Group of Frequency References and Dissemination

Department of Coherence Optics

ISI CAS Institute of Scientific Instruments The Czech Academy of Sciences

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THEMATIC RESEARCH FOCUS

Research area

- Time and frequency metrology
- Frequency-stabilised laser standards and optical frequency references
- Methods of laser spectroscopy
- High-finesse optical cavities for sub-Hz linewidth lasers
- Dissemination of precise time and frequency signals through optical links
- Analog and digital electronics systems for metrological applications

Excellence

- Development and characterisation of high-stable lasers and laser standards
- Design and development of optical frequency references/absorption cells and high-finesse optical cavities
- Laser spectroscopy
- Precise time and frequency signals transfers through optical fibre and free-space optical links
- Real-time signal processing electronics for time and frequency metrology
- Scientific glass components design and development

Mission

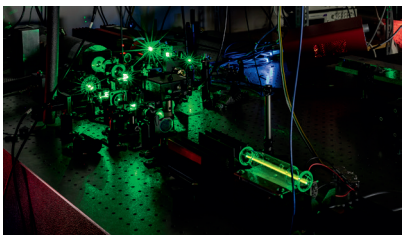
We investigate new scientific methods and develop advanced instruments for time and frequency metrology. Our research focuses on frequency-stabilised lasers, optical frequency references, and synchronising and disseminating precise time and frequency signals through optical links.

RECENT ACTIVITIES

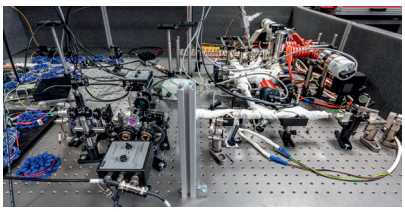
- Saturated absorption spectroscopy of "telecom" gases (HCN, acetylene) – accuracy improvement of HCN saturated spectra central frequencies
- Deep UV laser sources for metrological applications (optical clocks, optical inspection), development of 267 and 213 nm continuous-wave single-mode lasers
- Development of high-finesse optical cavities for sub-Hz linewidth lasers
- Optical frequency phase-coherent transfers through optical fibre and free-space optical links - national and cross-border/European Time & Frequency networks
- Methods for simultaneous transfers of precise time and optical frequencies through optical fibres
- Quantum encrypted communication with increased physical layer security and complex analysis of security risks of optical fibre networks
- Real-time signal processing electronics for time and frequency metrology
- Polarisation-independent high-speed photodetectors development
- Scientific glassware development - absorption reference cells for laser standards, global navigation satellite systems and quantum experiments, Dewar bottles for cryogenics

Fields of research results application

- Time and frequency metrology
- Remote time and frequency synchronisation and calibration
- Security sector applications and optical fibre sensing
- Quantum experiments with neutral atoms (atomic gasses)
- Optical telecommunications
- Global Navigation Satellite Systems



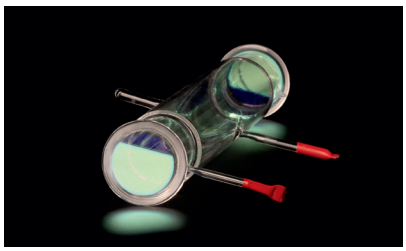
532 nm laser standard and iodine cells quality testing setup



HCN/C2H2 laser standards for telecom wavelengths

KEY RESEARCH EQUIPMENT

- Set of optical frequency standards operating at VIS and NIR wavelengths
- Optical frequency synthesisers (VIS+NIR), Hydrogen maser, Time and Frequency transfer GNSS receivers, wavelength meters
- Laboratory instrumentation for experiments with optics, vacuum technology and electronics
- Large ecosystem of in-house produced and customisable electronic modules
- Scientific glassware workshop and ultra-high vacuum laboratory

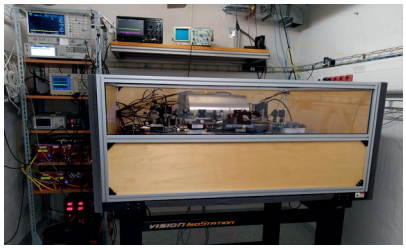


Multipass iodine absorption cell with combined HR and AR coatings

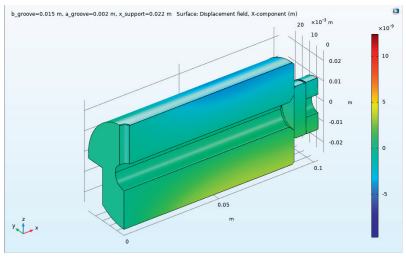
ACHIEVEMENTS

Articles

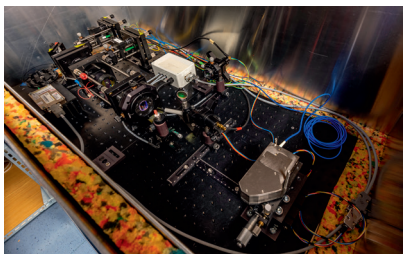
- **Absolute frequencies of H13C14N hydrogen cyanide transitions in the 1.5-μm region with the saturated spectroscopy and a sub-kHz scanning laser.**
  - HRABINA, Jan, HOŠEK, Martin, ŘEŘUCHA, Šimon, ČÍŽEK, Martin, PILÁT, Zdeněk, ZUCCO, M., LAZAR, Josef, ČÍP, Ondřej. Optics Letters. 2022, 47(21), 5704-5707.
- **Coherent fibre link for synchronisation of delocalized atomic clocks.**
  - ČÍŽEK, Martin, PRAVDOVÁ, Lenka, PHAM, Minh Tuan, LEŠUNDÁK, Adam, HRABINA, Jan, LAZAR, Josef, PRONEBNER, T., AEIKENS, E., PREMPER, J., HAVLIŠ, O., VELC, R., SMOTLACHA, V., ALTMANNOVÁ, L., SCHUMM, T., VOJTĚCH, J., NIESSNER, A., ČÍP, Ondřej. Optics Express. 2022, 30(4), 5450-5464.
- **Phase-Noise Characterization in Stable Optical Frequency Transfer over Free Space and Fiber Link Testbeds.**
  - BARCÍK, P., HRABINA, Jan, ČÍŽEK, Martin, KOLKA, Z., SKRYJA, P., PRAVDOVÁ, Lenka, ČÍP, Ondřej, HUDCOVÁ, L., HAVLIŠ, O., VOJTĚCH, J. Electronics. 2023, 12(23), 4870.
- **Characterization of sensitivity of optical fiber cables to acoustic vibrations.**
  - DEJDAR, P., MOKRÝ, O., ČÍŽEK, Martin, RAJMIC, P., MÜNSTER, P., SCHIMMEL, J., PRAVDOVÁ, Lenka, HORVÁTH, T., ČÍP, Ondřej. Scientific Reports. 2023, 13(1), 7068
- **Production and measuring methods and procedures in precision optical cavities production.**
  - BENEŠ, Jiří, PROCHÁSKA, František, RAIL, Zdeněk, TOMKA, David, PRAVDOVÁ, Lenka, ČÍP, Ondřej. Journal of Instrumentation. 2022, 17(2), P02012.
- **Influence of coating technology and thermal annealing on the optical performance of AR coatings in iodine-filled absorption cells.**
  - OULEHLA, Jindřich, POKORNÝ, Pavel, HRABINA, Jan, HOLÁ, Miroslava, ČÍP, Ondřej, LAZAR, Josef. Optics Express. 2019, 27(7), 9361-9371
- **Iodine Absorption Cells Purity Testing.**
  - HRABINA, Jan, ZUCCO, M., PHILIPPE, Ch., PHAM, Minh Tuan, HOLÁ, Miroslava, ACEF, O., LAZAR, Josef, ČÍP, Ondřej. Sensors. 2017, 17(1), 1-13), 17010102.
- **Joint accurate time and stable frequency distribution infrastructure sharing fiber footprint with research network.**
  - VOJTĚCH, J., ŠLAPÁK, M., ŠKODA, P., RADIL, J., HAVLIŠ, O., ALTMANN, M., MÜNSTER, P., VELC, R., KUNDRÁT, J., ALTMANNOVÁ, L., VOHNOUT, R., HORVÁTH, T., HŮLA, M., SMOTLACHA, V., ČÍŽEK, Martin, PRAVDOVÁ, Lenka, ŘEŘUCHA, Šimon, HRABINA, Jan, ČÍP, Ondřej. Optical Engineering. 2017, 56(2), 1-7), 027101.
- **System for automatic gauge block length measurement optimized for secondary length metrology.**
  - BUCHTA, Zdeněk, ŠARBORT, Martin, ČÍŽEK, Martin, HUCL, Václav, ŘEŘUCHA, Šimon, PIKÁLEK, Tomáš, DVOŘÁČKOVÁ, Š., DVOŘÁČEK, F., KŮR, J., KONEČNÝ, P., WEIGL, M., LAZAR, Josef, ČÍP, Ondřej. Precision Engineering. 2017, 49(JULY), 322-331.
- **Comb mode filtering silver mirror cavity for spectroscopic distance measurement.**
  - ŠMÍD, Radek, HÄNSEL, A., PRAVDOVÁ, Lenka, SOBOTA, Jaroslav, ČÍP, Ondřej, BHATTACHARYA, N. Review of Scientific Instruments. 2016, 87(9), 093107:1-8.



High-finesse optical cavity for sub-Hz linewidth laser



SW simulations of high-finesse cavity vibrations sensitivity

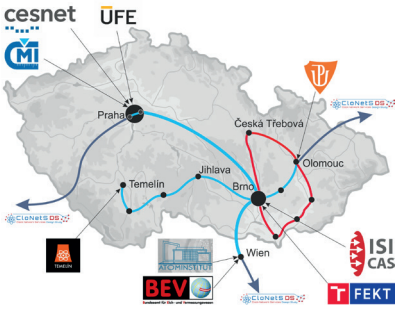


Fabry-Perot cavity as a conversion unit between IR and VIS wavelengths

- **Noise Suppression on the Tunable Laser for Precise Cavity Length Displacement Measurement.**
  – ŠMÍD, Radek, ČÍŽEK, Martin, MIKEL, Břetislav, HRABINA, Jan, LAZAR, Josef, ČÍP, Ondřej. Sensors. 2016, 16(9), 1428:1-11.
- **Comparison of Molecular Iodine Spectral Properties at 514.7 and 532 nm Wavelengths.**
  – HRABINA, Jan, ACEF, O., DU BURCK, F., CHIODO, N., CANDELA, Y., ŠARBORT, Martin, HOLÁ, Miroslava, LAZAR, Josef. Measurement Science Review. 2014, 14(4), 213-218.
- **Short-Range Six-Axis Interferometer Controlled Positioning for Scanning Probe Microscopy.**
  – LAZAR, Josef, KLAPETEK, P., VALTR, M., HRABINA, Jan, BUCHTA, Zdeněk, ČÍP, Ondřej, ČÍŽEK, Martin, OULEHLA, Jindřich, ŠERÝ, Mojmír. Sensors. 2014, 14(1), 877-886.
- **Spectral properties of molecular iodine in absorption cells filled to specified saturation pressure.**
  – HRABINA, Jan, ŠARBORT, Martin, ACEF, O., DU BURCK, F., CHIODO, N., HOLÁ, Miroslava, ČÍP, Ondřej, LAZAR, Josef. Applied Optics. 2014, 53(31), 7435-7441.
- **Two-Stage System Based on a Software-Defined Radio for Stabilizing of Optical Frequency Combs in Long-Term Experiments.**
  – ČÍŽEK, Martin, HUCL, Václav, HRABINA, Jan, ŠMÍD, Radek, MIKEL, Břetislav, LAZAR, Josef, ČÍP, Ondřej. Sensors. 2014, 14(1), 1757-1770.
- **Optical phase locking of two infrared continuous wave lasers separated by 100 THz.**
  – CHIODO, N., DU-BURCK, F., HRABINA, Jan, LOURS, M., CHEA, E., ACEF, O. Optics Letters. 2014, 39(10), 2936-2939.
- **CW frequency doubling of 1029 nm radiation using single pass bulk and waveguide PPLN crystals.**
  – CHIODO, N., DU BURCK, F., HRABINA, Jan, CANDELA, Y., WALLERAND, J. P., ACEF, O. Optics Communications. 2013, 311(15 January), 239-244.
- **Frequency Noise Properties of Lasers for Interferometry in Nanometrology.**
  – HRABINA, Jan, LAZAR, Josef, HOLÁ, Miroslava, ČÍP, Ondřej. Sensors. 2013, 13(2), 2206-2219. ISSN 1424-8220.
- **Multidimensional interferometric tool for the local probe microscopy nanometrology.**
  – HRABINA, Jan, LAZAR, Josef, KLAPETEK, P., ČÍP, Ondřej. Measurement Science and Technology. 2011, 22(9), 094030:1-8.
- **Absolute frequency shifts of iodine cells for laser stabilization. LAZAR,**
  – Josef, HRABINA, Jan, JEDLIČKA, Petr, ČÍP, Ondřej. Metrologia. 2009, 46(5), 450-456. ISSN 0026-1394.

Patents, utility models, awards

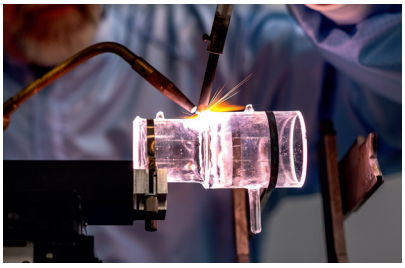
- **Reference unit for linear and saturation absorption spectroscopy containing a hollow-core microstructured optical fibre.**
  – HRABINA, Jan, JELÍNEK, Michal, MIKEL, Břetislav, HOLÁ, Miroslava, ČÍP, Ondřej, LAZAR, Josef. Utility model 33482. 4. 12. 2019.
- **Optical spectrometer optical frequency calibration module,**
  – MIKEL, Břetislav, ČÍP, Ondřej, ŘEŘUCHA, Šimon, ČÍŽEK, Martin, HRABINA, Jan, HUCL, Václav, JELÍNEK, Michal. Utility model 33453. 3. 12. 2019.
- **An electronic unit for compensation of delay fluctuations in a photonic link and a transmission assembly containing the unit.**
  – ČÍŽEK, Martin, PRAVDOVÁ, Lenka, HUCL, Václav, ŘEŘUCHA, Šimon, HRABINA, Jan, LAZAR, Josef, ČÍP, Ondřej. Utility model 32014. 28. 8. 2018.
- **Interferometric assembly for differential measurement of distance,**
  – LAZAR, Josef, ČÍP, Ondřej, HRABINA, Jan. CZ Patent 304317. 26. 2. 2014.



National Time and Frequency metrological network

Electronics modules for time and frequency signals dissemination

Vacuum manifold for absorption reference cells development and filling.



Scientific glassware workshop: development of absorption cell

Laser optical frequency stabilization module and stabilized laser and module assembly,

– MIKEL, Břetislav, ČÍP, Ondřej, LAZAR, Josef, HOLÍK, M., HRABINA, Jan, ČÍŽEK, Martin. Utility model 27406. 6. 10. 2014.

Laser optical frequency stabilization device,

– LAZAR, Josef, HRABINA, Jan. Utility model 27304. 4. 9. 2014.
– Jan Hrabina was awarded by the Czech Academy of Sciences with the "Otto Wichterle Award" (2014).

MAIN COLLABORATING PARTNERS

Collaboration with academic partners

– CESNET (Prague, CZ)
– Czech Metrology Institute (Prague and Brno, CZ)
– Technical University in Wien (Wien, Austria)
– Federal Office for Metrology and Surveying (Wien, Austria)
– Sorbonne Paris North University (Paris, France)
– Palacky University Olomouc (Olomouc, CZ)
– Brno University of Technology (Brno, CZ)
– Institute of Photonics and Electronics of the CAS (Prague, CZ)
– TOPTEC, Institute of Plasma Physic of the CAS (Turnov, CZ)
– Institute of Physics of the CAS (Prague, CZ)

Collaboration with companies

– German Aerospace Center (Bremen, Germany)
– ČD – Telematika (Prague, CZ)
– Japan Aerospace Exploration Agency (Ibaraki, Japan)
– Meopta (Přerov, CZ)
– Nuclear Power Plant Temelín (Temelín, CZ)

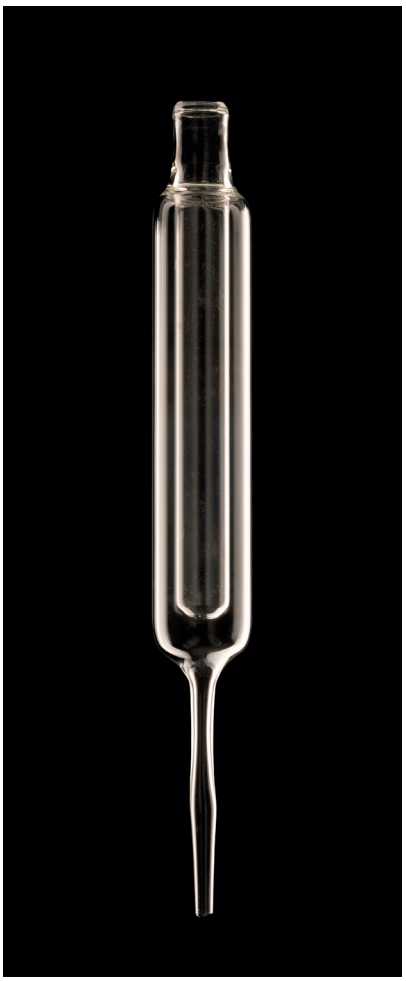
EXPECTATIONS

What can we offer

– Expertise in frequency-stabilised lasers and optical frequency references
– Expertise in laser absorption spectroscopy
– Wavelength calibration and measurement services
– Advanced instrumentation for real-time signal processing in time and frequency metrology
– Instrumentation for time and frequency metrological optical coherent links, repeater laser stations
– Scientific glass components development

What are we looking for

– Cooperation on joint basic and applied research projects of time and frequency metrology and related topics.



Scientific glassware workshop: Dewar bottle for cryogenics