PHYSIKALISCH-TECHNISCHE BUNDESANSTALT (PTB)
BRAUNSCHWEIG AND BERLIN, GERMANY

BOOK OF ABSTRACTS

2nd International Workshop on Spectroscopic Thermometry

- PriSpecTemp Final Stakeholder Workshop

Date: 21 October 2026
Location: Virtual Event / Hosted Online by PTB

Editors:
Gang Li, Rainer Stosch and PriSpecTemp Consortium

Organisation committee:

Gang Li, Livio Gianfrani, Daniel Lisak, Graham Machin

Project Website and Consortium: https://www.prispectemp.ptb.de/home

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EURAMET

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Workshop Program

Time	Session / Presentation	Speaker / Moderator
WELCOME & PLENARY		
09:00 - 09:20 CEST	Welcome W1	Gang Li & Rainer Stosch (PTB)
09:20 - 09:50	Plenary P1	Graham Machin (NPL)
SESSION 1: Line-Intensity Ratio Thermometry (LRT) & Ro-Vibrational Spectroscopic Gas Thermometry (RVSGT) (Chair: Livio Gianfrani)		
09:50 - 10:10	Talk 1a	Daniel Lisak (UMK)
10:10 - 10:30	Talk 1b	Yan Tan (USTC)
10:30 - 10:50	Talk 1c	Can Gözönünde (TUBITAK UME)
10:50 - 11:10	Morning Coffee Break	
10:10 - 11:30	Talk 1d	Yu-Rong Xu (UMK)
11:30 - 11:50	Talk 1e	Kianoosh Hadidi (JV)
11:50 - 12:10	Talk 1f	Yukiko Shimizu, Sho Okubo, and Hajime Inaba (AIST)
SESSION 2: Doppler-Broadening Thermometry (DBT) & Refractive-Index Gas Thermometry (RIGT) (Chair: Graham Machin)		
12:10 - 12:30	Talk 2a	Shuiming Hu (USTC)
12:30 - 12:50	Talk 2b	Livio Gianfrani (UniCampania)
12:50 - 13:50	**Lunch Break**	
13:50 - 14:10	Talk 2c	Carmen Garcia Izquierdo (CEM)
14:10 - 14:30	Talk 2d	Tom Rubin (PTB)
SESSION 3: Low & High Temperature Spectroscopic Thermometry (Chair: Daniel Lisak)		
14:30 - 14:50	Talk 3a	Aidan Arnold (UniStrathclyde)
14:50 - 15:10	Talk 3b	Xiaofeng Lu (NIM)
15:10 - 15:30	Talk 3c	Piotr Wcisło (UMK)
15:30 - 15:50	Afternoon Coffee Break	
SESSION 4: Atmospheric Applications (Chair: Gang Li)		
15:50 - 16:10	Talk 4a	Iouli Gordon (Harvard CfA)
16:10 - 16:30	Talk 4b	Lukas Petera (ODU)
16:30 - 16:50	Talk 4c	Adam Fleisher (NIST)
16:50 - 17:10	Talk 4d	Keeyoon Sung (NASA JPL)
DISCUSSION		
17:10 - 17:40	Panel Discussion	Moderated by Session Chairs & Project PMB Members

Abstracts

Talk W1: The EURAMET 22IEM03 PriSpecTemp project: “Primary Spectrometric Thermometry for Gases”

Author(s) / Speaker: **Gang Li** (Physikalisch-Technische Bundesanstalt), Kianoosh Hadidi (JV), Carmen G. Izquierdo (CEM), Aleksandra Kyuberis (RUG), H. Nasibli (TUBITAK), **Rainer Stosch** (PTB), and the PriSpecTemp consortium

Accurate gas temperature measurements are vital for climate monitoring and industrial processes, yet conventional contact thermometers suffer from biases due to radiation, low gas thermal conductivity and self-heating. The 22IEM03 PriSpecTemp project [1] advances non-contact primary spectrometric thermometry to overcome these limitations, targeting traceable gas temperature measurements over 200–400 K with sub-25 mK uncertainty.

The methodology combines high-accuracy quantum mechanical calculations of molecular line parameters (CO, CO_2, O_2) with advanced spectroscopic techniques, including Fourier-transform spectroscopy (FTS) [2], cavity ring-down spectroscopy (CRDS)[2], cavity mode dispersion spectroscopy (CMDS) [2,3], Dual-comb spectroscopy (DCS)[4]. Cross-validation against ITS-90 standards and refractive index gas thermometry (RIGT) ensures metrological robustness. Key results include multi-line rovibrational thermometry using CO, achieving 24 mK uncertainty at 296 K, and 0.1%-accuracy line intensity measurements for CO, validated through international comparisons CCQM-P229[2,5]. A novel isothermal optical gas cell bridging spectroscopic and contact methods demonstrated temperature uniformity < 10 mK level [6].

The project’s outcomes reduce calibration uncertainties for industrial thermometers, benefiting sectors like environmental monitoring aerospace and pharmaceuticals. Integration with HITRAN and engagement with standardization bodies (CIPM, EURAMET) ensure long-term impact. By advancing spectrometric thermometry, the project supports climate science through improved atmospheric temperature data and contributes to energy-efficient industrial processes. This project establishes a foundation for next-generation thermodynamic gas temperature standards, aligning with global efforts to address climate change and industrial challenges. The project (22IEM03 PriSpecTemp) has received funding from the European Partnership on Metrology, co-financed from the European Union’s Horizon Europe Research and Innovation Programme and by the Participating States.”

References:

[1] EURAMET EPM 22IEM03 PriSpecTemp project: https://www.prispectemp.ptb.de/home
[2] J T Hodges et al., Metrologia 62 08006 (2025)
[3] Cygan et al., Sci. Adv. 11, eadp8556 (2025)
[4] M. Roiz et al., Opt. Lett. 49, 2473-2476 (2024).
[5] G. Li et al. Measurement:Sensors (2025) doi.org/10.1016/j.measen.2025.101850
[6] K.Hadidi, and G.Li, Measurement:Sensors (2025) doi.org/10.1016/j.measen.2024.101639

Plenary P1: The international system of units, the kelvin redefinition and its impact on temperature traceability

Author(s) / Speaker: **Professor Graham Machin** FRS, FREng, DSc, DPhil (Oxon) (National Physical Laboratory, Teddington, UK)

Abstract:

The international system of units (the SI) had its origins in the metric system, established at the time of the French revolution. In the beginning the metric system was only used in France and consisted only of the metre and the kilogram. A great step forward for measurement took place in 1875 with the signing of the metre convention which laid the groundwork for the globalisation of the metric units, and out of which evolved the SI. From those beginnings the SI has grown into a global phenomenon covering the measurements required to facilitate over 99% of all global economic activity. The SI is a coherent unit system comprised of seven base units consisting of mass, length, time, electric current, temperature, amount of substance and luminous intensity.

It might be surprising but the unit of temperature the kelvin was only defined in 1954, perhaps even more so because the foundational ideas of absolute temperature arose mainly from the work of Lord Kelvin (then William Thomson) in the late 1840s to mid-1850s [1].

In this talk Professor Machin will introduce the origin and development of the SI. He will then trace the evolution of the temperature unit, from its empirical origins in the 17th and 18th centuries, to the work of Lord Kelvin in the 19th Century, to the advent of defined temperature scales in 1927, the introduction of the SI unit of temperature, the kelvin, in 1954, up to present day when the kelvin was redefined in May 2019, in terms of a fixed value of the Boltzmann constant, k [2, 3, 4]. In the latter part of his talk, the speaker will discuss the implications of the redefined kelvin and how this could profoundly impact the provision of temperature traceability to end users in industry and elsewhere in the decades to come [5, 6, 7].

References:

[1] Machin, G., “Evolution of temperature measurement: beginnings, progress and prospects”, HAPP Conference on “Physics and the Science of Living Things” J. Phys.: Conf. Ser. 2877 012112 (2024) DOI 10.1088/1742-6596/2877/1/012112

[2] Machin, G., “The Kelvin redefined”, Meas. Sci. Technol. 29 022001 (11pp) (2018) https://doi.org/10.1088/1361-6501/aa9ddb

[3] Machin, G., Sadli, M., Engert., J., Kirste, A., Pearce, J., Gavioso, R., “Progress with realizing the redefined kelvin”, Proceedings of the 10th International Temperature Symposium, AIP Conf. Proc. 3230, 020001 (2024) https://doi.org/10.1063/5.0234456

[4] Machin, G, Gaiser, C., Rourke, P.M.C., “The redefined kelvin – progress and prospects”, Phil Trans Roy. Soc. A 384: 20240463.https://doi.org/10.1098/rsta.2024.0463 (Jan 2026)

[5] Dedyulin, S., Ahmed, Z., Machin, G., “Emerging technologies in the field of thermometry”, Meas. Sci. & Technol. 33 092001 (26pp) (2022) https://doi.org/10.1088/1361-6501/ac75b1

[6] Machin, G., Agnew, N., Yamsiri, A., Arnold, A., Riis, E., Sweeney, S., “Standard photonic (Quantum) thermometry in the UK”, Measurement: Sensors, 101775 (2025) https://doi.org/10.1016/j.measen.2024.101775

[7] Pearce, J.V., Machin, G. Todd, A.D.W., Martín, M.J., Pan, Y., Zhou, K., Olsen, A.A.F., “Future traceability of practical primary thermometry and self-validating thermometry” Phil. Trans. R. Soc. A 384: 20240453. https://doi.org/10.1098/rsta.2024.0453 (Jan 2026)

Talk 1a: Line-ratio thermometry using cavity mode-dispersion spectroscopy and ab initio CO (3-0)-band line intensities

Author(s) / Speaker: **Daniel Lisak**, Vittorio D'Agostino, Szymon Wójtewicz, Agata Cygan, Marcin Gibas, Piotr Wcisło, Roman Ciuryło, Oleg L. Polyansky, Nikolai F. Zobov, Jonathan Tennyson, Katarzyna Bielska (Nicolaus Copernicus University in Toruń & partners)

Abstract:

We present a spectroscopic approach to primary gas thermometry [1] based on line-intensity-ratio thermometry (LRT), cavity mode-dispersion spectroscopy (CMDS) [2,3], and *ab initio* molecular line intensities [4]. Using transitions from the CO (3–0) vibrational band near 1.57 μm, CMDS provides highly precise measurements of molecular line areas through shifts of optical-cavity resonance frequencies. In our first implementation [1], LRT based on *ab initio* line intensities achieved a relative standard uncertainty of 82 ppm, corresponding to 24 mK at 296 K – over an order of magnitude lower than previously reported spectroscopic thermometry at pressures above 1.2 kPa. This result also enabled fully optical sub-permille-accuracy measurement of gas concentration over the range from 50 Pa to 20 kPa.

We further investigate the influence of reference spectroscopic data on the accuracy and internal consistency of LRT by reanalyzing the same spectra of ten CO transitions using newly available *ab initio* line-intensity ratios [5]. The updated intensities reduce the dispersion of temperatures obtained from different line pairs by approximately an order of magnitude [6]. For seven line pairs, the standard error of the mean (SEM) of retrieved temperatures is only 1.3 mK, while the weighted mean spectroscopic temperature agrees with the independently measured gas-cell temperature within a few millikelvin. The resulting combined standard uncertainty of the mean spectroscopic temperature is 19 mK, or 62 ppm at 296 K, with the dominant contribution originating from spectral line-shape modeling rather than from the reference line intensities. These results demonstrate the potential of combining CMDS with high-accuracy *ab initio* spectroscopy for precise and calibration-free gas thermometry.

References:

[1] D. Lisak, V. D'Agostino, S. Wójtewicz, A. Cygan, M. Gibas, P. Wcisło, R. Ciuryło, K. Bielska, *Leveraging Resonant Frequencies of an Optical Cavity for Spectroscopic Measurement of Gas Temperature and Concentration*, Phys. Rev. Lett. 135, 103201 (2025).

[2] A. Cygan, P. Wcisło, S. Wójtewicz, P. Masłowski, J. T. Hodges, R. Ciuryło, D. Lisak, *One-dimensional frequency-based spectroscopy*, Opt. Express 23, 14472 (2015).

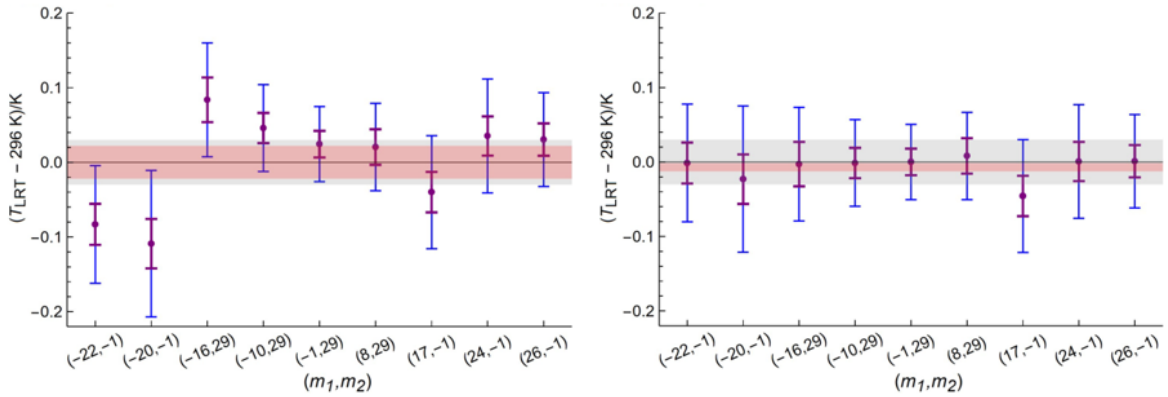
[3] A. Cygan, P. Wcisło, S. Wójtewicz, G. Kowzan, M. Zaborowski, D. Charczun, K. Bielska, R. S. Trawiński, R. Ciuryło, P. Masłowski, D. Lisak, *High-accuracy and wide dynamic range frequency-based dispersion spectroscopy in an optical cavity*, Opt. Express 27, 21810 (2019).

[4] K. Bielska, A. A. Kyuberis, Z. D. Reed, G. Li, A. Cygan, R. Ciuryło, E. M. Adkins, L. Lodi, N. F. Zobov, V. Ebert, D. Lisak, J. T. Hodges, J. Tennyson, and O. L. Polyansky, *Subpromille*

measurements and calculations of CO (3–0) overtone line intensities, Phys. Rev. Lett. 129, 043002 (2022).

[5] J.-K. Li, J. Wang, R.-H. Yin, Q. Huang, Y. Tan, C.-L. Hu, Y. R. Sun, O. L. Polyansky, N. F. Zobov, E. I. Lebedev, R. Stosch, J. Tennyson, G. Li, S.-M. Hu. *Unprecedented accuracy in molecular line-intensity ratios from frequency-based measurements*, Sci. Adv. 11(38), eadz6560 (2025).

[6] D. Lisak, S. Wójtewicz, A. Cygan, P. Wcisło, R. Ciuryło, O. L. Polyansky, N. F. Zobov, J. Tennyson, K. Bielska, *Impact of reference line intensities on primary spectroscopic thermometry*, submitted at Aug 28, 2026.



[Graphical Abstract / Visual Summary for Talk 1a]

Differences between spectroscopic gas temperature, T_{LRT}, measured with CMDS, and the reference temperature of the gas cell (T_{cell} = 296.00(3) K) for different spectral line pairs (m_1, m_2) of CO (3-0) band, obtained with: UCL2022 (left plot), and UCL2025 (right plot) ab initio line ratios. The error bars correspond to combined (blue) and statistical (purple) standard uncertainties. The colored bands correspond to the ± statistical SEM of T_{LRT} (red), and the combined standard uncertainty of T_{cell} (gray).

Talk 1b: Line-Ratio Thermometry (LRT) with Sub-millikelvin Precision Using Dual-Wavelength Cavity Mode-Dispersion Spectroscopy

Author(s) / Speaker: Yan Tan, Shui-Ming Hu, Jin Wang, Jin-Ke Li, Qi Huang, Hui Liang (University of Science and Technology of China)

Abstract:

Line-intensity ratio thermometry (LRT) determines gas temperature from the ratio of two rovibrational transition intensities of the same molecule, providing direct traceability to the Boltzmann constant and the SI definition of the kelvin. However, its accuracy has been limited both by experimental precision and by the reliability of theoretical transition-intensity ratios.

We demonstrate LRT at the parts-per-million (ppm) level using dual-wavelength cavity mode-dispersion spectroscopy (DW-CMDS), an all-frequency-domain technique in which two phase-stabilized lasers are simultaneously locked to a high-finesse optical cavity. Because both spectral axes correspond to precisely measurable frequencies, common-mode systematic drifts cancel in the measured ratios, yielding line-intensity ratios with fractional uncertainties of 3×10^{-5}, a 30-fold improvement over the prior 0.1% benchmark.

Applied to thermometry, the CO R(0)/R(20) line pair yields a temperature of 298.9330 K with a statistical uncertainty of 0.5 mK and a systematic uncertainty of 2.0 mK, in agreement with the platinum-sensor reference within its calibration uncertainty; this corresponds to an approximately 6.7 ppm systematic contribution and represents the highest accuracy in optical thermometry to date. Extending the method to the H_2 (2-0) quadrupole band, the S(0)/Q(1) transition-rate ratio was determined as 0.657448(16)stat(85)sys with an Allan deviation of 4×10^{-5} (about 12 mK), consistent with non-adiabatic perturbation theory at the −0.11(15)‰ level.

These results establish DW-CMDS as a molecule-agnostic platform for SI-traceable primary thermometry, with a clear path toward 10^{-6}-level measurements and applications from combustion diagnostics to atmospheric monitoring.

Reference:

[1] J.-K. Li, J. Wang, R.-H. Yin, Q. Huang, Y. Tan, C.-L. Hu, Y. R. Sun, O. L. Polyansky, N. F. Zobov, E. I. Lebedev, R. Stosch, J. Tennyson, G. Li, S.-M. Hu, Unprecedented accuracy in molecular line-intensity ratios from frequency-based measurements, Sci. Adv. 11, eadz6560 (2025).

[2] R. Gotti, M. Lamperti, D. Gatti, M. Marangoni, Laser-based primary thermometry: A review, J. Phys. Chem. Ref. Data 50, 031501 (2021).

[3] K. Bielska, A. A. Kyuberis, Z. D. Reed, G. Li, A. Cygan, R. Ciuryło, E. M. Adkins, L. Lodi, N. F. Zobov, V. Ebert, D. Lisak, J. T. Hodges, J. Tennyson, O. L. Polyansky, Subpromille measurements and calculations of CO (3-0) overtone line intensities, Phys. Rev. Lett. 129, 043002 (2022).

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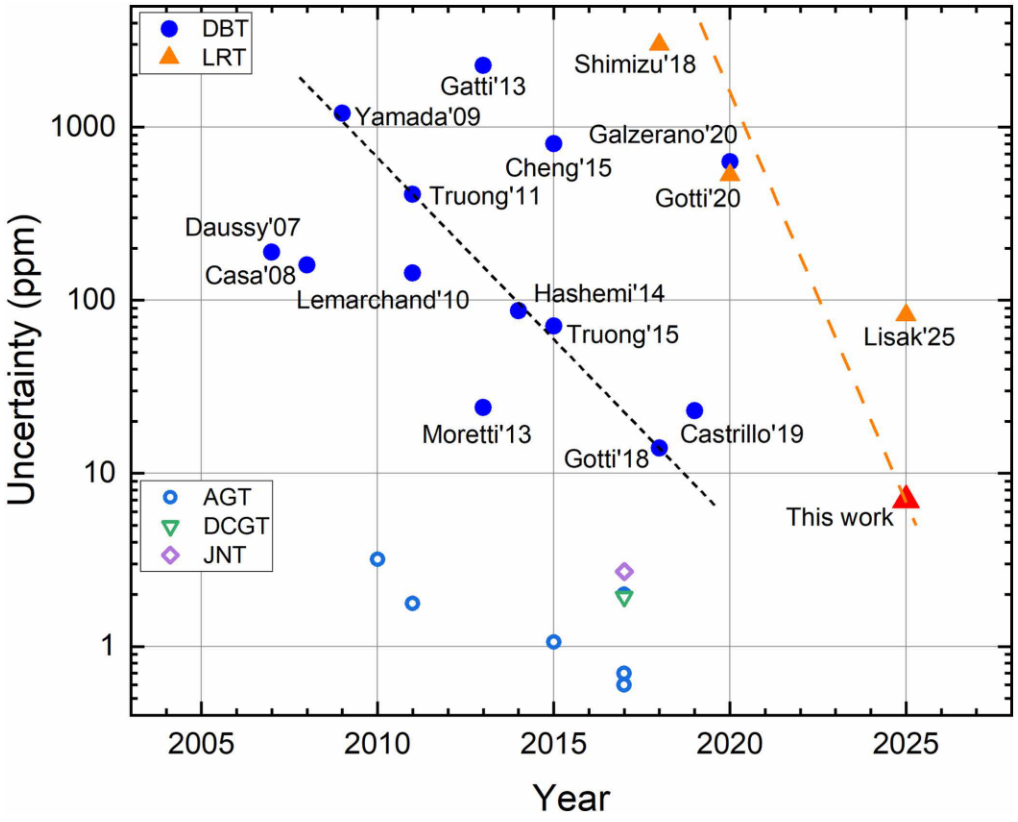

[Graphical Abstract / Visual Summary for Talk 1b]

Thermometry based on optical spectroscopy. Adapted from Li et al., Sci. Adv. 11, eadz6560 (2025).

Talk 1c: Ro–Vibrational Spectroscopic Gas Thermometry with FTIR Spectrometer

Author(s) / Speaker: **Can Gözönünde**, Hümbet Nasibli (TUBITAK-UME, National Metrology Institute, Gebze, Türkiye)

Abstract:

This work establishes gas temperature measurement from the ro-vibrational structure of an infrared absorption band, using a Fourier transform spectrometer at moderate resolution with a purpose-built thermostatic cell, and validates it against SI-traceable contact thermometry. Results are shown for CO, chosen because its reference line intensities are known to sub-permille accuracy [1].

Most gas thermometry by absorption spectroscopy uses lasers — TDLAS, CRDS, comb-based methods —where individual transitions are fully resolved and the instrument function is narrower than the absorption profile [2]. Fourier transform spectrometers at moderate resolution operate in the opposite regime, with an instrument function several times broader than the lines. They are also far more widely deployed, and the rotational distribution that encodes temperature is present in every spectrum they record [3].

Retrieving it requires clearing an obstacle absent from the laser methods. Where the instrument function is broader than the lines and the line centres are optically thick, the recorded depth understates the true optical depth by nearly an order of magnitude; integrating measured absorbance then biases the retrieved temperature. In this work we present how the effect arises, how to remove it by construction, and a diagnostic using transitions of equal lower-state energy.

Validation follows carbon monoxide in a 20 m multipass cell over 300–333 K against SI-traceable contact thermometry, with two retrievals — a full-band fit and a regression over lower-state energy — agreeing with the reference and with each other at the sub-kelvin level. Because the absorber column, optical path length, mole fraction and absolute intensity scale enter the forward model only as a product, allowing the column to float absorb any uniform error among them; we demonstrate by direct perturbation that their sensitivity coefficients are essentially negligible. The accuracy is consequently bounded by the differential accuracy of tabulated line intensities rather than by the apparatus.

References:

[1] Li, J. K., Wang, J., Yin, R. H., Huang, Q., Tan, Y., Hu, C. L., Sun, Y. R., Polyansky, O. L., Zobov, N. F., Lebedev, E. I., Stosch, R., Tennyson, J., Li, G., Hu, S. M., Unprecedented accuracy in molecular line-intensity ratios from frequency-based measurements, Science Advances, 11, eado7658 (2025).

[2] Gotti, R., Lamperti, M., Gatti, D., Marangoni, M., Laser-based primary thermometry: A review, Journal of Physical and Chemical Reference Data, 50, 031501 (2021).

[3] Frey, M., Sha, M. K., Hase, F., Kiel, M., Blumenstock, T., Harig, R., Surawicz, G., Deutscher, N. M., Shiomi, K., Franklin, J. E., Bösch, H., Building the COllaborative Carbon Column Observing Network (COCCON): long-term stability and ensemble performance of the

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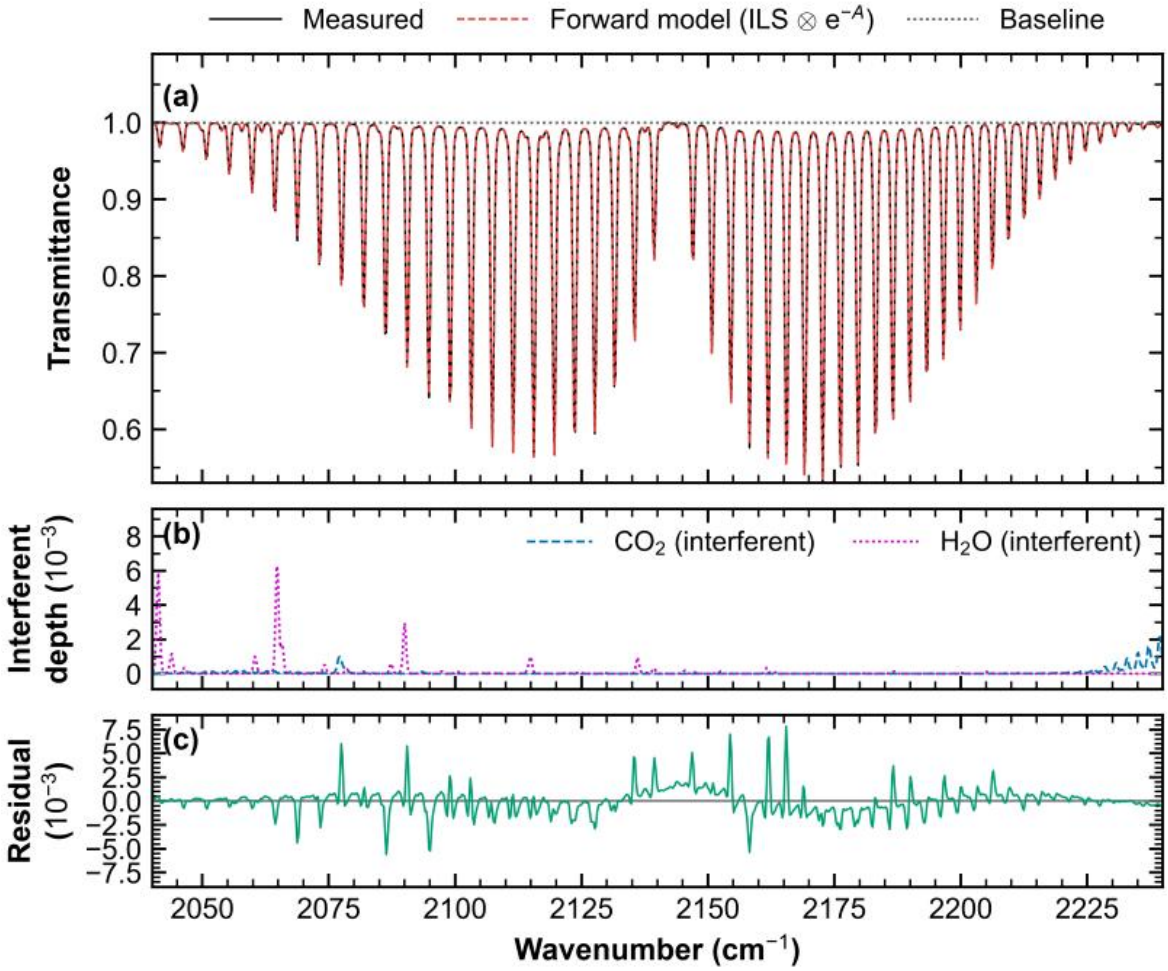


[Graphical Abstract / Visual Summary for Talk 1c]

Talk 1d: High-precision gas thermometry based on broadband optical frequency comb spectroscopy

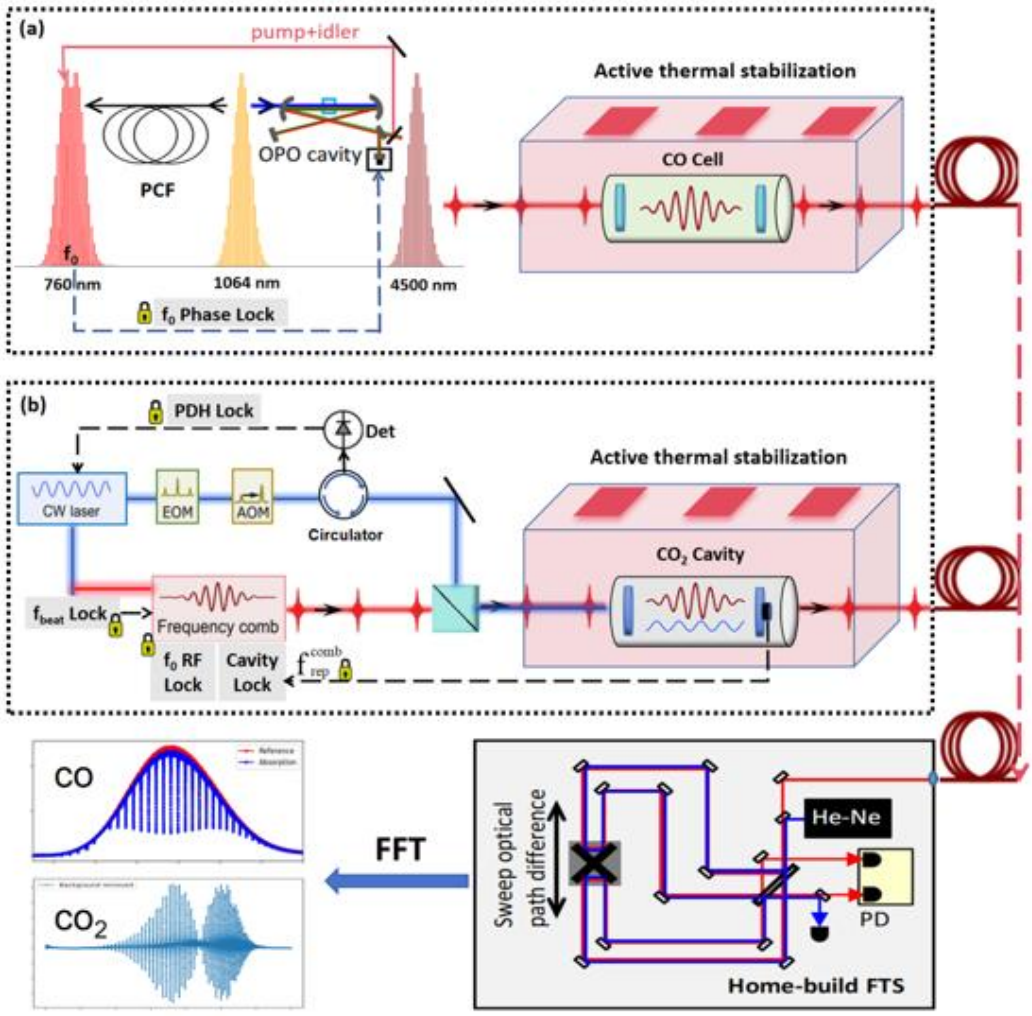
Author(s) / Speaker: Yu-Rong Xu, Akiko Nishiyama, Grzegorz Kowzan, Dominik Charczun, Szymon Wójtewicz, Katarzyna Bielska, Shui-Ming Hu, Piotr Maslowski and Daniel Lisak (Nicolaus Copernicus University in Toruń & partners)

Abstract:
Accurate gas thermometry is vital for metrology, environmental sensing, and process control, yet conventional contact methods suffer from self-heating and radiative errors. Line-intensity ratio thermometry overcomes these limits by probing Boltzmann-distributed molecular populations across dozens to hundreds of transitions, yielding high precision and reduced sensitivity to line-shape effects. In this work, broadband optical frequency comb spectroscopy is applied to high-precision temperature retrievals for the CO (1–0) and CO_2 (30012) bands.

For the strong CO (1–0) band near 4.7 μm, a mid-infrared optical frequency comb combined with a mechanical Fourier-transform spectrometer (OFC-FTS) achieved high-signal-to-noise spectra over a short 72-cm path length. Temperatures retrieved via zero-intercept Boltzmann plots across a 45 K experimental range agree with calibrated reference values within ~100 mK (statistical uncertainties: 86–216 mK). Compared to the previous near-infrared comb-based system, this approach improves both accuracy and precision by nearly an order of magnitude.

For the weaker CO2 (30012) band near 1.57 μm, cavity mode-dispersion spectroscopy (CMDS) retrieved line intensities showing excellent agreement with HITRAN2024 (0.32% mean deviation) and HITRAN2020 (0.05% mean deviation), with a global bias uncertainty of only 0.09%. By applying global Boltzmann fits and selectively excluding central, strongly absorbing lines to optimize precision, the retrieved temperatures over a 43 K range agreed with calibrated cell references within 0.32 K (statistical uncertainties: 291–483 mK).

Overall, these results establish broadband optical frequency comb spectroscopy as a versatile, robust, and highly accurate platform for primary gas thermometry and spectroscopic database refinement.



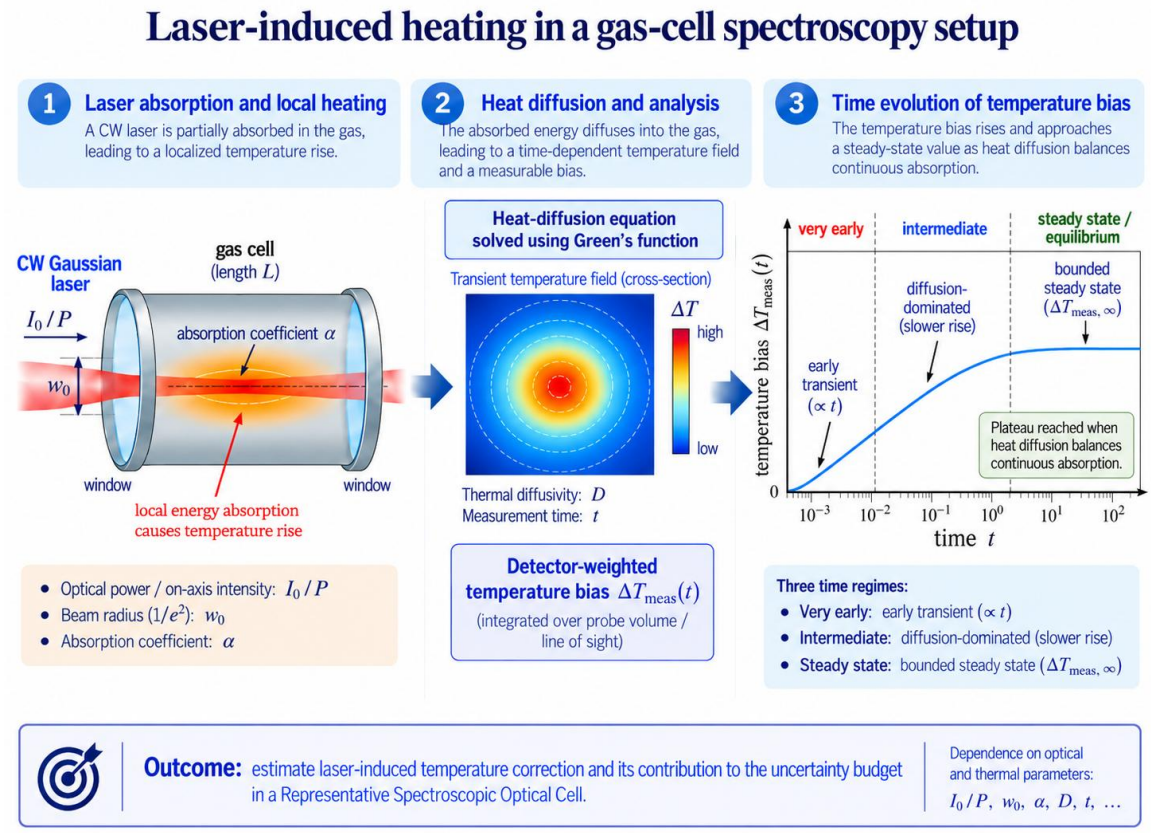
[Graphical Abstract / Visual Summary for Talk 1d]

Talk 1e: Laser-induced heating in spectroscopic thermometry

Author(s) / Speaker: Kianoosh Hadidi (Norwegian Metrology Service - Justervesenet)

Abstract:

Laser-induced heating can cause a systematic temperature bias in precision spectroscopic measurements and is not negligible when millikelvin-level accuracy is required. This effect has been investigated in a representative gas-cell spectroscopy setup using a continuous-wave Gaussian laser beam. The temperature response has been analysed using the heat-diffusion equation, taking into account the spatial distribution of the laser beam and the absorption of optical power along the gas cell. The analysis evaluates how the relevant optical and thermal properties of the system, together with the measurement duration, affect the magnitude and evolution of the induced temperature rise. Different temporal regimes, from the early transient response to longer measurement times, have also been considered. The analysis shows how the magnitude of the temperature bias depends on both optical and thermal parameters. The results provide a practical basis for estimating laser-induced temperature corrections and evaluating their contribution to the uncertainty budget in high-accuracy spectroscopic thermometry.



[Graphical Abstract / Visual Summary for Talk 1e]

Talk 1e: Laser-induced heating in spectroscopic thermometry

Author(s) / Speaker: **Yukiko Shimizu**, Sho Okubo, and **Hajime Inaba** (National Metrology Institute of Japan (NMIJ), National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan)

Abstract:
Rotational-State Distribution Thermometry (RDT) is a spectroscopic thermometry method that determines gas temperature from the Boltzmann population distribution among molecular rotational states. By analyzing numerous rovibrational absorption lines over a broad spectral range, RDT can determine temperature from the collective information contained in the absorption spectrum rather than relying on a limited number of spectral lines.

We are developing an RDT technique based on near-infrared dual-comb spectroscopy of acetylene (C_2H_2). Dual-comb spectroscopy enables the simultaneous observation of a large number of molecular transitions over a broad spectral range while maintaining high spectral resolution. By utilizing multiple transitions, we expect to achieve more accurate temperature determinations than when using a single transition.

In this presentation, we introduce the principle of RDT and its implementation using dual-comb spectroscopy for gas temperature measurement at approximately 27 °C. Using acetylene as a model molecule, approximately 50 rovibrational absorption lines over a spectral bandwidth of 5 THz were measured in the 1.5-μm region.

Recent experimental results will be presented to demonstrate the performance of the technique. We will also discuss the characteristics and advantages of RDT and its potential for non-contact thermodynamic temperature measurement.

Talk 2a: Doppler-Broadening Thermometry based on Cavity-Mode Dispersion Spectroscopy of CO

Author(s) / Speaker: Q. Huang, J. Wang, R.-H. Yin, Y. Tan, C.-F. Cheng, Y. R. Sun, A.-W. Liu, **S.-M. Hu** (University of Science and Technology of China)

Abstract:
Doppler broadening thermometry (DBT) links the Doppler width of atomic or molecular transitions to thermodynamic temperature, providing an optical route to the kelvin [1]. Molecular DBT, however, remains limited by collisional effects and line-shape model dependence; the best previous result reached about 14 ppm uncertainty but with roughly 30 ppm deviation [2]. Here we demonstrate all-frequency-domain DBT using cavity mode-dispersion spectroscopy (CMDS) [3] with a high-finesse optical cavity (0.6 kHz mode width). We measure the R(10) transition of CO at 1567 nm over 2–17 Pa. A global Voigt analysis yields a collision-broadening coefficient of 18.52(19) kHz/Pa and a temperature deviation of −2.0 ± 3.6 mK from calibrated platinum resistance thermometers, with 7 ppm statistical and 9 ppm systematic uncertainty. The result is insensitive to line-shape models after pressure correction [4]. On the one hand, this method provides a rigorous test of line-shape models; on the other hand, with high-precision line-shape parameters, its applicable range can be extended to higher pressures, benefiting collision physics, atmospheric remote sensing, and quantum-based gas metrology.

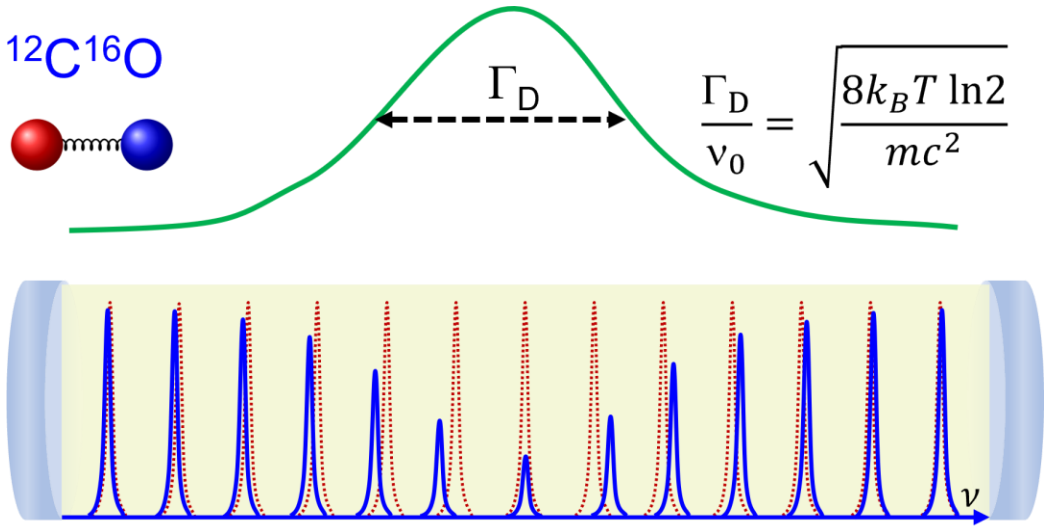
References:

[1] C. Daussy, M. Guinet, A. Amy-Klein, K. Djerroud, Y. Hermier, S. Briaudeau, Ch. J. Bordé, and C. Chardonnet, Direct determination of the Boltzmann constant by an optical method, Phys. Rev. Lett., 98, 250801 (2007).

[2] R. Gotti, L. Moretti, D. Gatti, A. Castrillo, G. Galzerano, P. Laporta, L. Gianfrani, and M. Marangoni, Cavity-ring-down Doppler-broadening primary thermometry, Phys. Rev. A, 97, 012512 (2018).

[3] A. Cygan, P. Wcisło, S. Wójtowicz, P. Masłowski, J. T. Hodges, R. Ciuryło, and D. Lisak, One-dimensional frequency-based spectroscopy, Opt. Express, 23, 14472 (2015).

[4] Q. Huang, J. Wang, R.-H. Yin, Y. Tan, C.-F. Cheng, Y. R. Sun, A.-W. Liu, and S.-M. Hu, Cavity-enhanced Doppler-broadening thermometry via all-frequency metrology, Phys. Rev. Lett., 135, 223002 (2025).



[Graphical Abstract / Visual Summary for Talk 2a]

An overtone transition of CO changes resonances of nearby modes in a high-finesse cavity, and the dispersion spectrum is used for Doppler-broadening thermometry.

Talk 2b: Comb-linked cavity-ring-down Doppler-broadening primary thermometry

Author(s) / Speaker: Antonio Castrillo, Vittorio D'Agostino, Eugenio Fasci, Muhammad Asad Khan, Andrea Merlone, **Livio Gianfrani** (Università degli Studi della Campania "Luigi Vanvitelli", Caserta, Italy & National Institute of Metrological Research, Torino, Italy)

Abstract:
Laser spectroscopic methods of primary gas thermometry have undergone significant developments in the last few years. Cavity mode dispersion spectroscopy (CMDS) has opened the route to all-frequency-domain Doppler broadening thermometry and line-ratio thermometry, enabling the achievement of mK-level uncertainty [1-3]. Meanwhile, the development of comb-linked cavity ring-down spectroscopy is progressing with new strategies and technical solutions to improve the measurement precision and accuracy.

Here we report on a novel scheme of comb-linked cavity-ring-down spectroscopy for Doppler broadening thermometry in a low-pressure CO_2 gas sample. The spectrometer is an upgraded version of the one described in [4], with a different operating wavelength (around 2 μm, rather than 1.578 μm) and an improved temperature stabilization system, which is directly traceable to the International Temperature Scale of 1990 (ITS-90). The first results will be presented and discussed.

References:

[1] Q. Huang, J. Wang, R.-H. Yin, Y. Tan, C.-F. Cheng, Y. R. Sun, A.-W. Liu, and S.-M. Hu, Cavity-enhanced Doppler-broadening thermometry via all-frequency metrology, Phys. Rev. Lett., 135, 223002 (2025).

[2] D. Lisak, V. D'Agostino, S. Wójtewicz, A. Cygan, M. Gibas, P. Wcisło, R. Ciuryło, K. Bielska, Leveraging Resonant Frequencies of an Optical Cavity for Spectroscopic Measurement of Gas Temperature and Concentration, Phys. Rev. Lett. 135, 103201 (2025).

[3] J.-K. Li, J. Wang, R.-H. Yin, Q. Huang, Y. Tan, C.-L. Hu, Y. R. Sun, O. L. Polyansky, N. F. Zobov, E. I. Lebedev, R. Stosch, J. Tennyson, G. Li, S.-M. Hu. Unprecedented accuracy in molecular line-intensity ratios from frequency-based measurements, Sci. Adv. 11(38), eadz6560 (2025).

[4] R. Gotti, L. Moretti, D. Gatti, A. Castrillo, G. Galzerano, P. Laporta, L. Gianfrani, and M. Marangoni, Cavity-ring-down Doppler-broadening primary thermometry, Phys. Rev. A, 97, 012512 (2018).

Talk 2c: Exploring Fabry Perot Interferometer as gas thermometer. CEM experiment.

Author(s) / Speaker: **Carmen García Izquierdo**, Juan Antonio García Berzosa, Jesús Marcos Torero (CEM, Centro Español de Metrología, Tres Cantos, Spain)

Abstract:

The new definition of the International System of units in 2019 is based on fundamental constants instead on physical artefact, allowing the exploration of quantum metrology (the interaction between light and matter) as the new techniques for the development of primary standards. This is the case for the unit of pressure, pascal, to be materialized, for instance, by experiments based on Fabry-Perot refractometry. The series of European projects Quantum Pascal, MQB Pascal and EQB pascal where CEM has been involved, Fabry-Perot interferometry as pressure standard was studied, materialized, optimized and additional metrological applications are under exploration. One of the possible applications is the use of Fabry-Perot interferometry as gas thermometer, whose suitability is analysed in the frame of PrySpecTemp project by CEM.

This communication outlines the CEM experiment in developing and implementing a Fabry-Perot experiment since the initial design up to a more consolidated composition. The CEM experiment is described with indications of the key elements and components to be improved and optimized for its use as gas thermometer.

Talk 2d: Refractive-Index Gas Thermometry by Fabry–Pérot Refractometry: Two New Approaches to Gas-Independent Measurements.

Author(s) / Speaker: **Tom Rubin**, André Kussicke, Sara Gehauf, Isak Silander, Yuanchao Yang (Physikalisch-Technische Bundesanstalt & partners)

Abstract:
Since the redefinition of the SI in 2019, significant advances have been made in quantum-based pressure realization using Fabry–Pérot refractometry (FPR). In this approach, pressure is determined from gas density rather than from force per unit area [1]. Since temperature enters directly into the equation of state, accurate temperature determination is therefore essential for achieving low measurement uncertainties. At PTB, pressure measurements using FPR currently reach uncertainties below 5 ppm (k = 1).

Conversely, when the pressure is known, FPR can also be used to determine the thermodynamic temperature of the gas [2]. At room temperature, a pressure uncertainty of 5 ppm corresponds to a temperature difference of approximately 1.5 mK. A key advantage of this approach is that the thermodynamic gas temperature can be determined directly and contact-free, without the need for a temperature sensor inside the gas [3].

Until now, the application of FPR to gas analysis has been limited by the stringent gas-purity requirements of the reference gases used for the measurements, restricting its application mainly to helium, argon, and nitrogen. This talk presents two approaches that overcome this limitation and enable gas-independent FPR [4]. This opens the way for FPR to be used for the precise characterization of relevant gas parameters, such as molecular absorption line strengths. In particular, the pressure and temperature of gas mixtures containing small concentrations of CO or CO_2 in a nitrogen matrix or in air can be determined with high accuracy. Figure 1 illustrates a real-time measurement of ambient air pressure using a Fabry–Pérot refractometer (FPR) operated with pure nitrogen at PTB Berlin. There were no impurities of the nitrogen by the measurand gas (ambient air) and therefore the purity of used the nitrogen stayed better than 99.9999% inside the FP-refractometer.

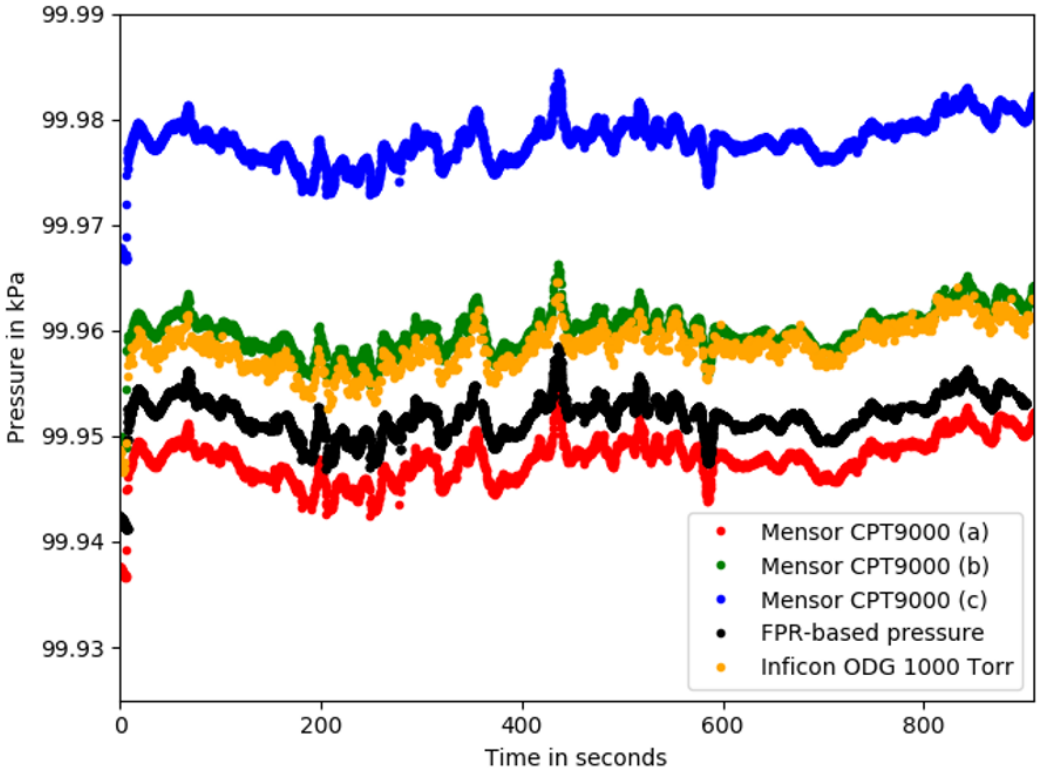
References:

[1] Jousten, Karl, et al. "Perspectives for a new realization of the pascal by optical methods." Metrologia 54.6: S146-S161 (2017).

[2] Egan, Patrick F., and Yuanchao Yang. "Optical n (p, T 90) measurement suite 1: He, Ar, and N 2." International Journal of Thermophysics 44.12: 181 (2023).

[3] Rubin, T., et al. "Thermodynamic effects in a gas modulated Invar-based dual Fabry–Pérot cavity refractometer." Metrologia 59.3: 035003 (2022).

[4] Silander, Isak, et al. "Diffusion-isolated pressure equilibration for multigas refractometry." Journal of Vacuum Science & Technology B 44.3 (2026).



[Graphical Abstract / Visual Summary for Talk 2d]

Real-time measurement of ambient air pressure using a Fabry–Pérot refractometer (FPR) operated with pure nitrogen at PTB Berlin. The observed fluctuations correspond to variations in ambient pressure and are resolved by the refractometer with sub-second temporal resolution.

Talk 3a: Practical primary thermometry via alkali-metal-vapour Doppler broadening

Author(s) / Speaker: Nicola Agnew, Veronika Vohníková, Erling Riis, Graham Machin, **Aidan S. Arnold** (Department of Physics, University of Strathclyde, Glasgow, Scotland, UK & National Physical Laboratory, Teddington, UK)

Abstract:
Doppler-broadening thermometry (DBT) can be used as a calibration-free primary thermometer suitable for practical applications, e.g. reliably measuring temperatures over long periods of time in environments where sensor retrieval for recalibration is impractical. We report on our proof-of-concept investigations into DBT with alkali-metal-vapour cells, with a particular focus on both absorption [1] and frequency accuracy during scans. We reach sub-kelvin temperature accuracy, and experimental absorption-fit residuals below 0.05%, in a simple set-up [2]. The outlook for portable, practical devices is bright, with clear prospects for future improvement.

References:

[1] Agnew N, Machin G, Riis E, Arnold AS. 2024 AIP Conf. Proc 3230, 110002. (doi: 10.1063/5.0234155)

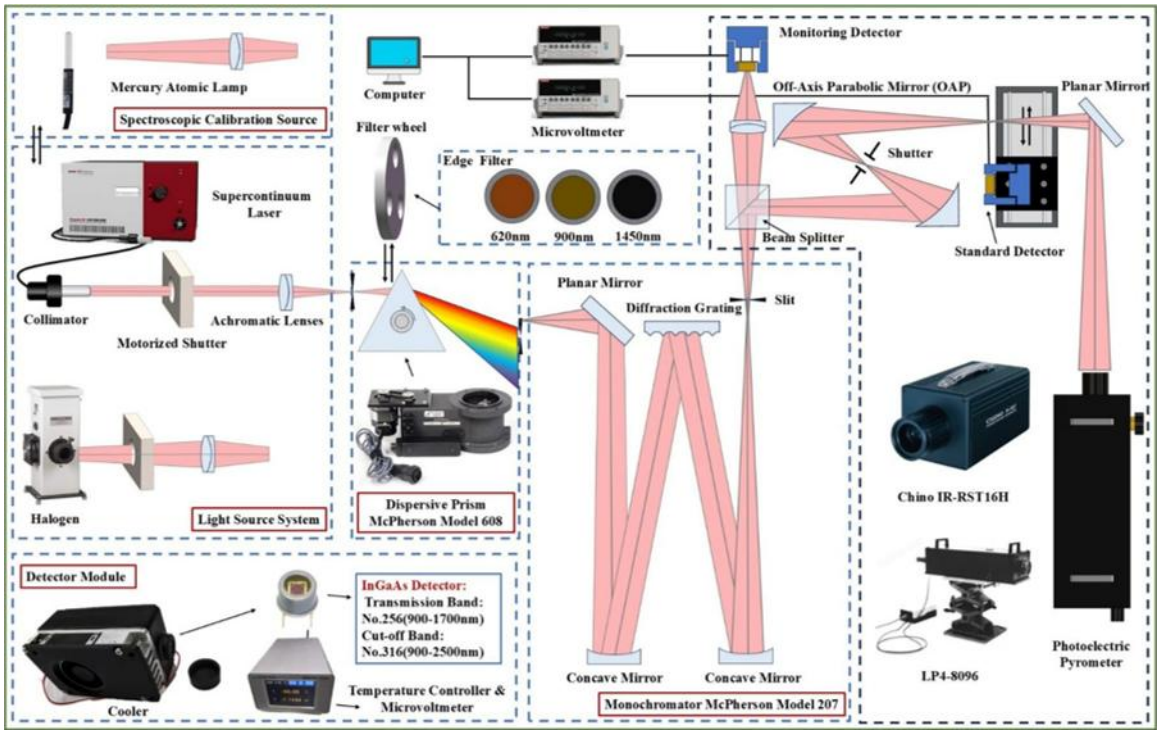
[2] Agnew N, Vohnikova V, Riis E, Machin G, Arnold AS. 2026 Phil. Trans. R. Soc. A 384 (2312): 20240455. (doi: 10.1098/rsta.2024.0455)

Talk 3b: Research Progress on Spectroscopic Radiation Thermometry for Thermodynamic Temperature Measurement at NIM

Author(s) / Speaker: **Xiaofeng Lu**, Tingting Zhang, Baoling An, Wei Dong (No.18, Bei San Huan Dong Lu, Chaoyang District, Beijing, China)

Abstract:

Thermodynamic temperature measurement in radiation thermometry has been systematically conducted from low to high temperatures at the National Institute of Metrology (NIM), China. In the high temperature range, the thermodynamic temperature measurement using a 633nm filter radiometer were determined in the absolute radiation hybrid method. Including the Cu freezing point and the Co–C, Pt–C, and Re–C high-temperature fixed points were determinated. The hybrid method was also extended to complete $T–T_{90}$ measurements for the Al–Cu, Al, and Ag fixed points using a 900 nm filter radiometer. In the medium temperature range, a relative thermodynamic temperature method was developed. In terms of spectral responsivity measurement of a 1.6 μm pyrometer, a near-infrared broadband spectral responsivity measurement system established covering 600 nm to 2500 nm. The system employs a McPherson Model 207 double monochromator as the core dispersive element. It adopts a dual-source configuration consisting of a tungsten-halogen lamp and a supercontinuum laser to realize precise characterization of the spectral responsivity, whose in-band peak center wavelength is 1550 nm and out-of-band relative responsivity can reach the 10^{-7} level. Based on this foundation, the visible relative spectral responsivity system was further improved: the supercontinuum laser replaced the tungsten-halogen lamp, boosting output power by 2–3 orders of magnitude; a dual-reflection output optical path was designed to replace the transmissive configuration for enhanced stray light suppression; and a Fourier transform spectrometer was introduced for cross-verification of the monochromator output wavelength, reducing the effective wavelength evaluation uncertainty to 0.03 nm and extending the measurable out-of-band responsivity from 10^{-6} to 10^{-8}. These efforts have established a wide-temperature radiation thermometry system covering from the Zn fixed point to the WC–C fixed point (approximately 420 °C to 3020 K), providing critical data support for the future new International Temperature Scale and the implementation of the new Kelvin definition.

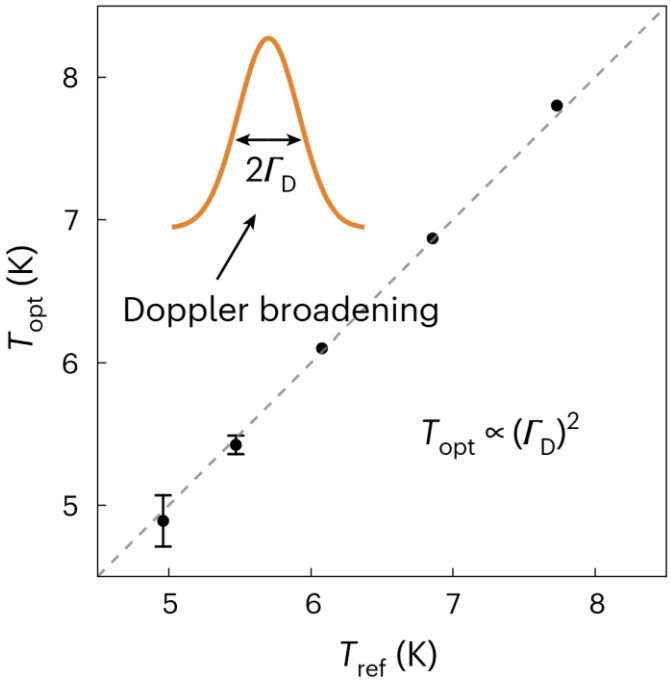


[Graphical Abstract / Visual Summary for Talk 3b]

Talk 3c: Primary thermometry in the deep cryogenic regime based on cavity-enhanced H2 spectroscopy

Author(s) / Speaker: **Piotr Wcisło** (Nicolaus Copernicus University, Torun, Poland)

Abstract:
I will present our cryogenic cavity-enhanced spectrometer and will show the first results on primary thermometry obtained with cryogenic H2 sample.



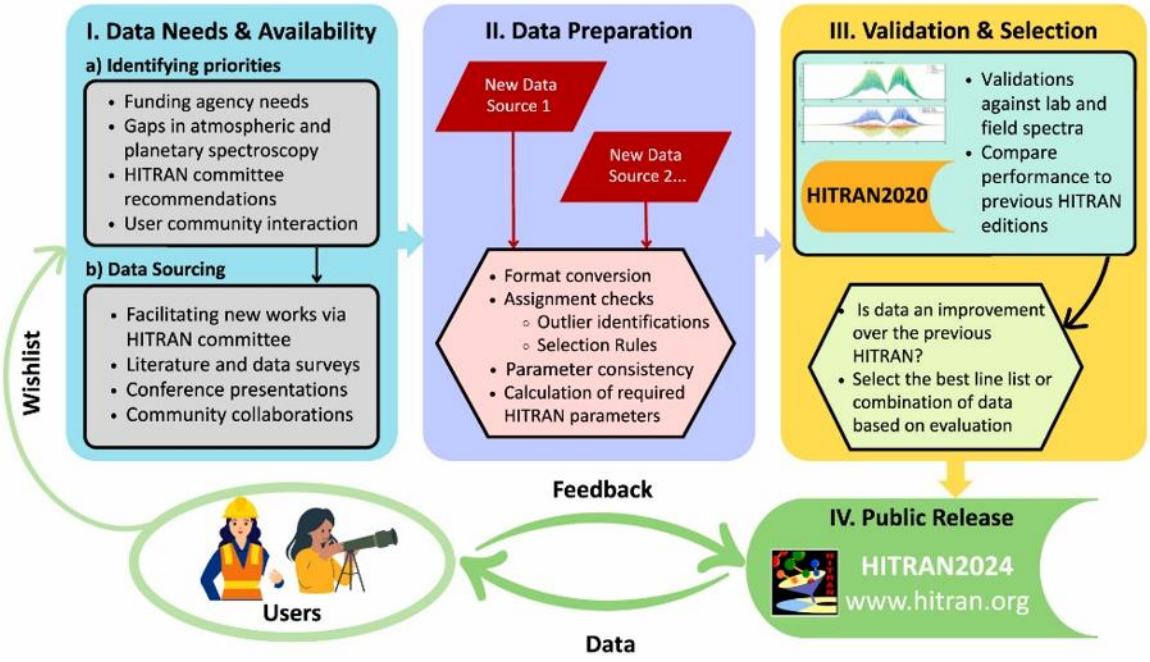
[Graphical Abstract / Visual Summary for Talk 3c]

Our first realization of cryogenic thermometry based on H_2 spectroscopy compared to commercial cryogenic temperature sensor. The figure comes from Ref. [1].

Talk 4a: HITRAN PACT: Practicality, Accuracy, Completeness and Traceability of spectral parameters in HITRAN2024

Author(s) / Speaker: **Iouli E. Gordon**, Robert J. Hargreaves, Thibault Bertin, Fran M. Gomez, Laurence S. Rothman (Center for Astrophysics | Harvard & Smithsonian, Cambridge, MA, USA)

Abstract:
Work on the new editions of the HITRAN database involves validating and implementing new data, improving and extending the parametrization of the spectral properties in the database, as well as improving user experience. Extensive validation efforts and user feedback have demonstrated that the HITRAN2024 edition features significant expansion and improvements relative to HITRAN2020. This talk will briefly summarize the main successes of this edition, which is already in active use in a variety of atmospheric and astrophysical studies. We will outline priorities for future improvements, including filling remaining data gaps and pursuing more consistent parameterizations. These priorities are typically guided by ongoing funded efforts in atmospheric and planetary spectroscopy.



[Graphical Abstract / Visual Summary for Talk 4a]

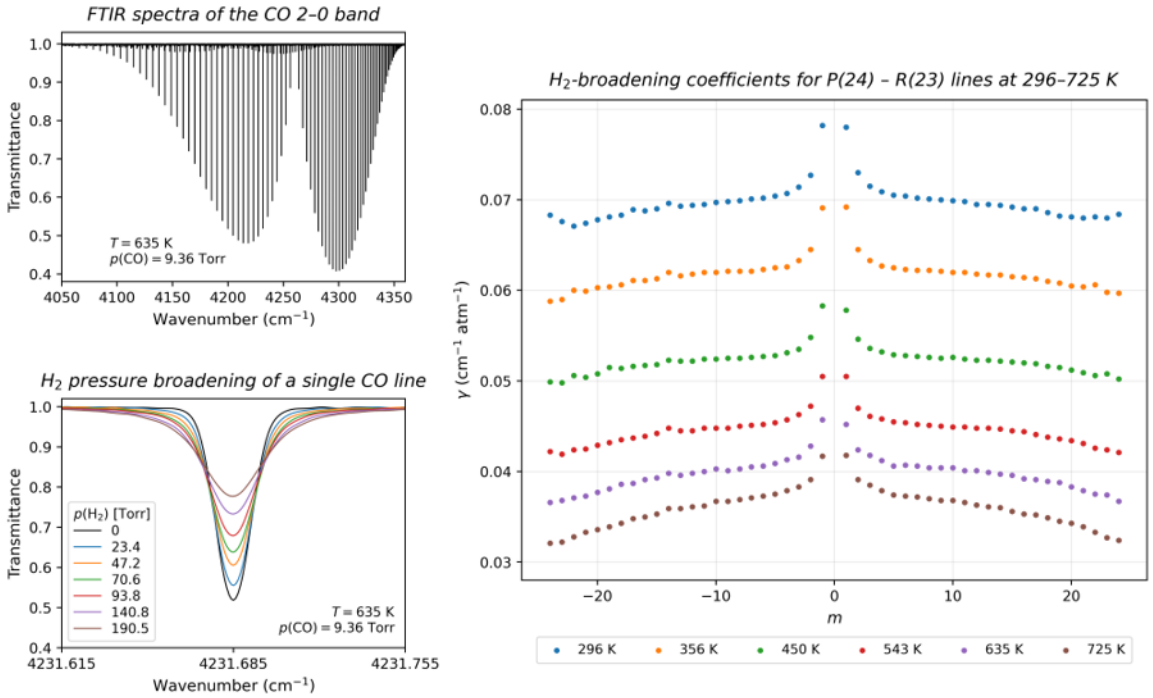
Flow diagram of the path of the data incorporated in HITRAN2024. The diagram highlights setting priorities; obtaining new data, which could be theoretical, experimental, or semi-empirical; calculating parameters necessary for these data to be converted into the HITRAN format; validating the data against each other, previous HITRAN, and laboratory and field data; and finally identifying the best set of parameters to be included in HITRAN2024.

Talk 4b: 2-0 overtone band of CO broadened by H2 at high temperatures

Author(s) / Speaker: **Lukas Petera**, Jeffrey Pearson, and Peter Bernath (Old Dominion University, Norfolk, VA, United States)

Abstract:

Recently, research on exoplanets has focused on characterization of exoplanet atmospheres using spectra. Modeling exoplanet atmospheres relies on line lists to simulate key species using databases such as HITRAN or ExoMol. Improving these line lists is crucial to increase the accuracy of these models especially for important species like CO, CO2, NH3, CH4, and so forth. We provide the first laboratory measurements of pressure-induced broadening of the first overtone (2–0) band of carbon monoxide (CO) by molecular hydrogen (H2) in the temperature range 296–725 K. The measurements were carried out using high-resolution Fourier-transform infrared (FTIR) spectroscopy. Pressure broadening coefficients and their temperature dependence were determined for 48 rovibrational lines of 12C16O, spanning the P(24)–R(23) transitions using a multi-spectra fitting program developed in Brussels. The temperature dependence of the broadening coefficients is well described by a single power-law formula. These results provide new inputs for spectroscopic databases used in the detection and retrieval of CO from astrophysical spectra.



[Graphical Abstract / Visual Summary for Talk 4b]

Talk 4c: Temperature-insensitive isotope ratio spectroscopy and rapid comb-based temperature measurements

Author(s) / Speaker: **Adam J. Fleisher**, Abneesh Srivastava, Joseph T. Hodges (National Institute of Standards and Technology, Gaithersburg, MD, USA)

Abstract:
Primary spectroscopic thermometry (PST) leverages the sensitivity of atomic and molecular line shapes, line strengths and their ratios to changes in local temperature. To better understand potential sources of systematic bias and uncertainty in PST, it is valuable to study lessons learned from spectroscopic experiments designed to be immune to temperature changes or drifts. Here we discuss temperature-insensitive experiments in isotope ratio spectroscopy and how their area-ratio design features can inform advanced PST approaches. Additionally, we will also introduce precise experiments in photonic temperature sensing using rapid-acquisition dual-comb techniques.

Talk 4d: FT-IR measurements of the O2 collision-induced absorption (cia) in the 565-700 nm region at very high pressures

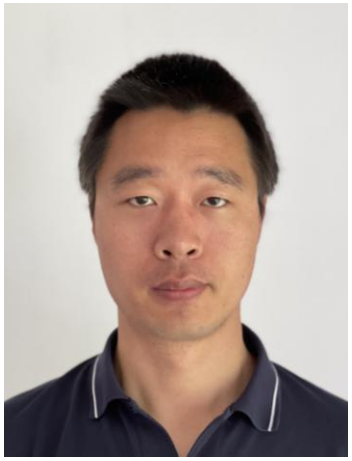
Author(s) / Speaker: **Keeyoon Sung** and JPL molecular spectroscopy team (Jet Propulsion Laboratory, California Institute of Technology)

Abstract:

Atmospheric O_2 shows several distinctive band features in the near-infrared and visible regions at 760, 687, 630, and 577 nm, labeled as A, B, γ, and δ band, respectively. The rovibronic A and B bands are dominated by monomer line absorption contributions. An additional absorption, however, has been observed in laboratory and atmospheric spectra, attributed to collision-induced absorption (cia). However, these cia features are intrinsically weak to characterize in the conventional laboratory setting. In order to utilize its density-square dependence, we obtained multiple spectra of pure O2 and Dry Air at various high pressures (up to 131 bars) at room temperature. Actual number density was estimated through the 2nd virial coefficients. Any monomer resonance contribution in the 687 nm region was removed by simulating the O2(B) band with speed-dependent Voigt profile with Rosenkranz line mixing derived full line mixing coefficient modeling. The integrated cia was measured to be $3.2(6)\times10^{-6}$ $cm^{-2}/Amagat^2$ for the O2(B) band region, which is significantly lower than literature values. For the two double transition bands in the 630 and 577 nm regions, their integrated cia were measured to be: 2.50(14) and $3.26(18)\times10^{-4}$ $cm^{-2}/Amagat^2$, respectively.

Speaker Biographies

Gang Li



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Dr. Gang Li is a senior scientist in department 3.1 with over 15 years' experience in molecular spectroscopy and spectral line databases, author of over 43 peer-viewed high impact publications with more than 6000 citations. Previously worked on the international HITRAN database. Coordinator of the EPM "22IEM03 PriSpecTemp" and "24GRD06 MetCTG" projects.

Rainer Stosch

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Rainer Stosch is the head of department "General and Inorganic Chemistry", Lecturer at the Technical University of Braunschweig (Course: 'Metrology in Chemistry and Chemical Measurement Techniques'), over 26 years' experience in Chemical Metrology, specializing in Optical Spectroscopy (including Raman, FT-IR, UV-Vis), Author or co-author of 70 peer-reviewed papers, Active member of the BIPM CCQM Working Groups on Inorganic Analysis (IAWG) and Surface Analysis (SAWG), Convenor of the Euramet Technical Committee for Metrology in Chemistry (TC-MC) Sub-Committee on Inorganic Analysis (SC-IA).

Graham Machin

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Graham is a NPL Senior Fellow, has >35 years' thermometry research experience, published >280 papers and given numerous international keynote/plenary talks including the "James Schooley Invited Plenary Lecture" at the 10th International Temperature Symposium. He holds visiting/honorary professorships at Birmingham, Glasgow and Strathclyde Universities. He represents the UK on the Consultative Committee of Thermometry (CCT), was chair of the Euramet Technical Committee for Thermometry (2014-2018) and President of the Institute of Measurement and Control (2018-2019). He has been given numerous awards for his work including elected Fellow of the Royal Academy of Engineering (2019), awarded the InstMC Harold Hartley medal for "outstanding contributions to the technology of measurement and control" (2021), elected Honorary InstMC Fellow (2024) and Fellow of the Royal Society (2025). He has wide ranging research interests in thermometry e.g. future kelvin, driftless practical thermometry, clinical thermometry, photonic thermometry and leads NPL's metrology activity for nuclear decommissioning.

Daniel Lisak

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Daniel Lisak is Professor of Physics at Nicolaus Copernicus University in Toruń, Poland, specializing in high-precision molecular spectroscopy and optical metrology. His research focuses on cavity-enhanced laser spectroscopy, advanced molecular line-shape studies, and quantum-based optical standards for gas temperature, pressure, and concentration. He co-developed cavity mode dispersion spectroscopy (CMDS) and has co-authored 170 scientific publications. He has conducted research at leading metrology institutes, including NIST (USA) and AIST/NMIJ (Japan), and contributed to the development of the Polish Optical Atomic Clock. His achievements have been recognized by the NIST CSTL Technical Achievement Award, a JSPS Invitation Fellowship, and the Polish Minister of Science and Higher Education Award for fundamental research. His recent research advances cavity-enhanced spectroscopy for precision thermometry, gas metrology, and quantum sensing, including molecular spectroscopy in the deep cryogenic regime. https://orcid.org/0000-0001-5545-7989

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Dr. Yan Tan is a researcher at the Hefei National Research Center for Physical Sciences at the Microscale and the Hefei National Laboratory, University of Science and Technology of China (USTC). Research interests include high-precision molecular spectroscopy, cavity-enhanced dispersion and absorption spectroscopy, collisional line-shape analysis, and quantum gas metrology.

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Can Gözönünde is a Researcher at TÜBİTAK UME, Türkiye's National Metrology Institute, working in the field of thermodynamic metrology, and a Ph.D. candidate in Physics at Gebze Technical University. His research focuses on primary thermometry, spectroscopic temperature measurements, radiation thermometry, high-temperature fixed-point metrology, and humidity metrology, with particular interest in developing accurate and traceable optical measurement techniques. He has contributed to international research projects and publications on high-temperature fixed points, radiation thermometry, and primary-level radiometric scale realization. His recent work includes the development of primary spectrometric thermometry methods based on gas spectroscopy and Fourier-transform infrared spectroscopy, as well as Dual-Comb Spectroscopy.

Yu-Rong Xu

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Yurong Xu is a Postdoctoral Researcher at Nicolaus Copernicus University, Poland. She received her Ph.D. in Chemical Physics from the University of Science and Technology

of China (USTC) in 2025. Her research focuses on gas optical metrology, high-precision molecular and laser spectroscopy, and precision spectroscopy for metrology and tests of fundamental physics. Her research experience includes the development and application of cavity-enhanced molecular spectroscopy techniques, including cavity mode-dispersion spectroscopy (CMDS), cavity ring-down spectroscopy (CRDS), and Fourier-transform absorption spectroscopy, for precision measurements of CO_2 and O_2, gas pressure metrology, and optical frequency comb-based gas thermometry. She has published research in journals including the Journal of Chemical Physics, Physical Review A, and Acta Physica Sinica.

Kianoosh Hadidi

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PhD in Materials Physics, working as a Senior Engineer in the Temperature Group at the Norwegian Metrology Institute (Justervesenet), with expertise in temperature metrology, and simulation, with a current focus on heat-transfer modelling.

Yukiko Shimizu

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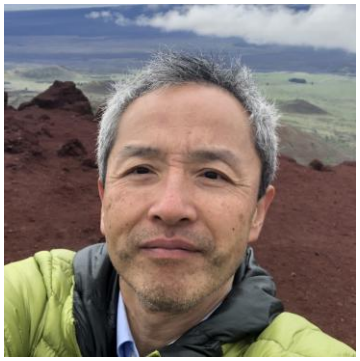
Yukiko Shimizu is a Principal Research Manager at the National Metrology Institute of Japan (NMIJ), National Institute of Advanced Industrial Science and Technology (AIST), Japan. Her research focuses on radiation thermometry, thermodynamic temperature measurement, and spectroscopic thermometry. She has contributed to the development and dissemination of temperature standards, particularly in radiation thermometry, as well as the development of advanced spectroscopic techniques for non-contact temperature measurement. Her recent research focuses on rotational-state distribution thermometry (RDT) using dual-comb spectroscopy, aiming to establish a method for non-contact thermodynamic temperature measurement based on molecular rotational-state populations. She is a member of the IUPAP Commission C2 (SUNAMCO).

Hajime Inaba



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Hajime Inaba is the Leader of the Optical Frequency Measurement Group at the National Metrology Institute of Japan (NMIJ), National Institute of Advanced Industrial Science and Technology (AIST), Japan. His research centers on optical frequency comb generation, control, and applications in precision metrology. He has developed fiber-based comb technologies for optical frequency measurement and contributed to the realization and dissemination of Japan's national length standard. His achievements also include low-noise optical frequency combs, linewidth transfer from ultrastable lasers to lasers at different wavelengths, and broadband visible combs for wavelength calibration of high-resolution astronomical spectrographs. His current work focuses on enhancing astronomical combs, developing frequency-stabilized lasers as potential alternatives to hydrogen masers, and improving the sensitivity of molecular spectroscopy.

Shui-Ming Hu

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Shui-Ming Hu received his B.S. (1995) and Ph.D. (2000) in Chemical Physics from the University of Science and Technology of China (USTC), followed by postdoctoral research at Rice University and Argonne National Laboratory. He currently serves as Professor of Chemical Physics and Instrumentation at USTC and the Hefei National Laboratory. His research focuses on developing laser spectroscopy techniques with ultrahigh precision and sensitivity, with applications spanning fundamental studies of atomic and molecular physics, chemical kinetics, optical metrology, and trace detection.

Tom Rubin

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Tom Rubin heads the Photonic Pressure Measurement Group at Physikalisch-Technische Bundesanstalt (PTB) in Berlin. He holds a PhD in physics, focusing on precise partial-pressure measurements using absorption spectroscopy. He coordinated the international projects QuantumPascal and MQB-Pascal and continues to contribute to the current EQB-Pascal project. He also founded a startup dedicated to the development and commercialization of quantum-based pressure standards. Tom Rubin

holds a second PhD in medical sciences, based on the retrospective analysis of more than 10,000 breath-gas kinetics for liver function assessment. He developed the measurement device used to acquire these data and currently coordinates the EU project Breath-MET – Metrology for Breath Gas Analysis. Among his notable scientific contributions is the identification of an error in the calculation of the optical path length of the widely used Herriott cell, together with the derivation of a rigorous formula that does not rely on approximations.

Carmen García Izquierdo

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Carmen García Izquierdo has been the head of Mass and Mechanical quantities department at CEM since 2022. He has been working in metrology for more than 25 years, with high background on thermal metrology where she worked for around 20 years. Currently, she is the Spanish representative at CIPM-CCM, Euramet TCM and with high involvement in the Euramet Metrology Network on Climate and Ocean Observations, being the vice-chair of the atmosphere section. In addition, she is involved in several expert teams of WMO and GCOS. She is now responsible for the development of a pressure standard by Fabry-Perot interferometry at CEM, taking part in the series of European projects Quantum Pascal: Quantum Pascal, MQB Pascal and EQB Pascal.

Livio Gianfrani

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Livio Gianfrani is Full Professor of Atomic Physics at the Department of Mathematics and Physics (DMF) of the University of Campania "Luigi Vanvitelli", in Caserta, Italy. He is responsible for the Laser Spectroscopy laboratories and coordinates the Group of Atoms, Molecules and Precision Measurements. He is member of the EGAS board, EGAS standing for European Group on Atomic Systems, a division of the European Physical Society. L.G. has long-standing experience of experimental research in: atomic, molecular and optical physics; light-matter interaction; fundamental metrology; fundamental tests and measurements; cavity-enhanced spectroscopy; comb-calibrated spectroscopy; development of spectroscopic methods for chemical and isotopic analysis.

His most important achievements include: isotope shift spectroscopy and King-plot nonlinearities in Hg vapors; implementation of the new kelvin by means of Doppler broadening gas thermometry; QED tests in molecular hydrogen; spectroscopic determination of the Boltzmann constant; precision measurements of line intensity factors for greenhouse gases; experimental tests of line shape theories; development of ultra-sensitive cavity-enhanced techniques; development of laser spectroscopy for stable isotope ratio analysis; experimental test of the symmetrization postulate for spin-0 particles.

He is the author/co-author of about 170 scientific publications, which have gained roughly 4000 citations, so far, with an h-index of 35 (source: Scopus, September 2026).

Aidan Arnold

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I am a Reader at University of Strathclyde and have been working in atomic physics for thirty years. I made the first UK Bose-Einstein condensate (BEC) in my PhD (Guardian 8/10/1998), followed by the world's first delta-kick cooling of BECs, ring traps for BECs, and single-beam tetrahedral magneto-optical trap geometries. I also lead experiments in thermal atomic vapours: Doppler-broadening thermometry and four-wave mixing with structured light.

Xiaofeng Lu

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Dr. Lu Xiaofeng has been working in the Radiation Thermometry Laboratory of NIM for almost twenty years. He has served as a visiting scholar at PTB, NPL NMIJ for several months. His main research focuses on radiation thermometry, high-temperature fixed points, and thermodynamic temperature measurement. He is the chair of WG radiation thermometry in APMP TCT and member of the CCT WG-NCTh.

Piotr Wcisło

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Dr. Iouli Gordon is a Physicist at the Smithsonian Astrophysical Observatory, part of the Center for Astrophysics | Harvard & Smithsonian, where he serves as Chair of the Atomic and Molecular Physics Division and Director of the HITRAN molecular spectroscopic database project. His research focuses on molecular spectroscopy and its applications to radiative transfer, atmospheric remote sensing, planetary science, and astrophysics. He has led the HITRAN project for a decade, overseeing major expansions of its spectroscopic content, infrastructure, and applications, including the recent HITRAN2024 edition. His broader research interests include advanced line-shape parameters, spectroscopic database development, and emerging applications of molecular spectroscopy. He is an active advocate for open science.

Lukas Petera

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Dr. Lukas Petera is a postdoctoral researcher working with Professor Peter Bernath at Old Dominion University in Norfolk, Virginia, USA. In 2024, he earned a Ph.D. in inorganic chemistry from Charles University in Prague, Czech Republic. Her current research focuses on high-resolution Fourier-transform infrared spectroscopy of molecules at elevated temperatures, particularly pressure-broadening effects relevant to planetary and stellar atmospheres. Before joining Old Dominion University, he worked at the J. Heyrovský Institute of Physical Chemistry in Prague, Czech Republic, where he investigated impact-induced chemistry in model planetary atmospheres using laser-generated plasma. He also studied interplanetary material, including meteorites and samples returned from asteroid (162173) Ryugu, using advanced electron microscopy techniques. In 2021, his master's thesis received the Werner von Siemens Award and the Academia Publishing House Award. Her broader research interests include atomic and molecular spectroscopy, laboratory astrophysics, planetary science, and origin-of-life studies.

Adam J. Fleisher

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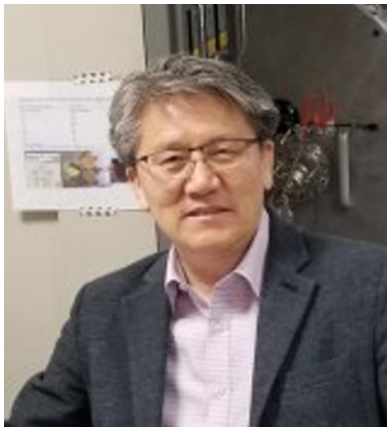
Adam J. Fleisher is the Acting Leader of the Optical Measurements Group at NIST, USA. The group focuses on performing precision molecular spectroscopy to benchmark line lists, developing ultrasensitive laser methods to study isotopic composition, and advancing direct frequency comb spectroscopy in new wavelength regimes and in extreme chemical and sensing environments.

Keeyoon Sung



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Dr. Keeyoon Sung is a research scientist at the Jet Propulsion Laboratory. His specialties are laboratory molecular spectroscopy in the infrared, atmospheric remote sensing with FT-IR, and spectrum fitting algorithm developments. He has completed many NASA NRA projects on laboratory spectroscopy for a broad range of atmospheric molecules (e.g. CH4, O2, CO2, H2O NH3, OCS, hydrocarbons, nitriles, etc.) in support of NASA Planetary and Earth science missions. Under his management, his laboratory with a high-resolution FT-IR (spectrally covering 0.65-500 μm) has become a major research asset for molecular spectroscopy at JPL. He is a regular contributor to the HITRAN databases. Currently he is leading a few active laboratory spectroscopic projects on planetary science and astrophysics.