NanoScale 2019, PTB Braunschweig, October 15th/16th, 2019

Poster Presentations

General

G_1	**Adoption of the lattice parameter of silicon as a secondary length standard in the 2019 update to the *Mise en Pratique* for the metre** 1) Andrew Yacoot; 2) Ingo Busch, Harald Bosse, Gaoliang Dai, Ludger Koenders, Ulrich Kuetgens; 3) Ron Dixon; 4) Enrico Massa; 5) Jørgen Garnæs 1) National Physical Laboratory, Hampton Road, Teddington Middlesex, TW11 0LW, UK 2) Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, DE 3) National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA 4) Instituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, 10135 Torino, IT 5) Danish Fundamental Metrology, Matematiktorvet 307, DK-2800 Kgs. Lyngby, DK

Methods

M_1	**A statistical method for pitch measurement and evaluation** 1),2) Xiaoyu Cai; 2) Yuan Li, Junjie Wu, Lihua Lei, Jiasi Wei 1) University of Shanghai for Science and Technology, 516 Jungong Rd., Shanghai, CN 2) Shanghai Institute of Measurement and Technology, 1500 Zhangheng Rd.,Shanghai, CN
M_2	**Highly-sensitive laser focus positioning method with sub-micrometre accuracy** D. Kolenov, S.F. Pereira and H.P. Urbach Delft University of Technology (TU Delft), Lorentzweg 1, 2628 CJ Delft, NL
M_3	**Transfer matrix modelling for displacement measuring interferometer design** 1) A. Bridges, A. Yacoot; 2) A. Bridges, T. Kissinger, R.P. Tatam 1) National Physical Laboratory (NPL), Hampton Road, Teddington, Middlesex, TW11 0LW, UK 2) Centre for Engineering Photonics, Cranfield University, Cranfield, MK43 0AL, UK
M_4	**Minimisation of Abbe error on the LNE's metrological AFM by alignment of interferometer laser beams using a CCD camera** D. Ahamed, S. Ducourtieux and A. Delvallee Laboratoire national de metrologie et d'essais (LNE), 29 avenue Roger Hennequin, 78197 Trappes Cedex, FR
M_5	**Differential readings for capacitance-based controls of attitude and displacements at the micro/nano scale** G.B. Picotto, A. Sosso Instituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, 10135 Torino, IT

Instrumentation	
I_01	**Towards super resolution microscopy using photonic nanojet** P-E. Hansen and S.A. Jensen DFM A/S, Kogle Alle 5, 2970 Hørsholm, DK
I_02	**Enhanced measurement accuracy of nanostructures using Hybrid Metrology** P-E. Hansen and J.S. Madsen DFM A/S, Kogle Alle 5, 2970 Hørsholm, DK
I_03	**3D super-resolution nanoscopy** 1)2) I. Kassamakov; 2) G. Maconi; 1) M. Järvinen, T. Vainikka, A. Nolvi, P. Raatikainen, I. Ninca, T. Ylitalo; 3) V. Korpelainen, A. Lassila; 1) K. Ahlers; 2) Edward Hæggström 1) Nanojet Inc., Pursimiehenkatu 26 C, 00150 Helsinki, FI 2) University of Helsinki, Fabianinkatu 33, 00014 Helsinki, FI 3) VTT MIKES, Tekniikantie 1, Espoo, FI
I_04	**Metrological UV Microscope in NIM** 1)2) Qi Li; 1) Sitian Gao, Yushu Shi, Wei Li, Lu Huang 1) National Institute of Metrology (NIM), No. 18 Bei San Huan Road, 100029, Beijing, CN 2) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
I_05	**Integration of a UV-Microscope in the Nanometer Comparator at PTB: First results** Rainer Köning, Eugen Schötka, Matthias Schumann, Jens Fluegge, Jan Krüger, Harald Bosse Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
I_06	**Single beam 3-DoF Interferometer using a CMOS camera** 1)2) L. Yu, J. Tan; 3) L. Yu, C. Werner, H. Danzebrink, J. Flügge; 4) G. Molnar 1) Center of Ultra-precision Optoelectronic Instrument Engineering, Harbin Institute of Technology, Harbin 150080, CN 2) Key Lab of Ultra-precision Intelligent Instrumentation (Harbin Institute of Technology), Ministry of Industry and Information Technology, Harbin 150080, CN 3) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 4) MPro GmbH, Zum Bahnhof 9, 98593 Floh-Seligenthal
I_07	**ISI Differential Interferometer with In-Axis Sensing of Mirror Tilt** S. Rerucha, M. Hola, M. Sarbort, J. Hrabina, J. Oulehla, O. Cip, J. Lazar Institute of Scientific Instruments of the CAS (ISI), Kralovopolska 147, 612 64 Brno, CZ
I_08	**Cost-effective heterodyne interferometer with minimal periodic nonlinearities** D. Vobornik, B. J. Eves NRC Metrology, National Research Council of Canada, CA

I_09	**Design of metrological atomic force microscope (MAFM) with sub-nanometer measurement uncertainty** J. Nysten, V. Korpelainen, J. Seppä and A. Lassila VTT MIKES, Tekniikantie 1, Espoo, FI
I_10	**Validation of the LNE's metrological AFM: a new reference tool for dimensional measurement at the nanoscale in France** 1) S. Ducourtieux, A. Delvallée, P. Ceria; 2) C. Ulysse 1) Laboratiore National de metrologie et d'Essais (LNE), Trappes, FR 2) C2N/CNRS, Palaiseau, FR
I_11	**Nanopositioning and nanomeasuring machines for cross-scale measurement, fabrication and manipulation with sub-nanometer precision** 1) E. Manske, R. Füßl, I. Rangelow, S. Ortlepp, R. Mastylo, U. Blumröder, L. Weidenfeller, J. Kirchner, M. Hofmann, S. Suppreti; 2) M. Kühnel; 3) P. Köchert 1) Technische Universität Ilmenau, PF 100565, 98684 Ilmenau, DE 2) SIOS Messtechnik GmbH, Am Vogelherd 36, 98693 Ilmenau, DE 3) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
I_12	**True 3D-AFM sensor for nanometrology** 1) J. Thiesler, G. Dai, K. Fromm, H. Wolff, R. Popadic; 2) R. Tutsch 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) Technische Universität Braunschweig, IPROM, Schleinitzstraße 20, 38106 Braunschweig, DE
I_13	**Selecting the optimum vibration mode for contact resonance scanning using large-size piezoresistive microprobes** 1)2) Michael Fahrbach, Erwin Peiner; 3) Sebastian Backes, Brunero Cappella 1) Institute of Semiconductor Technology (IHT), Braunschweig Institute of Technology, Hans-Sommer-Straße 66, 38106 Braunschweig, DE 2) Laboratory for Emerging Nanometrology (LENA), Langer Kamp 6a/b, 38106 Braunschweig, DE 3) Bundesanstalt für Materialforschung und -prüfung (BAM), Unter den Eichen 44-46, 12203 Berlin, DE
I_14	**Design and performance of a test rig for evaluation of nanopositioning stages** 1) Andrew Yacoot; 2)3) Petr Klapetek; 2) Miroslav Valtr, Petr Gorlich; 1) Herve Dongmo, Giovanni M. Lazzerini, Angus Bridges 1) National Physical Laboratory, Hampton Road, Teddington Middlesex, TW11 0LW, UK 2) Czech Metrology Institute, Okružní 31, 638 00 Brno, CZ 3) CEITEC, Brno University of Technology, Purkyňova 123, 638 00 Brno, CZ

Calibration	
C_01	**Calibration of step height standards by using Large Range Nanomeasuring Machine NMM and Laser Sensor** L. Carcedo, M. M. Ozaita, E. Prieto Centro Español de Mertología (CEM), C/ Alfar nº 2, 28760 Tres Cantos, Madrid, ES
C_02	**Reference-scan-based correction method of nonlinear drift of atomic force microscopy with sub-nanometer precision** Ryosuke Kizu, Ichiko Misumi, Akiko Hirai and Satoshi Gonda National Metrology Institute of Japan (NMIJ), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba Central 3, 1-1-1 Umezono, Tsukuba, Ibaraki 305-8563, JP
C_03	**How levelling and scan line correction ruins roughness measurement** 1) David Nečas; 2) Petr Klapetek 1) CEITEC Masaryk University, Kamenice 5, 62500 Brno, CZ 2) Czech Metrology Institute, Okružní 31, 63800 Brno, CZ
C_04	**The role of precise sample positioning in the study of materials morphology changes and correlative microscopy investigations** A. Sikora Electrotechnical Institute, Division of Electrotechnology and Materials Science, M. Skłodowskiej-Curie 55/61, 50-369 Wrocław, PL
C_05	**3D Electron Microscopy for Imaging & Characterization of Tactile Probing Tips** 1) J. Langfahl-Klabes, T. Ahbe, M. Xu, T. Klein, U. Brand; 2) M. Hemmleb, U. Grauel; 3) M. Ritter; 4) R. Tutsch 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) point electronic GmbH, Erich-Neuß-Weg 15, 06120 Halle (Saale), DE 3) Technische Universität Hamburg, Betriebseinheit Elektronenmikroskopie, Eißendorfer Straße 42, 21073 Hamburg, DE 4) Technische Universität Braunschweig, IPROM, Schleinitzstraße 20, 38106 Braunschweig, DE
C_06	**Calibration of 3D reference standards using metrological large range AFM and calibrated confocal microscopy** 1) M. Hemmleb; 2) M. Ritter; 3) G.Dai, A. Felgner, T. Dziomba, L. Koenders 1) point electronic GmbH, Erich-Neuß-Weg 15, 06120 Halle (Saale), DE 2) Technische Universität Hamburg, Betriebseinheit Elektronenmikroskopie, Eißendorfer Straße 42, 21073 Hamburg, DE 3) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
C_07	**Structure resolution being the upper band limit in optical roughness measurements** D. Hueser, L. Koenders, A. Felgner, S. Gao Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE

C_08	**Investigation of 3D optical microscopy topography fidelity using a chirp-calibration standard** Sai Gao, André Felgner, Dorothee Hueser and Ludger Koenders Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
C_09	**Areal Surface Texture: Material Measures with Anisotropic Roughness** 1) J. Frühauf, E. Gärtner 2) A. Felgner, D. Hüser, T. Dziomba 1) SimetricS GmbH, Am Südhang 5, 09212 Limbach-Oberfrohna, DE 2) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
C_10	**Contrast enhanced white-light interferometry for increased lateral resolution** Matthias Liedmann, Torsten Machleidt and Max Schneider Gesellschaft für Bild- und Signalverarbeitung (GBS) mbH, Werner-von-Siemens-Straße 10, 98693 Ilmenau, DE
C_11	**Potential features for extreme resolving power assessment on the NPL Areal Standard for surface topography measuring instruments** 1) C. W. Jones, P. See, L. P. Nimishakavi, D. O'Conner; 2) C. L. Giusca 1) National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, UK 2) Cranfield University, College Rd, Cranfield, Bedford MK43 0AL, UK
C_12	**A dimensional standard for providing SI-traceability in confocal micro-Raman spectroscopy** R. Stosch, T. Dziomba, T. Weimann, P. Hinze, S. Wundrack, J. Molle Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
C_13	**Gold Nano Hall Sensors for Traceable Scanning Probe Magnetic Field Microscopy** 1) Manuela Gerken, Thomas Weimann, Sibylle Sievers and Hans Werner Schumacher; 2) Aurélie Solignac 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) SPEC, CEA, CNRS, Université Paris-Saclay, CEA Saclay, Gif sur Yvette Cedex, FR
C_14	**Round robin test on quantitative nanometer scale stray field measurement by magnetic force microscope** 1) X. K. Hu, G. Dai, S. Sievers, H. W. Schumacher; 2) V. Neu, Y. Tang; 3) M. Ulvr, P. Klapetek, M. Havlíček; 4) H. Corte-León 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), DE 3) Czech Metrology Institute (CMI), CZ 4) National Physical Laboratory (NPL), Middlesex TW11 0LW, UK

Nano-Mechanics	
NM_1	**Possibility for SI-traceable determination of the spring constant of a stiff cantilever using the nanonewton force facility based on electrostatic methods** Vladimir Nestorov, Zhi Li Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
NM_2	**Calibration of the probing force and the tip area function in atomic force microscopy using reference artefacts and soft reference materials** 1) Zhi Li, Uwe Brand, Sai Gao, Thomas Ahbe; 2) Jørgen Garnæs, Guanghong Zeng, Jacob Larsen, Kai Dirscherl 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) Dansk Fundamental Metrologi A/S, Kogle Alle 5, 2970 Hørsholm, DK
NM_3	**Traceable characterization of the dynamic performance of a nano-positioning stage for dynamic mechanical analysis** 1) Yonggang Yan; 2) Zhi Li, Uwe Brand 1) School of Mechanical and Power Engineering, Henan Polytechnic University, Jiaozuo, Henan 454003 PR, CN 2) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
NM_4	**Fibre interferometry based mechanical properties measurements in Scanning Probe Microscopy** 1) P. Klapetek, V. Duchon, V. Hortvik, M. Valtr; 2) H. Dongmo, A. Yacoot 1) Czech Metrology Institute, Okružní 31, 638 00 Brno, CZ 2) National Physical Laboratory, Hampton Road, Teddington Middlesex, TW11 0LW, UK
Line Edge Roughness	
LER_1	**Comparison of state-of the-art rigorous simulation tools by analyzing the specific image modeling results on photomasks in the field of UV – optical microscopy** Jan Krüger, Rainer Köning, Bernd Bodermann Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
LER_2	**(Optical) Metrology for structural imperfections in nanostructures** 1)2) Thomas Siefke; 1) Alexander Diener, Matthias Wurm, Dieter Skroblin, Analía Fernández Herrero, Victor Soltwisch, Bernd Bodermann; 1)3) Stefanie Kroker; 4) Jürgen Probst 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) Friedrich-Schiller-Universität Jena, Institute of Applied Physics, 07743 Jena, DE 3) Technische Universität Braunschweig, LENA Laboratory for Emerging Nanometrology, 38106 Braunschweig, DE 4) Helmholtz-Zentrum Berlin, 12489 Berlin, DE

LER_3	**Adaptive-angle-scanning method for 3D-AFM measurement with tailored CD probe** R. Zhang, S. Wu, X. Fu, X.D. Hu State Key Lab of Precision Measurement Technology and Instruments, Tianjin University, 300072 Tianjin, CN
LER_4	**Degradation effects of Line Edge Roughness in nanoelectronics: Hierarchical characterization, Edge Placement Error and cut failures** V. Constantoudis, G. Papavieros, E. Gogolides Institute of Nanoscience and Nanotechnology, NCSR Demokritos & Nanometrisis p.c., Patr. Gregoriou E & 27 Neapoleos Str, 15341 Agia Paraskevi, GR
LER_5	**Deep Learning Nanometrology of Line Edge Roughness** 1)5) E. Giannatou; 1)2) V. Constantoudis, E. Gogolides; 1)2)4) G. Papavieros; 3) G. Lorusso, V. Rutigliani, F. Van Roey; 5) H. Papageorgiou 1) Nanometrisis P.C., TEPA Lefkippos, 15341 Ag. Paraskevi, GR 2) N.C.S.R. Demokritos, Institute of Nanoscience & Nanotechnology, 15310 Ag. Paraskevi, GR 3) IMEC, Kapeldreef 75, 3001 Leuven, BE 4) Aristotle University of Thessaloniki, Physics Department, 4124, Thessaloniki, GR 5) Athena R.C., Institute for Language and Speech Processing (ILSP), 15125 Marousi, GR
LER_6	**Line Edge Roughness (LER) metrology: Improving the accuracy using Hidden Markov Models (HMMs)** 1)2)4) G. Papavieros; 1)2) V. Constantoudis, E. Gogolides; 2) E. Giannatou; 3) I. Kontoyiannis 1) Institute of Nanoscience and Nanotechnology, NCSR Demokritos, Agia Paraskevi, 15341, GR 2) Nanometrisis P.C., Agia Paraskevi, 15341, Athens, GR 3) University of Cambridge, UK 4) Aristotle University of Thessaloniki, Physics Department, 4124, Thessaloniki, GR
	Nanoparticles
NP_1	**Methodology to evaluate the uncertainty associated with nanoparticle dimensional measurements by SEM** 1) L. Crouzier, A. Delvallée, L. Devoille, S. Ducourtieux, N. Feltin; 2) A. Allard 1) Laboratoire national de metrologie et d'essais - Nanometrology, 29 avenue Roger Hennequin, 78197 Trappes Cedex, FR 2) Laboratoire national de metrologie et d'essais – Mathematics and Statistics Department, 29 avenue Roger Hennequin, 78197 Trappes Cedex, FR
NP_2	**Characterization of non-spherical nanoparticles: Evaluation of image analysis routines using simulated TSEM micrographs** T. Klein, D. Hüser, M. Neuwirth, W. Häßler-Grohne, D. Bergmann and E. Buhr Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
NP_3	**Polystrene nanoparticle deformation – range extended** Sylvain Hauser and Felix Meli Swiss Federal Institute of Metrology, METAS, Lindenweg 50, CH-3003 Bern-Wabern, CH

NP_4	**Tip-sample interactions in the AFM study of rod-shaped nanostructures** 1) G. B. Picotto, L. Ribotta; 2) M. Vallino 1) Instituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, 10135 Torino, IT 2) Instituto per la Protezione Sostenibile delle Piante, Strada delle Cacce 73, 10135 Torino, IT
NP_5	**The Apparent Hydrodynamic Diameter of Nanoparticles Measured by Multiple-Angle Dynamic Light Scattering** 1) Lu Huang, Sitian Gao, Yushu Shi; 2) Miao Sun 1) National Institute of Metrology, Beijing 100029, CN 2) Beijing Information Science and Technology University, Beijing 100192, CN
NP_6	**DNA Origami Sensing Platform for Single-Molecule Detection with Surface-Enhanced Raman Spectroscopy (SERS)** Z. Wang, J. Molle, S. Wundrack, R. Stosch Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
NP_7	**DNA origami Nanostructures as breadboard for surface-enhanced Raman spectroscopy (SERS) of biological markers** 1) J. Molle, R. Stosch, Z. Wang; 2) B. Lalkens 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) TU Braunschweig LENA, Langer Kamp 6a/b, 38106 Braunschweig, DE
Applications	
A_01	**Nanospectroscopy for Structure-Property Correlation at the Nanoscale** Deb Roy and colleagues Swansea University, Swansea, UK National Physical Laboratory, UK King's College London, UK
A_02	**Design Study for the the Application of Plasmonic Lenses in Mueller Matrix Ellipsometry** 1) T. Käseberg, B. Bodermann; 1)2) T. Siefke; 1)3) S. Kroker 1) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 2) Friedrich-Schiller-Universität Jena, Abbe Center of Photonics, Institute of Applied Physics, Max-Wien-Platz 1, 07743 Jena, DE 3) TU Braunschweig LENA, Langer Kamp 6a/b, 38106 Braunschweig, DE
A_03	**Correlation of small angle X-ray scattering data and optical absorption spectroscopy to characterize semiconductor nanocrystals** 1)2)3) J. C. Porsiel; 2) A. Schirmacher; 2)3) E. Buhr; 1)3) E. Garnweithner 1) Institute for Particle Technology (iPAT), TU Braunschweig, Volkmaroder Str. 5, 38104 Braunschweig, DE 2) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE 3) TU Braunschweig LENA, Langer Kamp 6a/b, 38106 Braunschweig, DE

A_04	**Sensitivity analysis for parameter retrieval of subwavelength gratings using coherent Fourier scatterometry** L. Siaudinyte, S. F. Pereira Delft University of Technology, Faculty of Applied Sciences, Imaging Physics Department Optics Research Group, Lorentzweg 1, 2628CJ, Delft, NL
A_05	**Dipped tip-on-cantilever mass sensor for particle sampling and detection** 1)2) Wilson Ombati Nyang'au; 1)3) Andi Setiono; 1) Angelika Schmidt, Erwin Peiner; 4) Harald Bosse 1) IHT & LENA, Technische Universität Braunschweig, 38106 Braunschweig, DE 2) Department of Metrology, Kenya Bureau of Standards (KEBS), Nairobi, KE 3) Research Center for Physics, Indonesian Institute of Sciences (LIPI), Banten, ID 4) Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE
A_06	**Characterisation of 4D printed structure through microgeometry analysis** Anna Trych-Wildner, Łukasz Ślusarski Central Office of Measures, Length Laboratory, ul. Elektoralna 2, 00-139 Warsaw, PL
A_07	**Characterization of weathered PVC profiles by confocal scanning microscopy** Horst Purwin, Ralf Theissmann KRONOS INTERNATIONAL, Inc., Research Services, Peschstr. 5, 51373 Leverkusen, DE
A_08	**Thin film conformality analysis with microscopic PillarHall lateral high aspect ratio structures: Uncertainty estimates** 1) Virpi Korpelainen, Oili Ylivaara, Feng Gao, Mikko Utriainen; 2) Markku Ylilammi; 3) Riikka Puurunen 1)VTT Technical Research Centre of Finland Ltd, P.O. Box 1000, FI-02044 VTT, Espoo, FI 2) Retired from VTT, Espoo, FI 3) Aalto University, FI-00076 Aalto, FI
A_09	**The Development of X-ray Metrology for Thin Film Thickness in Semiconductor Inspection** Guo-Dung Chen, Bo-Ching He, Chun-Ting Liu, Wei-En Fu and Wen-Li Wu Center for Measurement Standards, Industrial Technology Research Institute, Hsinchu, Taiwan 321 KuangFu Rd. Sect 2, Hsinchu, TW
A_10	**Measuring the inner profile of cavitation nozzles with Profilscanner** Min Xu, Corinna Kroner, Daniel Schumann and Uwe Brand Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, DE