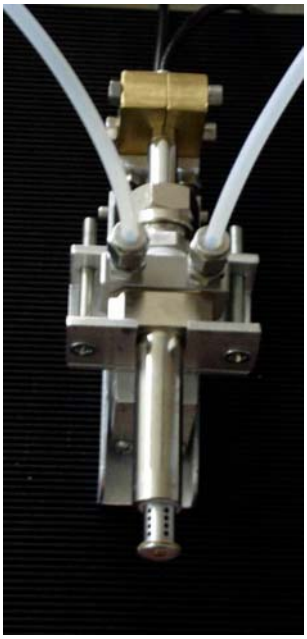
Studies on the use of a chilled mirror hygrometer as the transfer standard were continued with Industrial Research Ltd (New Zealand). The tests for the saturator-based comparator were completed. All the results were reported at the ISHM 2002 Conference in Taipei (September 2002).



Unsatisfactory condensed layer on the mirror of a dew point hygrometer.

According to the results, the sample flow rate significantly affects the performance of chilled mirror hygrometers. The effect of the mirror cleaning method, however, seems to be insignificant if there is no visible contamination on the mirror. Tests with a larger number of hygrometers and in a wider dew-point temperature range are needed for general conclusions.

The results also show that the thermal control in the dew-point sensor head of the comparator should be improved. The RH sensor head construction seems to be promising.



A new RH sensor head for a saturator-based humidity comparator.

Extending the measurement range of the MIKES Humidity Laboratory

A new dew-point temperature generator system was designed to cover the range –80 °C to +85 °C. The low-range saturator system was constructed by developing the MSPG generator further. The extended uncertainty of the realised dew-point temperature scale is between 0.04 °C and 0.06 °C in the range above –60 °C. Tests in the range below –60 °C will be completed in 2003.

A new test chamber system for relative humidity calibrations was designed. The temperature range in calibrations will cover –40 °C to +85 °C.

The results of the project were reported at the ISHM 2002 Conference in Taipei (September 2002).

International comparisons

CCT-K5: "Key comparison on humidity standards", Participants: China, ES, FI, IT, Japan, NL, RUS, Singapore, UK, USA. Measurements started at the pilot laboratory (NPL, UK). Measurements at MIKES in March to April 2003.

EUROMET 621: "Key comparison(s) in humidity (dew-point temperature)". Regional key comparison co-ordinated by MIKES. 22 participants including Russia and South Africa. The comparison scheme with three parallel loops was planned and an early draft technical protocol was prepared. First measurements at MIKES in summer 2003.

International (EA or other) intercomparisons for accredited calibration laboratories

M-02TdC001: "Comparison of dew-point temperature calibrations". Within the MIKES customer service, a dew-point temperature comparison was co-ordinated and piloted by the MIKES Humidity Laboratory in 2002. Two laboratories in Finland and Sweden participated in the project. Measurements were completed in August 2002. The final report will be completed in February 2003.

National intercomparisons for accredited calibration laboratories

M-02RHC001: "Comparison of relative humidity calibrations". Within the MIKES customer service, a relative humidity comparison was co-ordinated by the MIKES Humidity Laboratory in 2002. One Finnish laboratory participated in the project. Measurements were completed in November 2002. The final report will be completed in March 2003.

Publications

M. Heinonen, A comparison of humidity standards at seven European national standards laboratories, *Metrologia* **39** (2002) 303-308.

M. Heinonen, The concept of humidity in metrology, submitted to *Metrologia*.

Conferences

M. Heinonen, J. Lovell-Smith, Investigation of chilled mirror hygrometers, in: *ISHM 2002 Taiwan. Papers from the 4th International Symposium on Humidity and Moisture*, ITRI 2002, pp. 397-404.

M. Heinonen, A new equipment for dew-point temperature investigations and calibrations, in: *ISHM 2002 Taiwan. Papers from the 4th International Symposium on Humidity and Moisture*, ITRI 2002, pp. 485-492.

M. Heinonen, A saturator-based transfer standard for humidity, in: *ISHM 2002 Taiwan. Papers from the 4th International Symposium on Humidity and Moisture*, ITRI 2002, pp. 506-512.

Reports

M. Heinonen, Kosteusmittauksista enemmän hyötyä, Tiimalasi 1/2002.

S. Semenoja, T. Ehder, A. Lassila, M. Heinonen (editors), Metrologiasta lyhyesti, suomennettu painos 2002, Mittatekniikan keskus, Helsinki.

Lectures

M. Heinonen, Kosteusmittausten luotettavuus, RT-täydennyskoulutus: Kosteusmittausten luotettavuus rakentamisessa ja kiinteistön ylläpidossa, Rakennustieto Oy, 5 March 2002, Helsinki.

M. Heinonen, Previous European comparisons in humidity, EUROMET Humidity Workshop, Warsaw, Poland, 8 April 2002.

M. Heinonen, Investigation of chilled mirror hygrometers, 4th International Symposium on Humidity and Moisture (ISHM2002), Taiwan, 16-19 September 2002.

M. Heinonen, MIKES activities on humidity standards, NMIJ/AIST, Tsukuba, Japan, 17 December 2002.

Other activities

M. Heinonen is a member of the Expert Group on Temperature Measurements, Advisory Commission for Metrology.

M. Heinonen is a member of the Working Group 5 (CMC tables, humidity) of EUROMET/THERM.

M. Heinonen acted as a referee for Metrologia.

M. Heinonen is a member of the planning committee of the AEL-INSKO training course on humidity and moisture measurements in industry.

A peer review of the MIKES Humidity Laboratory was carried out by SWEDAC (Technical expert: Mark Stevens, NPL).

M. Heinonen is chairman of a EUROMET Expert Group on Humidity.

M. Heinonen represented FINAS at the meeting of the EA Temperature and Humidity Experts Group, IPQ, Portugal, 26 to 27 September 2002.

A co-operative project on dew-point temperature standards was initiated with SP (Sweden).

A co-operative project on testing pressure and humidity sensors at low temperatures was carried out with the Finnish Meteorological Institute.

Tests for a new type of condensation hygrometer were carried out for Vaisala Oyj.

M. Heinonen was a member of the Peer Review Team at the NMIJ/AIST, Tsukuba, Japan, 16 to 18 December 2002.

M. Heinonen is a member of the planning committee of a seminar on moisture measurements in buildings (Advisory Commission for Metrology).

Visitors

Mark Stevens, NPL, UK, 5 to 6 February 2002.

Per Jacobson, Svein Ruud, SP, Sweden, 10 December 2002.

Ionising radiation

Air kerma • Reference air kerma rate • Absorbed dose to water • Absorbed dose to soft tissue • Ambient dose equivalent • Directional dose equivalent • Personal dose equivalent

Antti Kosunen	Head of Laboratory, Physicist
Tuomo Komppa	Physicist
Ilkka Jokelainen	Physicist
Olli Harju	Physicist
Teuvo Parviainen	Technician
Harri Lindroos	Technician
Ilkka Aropalo	Technician
Matti Toivonen	Physicist
Markku Tapiovaara	Physicist
Hannu Järvinen	Physicist
Petri Sipilä	Physicist
Ritva Parkkinen	Physicist
Carita Ruuhonen	Secretary

Radiation and Nuclear Safety Authority is the National Standards Laboratory for ionising radiation quantities.

Air kerma, absorbed dose to water: Secondary standards are ionisation chambers used with the irradiation facilities for ^{60}Co and ^{137}Cs gamma radiation and X-ray equipment (10-320 kV). The standard chambers are calibrated at BIPM, France (therapy level) and at PTB, Germany (protection level).

Ambient dose equivalent, directional dose equivalent, personal dose equivalent, absorbed dose to soft tissue: For gamma and X radiation the dose equivalent quantities are determined using the air kerma standards and physical conversion factors. For beta radiation the standards are beta ray sources (^{90}Sr/^{90}Y) calibrated at PTB, Germany. Other standard beta sources (^{204}Tl and ^{147}Pm) are calibrated in the laboratory using an extrapolation ionisation chamber (a primary standard) and physical data. For fast neutrons the secondary standard is a ^{241}Am-^{9}Be radioactive source calibrated at NPL, UK. For other ^{241}Am-^{9}Be radioactive sources with different activities the transfer standard is a proportional counter.

Reference air kerma rate: Standards are two well-type ionisation chambers with a calibrated ^{60}Co radioactive source. The calibration of the standard ^{60}Co gamma source is traceable to BIPM, France through the air kerma standards of the laboratory. For gamma sources of ^{125}I, ^{195}Ir, ^{137}Cs, and ^{103}Pd the calibrations of the well chambers are also traceable to NIST, USA through the calibrations at the dosimetry laboratory of the University of Wisconsin, USA.

Maintenance

The quality of all equipment used for calibration and testing was controlled regularly according to a documented quality control programme. The stability of the secondary standards remained good. The established action levels for stability test results were not exceeded. For X-rays a new BIPM equivalent set of radiation qualities was established.

The renovation of the irradiation facility used for protection level calibrations was started. As a whole, the renovation process includes implementation of a new radiation beam collimator and the electronics of the source selector/shutter system. New ^{137}Cs radiation sources are planned to be implemented within the next few years.

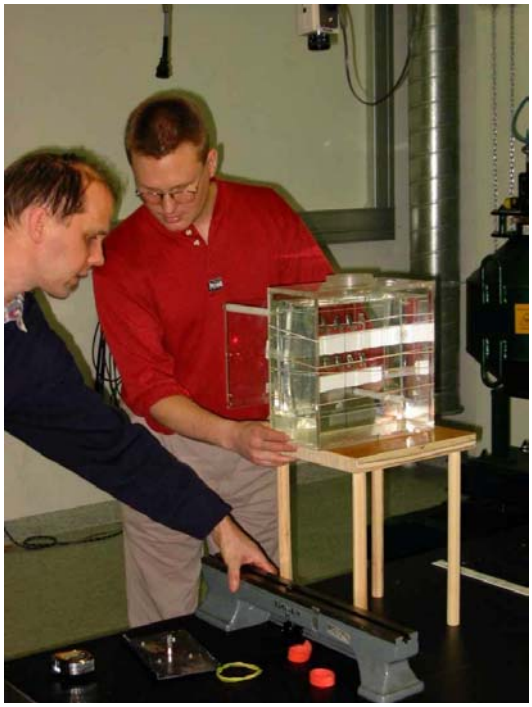
Development

Measurement and calibration methods for boron neutron capture therapy (BNCT) were studied. The laboratory participated in an EU-funded shared cost project under the Standards, Measurement and Testing Program for 1998-2000. The aim of the project is to develop a European Code of Practice for BNCT dosimetry. Eleven partners from seven countries are participating in the project, which is expected to be finished in 2003.

In the period 2001-2003 the calibration method of dosemeters used for external beam radiotherapy will be changed. The *air kerma* based approach will be superseded by the standards and methods of *absorbed dose to water*. The methods for dose measurement and calibration to be used in Finland will mainly be based on the new guidance of the International Atomic Energy Commission (IAEA). The adoption of the *absorbed dose to water* approach is done in close co-operation with the SSDLs of Sweden and Norway. For ionisation chamber detectors used in external beam radiotherapy the first calibrations for radiotherapy clinics were delivered. The first draft of the "National Code of Practice for radiotherapy dosimetry" including external beam and brachytherapy dosimetry was presented at the International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, IAEA, Vienna.

The laboratory is participating in an EU shared cost project of digital imaging, interventional radiology and dosimetry, DIMOND III. Linked to the needs also detected in this project, the calibration and measurement methods for *dose-area product (DAP)* meters used in X-ray diagnostic dosimetry have been outlined. Tests for DAP calibrations were performed and a draft for the method was discussed in a meeting with Finnish experts of medical X-ray technique.

For co-ordination the implementation of the MRA in the area of ionising radiation a meeting was arranged with representatives of the Finnish Centre for Metrology and Accreditation and the Radiation and Nuclear Safety Authority-STUK.



Irradiation of personal dosemeters for quantity of dose equivalent. Set-up of dosemeters on a water phantom.

Intercomparisons

In 2002 the laboratory participated in the regular annual dosimetry audit comparison for absorbed dose to water arranged within the Network of Secondary Standard Dosimetry Laboratories of the International Atomic Energy Agency (IAEA)/WHO. This comparison was arranged using thermoluminescent dosemeters as transfer instruments. Measurements were performed using the ^{60}Co gamma radiation beam at the laboratory of STUK and a 6 MV photon beam of a medical accelerator (at a radiotherapy clinic). The results of STUK deviated from the reference value of IAEA by –0.5 % for ^{60}Co gamma radiation, and by 0.6 % for 6 MV photons. Both these results were well within the action limit of 3.5 % stated by the IAEA. The combined uncertainties (1 SD with coverage factor 2) were approximately 1.0 % for ^{60}Co gamma radiation and 1.2 % for 6 MV photons.

The preliminary results of the two comparisons performed in 2001 and organised by European Co-operation for Accreditation (EA): *Interlaboratory comparison (IR3), calibration of a radiation protection dosemeter and Interlaboratory comparison (IR4), calibration of a personal dosemeter for personal dose equivalent $H_p(10)$* were available. The preliminary results indicate good consistency relative to the stated uncertainties and to the reference values of the comparisons.

The laboratory participated in the evaluation of the results of EUROMET 526 comparison; *calibration of dosemeters used in mammography with different X-ray qualities (20 kV to 50 kV).* The final report of the comparison is due to be published in 2003.

Conferences

Kosunen A, Sipilä P, Järvinen H, Parkkinen R, Jokelainen I. A Finnish national code of practice for reference dosimetry of radiation therapy. Book of extended synopses. IAEA-CN-96. International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, Vienna, Austria, 25-28 November 2002: 47.

Parkkinen R, Kosunen A, Sipilä P, Järvinen H. Development of calibration procedures for the electron beam calibration of plane parallel ionization chambers. Book of extended synopses. IAEA-CN-96. International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, Vienna, Austria, 25-28 November 2002: 66-67.

Karppinen J, Tapiovaara M, Järvinen H. The dose-length product (DLP) is the basic dosimetric quantity in CT. Book of extended synopses. IAEA-CN-96. International Symposium on Standards and Codes of Practice in Medical Radiation Dosimetry, Vienna, Austria, 25-28 November 2002:80-81.

Sipilä P, Järvinen H, Parkkinen R. Dosimetry of cardiovascular beta source. In Abstract Book of the 21th Annual ESTRO Meeting. Radiotherapy & Oncology 2002; Vol. 64, Supplement 1: S21.

Gainey MB, Green S, Uusi-Simola J, Kortesniemi M, Koivunoro H, Seppälä T, Kosunen A. A preliminary in phantom dosimetry intercomparison using TEPCs and ICs performed at the FiR 1 reactor in Finland. Proceedings of Research and Development in Neutron Capture Therapy, Essen, Germany, 8-13 September 2002: 477-481.

Uusi-Simola J, Seppälä T, Kosunen A, Savolainen S. Microdosimetric measurements at FiR 1 using tissue equivalent proportional counter. Proceedings of Research and Development in Neutron Capture Therapy, Essen, Germany, 8-13 September 2002: 379-381.

Kosunen A, Savolainen S, Järvinen H, Auterinen L, Uusi-Simola J, Karila J, Seppälä T, Serén T, Kortesniemi M, Koivunoro H. The code of practice for dosimetry of BNCT in Europe: The Finnish contribution to the project. Proceedings of the 36th annual conference of the Finnish Physical Society, Joensuu, Finland, 14-16 March 2002: 145.

Uusi-Simola J, Kosunen A, Koivunoro H, Savolainen S. Proportional counter based microdosimetry for BNCT. Proceedings of the 36th annual conference of the Finnish Physical Society, Joensuu, Finland, 14-16 March 2002:149.

Quai E, Padovani R, Peterzol A, Vaño E, Guibelalde E, Toivonen M. Maximum dose assessment in interventional cardiology: large area detectors and calculation methods. Book of abstracts: Towards harmonisation of radiation protection in Europe. European IRPA Congress, Florence, Italy, 8-11 October 2002: 233.

Lectures

Finnish national code of practice for reference dosimetry of radiation therapy. Lectures by Kosunen A., Jokelainen I., Parkkinen R. and Sipilä P. The Annual meeting of Finnish radiotherapy physicists and STUK, Lappeenranta, Finland, 23 – 24 May 2002. (In Finnish).

Calibration of DAP meters. Lecture by Komppa T. Meeting of Finnish experts of medical X-ray technique and STUK, Savitaipale, Finland, 29 - 30 September 2002. (In Finnish).

Other activities

The laboratory is a member of the IAEA/WHO International Network of the SSDLs.

Antti Kosunen and Ritva Parkkinen participated in the Nordic meeting on radiation dosimetry, September 30 – October 1, 2002. Oslo, Norway.

Antti Kosunen participated in EUROMET–IR Workshop and Contact Person Meeting of the Technical Committee, 9 – 11 October 2002. Lisbon, Portugal.

Laboratory staff has following memberships:

National Board on Metrology, Antti Kosunen (member).

Eurolab-Finland, Antti Kosunen (member).

Nordisk arbetsgrupp inom dosimetri (Nordic dosimetry group), Antti Kosunen (member).

NACP (Nordic Association on Clinical Physics), Ritva Parkkinen (member).

EUROMET-RAD, Antti Kosunen (contact person).

ESTRO (European Society for Therapeutic Radiology and Oncology), Physics Committee Hannu Järvinen (member).

ICRU (International Commission on Radiation Units and Measurements), Report Committee on Beta Rays for Therapeutic Applications, Hannu Järvinen (chairperson).

ICRU (International Commission on Radiation Units and Measurements), Report Committee on Dosimetric Procedures in Diagnostic Radiology, Hannu Järvinen (member).

ICRU (International Commission on Radiation Units and Measurements), Report Committee on Mammography: Assessment of Image Quality, Markku Tapiovaara (member).

AAPM (American Association of Physics in Medicine), Antti Kosunen (member).

Editorial Board of Radiation Protection Dosimetry, Matti Toivonen (member).

IEC TC 62 (Electrical Equipment in Medical Practice) /SC62C (Equipment for Radiotherapy, Nuclear Medicine and Radiation Dosimetry), Petri Sipilä (contact person and member of the national board).

IEC TC 62 (Electrical Equipment in Medical Practice) /SC 62C (Equipment for Radiotherapy, Nuclear Medicine and Radiation Dosimetry) /WG 3 (Performance of Dosemeters), Antti Kosunen (member of the national board).

IEC TC 62 (Electrical Equipment in Medical Practice) /SC 62C (Equipment for Radiotherapy, Nuclear Medicine and Radiation Dosimetry) /WG 1 (Beam Teletherapy and Particle Accelerators), Petri Sipilä (member of the national board).

IEC TC 62 (Electrical Equipment in Medical Practice), Markku Tapiovaara (member of the national board).

IEC TC 62 (Electrical Equipment in Medical Practice) /SC 62 B (Diagnostic Imaging Equipment), Markku Tapiovaara (contact person and member of the national board).

IEC TC 62 (Electrical Equipment in Medical Practice) /SC 62 B (Diagnostic Imaging Equipment) /WG 20 (Terminology in Medical Radiology), Tuomo Komppa (member of the working group).

ISO TC 85 (Nuclear Energy) /SC 2 (Radiation Protection), Ilkka Jokelainen (contact person and member of the national board).

CENELEC TC 62 (Electrical Equipment in Medical Practice).

Markku Tapiovaara (member of the national board).

Length

Length

Antti Lassila	Senior Research Scientist, Head of Laboratory, Group Leader
Mikko Merimaa	Senior Research Scientist
Kaj Nyholm	Senior Research Scientist
Virpi Korpelainen	Research Scientist
Jarkko Unkuri	Research Scientist
Jari Tuominiemi	Trainee

Realisation, traceability

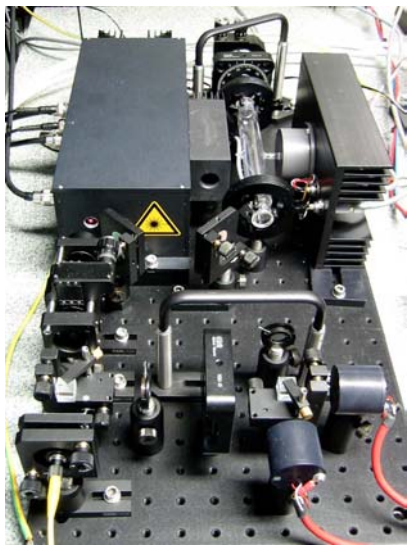
The Finnish primary standard for length is realised by three iodine-stabilised 633 nm helium-neon lasers operated according to the recommendations given by CGPM and CIPM. The expanded uncertainty of the realisation is 5×10^{-11}. In addition, the metre is realised at 543.5 nm wavelength with two iodine-stabilised green He-Ne lasers and at 532 nm wavelength with one iodine-stabilised Nd:YAG laser. These lasers form the basis for traceable length measurements in Finland.

Maintenance

The iodine-stabilised lasers at 633 nm, 543.5 nm, and 532 nm have been maintained in the qualified conditions. Correct operation of the lasers is ensured by regular participation in international comparisons. The calibration service at 532 nm was launched. Interferometers for calibration of long gauge blocks and line scales and a 30 m interferometric measurement rail have been maintained in operational condition. A new versatile measurement program for calibrations with a 30 m interferometric rail has been develop and tested. The program replaced an earlier commercial program and has improved properties for temperature, humidity and pressure measurements. It can also control two separate interferometers for simultaneous measurement of displacement and angle.

Development

Development of an iodine-stabilised Nd:YAG laser at 532 nm

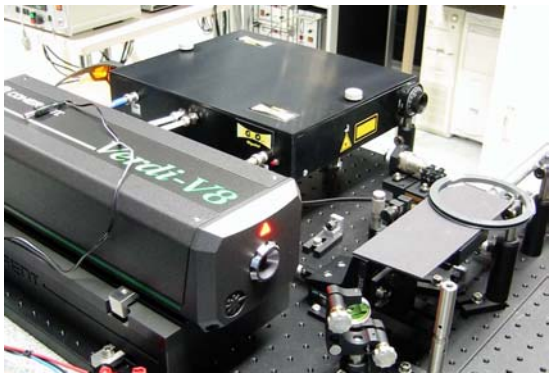


Photograph of the frequency stabilisation set-up.

The frequency stabilisation of the MIKES Nd:YAG laser is based on observing the saturated

absorption of iodine at 532 nm in an external iodine cell. The Nd:YAG laser is directly modulated and the standard third-harmonic detection technique is used. The laser system was characterised in 2001 in an international comparison of Nd:YAG lasers (BIPM, May 2001). Since then the frequency stabilisation set-up has been further improved. The size of the laser set-up has been reduced by one-third and the set-up can now be accommodated with longer iodine cells. An attenuated infrared output is also added for e.g. frequency comb applications. This is a collaboration project with Helsinki University of Technology.

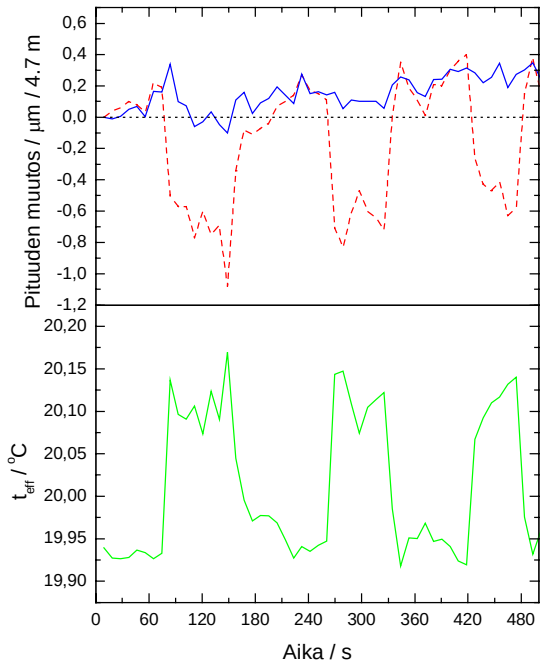
Development of a frequency comb for absolute frequency measurements at the optical range



Photograph of the pump-laser (Verdi-V8), Ti:S laser, fibre collimator and PCF coil.

A new research project was started to construct an optical frequency comb for direct frequency measurements in the optical range. A commercial femtosecond Ti:Sapphire laser (Gigaoptics GigaJet 20) and photonic crystal fibre (PCF) are used to generate a frequency comb extending over a full optical octave. The PCF-expanded frequency comb is collimated into free space and particular frequency ranges are separated for frequency measurements. The frequency comb repetition rate will be locked to a frequency stabilised Nd:YAG laser ($\sigma(2,\tau) \approx 1\times10^{-13}$ at $\tau = 1$ s), which serves as a low-noise oscillator. The repetition rate and frequency comb offset frequency are then determined and referenced against a Cs-atomic clock, which provides a link to the primary frequency standard. To date, most of the components have been purchased or constructed and generation of the frequency comb has been demonstrated. The first absolute frequency measurements will be carried out in 2003. This is a collaboration project with Helsinki University of Technology.

Development of an acoustic method for measurement of the refractive index of air



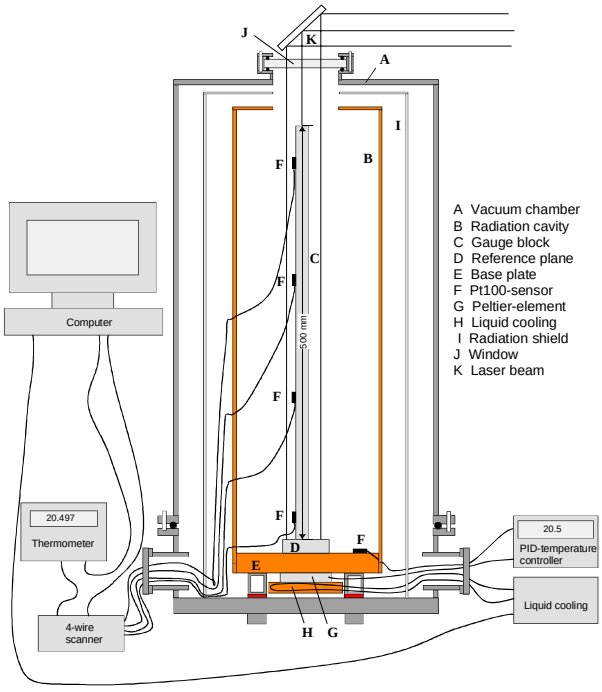
Uncorrected (---) and corrected (—) length differences and (—) effective temperature along the laser beam path. The refractive index, used in the correction, is measured acoustically.

During this project we developed an acoustic method for the measurement of effective air temperature along a laser beam path, and studied the theory and the possibilities of the method. The speed of ultrasound is measured and used to calculate the effective temperature or the refractive index of air. The acoustic transducers are placed symmetrically around a beam splitter and corner cube of the interferometer. Therefore, the time of flight of sound is measured simultaneously over the same distance measured with the length interferometer. The parameters of the Cramer equation for speed of sound were modified to reproduce the measured group velocity of 50 kHz ultrasound. Equations for the effective temperature and the refractive index of air as a function of speed of 50 kHz ultrasound were developed. The standard uncertainty level of 20 mK in determination of effective air temperature could be reached. This corresponds to the relative standard uncertainty of 2×10^{-8} in the refractive index of air. Some results are shown in adjacent figure. The fixed distance (about 4.7 m) was measured using a laser interferometer and the refractive index was measured with an acoustic method. The path was disturbed three times by warm electric radiator. The length differences of magnitude 1 µm were

compensated by acoustic measurement. The project was carried out in co-operation with Data EVM Ltd and it was partly funded by the National Technology Agency (TEKES). This is a joint project with dimensional metrology laboratory.

Development of calibration facility for thermal expansion coefficient

In precision length measurements, the accurate and traceable value of the linear thermal expansion coefficient (LTEC) is needed. A device for interferometric determination of the LTEC of gauge blocks was constructed. Minimum



Schematics of the device.

temperature gradients in a gauge block with 500 mm maximum length and relatively fast operation were the objectives of this project.

For controlled temperature change, the artefacts are placed inside a separate vacuum chamber with an isothermal radiation cavity, where the laser beam of the interferometer can be directed. Two radiation shields form a nearly uniform temperature around the gauge block and protect it from heat radiation from the chamber walls. The temperature is set by changing the temperature of a base plate with two peltier elements. The other side of the peltier element is attached to a water-cooled aluminium plate. The configuration of the chamber and control electronics is presented in figure.

The first test measurements have been done. Typical temperature gradients in a 100 mm steel gauge block are approximately 50 mK. Based on uncertainty analysis LTEC can be measured with an expanded uncertainty of 0.04×10^{-6} 1/K (k=2) for 100 mm gauge blocks. An article about the equipment will be presented at XVII IMEKO World Congress, 2003.

Development project for nanometrology

The construction of a metrological AFM has proceeded. A flexure guided digital piezo-driven xyz table has been acquired for positioning elements. Position measurement will be done by an online measuring 3-d heterodyne interferometer utilising Abbé's principle. The final target of the project is a traceable AFM for calibration of transfer standards of modern microscopes.

The length laboratory has taken part in the preparation of a joint application of European NMIs to the 6th framework program of the EU. The objective of the NANOMET proposal is co-ordinated improvement of nanometre-scale metrology in Europe.

International comparisons

CCL-WGDM nano-3: Line scales

Participants: PTB (DE, Pilot), MIKES (FI) and 13 other NMIs.
The measurements for line scale comparison nano-3 were carried out at MIKES in May 2001. Fifteen laboratories completed the measurements in the period April 2000 to April 2002. The comparison report is under preparation by PTB.

Euromet.L-K2: Long gauge blocks

Participants: NPL (UK, Pilot), MIKES (FI) and 19 other NMIs.
The measurements for the key comparison were carried out in May 2002. The circulation between participants is still ongoing.

Euromet project 639: Northern European comparison: Calibration of gauge blocks by mechanical comparison

Participants: MIKES (FI, pilot), SP (SE), Metrosert (EE), LNMC (LV) and VMC (LT).
The Northern European comparison "Calibration of gauge blocks by mechanical comparison" has been completed. The subject of the comparison was calibration of 11 steel gauge blocks from 0.5 mm to

300 mm. The participants were requested to calibrate the blocks by mechanical comparison with their laboratory's reference gauge blocks as regulated in ISO 3650. The circulation of artefacts among the participants took approximately 5 months. The main purpose of the comparison was to test the ability of the participating laboratories to carry out mechanical gauge block calibrations.

The comparison data were analysed by calculating the weighted mean and corresponding uncertainty for the results of each gauge block. Next the E_n value was used to analyse the statistical consistency of the laboratories' results. The results of the comparison show that the laboratories agree well with the uncertainties they announce, with a statistically insignificant exception. The variation in length values f_o-f_u was quite consistent for most of the gauges. A more detailed final report has been published as MIKES Publication J4/2002. The report is downloadable from MIKES' www-site: http://www.mikes.fi/documents/upload/MIKES_Publication_J4_2002.pdf.

Comparison of 543.5 nm iodine-stabilised HeNe lasers at BIPM

Participants: NPL, CMI, MIKES, IMGC, DFM, NIM and BIPM.

The MGI2 laser of MIKES participated in an international comparison of frequencies of the iodine-stabilised He-Ne lasers at 543 nm held at BIPM, France, in February 2002. Absolute frequency measurement of the R(12)26–0 and R(106)28–0 transitions in 127I2 at 543 nm were also carried out. The principal goal of this comparison was to make a statement of the degree of confidence of such lasers knowing that they are used as a wavelength standard. The results fall excellently within the "mise en pratique" uncertainty.

Publications

M. Merimaa, T. Lindvall, I. Tittonen, and E. Ikonen, "All-optical atomic clock based on coherent population trapping in ^{85}Rb", accepted for publication in *Journal of the Optical Society of America B*.

S. Picard, L. Robertsson, L.-S. Ma, K. Nyholm, M. Merimaa, T. E. Ahola, P. Balling, P. Kren and J.-P. Wallerand, "A comparison of $^{127}I_2$-stabilized requency-doubled Nd:YAG lasers at the BIPM", accepted for publication in *Applied Optics*.

K. Nyholm, M. Merimaa, T. Ahola, and A. Lassila, "Frequency stabilization of a diode-pumped Nd:YAG laser at 532 nm to iodine by using third-harmonic technique", accepted for publication in *IEEE Transactions on Instrumentation and Measurement*.

S. Picard, L. Robertsson, L.-S. Ma, Y. Millerioux, P. Juncar, J.-P. Wallerand, P. Balling, P. Kren, K. Nyholm, M. Merimaa, T. E. Ahola, and F.-L. Hong, "Results from international comparisons at the BIPM providing a world-wide reference network of $^{127}I_2$ stabilized frequency-doubled Nd:YAG lasers", accepted for publication in *IEEE Transactions on Instrumentation and Measurement*.

Conferences

K. Nyholm, M. Merimaa, T. Ahola, and A. Lassila, "Frequency stabilization of a diode-pumped Nd:YAG laser at 532 nm to iodine by using third-harmonic technique", in proceedings of the *Conference on Precision Electromagnetic Measurements*, Ottawa, Canada, June 16 – 21, 2002, pp. 474-475.

B. Hemming, I. Palosuo and A. Lassila, "Design of a calibration machine for optical two-dimensional length standards", in proceedings of SPIE vol. **4902** / *Optomechatronic Systems III*, Stuttgart, Germany, November 12–14, 2002, pp. 670-678.

S. Picard, L. Robertsson, L.-S. Ma, K. Nyholm, M. Merimaa, T. E. Ahola, P. Balling, P. Kren, J.-P. Wallerand, "Results from international comparisons at the BIPM: providing a world wide reference network of $^{127}I_2$-stabilized frequency-doubled Nd:YAG laser", in proceedings of the *Conference on Precision Electromagnetic Measurements*, Ottawa, Canada, June 16 – 21, 2002, pp. 212-213.

M. Merimaa, "Compact frequency stabilized lasers", in proceedings of SPIE vol. 4647/*Functional Integration of Opto-Electro-Mechanical Devices and Systems*, San Jose, USA, January 19-25, 2002, pp. 22-35. (invited).

K. Nyholm, "Optical frequency standard at 532 nm", in proceedings of the *XXXVI Annual Conference of the Finnish Physical Society*, Joensuu, Finland, March 14–16, 2002.

Intercomparison reports

A. Lassila, "Northern European Comparison: Calibration of gauge blocks by mechanical comparison, final report", *MIKES publication* J4/2002, 16 p.

S. Picard, L. Robertsson, L.-S. Ma, K. Nyholm, M. Merimaa, T. E. Ahola, P. Balling, P. Kren and J.-P. Wallerand, "A comparison of $^{127}I_2$-stabilized frequency-doubled Nd:YAG lasers at the BIPM", accepted for publication in *Applied Optics.*

Lectures

A. Lassila: "EA-4/02 mukainen epävarmuuslaskenta", *Pituusmittausten epävarmuuslaskenta* seminar at MIKES, February 1, 2002.

K. Nyholm: "Length metrology", Department of Physics, Åbo Akademi, March 22, 2002.

J. Unkuri: "Interferometrinen lämpöpitenemis-kertoimen määritys", *Mittaukset konepajassa* seminar, Kirkkonummi, MIKES, May 30, 2002.

A. Lassila: "Pituusmetrologia", Production Engineering, Tampere University of Technology, November 7, 2002.

Other activities

A. Lassila, secretary of the Expert Group on Length Measurements, Advisory Commission for Metrology.

A. Lassila was a MIKES delegate at the meeting of CCL-WGDM (Working Group On Dimensional Metrology), BIPM, September 17-18, 2002.

A. Lassila participated in the EUROMET Length Contact Persons Meeting at Maribor, Slovenia, November 14-15, 2002.

A. Lassila participated in an excursion to PTB, METAS and NPL together with design team of MIKES new construction, April 8-11, 2002.

The length group arranged a seminar "Pituusmittausten epävarmuuslaskenta" at MIKES, February 1, 2002.

Visits

A. Lassila visited Length section of NPL, April 12, 2002.

K. Nyholm visited BIPM, February 4-8, 2002.

J. Unkuri visited SP, May 31, 2002.

M. Frennberg (SP) visited length laboratory, February 4-5, 2002.

J. W. Nieuwenkamp (Nmi-VSL) visited length laboratory, May 3, 2002.

M. McCarthy (NPL) visited length laboratory, October 2, 2002.

Several other visitors from Finnish and foreign institutes and industry.

Length - dimensional metrology

Length • Angle • Flatness • Straightness • Roundness • Cylindricity • Surface roughness

Veli-Pekka Esala	Senior Research Scientist, Head of Laboratory
Heikki Lehto	Senior Research Scientist, part time position
Björn Hemming	Senior Research Scientist
Ilkka Palosuo	Research Scientist
Raimo Mylläri	Research Assistant, part time position
Ilkka Raeluoto	Research Assistant
Asko Rantanen	Research Assistant

Length: Displacement measuring laser-interferometers and frequency-stabilised lasers (red and green) were calibrated against iodine stabilised He-Ne lasers. Reference standard gauge blocks were calibrated by a Twyman-Green interferometer with stabilised red and green He-Ne lasers.

Calibration of a collimator to the targets at different distances using align telescope and error separation technique.

Angle: Angle polygons were calibrated with two autocollimators. Autocollimators and the angle options of the laser-interferometers were calibrated with a tangential bar and length measuring instruments. Angle tables were calibrated with polygon and autocollimators using the error separation method.

Calibration of vertical scale of a theodolite with collimator and vertical rotary table.

Flatness: Optical flats up to 150 mm diameter were calibrated using a Fizeau interferometer. Large surface plates were calibrated by a laser-interferometer with angle options by measuring straightness in three directions.

Straightness: Straightness standards were calibrated by a laser interferometer with angle options.

Roundness: Roundness standards (glass ball, flick standards and oval standards) were calibrated with a roundness measuring machine (using multi-step error separation method), length measuring instruments and form measuring instruments. The roundness measuring machine was calibrated with the roundness standards and using the laser-interferometer as scale for the sensor.

Cylindricity: Cylindricity is based on roundness and straightness measurements. The standards were calibrated using error separation (reverse) for straightness.

Surface roughness: The surface roughness measuring machine was calibrated with gauge blocks, optical flats, an autocollimator, laser-interferometer and reference roughness standards.

All other standards and measuring machines were calibrated and maintained according to the documented routines.

Maintenance

Development

Automatic calibration of micrometers

The aim of this project is to develop automatic calibration of micrometers using machine vision. The accuracy of automatic calibration is better than that of manual calibration. In addition, automation makes it possible to take more readings, providing much more information on the properties of the micrometer screw.

2D-optics

The aim of this project is to develop a measuring and calibration instrument for optical 2-dimensional standards. The technical aims for the calibration instrument are:

- measuring range 150 x 150 mm
- expanded uncertainty ± 0.1 µm (k=2).

The mechanics of the equipment consists of an XY table with air bearings, a plane-mirror interferometer system for position measurement, a machine vision-based detection system, and environmental (temperature, pressure and humidity) sensors for the refractive index of air compensation. The measuring software is almost ready and final testing of the system is underway. A detailed uncertainty analysis of position measurement was presented at a SPIE's conference in Stuttgart November 2002.

Traceability of angle measurements

The aim of this project is to develop our accuracy and routine for calibration of polygons, angle gauge blocks, angle optics of the laser-interferometer, autocollimators, theodolites, and several other angle measuring instruments. During 2002 we developed new procedures for calibration of our vertical and horizontal rotary tables, planned a new system fixing the collimator during calibration of theodolites, and bought a new collimator (having four (4) targets at different optical distances) for calibration of the influence of focusing in optical measuring instruments.

Optical flats

The aim of this project is to improve the calibration of optical flats. A ZYGO GPI 6" Fizeau interferometer has been acquired and taken into use. The accuracy of the flatness measurement on a 150 mm diameter is better than 30 nm. Experiments are being performed to use a liquid surface as an absolute flatness reference.

Step Gauge

The aim of this project is to develop an accurate and easy-to-use measuring machine for step gauge calibration. Step gauges are useful length standards, for example in the calibration of co-ordinate measuring machines. The technical aims for the calibration instrument are:

- measuring range: 0-2000 mm
- expanded uncertainty ±0.5 µm/m (k=2).

International comparisons

Euromet 600 comparison of surface texture.
Measurements carried out in February 2002. No preliminary results received by the end of 2002.

National intercomparisons for accredited calibration laboratories

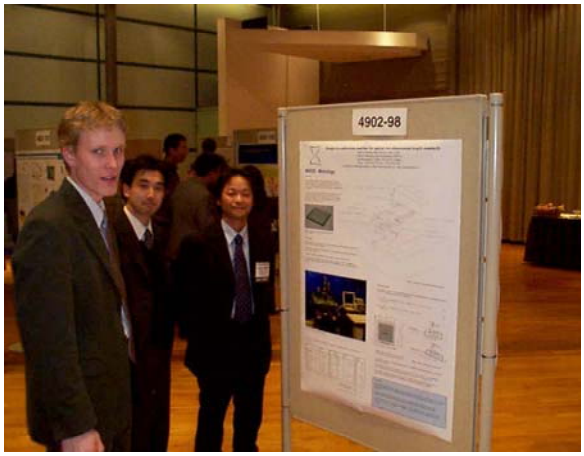
Tampere University of Technology arranged a national comparison for video measurement instruments. The laboratory for dimensional metrology co-operated in the arrangements and reference value measurements for this comparison.

Publications

B. Hemming and H. Lehto, "Calibration of dial indicators using machine vision", Measurement Science and Technology **13** (2002) 45-49.

Conferences

B. Hemming, I. Palosuo and A. Lassila, "Design of a calibration machine for optical two-dimensional length standards", in proceedings of SPIE vol. **4902** / *Optomechatronic Systems III*, Stuttgart, Germany, November 12–14, 2002, pp. 670-678.



Poster of 2D-optics project presented by Ilkka Palosuo (at left) at the SPIE conference *Optomechatronic systems III*.

Reports

B. Hemming and I. Palosuo, "Videomittalaitteet - kalibroinnilla konenäkö tarkaksi", Automaatioväylä **2** (2002).

Lectures

B. Hemming, "Stabiilisuusseuranta ja epävarmuuden arviointi", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

B. Hemming, "Mikrometrin kalibroinnin epävarmuus", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

A seminar on measurement uncertainty was arranged by length group in February 1st, 2002.

H. Lehto, "Pituusmittausten virhelähteitä", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

H. Lehto, "Pituusmittausten epävarmuus käytettäessä laserinterferometriä mittakoneen asteikkona", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

V.-P. Esala, "Kokeellinen toiminta epävarmuustekijöiden suuruuden arvioinnissa", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

V.-P. Esala, "Rengastulkin kalibroinnin epävarmuus", *Pituusmittausten epävarmuuslaskenta* (A seminar on measurement uncertainty), MIKES, February 1, 2002.

H. Lehto, "Digitaalisten kulmanmittauslaitteiden kalibrointi", *Mittaukset konepajassa*, MIKES, Kirkkonummi, May 30, 2002.

H. Lehto, “Kierremittalaitteiden kalibrointi”, Mittaukset konepajassa, MIKES, Kirkkonummi, May 30, 2002.

H. Lehto, “Lämpöpitenemisgradienttien vaikutus geometrisiin mittauksiin”, Mittaukset konepajassa, MIKES, Kirkkonummi, May 30, 2002.

V.-P. Esala, “RR-testit”, *Mittaukset konepajassa,* MIKES, Kirkkonummi, May 30, 2002.

V.-P. Esala, “Control 2002 kuulumiset”, *Mittaukset konepajassa*, MIKES, Kirkkonummi, May 30, 2002.

H. Lehto, ”Kalibroinnit tasolla”, *Mittausvälineiden huolto, tarkastus ja kalibrointi*, AEL, Helsinki, December 2002.

H. Lehto, “Kalibroinnit ilman kalibrointilaitteita”, *Mittausvälineiden huolto, tarkastus ja kalibrointi*, AEL, Helsinki, December 2002.

H. Lehto, “Kalibrointilaitteiden kalibrointi”, *Mittausvälineiden huolto, tarkastus ja kalibrointi*, AEL, Helsinki, December 2002.

H. Lehto, “Kulmanmittauslaitteiden kalibrointi”, *Mittausvälineiden huolto, tarkastus ja kalibrointi*, AEL, Helsinki, December 2002.

H. Lehto, “Korkeusmittalaitteiden ja pituus-mittalaitteiden kalibrointi”, *Mittausvälineiden huolto, tarkastus ja kalibrointi*, AEL, Helsinki, December 2002.

H. Lehto, “Kalibroinnit ja mittausepävarmuus auditoijan näkökulmasta”, Puolustusvoimat/ pääesikunta, Lievestuoreen varikko, February 2002.

V.-P. Esala, Konepajatekniikan mittausten harjoitukset, TKK Konetekniikka, Espoo, spring 2002.

Other activities

V.-P. Esala, member of the Expert Group on Length Measurements, Advisory Commission for Metrology.

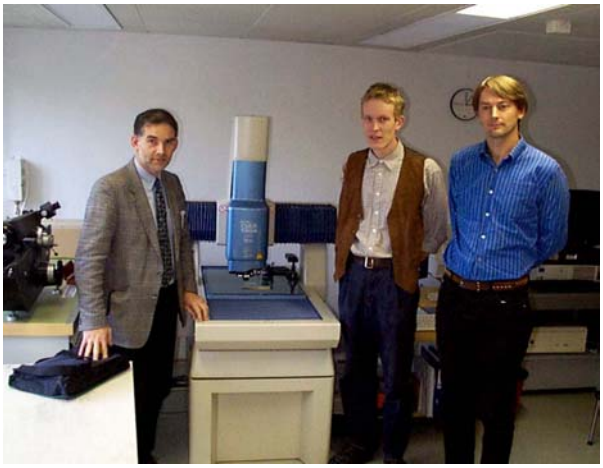
H. Lehto, chairman of working group on metrology, Excellence Finland (SLY).

Other partners in co-operation: IMEKO, SLY, SFS, AEL, EKAKK.

Visits

In 2002 we received many visitors from industry and metrology laboratories both in Finland and abroad.

The laboratory staff visited Mitutoyo Scandinavia in Stockholm in November 2002 (V.-P. Esala, R. Mylläri, A. Rantanen, B. Hemming, H. Lehto and I. Palosuo).



M. McCarthy (NPL) visited dimensional metrology, October 2, 2002.

Length - geodesy

Length

Markku Poutanen	Head of the Department of Geodesy and Geodynamics, Quality Manager
Jorma Jokela	Research scientist, Head of Laboratory
Mikko Takalo	Senior Research Scientist, Deputy Head of Laboratory
Joel Ahola	Research Scientist
Pasi Häkli	Research Scientist
Paavo Rouhiainen	Research scientist

Finnish Geodetic Institute is the National Standards Laboratory for length in geodesy.

Realisation, traceability

Absolute calibrations of quartz gauges (for the Väisälä interference comparator) and calibrations of laser interferometers (for rod calibration) are performed in other NMIs (PTB, MIKES) using internationally recommended laser wavelength standards. The quartz gauge system is maintained by comparisons at the Tuorla Observatory, University of Turku. The scale of the Nummela Standard Baseline is traceable through repeated interference measurements with the Väisälä comparator. Requirements of the ISO/IEC 17025 standard have been implemented in the new quality system of the NSL.

Maintenance

Calibration facilities for EDM instruments at the standard and calibration baselines in Nummela are maintained by projection and control measurements. Calibration facilities for horizontal and automated vertical calibration of levelling rods and system calibration of precise levelling are maintained in Masala.

Development

Three digital levelling systems from the FGI and one from the City of Kajaani were calibrated in the new system calibration comparator. Precise levelling rods from the national surveying and mapping institutes in Latvia, Lithuania, Sweden and Finland were calibrated using the vertical laser rod comparator. The length of a Latvian normal metre was measured using the horizontal laser rod comparator.

The 1320-m geodetic baseline in Lithuania was successfully re-measured in 2001 and proved stable, and was expanded to a test field for tacheometers and GPS equipment. The final report on this co-operation project between the FGI and the Vilnius Gediminas Technical University has now been completed.

The scale of the Eggemoen baseline in Norway was studied by performing a scale transfer from the Nummela Standard Baseline with high precision EDM in May. In September the scale was transferred further to the new Novoberde baseline in Kosovo. The measurements were performed by the Norwegian Mapping Authority. The final report on the measurements is in preparation.

In co-operation between the FGI and Posiva Ltd., a 511-m EDM baseline was established at the Olkiluoto nuclear power plant; the space distances were measured with the Kern Mekometer ME5000 from HUT. The baseline is a part of a GPS network used for local crustal deformation studies since 1994. The purpose is to confirm the scale of GPS observations and to improve the quality of GPS measurements. Calibrations with high precision EDM twice a year during GPS observation campaigns will be continued.

Capability in angle and length measurements was improved by purchasing new top-class tacheometer equipment with high precision reflectors. For the Väisälä interference comparators the National Survey and Cadastre, Denmark, presented the FGI with a set of valuable original parts. Planning of the new premises in Nummela was begun.

Controlling the scale of a local GPS network with high precision EDM.

Automatic calibration of the Zeiss DiNi12 digital levelling system.

Publications

J. Jokela, A. Būga, R. Putrimas and V. Tulevičius: Analysis of repeated calibration of Kyviskės Baseline. Geodezija ir kartografija XXVIII:4, 125-130.

Conferences

J. Ahola: Monitoring local crustal deformations using high precision GPS network. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen and H. Suurmäki), p. 76-79.

J. Jokela: Some contemporary activities in geodetic metrology in the FGI. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen and H. Suurmäki), p. 275-277.

M. Takalo and P. Rouhiainen: On system calibration of digital levels. Proceedings of the XIV General Meeting of the Nordic Geodetic Commission (Ed. M. Poutanen and H. Suurmäki), p. 278-283.

M. Takalo, P. Rouhiainen, P. Lehmuskoski and V. Saaranen: On the systematic behaviour of the digital levelling system Zeiss DiNi12. TS6.6 Engineering Surveys for Industry and Research. FIG XXII International Congress, Washington, D.C., USA, April 19-26, 2002.

Lectures

J. Jokela: Laadunhallinta geodeettisessa testaus- ja kalibrointitoiminnassa. Mittaus- ja kartoitustekniikan sekä geoinformatiikan tutkijakoulu, TKK, M-osasto, Espoo, 25-28 November 2002.

M. Takalo: Korkeuden mittausmenetelmistä ja kalibroinneista. Suurten rakenteiden mittaus – mittaajien pätevöitymiskoulutus. TKK, M-osasto, Espoo, 11-14 November 2002.

M. Takalo: Tests of the digital level Zeiss DiNi12. Meeting of the Working Group of Height Determination of the Nordic Geodetic Commission, HUT, Espoo, March 18-19, 2002.

M. Takalo: The FGI, Department of Geodesy and Geodynamics and the FGI calibration activities. During the visit to the Graz University of Technology, Austria, on February 9-13.

Visits and visitors

M. Takalo visited the system calibration laboratory in the Graz University of Technology, Austria, on February 9-13.

The Working Group of Height Determination of the Nordic Geodetic Commission visited Nummela on March 17.

Harry Bergkvist, Metria, Sweden, performed rod calibration in Masala on March 20-21.

Leif Grimstveit, Norwegian Mapping Authority, performed EDM calibration in Nummela on May 14-16 and 27-28.

A delegation from the State Bureau of Surveying and Mapping of China visited Masala on June 25.

Participants of the XIV General Meeting of the Nordic Geodetic Commission visited Masala on October 2.

Qi Weijun and Fang Aiping, Chinese Academy of Surveying and Mapping, got acquainted with the rod comparator during November 5-26, and visited Nummela on November 22.

Several other visitors and groups from Finland and abroad also visited the NSL during their visits and excursions to the FGI.

Other activities

M. Takalo is the chairperson for the Working Group of Height Determination of the Nordic Geodetic Commission.

Length - CMM

Dimensional quantities measured by a co-ordinate measuring machine (CMM)

Site calibrations of CMMs

Heikki Tikka	Head of Laboratory, Professor
Paul H. Andersson	Professor
Tero Ristonen	Laboratory Manager (calibrations by CMM)
Timo Antila	Laboratory Engineer (site calibr., specially 1D-measuring machines and machine tools)

Tampere University of Technology, Institute of Production Engineering, is nominated by MIKES to act as the Contract Laboratory for co-ordinate measurements.

The reference co-ordinate measuring machine (CMM) SIP CMM5 was calibrated by step gauge, gauge blocks and other reference standards in order to use the substitution method.

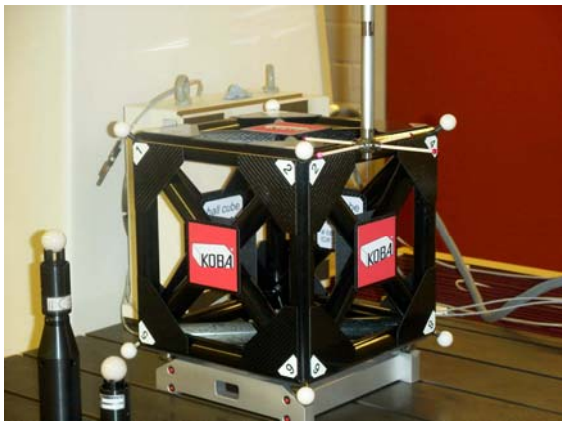
Calibration of the reference step gauge was done by Zeiss Oberkochen (accredited by DKD). Gauge blocks as well other standards were calibrated by the Centre for Metrology and Accreditation (MIKES) in Finland.

Periodical assessment was carried out by FINAS (Finnish Accreditation Service) according to ISO 17025. A new accreditation decision was given by FINAS in 2002.

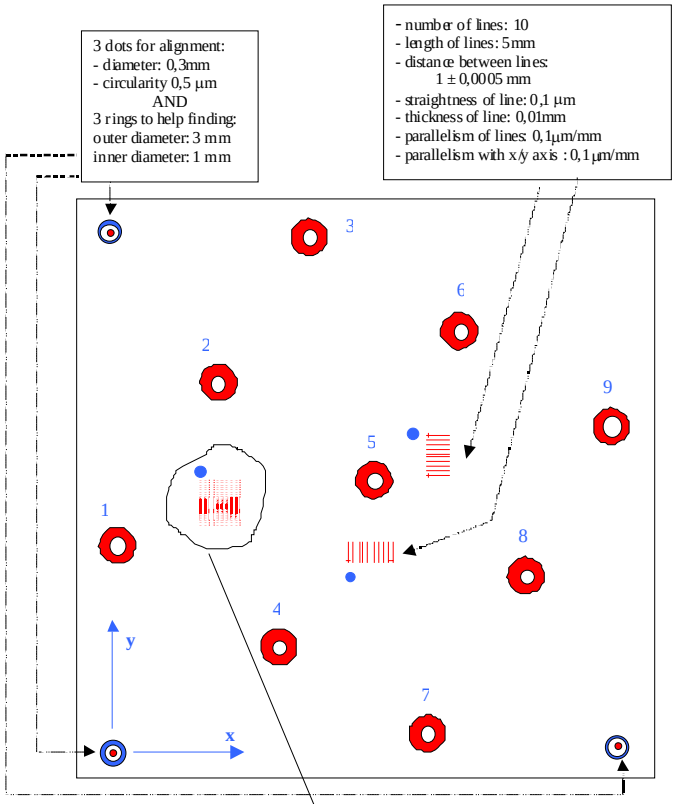
Only minor maintenance was required for our machines and control devices of laboratory conditions during 2002, including changes of oil, filters and fans.

Ball Cube

A new ball cube KOBA Q3 (Kolb & Bauman Germany) was taken into use on May 27th 2002. The distance between the 22 mm diameter spheres of same edge is 300 mm. The cube is used periodically to test the stability of the SIP CMM5 of K003. The next step is to study the possibilities also to calibrate some geometrical features of CMM using the Q3.



KOBA ball cube model Q3.



CIRCLES no: 1...9
The circularity should be less than 0,5 µm

Diameters for circles; (mm) *

number	outer-	inner-	thickness of ring
1	5	0,8	2,1
2	1	0,1	0,45
3	4	0,6	1,7
4	1,5	0,15	0,68
5	0,4	0,02	0,19
6	2	0,2	0,9
7	3	0,4	1,3
8	0,7	0,05	0,33
9	6	1	2,5

The transfer standard developed for intercomparison of visual CMMs in Finland. The figures and graduation marks are etched on glass substrate.

Intercomparison for video CMMs

A MIKES funded project is running to develop new objects for intercomparison for video co-ordinate measuring machines in Finland. One of the two items is described in the figure above. This is a transfer standard etched on a glass substrate. Another transfer standard is a hole plate assembled in four coloured bunches: black, gold and shiny steel.

Improvement of SIP CMM5

The latest project focuses on improving the SIP CMM 5 machine to get better repeatability, traceability and accuracy. A HP laser interferometer will be installed for direct measurement of the displacement of a stylus. The project is due to run in 2003 in co-operation with CMI (Czech Metrological Institute).

Easytrac

The EC project Easytrac run throughout 2002 and is due to end in March 2003. The tasks of K003 are to test new calibration methods for CMMs through practical measurements.

International comparisons

EA M23: "Long gauge blocks" in December 2001. Results: final report under preparation.

EA M22: "Taper Gauges", Pilot METAS. 2 inside and 2 outside standard, subjects of measurement half angle and diameter, October 2000.

Summary of results:

Morse 2 internal	Diameter	U95 (µm)	En	Angle (") last seconds only	U95 (")	En
METAS (refer. lab.)	17.7792	0.8		44	1.5	
K003	17.7794	1.6	0.14	44.8	2.0	0.32
Morse 3 external (ref)	23.8289	0.8		23.3	1.5	
K003	23.8287	1.6	-0.11	23.0	3.3	-0.08
ISO 7/24 45 internal (ref)	57.1613	0.8		51.0	1.5	
K003	57.1618	1.6	0.31	52.0	3.8	0.24
ISO 7/24 35 external (ref)	37.9314	0.7		51.7	1.5	
K003	37.9312	1.6	-0.11	51.2	4.4	-0.11

Reports

Seven reports were prepared during the Pro Plastic project funded by Finnish National Technology Agency (TEKES). The reports concentrate on improvement of accuracy with ordinary and video co-ordinate measuring machines. Problems related to visual inspection were also studied. The results are published in Finnish and can be ordered from the laboratory or the TEKES website.

Lectures

H. Tikka, "Ohjelmistojen verifiointi", *Mittaukset konepajassa*, MIKES, Kirkkonummi, May 30, 2002.

H. Tikka, "Kierteen mittaus koordinaattimittaus-koneella", *Mittaukset konepajassa*, MIKES, Kirkkonummi, May 30, 2002.

AEL – Centre for Technical Training gives periodical courses on measuring. Our institute has experience in lecturing on CMM technology.

IIR-Finland organised a course on uncertainty estimation. H. Tikka gave a lecture on EA-4/02.

Other activities

Direct training was given to Finnish industry on specified topics.

H. Tikka, member of Advisory Commission for Metrology.

H. Tikka, chairman of the Expert Group on Length Measurements, Advisory Commission for Metrology.

H. Tikka, member of Excellence Finland (SLY).

Laboratory organised a workshop on gear measurement by CMM with PTB and DTH, February 27 – 28, 2002.

Laboratory organised a meeting for the EC project Easytrac in Tampere, Finland, March 1, 2002.

Time

Time • Time interval • Frequency

Kalevi Kalliomäki	Senior Research Scientist, Head of Laboratory
Tapio Mansten	Senior Research Scientist
Anssi Rautiainen	Research Engineer, permanent position: VTT Information Technology

Realisation, traceability

Time: Two Cs clocks, 4 GPS receivers, 2 Loran-C clocks (NELS&RNS), and an automatic surveillance system.
Frequency: Two Cs clocks, two rubidium oscillators, several OCXO:s, and an automatic surveillance system.

Maintenance

The Efratom rubidium oscillator has been replaced by SRS Inc PRS10 rubidium. Due to a major power failure on October 3rd, backup power systems were redesigned and renewed. New 36 V standby batteries ensure continued operation of Cs-clocks in case of problems in the UPS system. The measurement system of the time laboratory was improved by changing primary coaxial cables to double shielded ones and replacing the Cs-cabinet fan. One of the two main GPS receivers (XR5) failed and was switched off for maintenance.

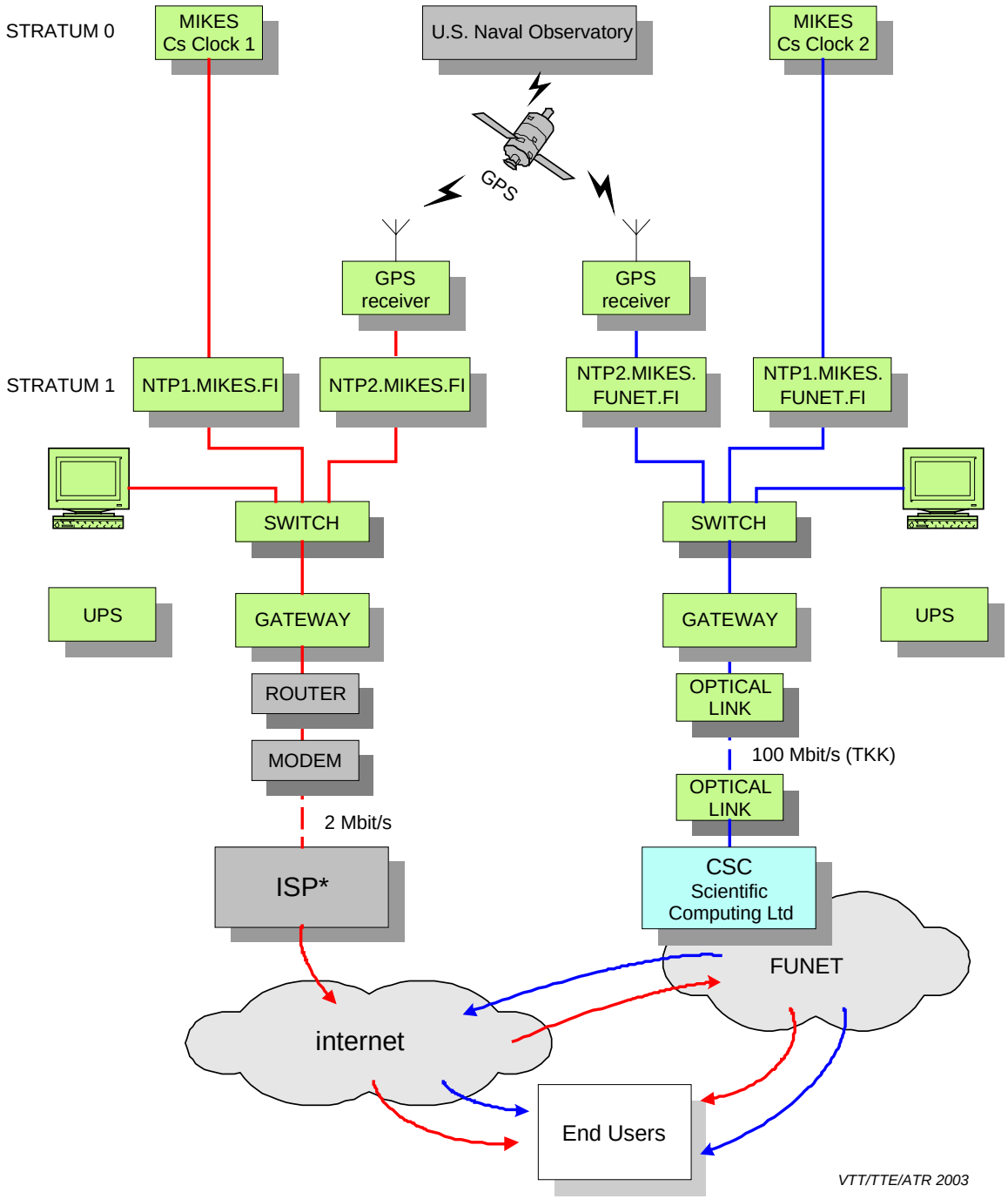
Development

NTP (National Network Time Protocol Servers for the Government and Communities)
A NTP server system, financed in part by the Ministry of Finance, was tested throughout the year. The system consists of four dedicated servers and two public servers and is locked to the official Finnish time of MIKES. The test phase was finished during 2002. The NTP system is now fully operational and is used by several organisations in Finland.

NTTS (Electric Time Stamp Service Certification Prototype)
A Time Stamp prototype system, which was started in co-operation with ICL and VRK (Population Register Centre), has been under test. Testing has been suspended due to problems in Datum Time Stamp Servers.

The alarm system has been renewed; all alarms now utilise GSM network. All essential analogue and digital measurement channels are monitored.

Standard Frequency Transmitter
A 100 W 25 MHz standard frequency transmitter is nearing completion. It will start to operate after final assembly.



Block diagram of the stratum 1 level NTP service of MIKES. Red lines correspond to the original route built in 2001 (ISP = Internet Service Supplier, Elisa/Kolumbus), blue lines correspond to the new route via CSC/FUNET. The names of the servers may change and they should be checked from MIKES.

International (EA or other) intercomparisons for accredited calibration laboratories

The EA-FR1 comparison has no final report yet. Only draft report by A. Barel (Nov. 3, 2000) exists.

Conferences

K. Kalliomäki, T. Mansten, J. Mannermaa, "GPS Disciplined Oscillators, Long Term Results". 16th European Frequency and Time Forum, St. Petersburg, 12-14 March 2002.

Other activities

A project to purchase hydrogen masers and associated equipment from Russia is going on and first delivery will be in February 2003.

Optics

Luminous intensity • Illuminance • Luminance • Luminous flux • Spectral irradiance • Spectral radiance • Colour co-ordinates • Colour temperature • Optical power • Fibre optic power • Transmittance • Reflectance • Spectral responsivity • Spectral diffuse reflectance • Optical wavelength

Erkki Ikonen	Professor, Head of the National Standards Laboratory
Jouni Envall	Research assistant
Jari Hovila	Research scientist
Jaana Hänninen	Administrative secretary (leave of absence from July 1)
Tomasz Jankowski	Research assistant
Petri Kärhä	Senior research scientist, Quality manager
Hanne Ludvigsen	Docent, Academy research fellow
Farshid Manoocheri	Senior research scientist, Head of calibration services
Mikko Merimaa	Senior research scientist
Seppo Metsälä	Laboratory technician (till November 30)
Saulius Nevas	Research scientist
Arto Niemelä	Research assistant (till July 31)
Tapio Niemi	Senior research scientist, Student advisor
Juha Nieminen	Research assistant
Mart Noorma	Research scientist
Soile Saloranta	Coordinator (from June 5)
Jesse Tuominen	Research scientist

Helsinki University of Technology, Metrology Research Institute, is designated by MIKES to act as the National Standards Laboratory for optical quantities.

The primary standard of optical power measurements is a cryogenic absolute radiometer operated with laser sources. Trap detectors and pyroelectric radiometers are used as transfer standards to other wavelengths and power levels. Units of luminous intensity and illuminance are realised with a reference photometer constructed from a trap detector, a V(λ) filter and a precision aperture. The unit of luminance is realised by measuring the luminous intensity of an integrating sphere source with known output area. Luminous flux is realised with a 1.5 m integrating sphere. The unit of spectral irradiance is realised with an absolutely characterised filter radiometer, with interchangeable band-pass filters. Values between discrete wavelengths are interpolated using physical models. Spectral radiance, colour co-ordinates and correlated colour temperature are derived from spectral irradiance measurements. Regular spectral transmittance of filters, regular spectral reflectance of optical components, diffuse reflectance factor, and spectral responsivity of detectors are calibrated using a reference spectrometer. Measurements of regular spectral reflectance are made using a dedicated apparatus in the reference spectrometer. Diffuse reflectance factor measurements are traceable to NRC and PTB. Spectral responsivity measurements are made with a trap detector as

reference. Optical wavelength is measured with a commercial spectrum analyser traceable to stabilised gas lasers.

Realisations of the quantities mentioned above were maintained. The main achievement in 2002 was the revision of the quality system to comply with ISO 17025. All missing quality manuals were written during the revision process. Thus all quantities of the laboratory are now included within the quality system. The quality system was audited both internally and by MIKES.

Development of absolute scale of spectral diffuse reflectance

Preliminary results of the bilateral comparison of spectral diffuse reflectance between the relative scales of HUT and MSL, New Zealand, have been received. The results indicate good agreement with the white samples. Some deviations noticed with grey samples are still under investigation. Instrumentation for realisation of the absolute scale has been designed, purchased, and characterised. However, considerable delays in the delivery of a monochromator for the source system did not allow completion of the project by the end of 2002.

New technique for the measurement of irradiance responsivity of filter radiometers

The frequency tuneable Ti:Sapphire laser has been used to characterise filter radiometers at 800 nm and at 900 nm wavelengths. The measurements have been compared with earlier methods for filter radiometer characterisations. The results were used for high-accuracy radiation temperature measurements.

Wavelength reference for optical communication

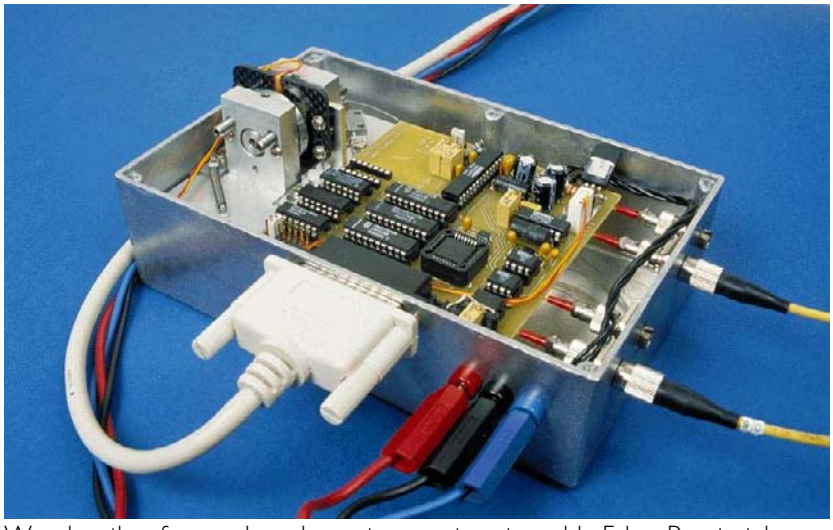
The goal of the project is to build a wavelength reference based on a temperature-tuneable Fabry-Perot etalon. The transmission spectrum of the etalon exhibits periodical transmission fringes, which can be used as a wavelength reference once the etalon properties (thickness, refractive index) are known. During 2002, the project was carried to completion. The developed device operates from 1300 nm to 1700 nm providing a reference with an absolute accuracy of ~1 pm. The device is compact, being only 18 cm long and is designed to be operated with a portable computer. The reference was also tested successfully in a WDM test bed at VTT monitoring channel wavelengths. The accomplishments of this work have been published in a Master's thesis [J. Tuominen, *Wavelength reference for optical communication*, Master's Thesis, 2002] and conference proceedings.

Extension of the wavelength regions of spectral irradiance and radiance

The purpose of this project is to extend the wavelength regions of the spectral irradiance and radiance scales to 200 nm – 2.5 μm. In 2002 work was carried out in the region 250–290 nm. Two new filters were purchased and characterised for this region. Preliminary test measurements indicated serious problems with stray light from the higher wavelength regions. The problem will be solved in future by using new solar blind detectors in the filter radiometer.

Intense UV radiation facility for calibration of radiometers

Building of the facility was started in late July/early August after receiving the single grating monochromator. The measurement setup was built and prepared for measurements during August. This work included the physical assembling of the setup, as well as preparing the software both to operate all the devices, and to co-ordinate different measurement procedures. During the autumn the setup was characterised by measuring several properties, including the slit function of the monochromator, the properties of the output beam and calibration of the wavelength scale. In late autumn some test calibrations were made, which include measuring the spectral irradiance



Wavelength reference based on a temperature-tuneable Fabry-Perot etalon.

responsivity of commercial UVA and UVB detectors. The tasks for 2003 are characterisation of new less noisy detectors, which are used as reference in irradiance measurements, and intercomparisons between different calibration methods.

Determination of radiation temperature using filter radiometers

In this collaboration project between HUT and the MIKES temperature laboratory, a new approach to measuring the radiation temperature of a black body radiator is being tested. Spectral irradiance of the high precision black body radiator is measured through a limiting set of two apertures. The set of tests performed during 2002 proved that it is possible to minimise the difference between this measurement method and a reference meter (ITS-90) down to the range between 3 K and 0.5 K. The range of measurements covered reached from 960 °C to 1500 °C, while the wavelengths of tested filters ranged from 500 nm to 900 nm. The tests performed in 2002 also indicated very strong sensitivity of the method to the angle introduced while turning the detector away from the axis of setup. In addition, various parallel scans of the radiator were performed.

International comparisons

CCPR-K1.a International comparison of spectral irradiance

The key comparison is on spectral irradiance measurements of tungsten lamps in the wavelength region from 250 nm to 2500 nm. HUT participates in the wavelength region 290–900 nm. HUT conducted their second round of measurements in September 2002. The lamps have been returned to NPL for final measurements. Draft A is expected in spring 2003.

CCPR-K2.a International comparison of spectral responsivity in the wavelength region 900 nm to 1600 nm

The measurements for this key comparison were carried out by HUT in 1999. No progress in 2002.

CCPR-K2.b International comparison of spectral responsivity in the visible region

The key comparison is on spectral responsivity measurements of trap detectors and photodiodes in the wavelength region from 300 nm to 1000 nm. The measurements for this comparison were carried out by HUT in 2000. Draft A-1 was circulated to participants in 2002. The results indicate good agreement for HUT within uncertainties.

CCPR-K6 International comparison of regular spectral transmittance

The key comparison is of spectral regular transmittance measurements in the wavelength region from 380 nm to 1000 nm. The measurements for this comparison were carried out by HUT in 2000. No progress in 2002.

CCPR-S2 International comparison of aperture area measurements

The measurements for this supplementary comparison were carried out by HUT in 2000. No progress in 2002.

Bilateral comparison of spectral irradiance with NIST, USA

The spectral irradiance scales of HUT and NIST (1992 scale) were compared in the 290–900 nm region. The comparison indicates an agreement except in the UVB region, where the discrepancies are slightly higher than the uncertainty of the comparison. During 2002, the comparison report was published in Metrologia [T. Kübarsepp, H.W. Yoon, S. Nevas, P. Kärhä and E. Ikonen, "Comparison of spectral irradiance scales between the NIST and the HUT", *Metrologia* **39**, 399-402 (2002)].

Bilateral comparison of illuminance with NIST, USA

The illuminance scales of NIST and HUT were compared in summer 2000. The comparison indicates an excellent agreement within the uncertainty of the comparison. The results have been published in Metrologia [J. Hovila, P. Toivanen, E. Ikonen, and Y. Ohno, "International comparison of the illuminance responsivity scales and units of luminous flux maintained at the HUT (Finland) and the NIST (USA)," *Metrologia* **39**, 219-223 (2002)].

Bilateral comparison of luminous flux with NIST, USA

The new luminous flux scale of HUT was compared with the scale of NIST in summer 2000. The comparison indicates an excellent agreement within the uncertainty of the comparison. The results have been published in Metrologia [J. Hovila, P. Toivanen, E. Ikonen, and Y. Ohno, "International comparison of the illuminance responsivity scales and units of luminous flux maintained at the HUT (Finland) and the NIST (USA)," *Metrologia* **39**, 219-

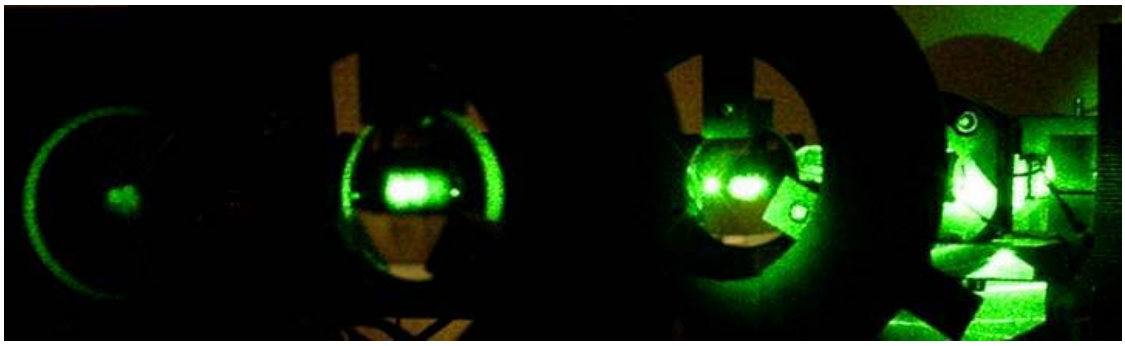
223 (2002)].

Improving the accuracy of ultraviolet radiation measurement

In this project funded by the SMT programme of the EU, novel filter radiometer techniques developed by HUT were used to compare various ultraviolet calibration facilities in Finland (HUT), France (BNM), and the UK (NPL). The results have been accepted for publication in Metrologia.

Bilateral comparison of spectral diffuse reflectance with MSL, New Zealand

The diffuse reflectance scale of HUT was compared with the scale of MSL. HUT conducted their part of the measurements in 2001. The results received in 2002 indicate good agreement with the white samples. The deviations noted with grey samples are still under investigation.



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K. Nyholm, M. Merimaa, T. Ahola, and A. Lassila, "Frequency stabilization of a diode-pumped

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L. Ylianttila, K. Jokela, and P. Kärhä, "Ageing of DXW-lamps", *Metrologia* (in press).

S. Nevas, F. Manoocheri, and E. Ikonen, "Determination of Thin Film Parameters from High Accuracy Measurements of Spectral Regular Transmittance", *Metrologia* (in press).

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S. Nevas, F. Manoocheri, and E. Ikonen, "Determination of thin film parameters from high accuracy measurements of spectral regular transmittance", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 78 (talk).

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T. Kübarsepp, H.W. Yoon, S. Nevas, P. Kärhä, and E. Ikonen, "Comparison measurements of spectral irradiance between NIST and HUT", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 102 (poster).

F. Manoocheri, S.W. Brown, and Y. Ohno, "Uncertainty of colorimetric calibration of displays at NIST", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 114 (poster).

J. Hovila, P. Toivanen, E. Ikonen, and Y. Ohno, "Comparison of illuminance responsivity and luminous flux units between HUT and NIST", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 116 (poster).

P. Kärhä, J. Envall, and E. Ikonen, "Study of fiber optic power measurements using photodiodes with and without integrating sphere", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 129 (poster).

M. Noorma, P. Toivanen, F. Manoocheri, and E. Ikonen, "Characterization of filter radiometers with wavelength-tunable laser source", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 155 (poster).

L. Ylianttila, K. Jokela, and P. Kärhä, "Ageing of DXW-lamps", *in Abstracts of NEWRAD2002*, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 20-24, 2002, p. 119 (poster).

M. Lehtonen, G. Genty, J. R. Jensen, M. Kaivola, and H. Ludvigsen, "Supercontinuum generation in highly birefringent photonic crystal fibers", in *Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM'02)*, Ottawa, Canada, paper TuP29 (poster).

K. Nyholm, M. Merimaa, T. Ahola, and A. Lassila, "Frequency stabilization of a diode-pumped Nd:YAG laser at 532 nm to iodine by using third-harmonic technique", in *Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM'02)*, Ottawa, Canada, June 16–21, 2002 (poster).

S. Picard, L. Robertsson, L.-S. Ma, K. Nyholm, M. Merimaa, T. E. Ahola, P. Balling, P. Kren, and J.-P. Wallerand, "Results from international comparisons at the BIPM: providing a world wide reference network of ^{127}I-satbilized frequency-doudled Nd:YAG laser", in *Proceedings of the Conference on Precision Electromagnetic Measurements (CPEM'02)*, Ottawa, Canada, June 16–21, 2002 (poster).

S. Nevas, F. Manoocheri, and E. Ikonen, "Determination of thin film parameters from high accuracy spectrophotometric measurements", in *Proceedings of the 4th Intern. Conf. on Materials for Microelectronics and Nanoengineering*, Hanasaari Cultural Centre, Espoo, Finland, June 10-12, 2002, p. 323-326 (poster).

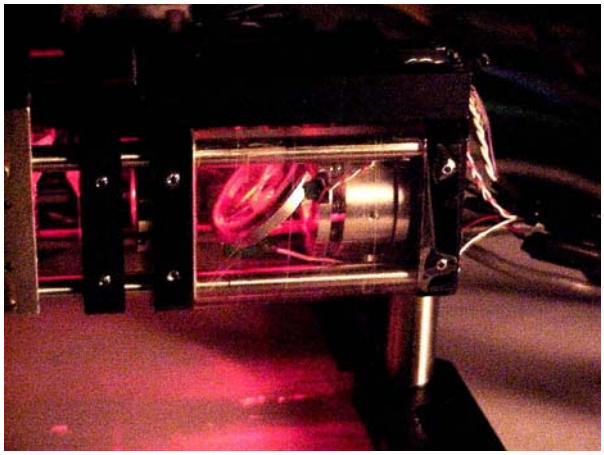
J. Tuominen, T. Niemi, P. Heimala, and H. Ludvigsen, "Compact wavelength reference for optical telecommunication based on a tunable silicon etalon", in *International Union of Radio Science - XXVIIth General Assembly (URSI'02)*, Maastricht, The Netherlands, August 17-24, 2002, paper p1512 (invited talk).

T. Niemi, H. Ludvigsen, F. Scholder, M. Legré, M. Wegmuller, N. Gisin, J.R. Jensen, A. Petersson, and P.M.W. Skovgaard, "Polarization properties of single-moded, large-mode area photonic crystal fibers", in *28th European Conference on Optical Communication (ECOC'02)*, Copenhagen, Denmark, 2002, paper M.S1.09 (talk).

L. Ylianttila, P. Kärhä, K. Jokela, and E. Ikonen, "A portable field calibrator for solar ultraviolet measurements", 5th Workshop on Ultraviolet Radiation Measurements, Kassandra, Halkidiki, Greece, October 7–8, 2002 (Poster) *UVNews* **7**, 16-17 (2002).

J. Envall, P. Kärhä, and E. Ikonen, "High-intensity setup for measuring spectral irradiance responsivities of UV meters", 5th Workshop on Ultraviolet Radiation Measurements, Kassandra, Halkidiki, Greece, October 7–8, 2002 (Poster) *UVNews* **7**, 18-19 (2002).

P. Kärhä, "Calibration and intercomparison issues with broadband UV meters", 5th Workshop on Ultraviolet Radiation Measurements, Kassandra, Halkidiki, Greece, October 7 – 8, 2002 (invited talk) *UVNews* **7**, 29-34 (2002).



A tuneable diode laser based on a transmission grating. The device is used as a frequency standard at 633 nm wavelength.

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J. Tuominen, T. Niemi, P. Heimala, and H. Ludvigsen, "Wavelength reference for optical telecommunications based on a tunable silicon etalon", *Proceedings of the XXXVI Annual Conference of the Finnish Physical Society, Selected Papers 7*, Joensuu, Finland, March 14–16, 2002, p. 72 (poster).

K. Nyholm, T. Ahola, M. Merimaa, and A. Lassila, "Optical frequency standard at 532 nm", *Proceedings of the XXXVI Annual Conference of the Finnish Physical Society, Selected Papers 7*, Joensuu, Finland, March 14–16, 2002, p. 73 (poster).

J. Envall, P. Kärhä, and E. Ikonen, "Study of fiber optic power measurements using photodiodes with and without integrating sphere", *Proceedings of the XXXVI Annual Conference of the Finnish Physical Society, Selected Papers 7*, Joensuu, Finland, March 14–16, 2002, p. 74 (poster).

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P. Kärhä, M. Noorma, T. Jankowski, T. Weckström, and E. Ikonen, "Radiometric determination of radiation temperatures", *Proceedings of Finnish Optics Days 2002*, Kajaani, Finland, April 24–26, 2002, p. 38 (poster).

Patents

S. Metsälä, Veröffentlichung DE 195 816 58 T1, Feinmechanische Einstellvorrichtung (Hienomekaaninen poikittaisasemointilaite), Deutsches Patent- und Marketamt, 2002, 23 p.

Reports

P. Kärhä (editor), *Annual report 2001*, Metrology Research Institute, Helsinki University of Technology, Espoo 2002, Metrology Research Institute Report 20/2002, 64 p.

M. Noorma, "Police speed measurement devices", *(in Estonian)*, *Tehnikamaailm* **11**, 86-88 (2002).

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P. Kärhä (editor), *UVNews*, The official newsletter of the Thematic Network for Ultraviolet Measurements, Issue **7**, Espoo 2002, 44 p.

Intercomparison reports

T. Kübarsepp, H.W. Yoon, S. Nevas, P. Kärhä and E. Ikonen, "Comparison of spectral irradiance scales between the NIST and the HUT", *Metrologia* **39**, 399-402 (2002).

J. Hovila, P. Toivanen, E. Ikonen, and Y. Ohno, "International comparison of the illuminance responsivity scales and units of luminous flux maintained at the HUT (Finland) and the NIST (USA)", *Metrologia* **39**, 219-223 (2002).

Conferences and Meetings

SPIE's Photonics West Meeting BiOS 2002, Optoelectronics 2002, LASE 2002, San Jose, California USA, January 19–25, 2002; *Mikko Merimaa.*

Meetings with Crystal Fibre A/S and NKT Innovations, Copenhagen, Denmark, February 8–10, 2002; *Hanne Ludvigsen.*

Estonian Physics Days, Tartu; Estonia, February 14–17, 2002; *Mart Noorma.*

XXXVI Annual Conference of the Finnish Physical Society, Joensuu, Finland, March 14–16, 2002; *Ilkka Tittonen, Kaj Nyholm, Mika Koskenvuori, Pekka Rantakari, Jouni Envall, Jesse Tuominen and Mikko Lehtonen.*

EUROMET Photometry and Radiometry TC meeting, Bern, Switzerland, April 7–9, 2002; *Erkki Ikonen.*

Finnish Optics Days, Kajaani, Finland, April 24–26, 2002; *Tomasz Jankowski and Mart Noorma.*

CLEO 2002, Long Beach, California, USA, May 19–24, 2002; *Goëry Genty.*

NEWRAD 2002, 8th International Conference on New Developments and Applications in Optical Radiometry, Gaithersburg, USA, May 19-23, 2002; *Erkki Ikonen, Farshid Manoocheri, Petri Kärhä, Jari Hovila, Saulius Nevas and Mart Noorma.*

UV Workshop, NIST, Gaithersburg, USA, May 24, 2002; *Erkki Ikonen, Petri Kärhä.*

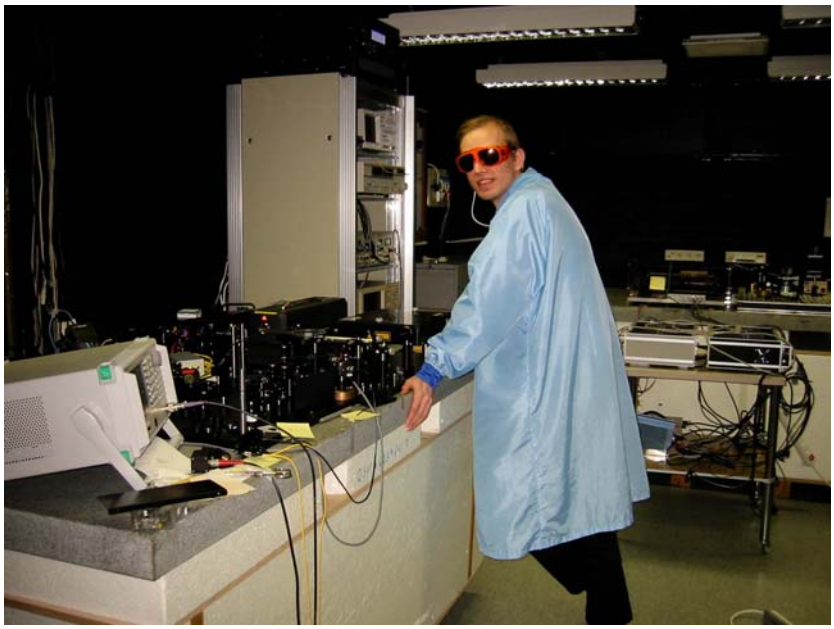
Final meeting of the EU-project "Improving the Accuracy of Ultraviolet Radiation Measurement", NMi-VSL, Delft, Netherlands, June 7, 2002; *Petri Kärhä.*

The 4th International Conference on Materials for Microelectronics and Nanoengineering, Espoo, Finland, June 10–12, 2002; *Saulius Nevas, Mika Koskenvuori.*

CPEM 2002, Ottawa, Canada, June 16–21, 2002; *Mikko Lehtonen, Mikko Merimaa.*

XXVII General Assembly URSI 2002, Maastricht, the Netherlands, August 17–24, 2002; *Jesse Tuominen.*

ECOC 2002, Copenhagen, Denmark, September 8-12, 2002; *Hanne Ludvigsen and Tapio Niemi.*



The strength of the laboratory lies mainly in its capable scientists.

Thematic Network for Ultraviolet Measurements, 5th Workshop on Ultraviolet Radiation Measurements, Kassandra, Halkidiki, Greece, October 6–8, 2002; *Petri Kärhä and Erkki Ikonen.*

NOT kick-off meeting at NKT Research, Copenhagen, Denmark, October 25, 2002; *Hanne Ludvigsen and Tapio Niemi.*

Metrology in European Research Area (MERA) Workshop, Rotterdam, the Netherlands, December 16-17, 2002; *Erkki Ikonen.*

Visits by the Laboratory Personnel

Mikko Merimaa, NIST National Institute of Standards and Technology, Boulder, USA, January 26, 2002 and JILA Joint Institute of Laboratory Astrophysics, University of Colorado, Boulder, USA, January 27, 2002.

Ilkka Tittonen, Markku Vainio and Ossi Kimmelma, KTH, Stockholm, Sweden, February 4–6, 2002.

Erkki Ikonen, ETH Zurich, Switzerland, April 10, 2002.

Erkki Ikonen, Farshid Manoocheri, Petri Kärhä, Jari Hovila, Saulius Nevas and Mart Noorma, National Institute of Standards and Technology (NIST, USA) May 23, 2002.

Petri Kärhä, NMi-VSL, Delft, the Netherlands, September 1-2, 2002.

Petri Kärhä and Erkki Ikonen, Aristotle University of Thessaloniki, Laboratory of Atmospheric Physics, Greece, October 8, 2002.

Visits to the Laboratory

Dr. Toomas Kübarsepp, Metrosert Ltd, Tartu, Estonia, January 14, 2002.

Dr. Yakov Sidorin, Optitune PLC, London, United Kingdom, February 4, May 30, June 5, 2002.

Prof. Alexander Tikhonravov, Moscow State University, Research Computing Center, Moscow, Russia, March 2–6, 2002.

Dr. Toomas Kübarsepp and Toomas Kolk, Metrosert Ltd, Tartu, Estonia, June 12, 2002.

Prof. Kristian Stubkjær, COM, Technical University of Denmark, June 12–15, 2002.

Dr. M. Kokarev, Moscow State University, Research Computing Center, Moscow, Russia, August 8, 2002.

Prof. J. Javanainen, University of Connecticut, Storrs, USA, September 17, 2002.

Mr. Pan Biqing, Mr. Zhang Yue, Mr. Wu Jian, Mrs. Wang Lanxiang, Mr. Liang Jin, and Mrs. Guo Xiaolin, NIM, China, October 4, 2002.

Memberships

Helsinki University of Technology, Metrology Research Institute (represented by Erkki Ikonen) is a member laboratory of the Comite Consultative Photometrie et Radiometrie (CCPR).

EUROMET, Photometry and Radiometry (Phora), Erkki Ikonen (Contact person).

Advisory Commission for Metrology, Pekka Wallin (Member).

Advisory Commission for Metrology, Optical quantities expert group, Pekka Wallin (Chairman), Erkki Ikonen (Member), Petri Kärhä (Member).

Advisory Commission for Metrology, Expert group in length metrology, Erkki Ikonen (Member).

COST Action 265, Measurement techniques for active and passive fibres to support future telecommunications standardisation, Hanne Ludvigsen (Contact person of Finland, Chairman of study group Characterisation of Photonic Crystal Fibres).

CIE TC2-47 Methods of characterization and calibration of broad-band UV radiometers, Petri Kärhä (Member).

Thematic Networks

HUT is the co-ordinator of the Thematic Network for Ultraviolet Measurements (http://metrology.hut.fi/uvnet/). The Network arranged its 5th Workshop in Thessaloniki, Greece on September 6-8, 2002.

OFMeC – Optical Fiber Measurement Club. HUT (Hanne Ludvigsen) is the co-ordinator of the activities in Finland (http://metrology.hut.fi /fiberopticsgroup/ofmc/ofmc.html). This action is a continuation of the EU-funded Thematic Network project "Fibre Optic Technology Network (FOToN)

Electricity

DC voltage • DC current • AC voltage • AC current • Resistance • Capacitance • Electric power • Electric energy

Antti Manninen	Senior Research Scientist, Group Leader
Tuomas Hyyppä	Trainee (1 June – 31 August)
Jussi Hämäläinen	Research Scientist (from 1 June)
Pekka Immonen	Research Scientist
Mikael Laitinen	Research Engineer (until 31 May)
Tapio Mansten	Senior Research Scientist
Jaani Nissilä	Research Scientist
Kari Ojasalo	Research Scientist
Risto Rajala	Research Engineer
Aleksandre Satrapinski	Research Scientist
Nikolai Tisnek	Research Scientist

Realisation, traceability

DC voltage: Josephson voltage standard, Zener standards, resistive voltage divider. Resistance: quantum-Hall standard, resistance standards. DC current: DC voltage/current shunts. AC voltage: multi-junction thermal AC/DC converters, Fluke 5790A ac voltage standard. AC current: Fluke 5790A ac voltage standard and A40 shunt resistors. Power (50 Hz): HEG power comparator, digital sampling wattmeter. Capacitance: Andeen-Hagerling 2500 capacitance bridge and GenRad capacitance standards. RF and microwave power from 10 MHz to 18 GHz (under development): Thermistor mount working standard traceable to NMi, Holland. RF and microwave attenuation from 300 kHz to 18 GHz, 0 dB to 90 dB (under development): Attenuation reference standard traceable to NPL, UK.

Maintenance

DC voltage: Automatic Zener comparison was suspended due to increased noise. Part of the voltage standard calibrations were carried out manually. Automatic measurement was restarted in December after calibration against the Josephson voltage standard.

Resistance: Resistance standards in ranges 10 mΩ – 10 kΩ were calibrated using the CCC resistance bridge. Tests of the transfer resistance standards developed at MIKES were carried out in collaboration with PTB. The standards were designed for use in Euromet resistance comparisons. A new temperature reference standard (model 2952R, manufactured by Hart Scientific) was purchased and calibrated, and has been used for calibration of temperature meters and sensors of the laboratory. The MIKES CCC bridge was studied for the measurements of low value resistors at frequencies below 1 Hz. The measurements of 10 mΩ standard showed that the combined standard uncertainty can be reduced to 2 parts in 10^7. A calibration chain from 100 kΩ to 10 TΩ was accomplished using the Hamon 100 kΩ per step resistance, the Guildline 9975 DCC resistance bridge and a current step-up. Preparations for modified Wheatstone bridge calibrations were made to extend the calibration

chain up to 100 TΩ and to measure the voltage dependencies of high value resistors. Special coaxial connectors, cables and tools were acquired to optimise the bridge cabling. Low value resistance standard calibrations with high currents up to 100 A for customer calibrations were started. The first steps in studying high value current dependencies were taken with the recently adopted computer controlled DCC bridge system.

Capacitance: Comparison of reference standards, several comparison periods/year.

AC voltage: The Fluke 5790A was calibrated and is used as the reference standard for ac voltage calibrations.

AC current: Some maintenance measurements were made. The Fluke 5790A was calibrated together with Fluke A40 shunt resistors and is used as the reference standard for ac current calibrations.

RF and microwave attenuation: The attenuation reference standard was calibrated at NPL, in the range from 0 dB to 90 dB in 1 dB steps. Calibration frequencies were 60 MHz, 5 GHz and 17 GHz.

Data management: The Access database applications "MikesBase" and "EleBase" were developed and implemented for calibration routines. The LabView based calibration programs for customer calibrations were upgraded and improved for easier editing.

General: CMC tables of electricity were updated in 2002 and are under review. A Fluke 5720A calibrator was acquired and has replaced the Fluke 5700A as the primary working standard for customer calibrations.

Risto Rajala performing a calibration using new instruments, Fluke 5720A calibrator and Fluke 8508A reference multimeter.

Development

AC current step-up

The parts were made for one low current shunt resistance construction.

Capacitance

A new measurement program was finished and a multi-channel temperature measurement system was added to the national standards laboratory of capacitance.

Impedance standards and bridges

A scheme of combined standard of resistance and capacitance for use in the quadrature bridge was investigated. Capacitance standards (two specially designed 1 nF ceramic capacitors) for the quadrature bridge were purchased, and the measurements of their characteristics were started. A temperature stabilised enclosure for two 100 kΩ ac standards and two 1 nF capacitors was designed and tested. The LabView program for automation of measurements with an ac resistance bridge was developed. A method of comparing two unlike impedances based on a CCC bridge operated in the frequency range 1.6 Hz – 16 Hz was proposed and analysed. Optimisation of a CCC can provide minimisation of the ac and dc ratio error well below 10^{-8}.

Josephson AC standard

The development of a quantum AC standard was continued in collaboration with VTT Microsensing. The first version of a 1 kHz 1 V AC voltage standard was designed and constructed in 2002, and is currently under test. It is based on externally shunted Josephson junction arrays developed by VTT. In our scheme, the array is biased with a square wave current source such that the voltage alternates between steps n = -2 and n = +2. The idea is to make the output of a stable AC voltage source traceable to the amplitude of the fundamental frequency component of this square wave. The comparison is done with a phase-

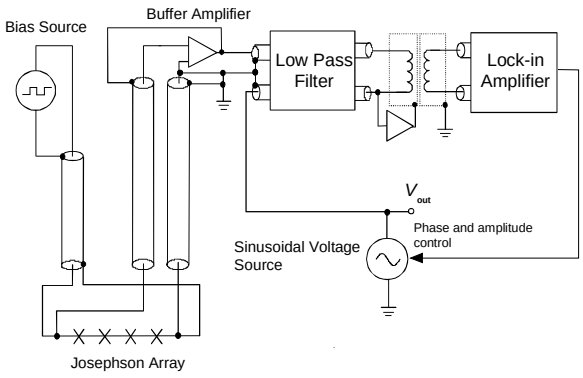
sensitive detector. The aim is to achieve an accuracy of 10^{-7} in 2003. The accuracy of the system depends critically on the accuracy of the step voltage. This again is highly affected by the sensitivity of the Josephson array to external electrical noise. Great effort has been put into studying this sensitivity and designing the bias and measurement electronics to meet the requirements. The accuracy (flatness) of the Josephson array voltage steps was investigated in EUROMET project 626 during 2001-2002. Two different programmable arrays were circulated in 10 laboratories to obtain experience on e.g. the sensitivity of the steps to noise. MIKES took part in this project, which was co-ordinated by PTB. It was found that the step voltages agree with those measured with conventional SIS junction arrays within the measurement uncertainty of less than 0.5 nV. Nevertheless, several laboratories, including MIKES, experienced problems with magnetic flux trapping and unstable voltage steps without sufficient filtering of measurement and bias leads.

EMMA

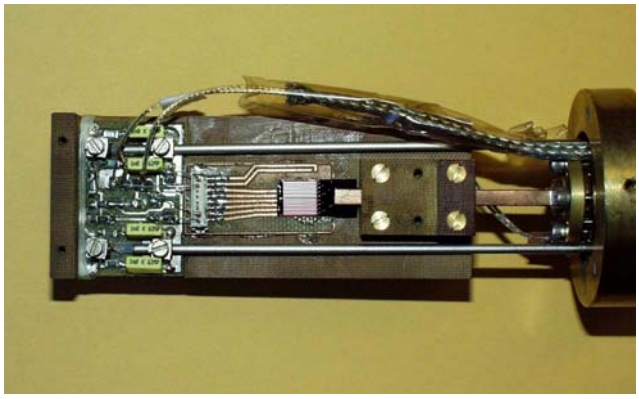
MIKES is participating in the European Union funded project EMMA (Electromechanical microcomponents for precision applications), which began on September 1, 2001. The aim of the project is to develop stable dc and ac/dc references, a microwave field amplitude sensor and precision inertial sensor. During 2002 MIKES mainly performed capacitive measurements to investigate the long-term stability of the components. Electrostatic charging effects have been the main source of instability, but the measurements indicate that this problem can be solved using a suitable metal coating.

High frequency power, attenuation, and S-parameter

Dr Jan De Vreede visited MIKES again for 2 weeks in summer 2002. This time the power measurement setup was completed to the stage where test measurements could be performed. With Dr De Vreede's guidance, automated uncertainty calculations were improved a step further. Also measurements with network analysers were investigated. A new attenuation reference has been built and this was calibrated at NPL. This reference has two attenuators in series with APC-2.4 connectors and is capable of 101 dB attenuation with 1 dB steps. The construction is equipped with N-type connectors and it has been calibrated in this configuration. MIKES has rented a new shielded room from VTT for high frequency metrology.



Measurement set-up of the 1 V 1 kHz AC voltage standard which is developed by MIKES in collaboration with VTT Microsensing. The idea is to make the output of a stable sinusoidal voltage source traceable to the amplitude of the fundamental frequency component of the square wave obtained from the Josephson array.



Josephson junction array chip of the AC voltage standard in the sample holder. The array chip with 16 clearly visible junction chains is in the centre of the picture.

International comparisons

CCEM K-9, AC/DC voltage transfer at 500 V and 1000 V. Key comparison. Participants: AREPA, BEV, BNM-LNE (pilot), CEM, CMI, CSIR-NML, CSIRO-NML, EIM, GUM, IEN, INETI, INTI, JV, KRISS, METAS, MIKES, NIM, NIST, NMi-VSL, NPL, NRC, OMH, PTB, SP, UME, VNIIM. Measurements at MIKES were performed in May 2000 and reported in September 2001. The comparison is continuing.

CCEM K-10, DC resistance 100 Ω. Key comparison. Participants: BIPM, CEM, CSIR-NML, CSIRO-NML, METAS, MIKES, NIM, NIST, NMIJ, NRC, PTB (pilot), SMU. The QHR measurements at MIKES were performed in February 2002 and reported in April 2002. The comparison is continuing.

CCEM.RF-K19.CL, Attenuation at 60 MHz and 5 GHz using a 50 ohm Type-N step attenuator. Key comparison. Participants: BNM-LNE, CMI, CSIR-NML, CSIRO-NML, IEN, KRISS, METAS, MIKES, NIM, NIST, NMIJ, NMi-VSL, NPL (pilot), NPLI, NRC, PTB, SIQ, SP, SPRING, UME, VNIIFTRI. Measurements at MIKES were performed in February 2002. They will be repeated at the end of the comparison in spring 2004.

EUROMET.EM.BIPM-K11 (EUROMET project 429), Comparison of 10 V electronic voltage standards. Key comparison. Participants: BEV, BIPM, BNM-LNE, CEM, CMI, DFM, EIM, INETI, JV, METAS, MIKES, NMi-VSL (pilot), NML, NPL, OMH, PTB, SIQ, SMD, SMU, SP, UME. Measurements at MIKES/VTT were performed in June 1999 and reported in January 2000. MIKES made some corrections to its results reported in Concept Draft B of the final report, which was distributed in March 2002. Draft B2 was circulated in September 2002. The results show reasonable degrees of equivalence between the participants. The overall accuracy of the comparison was limited by fluctuations of the travelling Zener standard. The result of MIKES was very good: the difference from the reference value of the group of four 10-V Zener standards was 0.034 μV with expanded uncertainty of 0.450 μV.

EUROMET.EM-K5 (EUROMET project 385), AC power measurement at 50 Hz. Key comparison. Participants: AREPA, BEV, CEM, CMI, GUM, IEN, INETI, JV, METAS, MIKES, NMi-VSL, NPL, OMH, PTB (pilot), SMD, SP, UME. Measurements in MIKES/VTT were completed in December 1999 and reported in March 2000. Draft A of the final report is still in progress.

EUROMET.EM-K8 (EUROMET project 449), Comparison of DC voltage ratios up to 1000 V. Key comparison. Participants: BEV, BNM-LCIE, CEM, CMI, DFM, EIM, IEN (pilot), INETI, JV, METAS, MIKES, NMi-VSL, NPL, OMH, PTB, SIQ, SMD, SMU, SP, UME. Measurements at MIKES/VTT were performed in November 1999 and reported in February 2000. Draft A of the final report was distributed in December 2002. Changes of drift in the travelling standard and the effect of collective heating have caused some problems. The results of MIKES are excellent.

EUROMET.EM-K11 (EUROMET project 464), AC/DC voltage transfer difference at low voltages. Key comparison. Participants: AREPA, BEV, BNM-LNE, CEM, CMI, IEN, INETI, JV, METAS, MIKES, NMi-VSL, NPL, OMH, PTB, SIQ, SP (pilot). The measurements at MIKES were performed in September 2000. The comparison loop was suspended to start key comparison CCEM-K11 and will be restarted at the end of the CCEM circulation.

EUROMET.EM-S11 (EUROMET project 473), Comparison of the measurement of current transformers. Supplementary comparison. Participants: BEV, BNM-LNE, CMI, GUM, HUT, IEN, Laborelec, METAS, MIKES, NPL (pilot), OMH, PTB, SP, UME. The measurements at MIKES were performed in May 2000 and reported in August 2000. The results from MIKES were later corrected due to the effect of burden differing from the nominal (5 VA). The MIKES measurements were made using a new method based on Rogowski coils or current shunts with outputs measured using digital multimeters; other participants (except HUT) used a standard transformer/comparator bridge. Draft A of the combined final report of EUROMET projects 473 and 612 was distributed in May 2002 and again in August 2002 after some corrections. All the results of MIKES agreed with the reference value within the expanded uncertainty.

International (EA or other) intercomparisons for accredited calibration laboratories

EA EL-25: A new draft report was published by COFRAC/LCIE in September 2002.

EA EL-27: The comparison device (a DMM, several quantities and ranges) was in Finland from October 19 to November 30, 2000, and visited five accredited laboratories during that time. The pilot laboratory has produced reference values only, no draft reports yet.

Publications

P. Helistö, J. Nissilä, K. Ojasalo, J.S. Penttilä, and H. Seppä, "AC voltage standard based on a programmable SIS array", accepted for publication in IEEE Trans. Instr. Meas.

P. Helistö and H. Seppä, "Analysis of international comparisons with the minimum variance method", accepted for publication in IEEE Trans. Instr. Meas.

R. Behr et al., "Analysis of different measurement set-ups for a programmable Josephson voltage standard", submitted for publication in IEEE Trans. Instr. Meas.

Conferences

A. Satrapinski, A. Rautiainen, and R. Rajala, "Resistance scaling from 10 mΩ to 10 kΩ at MIKES with cryogenic current comparator and Guildline bridges", Digest of 2002 Conference on Precision Electromagnetic Measurements (CPEM 2002), Ottawa, Canada, 16 - 21 June, 2002, pp. 56 - 57. Poster presented by A. Satrapinski.

A. Rautiainen, P. Helistö, T. Mansten, and H. Seppä, "50 Hz current measurements with Rogowski coils", Digest of 2002 Conference on Precision Electromagnetic Measurements (CPEM 2002), Ottawa, Canada, 16 - 21 June, 2002, pp. 230 - 231. Poster presented by A. Manninen.

T. Mansten, A. Rautiainen, and P. Helistö, "New AC current shunts of MIKES", Digest of 2002 Conference on Precision Electromagnetic Measurements (CPEM 2002), Ottawa, Canada, 16 - 21 June, 2002, pp. 370 - 371. Poster presented by A. Manninen.

J.S. Penttilä, P. Helistö, H. Seppä, J. Nissilä, and K. Ojasalo, "Towards quantum AC voltage standard", Digest of 2002 Conference on Precision Electromagnetic Measurements (CPEM 2002), Ottawa, Canada, 16 - 21 June, 2002, pp. 498 - 499. Poster presented by P. Helistö and H. Seppä.

A. Satrapinski, "Analysis of application of a cryogenic current comparator bridge for the measurements of capacitance standards", Digest of conference URSI, Espoo, October 2002, pp.195-197. Poster.

Lectures

A. Manninen, "Metrology of electricity, time, and acoustics in MIKES", Åbo Akademi, 8 March, 2002.

R. Rajala, "Traceability of a workload instrument", AEL – Centre for Technical Training, calibration seminar, Tampere, 17 April, 2002.

A. Manninen, " Metrology of electricity and time" (in Finnish), Tampere University of Technology, 6 November, 2002.

Other activities

J. Nissilä: Euromet 626 workshop, Berlin, 11 March, 2002, and visit to PTB, Braunschweig, 12 March, 2002.

A. Manninen and N. Tisnek: EMMA workshop on electromechanical stability, Espoo, 9 April, 2002.

A. Manninen and A. Satrapinski: Euromet expert meetings on QHR and JAVS and on AC-QHR, Ottawa, 15 June, 2002.

A. Satrapinski: Meetings in Measurements International Company and Guildline Company, Canada, 16 and 17 June, 2002.

A. Manninen: Euromet expert meeting on AC/DC transfer, Ottawa, 16 June, 2002.

A. Manninen and N. Tisnek: EMMA review meeting, Univ. Twente, 29 - 30 August.

A. Manninen: Euromet EM Technical Committee Meeting, Paris, 15 - 16 October, 2002.

A. Satrapinski: Visit to PTB for test of transfer standards and discussion on developments of impedance metrology, Braunschweig, Germany, 13 November, 2002.

A. Manninen: SET Metrology Workshop (COUNT) and visit to METAS, Bern, 20 - 22 November, 2002.

A. Manninen: Expert referee of ESF EUROCORES programme in self organised nanostructures.

P. Immonen: Reassessment of one accredited calibration laboratory.

R. Rajala: Reassessments of three accredited calibration laboratories.

A. Manninen: Member of Euromet EM Technical Committee.

A. Manninen: Secretary of advisory working group for electrical and time quantities of Finnish Advisory Commission for Metrology (MNK).

P. Immonen, K. Kalliomäki, and T. Mansten: Member of advisory working group for electrical and time quantities of Finnish Advisory Commission for Metrology (MNK).

Visit of Dr Jan de Vreede from NMi, 29 July - 10 August, 2002. RF training.

Visit of Dr Bernd Schumacher from PTB, 16 - 18 January, 2002. 100 Ω resistance comparisons.

Electricity group moved its offices (but not laboratories) into new premises hired from Helsinki University of Technology in the end of 2002. Address (Otakaari 7 B) did not change.

High voltage

Direct voltage • Alternating voltage • Voltage ratio • Alternating current • Current ratio • Phase displacement • Capacitance • Inductance • Loss factor • Lightning impulse voltage • Switching impulse voltage • Impulse current • Apparent charge • ESD discharge

Martti Aro	Professor, Head of the National Standards Laboratory
Jari Hällström	Technical manager
Marja-Leena Pykälä	Quality manager
Esa-Pekka Suomalainen	Senior researcher
Juri Chekurov	Researcher
Jukka Piiroinen	Researcher
Veli-Matti Niiranen	Operations engineer
Arja Hokkanen	Operations engineer
Jouni Mäkinen	Technician
Hannu Kokkola	Technician

Helsinki University of Technology, High Voltage Institute, is designated by MIKES to act as the National Standards Laboratory for high voltage measurements.

Realisation, traceability

HUT/HVI keeps standards on high voltages (>1000 V), high currents (>1000 A) and related quantities. The traceability of these is based on build-up from low level electrical measurements. Traceability for these comes from various National Metrology Institutes or accredited laboratories. Quantities and reference equipment kept by the HVI are the following:

Direct voltage - Resistive divider and precision voltmeter.

Alternating voltage - Standard capacitors, current comparator bridge, digitising precision voltmeter, and custom analysis software.

Voltage ratio - Standard capacitors and current comparator bridge.

Voltage phase displacement - Standard capacitors and current comparator bridge.

Alternating current - Shunt resistors, Rogowski coil, digitising precision voltmeter, and custom analysis software.

Current ratio - Shunt resistors, Rogowski coil, digitising precision voltmeters, and custom analysis software.

Current phase displacement - Shunt resistors, Rogowski coil, digitising precision voltmeters, and custom analysis software.

Capacitance - Standard capacitors and current comparator bridge.

Loss factor tanδ - Standard capacitors, loss resistors and current comparator bridge.

Inductance of high voltage reactors - Shunt resistors, Rogowski coil, digitising precision voltmeters, and custom analysis software.

Loss angle - Shunt resistors, Rogowski coil, digitising precision voltmeters, and custom analysis software.

Lightning impulse voltage - Impulse voltage calibrator, voltage divider, digital recorder with impulse analysis software.

Switching impulse voltage - Impulse voltage calibrator, voltage divider, digital recorder with impulse analysis software.

ESD impulse (2 kV - 8 kV) - ESD target, RF attenuators, oscilloscope, impulse analysis software, and precision voltmeter.

Impulse current - Shunt resistors, digital recorder with impulse analysis software.

Impulse charge - Partial discharge calibrator.

Realisations of the quantities mentioned above were maintained. Documentation and maintenance routines were kept according to the quality system based on Standard SFS-EN IEC/ISO 17025 (2000).

Worldwide comparison of lightning impulse voltage measuring systems has been ongoing since 1999. The High Voltage Institute (HVI) is the co-ordinator of this project, which has required continuous attention over the last 4 years. Both repairs to the complex system and preparation of the reports have demanded much of the HVI personnel.

Measurement arrangement in 400 kV lightning impulse voltage comparison.

In addition to active participation and co-ordination of international intercomparisons, the laboratory has had wide international co-operation with NMIs directly and within CIGRE WG 33.03 (high voltage testing and measuring techniques). Researchers have also taken part in international standardisation work within IEC TC 42 (high voltage testing techniques).

As a consequence of the MRA, the need to take part in formal comparison has increased. HVI has also participated in organising several international comparisons.

Updating the European table of calibration and measurement capabilities of National Metrology Institutes started in 2002. HVI is responsible for the review of high voltage entries together with the Swedish Testing and Research Institute (SP).

In 2002 a project to measure the temperature coefficients of all capacitors used in HVI calibration work was initiated and completed.

Extension of AC measurement range

In this project a gas insulated high voltage capacitor is being refurbished. The electrodes of the Schering-type capacitor are cleaned and their centring checked and measured. The voltage linearity of the capacitor is estimated based on measurement of the centring and stiffness of the electrodes. The non-linearity in capacitance from 1 kV to 500 kV is estimated to be less than 20 parts in 10^6.

The capacitor will be taken into use in the first quarter of 2003. The maximum voltage for both alternating voltage and capacitance calibrations will be then extended from 200 kV to 500 kV.

Intranet-based document handling

The goal of this project is to collect quality documents and descriptions of reference devices and systems at an easily accessible location. A large number of documents can now be browsed from any of the computers at HVI.

Calibration of instrument transformers

During 2002 the uncertainty estimates for both voltage and current transformer calibration service were re-evaluated.

Current transformer calibration is based on two digitising voltmeters used with a set of shunts and a Rogowski coil. Comparison results (EUROMET.EM-S11) became available in late autumn; they nicely supported the new estimates for both ratio error (from 120 to 150 parts in 10^6) and phase displacement (240 parts in 10^6).

In voltage transformer calibration the respective estimates for ratio error (60 to 80 parts in 10^6) and phase displacement (40 parts in 10^6) are also backed up by the preliminary results from an ongoing comparison (EUROMET 599). Either a current comparator bridge with high voltage capacitors, or two digitising voltmeters together with voltage dividers having a low phase error, is used for this measurement.

New reference for impulse voltage and impulse current calibration

The goal of this project is to build an impulse voltage measuring system for impulse voltages and currents. The signal from either the high voltage divider or high current probe is attenuated to match the input of a digital recorder. Records taken from single impulses are processed according to the definitions and requirements set by high voltage standards.

During 2002 a set of four attenuators was built. The rise time of these attenuators is less than 2 ns, they withstand impulse voltages up to 1500 volts, and the estimated uncertainty in the ratio, including thermal effects, is less than 50 parts in 10^6.

Once the update of the measurement software is ready (in spring 2003), the system will be ready for use. In addition to simplifying the calibration process, the uncertainties of impulse calibration will be lowered.

International comparisons

EUROMET.EM-S12 International comparison of impulse voltages

The comparison is of lightning impulse voltages, from 50 mV to 1000 V and from 80 kV to 400 kV; and of switching impulse voltages from 50 mV to 300 V. This project has been ongoing under HVI co-ordination since 1999. The last of the 26 laboratories performed the comparison measurements in October 2002; the final reports will be available by June 2003. This project has been partly funded by the Standards, Measurement and Testing Programme of the Commission of the European Communities (Contract number EU-SMT4-CT98-2270).

EUROMET.EM-S11 International comparison of current transformers

The comparison is of ratio error and phase displacement of current transformers, ratios ranging from 1000/5 A/A to 1/5 A/A. The measurements for this comparison were carried out by HVI in 2000, and the preliminary results became available in autumn 2002. HVI results match the reference value within the given uncertainties.

EUROMET.EM-S14 International comparison of direct voltage

The comparison is of direct voltage ratio, ratios ranging from 100 000/100 V/V to 100 000/1 V/V, and input voltages ranging from 1 kV to 100 kV. The measurements for this comparison were carried out by HVI in 2000. No progress was reported in 2002. According to the preliminary information HVI results match the reference value within the given uncertainties.

EUROMET 599 International comparison of voltage transformers

The comparison is of alternating voltage ratios ranging from 5000/100 V/V to 22000/100 V/V, and input voltages ranging from 2 kV to 26 kV. The measurements for this comparison were carried out by HVI in 2001. Preliminary results became available in 2002. HVI results match the reference value within the given uncertainties.

Bilateral comparison of direct voltage with LCOE, Spain

The comparison is of direct voltage up to 200 kV and direct voltage ratio 200 000 V / 20 V, input voltages ranging from 1 kV to 200 kV. The measurements for this comparison were carried out by HVI in autumn 2002. No results are available yet.

Bilateral comparison of capacitance and inductance with SP, Sweden

The comparison is of capacitance (50 μF) and its tanδ, and of inductance (4 mH) and its quality factor. The project is being run under HVI co-ordination. The measurements at SP were finished in autumn 2002. No results are available yet.

Trilateral comparison of impulse voltages with CSIRO, Australia and PTB, Germany

The comparison is of lightning and switching impulse voltages from 50 mV to 300 V. This project was motivated by the first results from

EUROMET.EM-S12. The project is being run under HVI co-ordination. The measurements were completed in autumn 2002 and the results are being submitted to ISH'03. HUT values match the reference value within the given uncertainties.

Reference coil for inductance comparison (4 mH, Q≈15). It is about 70 cm high and weighs about 50 kg.

Publications

J. Hällström: "A calculable impulse voltage calibrator", PhD thesis, Acta Polytechnica Scandinavica, El 109, Espoo 2002.

Conferences

J. Hällström, Y. Chekurov and M. Aro: "Calculable Impulse Voltage Calibrator for Calibration of Impulse Digitizers", IEEE Transactions on Instrumentation and Measurement, accepted for publication.

Intercomparison reports

M.-L. Pykälä, A. Hokkanen, J. Hällström: Lightning impulse measurements, comparison of HUT home systems to circulating system, TKK-Sjt-53, Espoo 2002.

M.-L. Pykälä, J. Hällström, M. Aro: Traceability and mutual recognizability of impulse voltage measurements – Report of results of second round. Commission of the European Communities, Contract EU-SMT4-CT98-2270. TKK-Sjt-54, 2002, 176 p.

Domestic committees

M. Aro: Chairman of Finnish National Committee of IEC TC 42 (High voltage testing techniques).

M. Aro and J. Hällström: Member of advisory working group for electrical quantities of Finnish Advisory Commission for Metrology (MNK).

International committees

M. Aro and J. Hällström: Member of CIGRE Working Group 33.03 (High voltage testing and measuring techniques).

M. Aro: Leader of Maintenance Team 13 of IEC 36B (Insulators for overhead lines) for revision of IEC Report 61211: Puncture testing on insulators. 19.9.2000 onwards.

J. Hällström: Reviewer of CMC data of high-voltage quantities in EUROMET.

J. Hällström: Leader of IEC TC 42 Maintenance Team for the IEC Standard series 61083: Instruments and software for measurements in high-voltage impulse tests.

J. Hällström: Leader of CIGRE Task Force TF 33.03.01 (Digital techniques in high voltage measurements).

International visitors

Visit of Prof. Michael Danikas from Demokritos University of Thrace in July – August 2002. Giving courses and separate lectures.

Visit of Dr. Anders Bergman, Anders Mannikov and Jon-Ivar Juvik from the Swedish National Testing and Research Institute (SP), November 1-4, 2002.

Visit of Prof. Dieter Kind, October 31 – November 1, 2002. Opponent for the PhD work of Jari Hällström.

International visits

J. Hällström visited Measurements International Inc., in Prescott Canada on the 18th of June 2002.

J. Hällström and M. Aro visited STRI in Ludvika, Sweden on the 21st of August 2002.

J. Hällström and M. Aro visited ABB factories in Ludvika, Sweden on the 21st of August 2002.

Acoustics

Sound pressure

Kari Ojasalo — Research Scientist
Antti Manninen — Senior Research Scientist
Jussi Hämäläinen — Research Scientist

The unit of sound pressure is realised by the closed coupler reciprocity technique using half inch and one inch standard condenser microphones. General method is described in standard IEC 1094-2.

Acoustics Laboratory of MIKES was nominated as the National Standards Laboratory of sound pressure in autumn of 2002. Maintenance measurements of laboratory microphones have been done twice. Small changes of sensitivity in some of the microphones was observed. Laboratory's own sound calibrators are used in conjunction with the customer calibrations to observe possible failures in measurements. This also improves tracing back the behaviour of the sound calibrators as the data is stored in database.

Programs for reciprocity calibrations and sound calibrators have been under constant improvement. New programs are being developed for substitution method calibration of microphone sensitivity and response.

Kari Ojasalo performing pistonphone calibration in the new National Standards Laboratory of sound pressure.

Lectures

K. Ojasalo, in INSKO seminar "Acoustic Measurements", Espoo, 5 - 6 February, 2002.

K. Ojasalo, "Calibration of measuring instruments for acoustical quantities" (in Finnish), MIKES seminar "Environmental noise measurements, emission and exposure", Tampere, 16 October, 2002.

Other activities

K. Ojasalo: EUROMET AUV Sound in Air Meeting and EUROMET TC-AUV Meeting, Warsaw, May 9–10, 2002.

K. Ojasalo: Secretary of advisory working group for acoustical quantities of Finnish Advisory Commission for Metrology (MNK).

A. Manninen: Member of advisory working group for acoustical quantities of Finnish Advisory Commission for Metrology (MNK).

Air quality

Gas (amount of substance)

Jari Walden	Head of Laboratory
Veijo Pohjola	Senior researcher, quality manager
Sisko Laurila	Research assistant
Kaisa Lusa	Researcher
Minna-Kristiina Sassi	Researcher
Helena Saari	Researcher
Raimo Kartastenpää	Senior Researcher
Tommi Häkkinen	Researcher
Kai Lindgren	Technician

Finnish Meteorological Institute, Air Quality Research, is nominated by MIKES to act as the Contract Laboratory for air quality measurements.

The quantity is realised by dynamic dilution of the reference gas standard. The reference gas standards of the laboratory are those of the secondary standards from the National Metrological Institute (NPL, NMi) or are pure gases, impurities of which are analysed at NMI. The uncertainty of the calibration concentration includes the uncertainty due to dilution (combination of the flow meter, pressure- and temperature meter), uncertainty of the dilution gas and uncertainty of the reference standard to the primary standard. The laboratory maintains the calibration services to the most common atmospheric gas pollutants.

The traceability of the reference standards (gas, flow meter, pressure and temperature probe) is to the NMI (NPL, NMi, LNE, MIKES).

The maintenance of the reference standards is through regular re-certification at NMI. The gas standards are normally re-certified once every 2 years and the other reference standards annually.

Intercomparisons

The laboratory participated in the EUROMET 414 and EUROMET 638 projects.

The EUROMET 414 project was co-ordinated by NPL and by PTB. The participating laboratories were those of the reference laboratories maintained the national ozone photometer in Europe. The project also included an intercomparison exercise (bilateral) with NIST/USA. The final report was published in autumn 2002. The result of the laboratory was excellent.

EUROMET 638 is followed the CCQM-K1c key comparison and was accepted by EUROMET as a regional key comparison. The objective of the project is the same as CCQM-K1c: to compare the measurement capabilities of national metrological institutes in measuring the amount of substance fractions of nitrogen monoxide in nitrogen. The intercomparison measurements were conducted in 2002 and draft report A will be ready in early 2003.

Publications

Waldén J, Saari H, Ruoho-Airola T. Background air quality in Finland in 2000. In: Rautjärvi H., Ukonmaanaho, L. and Raitio H. (eds.). Forest Condition Monitoring in Finland - National report 2001. Metsäntutkimuslaitoksen tiedonantoja 879: 23-41.

Intercomparison reports

Comparisons of National Photometric Ozone Primary Standards: Euromet Project 414. Centre for Optical and Analytical Measurement, National Physical Laboratory, Queens Road, Teddington, TW11 0LW.

Lectures

The laboratory organised a seminar on "Uncertainty of the measurements according to CEN standards" in December 2002. The training was aimed at personnel responsible for the measurements and reporting of air quality measurements to the EC.

Other activities

Member of the MetChem Gas Working Group.

Member of the CEN TC264 Working Group 12 "SO_2, NO_2, CO and O_3 in ambient air in Europe".

Member of the EC-Working Group Guidance Document for the Demonstration of Equivalence.

Overview of the calibration laboratory.

Contact information of the National Standards Laboratories

National Standards Laboratory	Quantity	Head of laboratory	Email address
MIKES Lönnrotinkatu 37 (Main office) FIN-00180 Helsinki tel. +358 9 616 761 fax +358 9 6167 467	mass pressure length temperature humidity	Kari Riski Markku Rantanen Antti Lassila Thua Weckström Martti Heinonen	kari.riski@mikes.fi markku.rantanen@mikes.fi antti.lassila@mikes.fi thua.weckstrom@mikes.fi martti.heinonen@mikes.fi
[1]Metallimiehenkuja 6 FIN-02150 Espoo tel. +358 9 616 761 fax +358 9 460 627	dimensional metrology[1]	Veli-Pekka Esala	veli-pekka.esala@mikes.fi
[2]Otakaari 7 B, FIN-02150 Espoo tel. +358 9 616 761 fax +358 9 456 5774	electricity[2] time and frequency[2] acoustics[2]	Antti Manninen Kalevi Kalliomäki Kari Ojasalo	antti.manninen@mikes.fi kalevi.kalliomaki@mikes.fi kari.ojasalo@mikes.fi
Helsinki University of Technology High Voltage Institute POB 3000, FIN-02015 HUT tel. +358 9 4511 fax +358 9 451 2395	high voltage	Martti Aro	martti.aro@hut.fi
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Information about Finnish accredited calibration laboratories can be found on the Internet pages of MIKES www.mikes.fi.

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