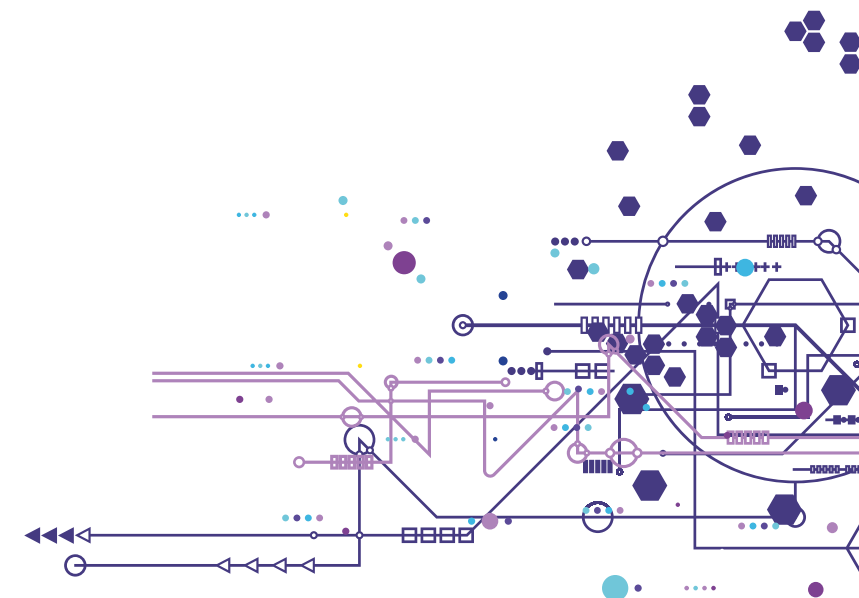
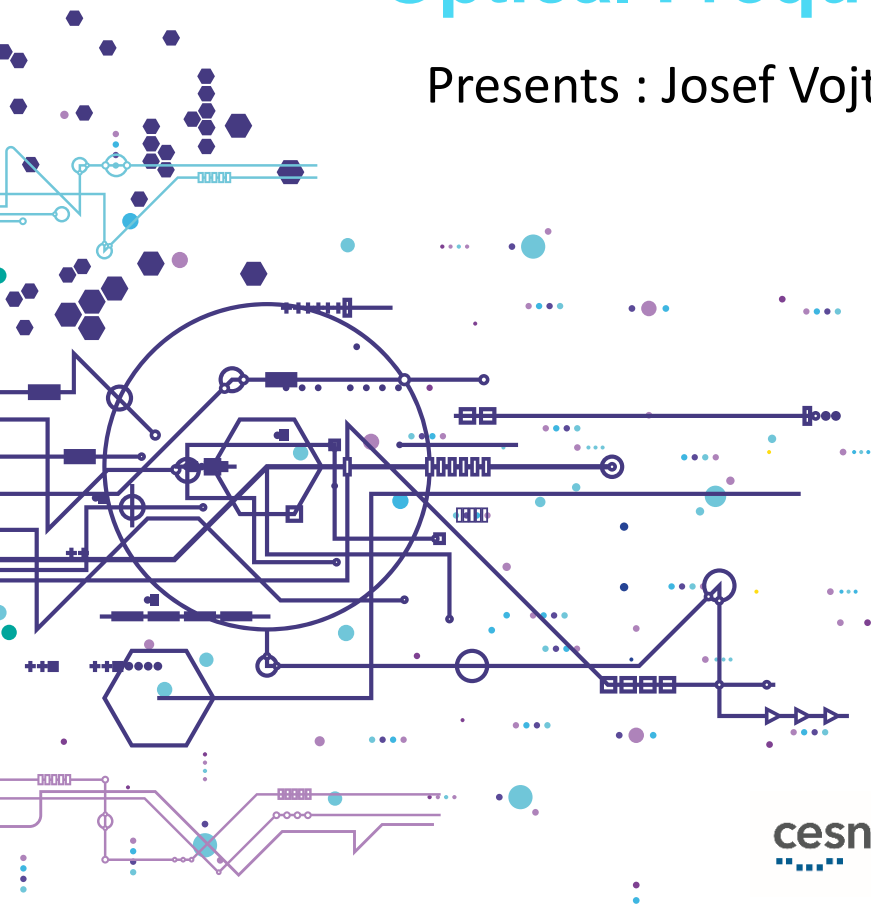


Services over Optical Spectrum



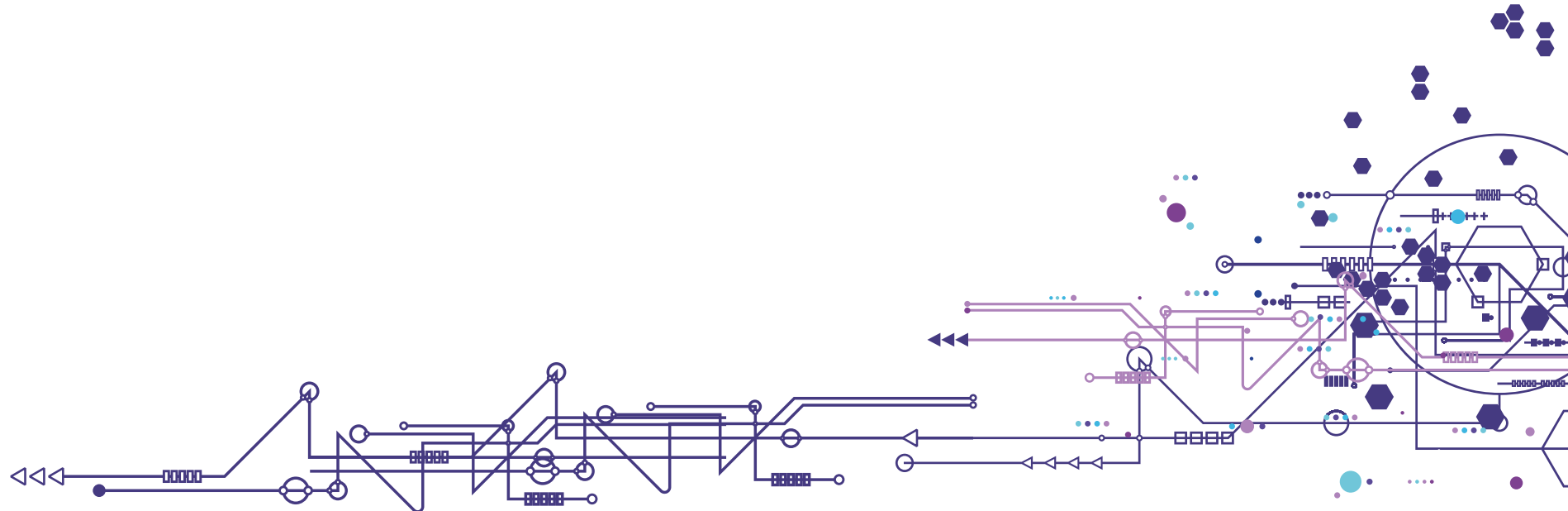
QKD, Transfer of Ultra-stable Coherent Optical Frequency, Fiber sensing

Presents : Josef Vojtěch, Dept. Optical networks, CESNET



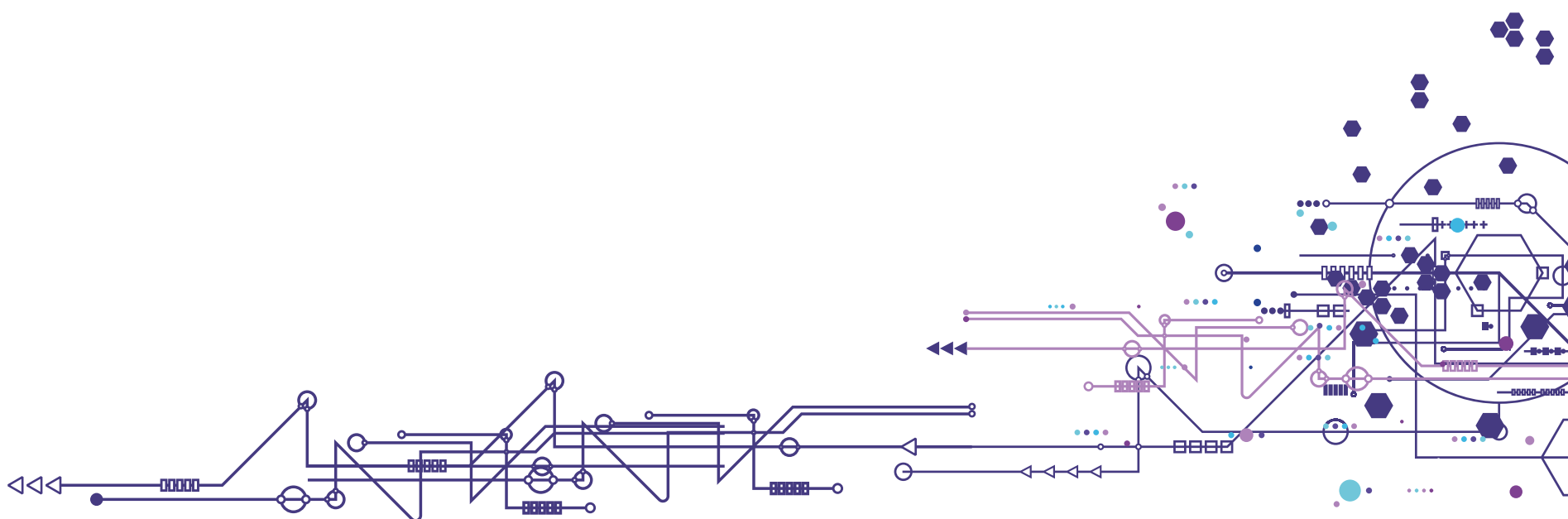
Outline

- Services over the optical spectrum
 - Ultrastable transmissions - interconnection of q sources of ultrastable optical frequency
 - Quantum technologies
 - Quantum Key Distribution - QKD
 - Fiber sensing



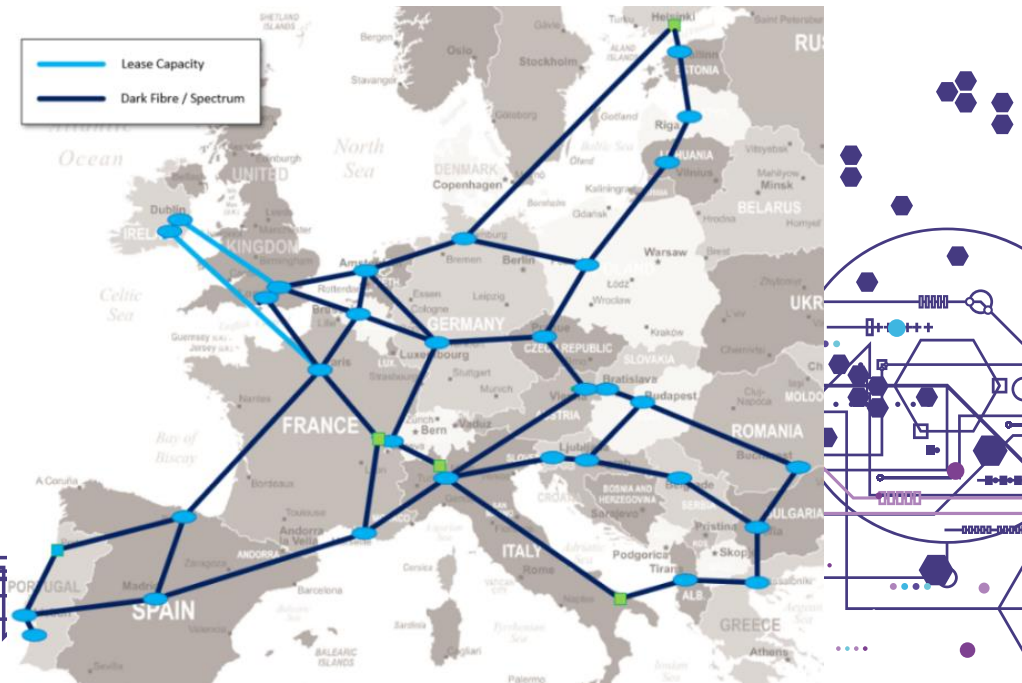
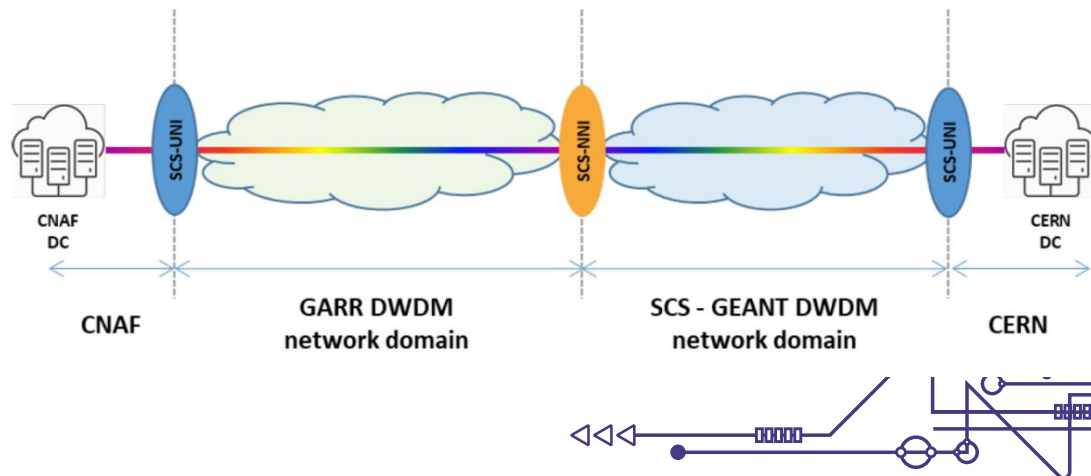


Services over the lit optical spectrum



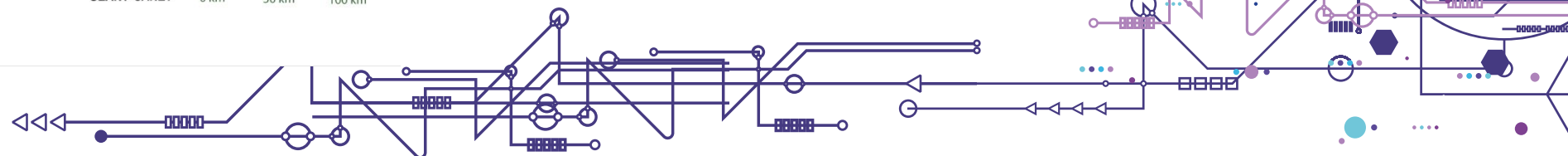
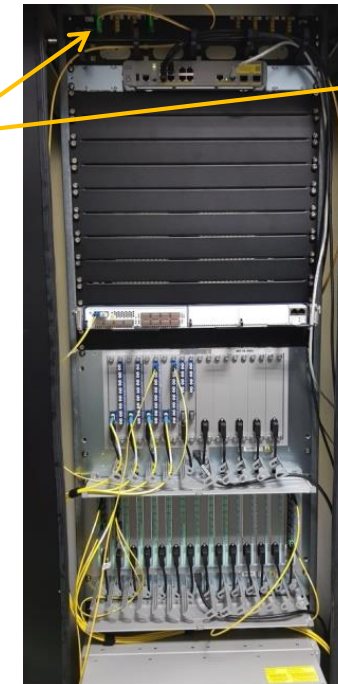
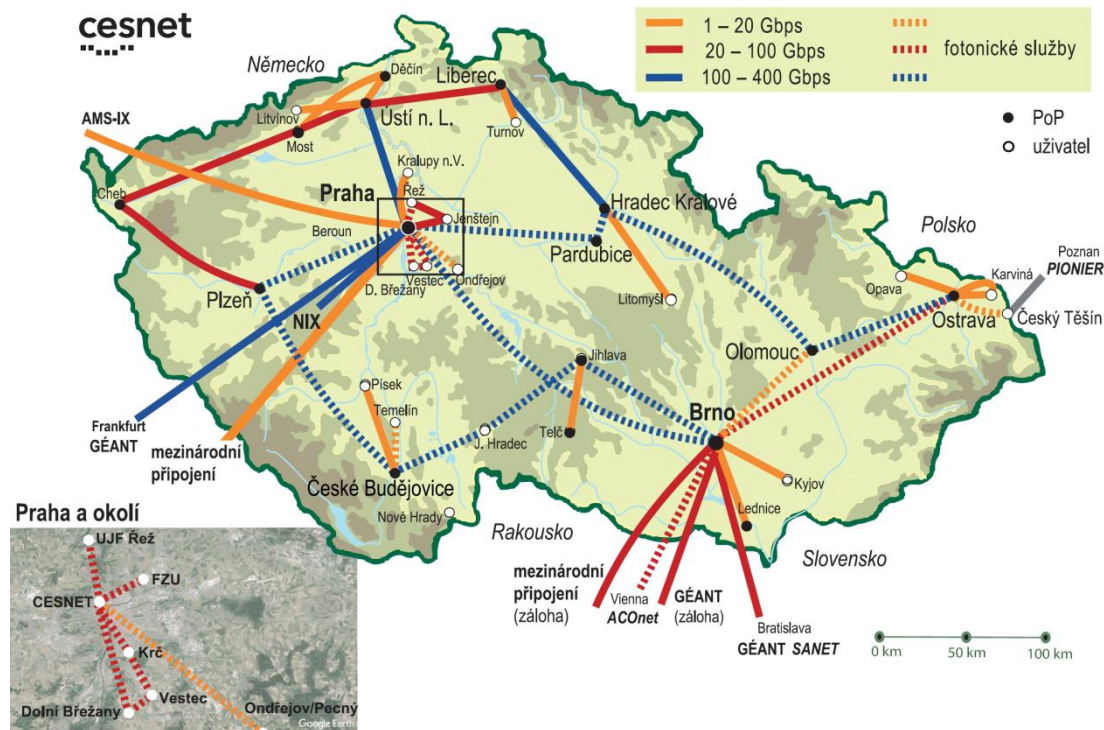
Services over the lit optical spectrum

- CESNET Photonics
 - Spectrum service - all optical transmission
 - Suitable for applications requiring high reproducibility
 - Enables real-time communication, including processes with demanding network response time requirements ("hard real time")
 - Enables faster upgrade cycle and response to transmission needs
- Change from fixed ITU 50GHz grid to flexible allocation
- Minimum channel width now 25 GHz, increments of 12.5 GHz. Maximum 388 increments, full C+ band.
- Spectrum Connection Service - we are also working on in the GÉANT GN4-3 project (856726 H2020), WP7 - the next generation network
- Service within GN5 (from 1.1.2023)



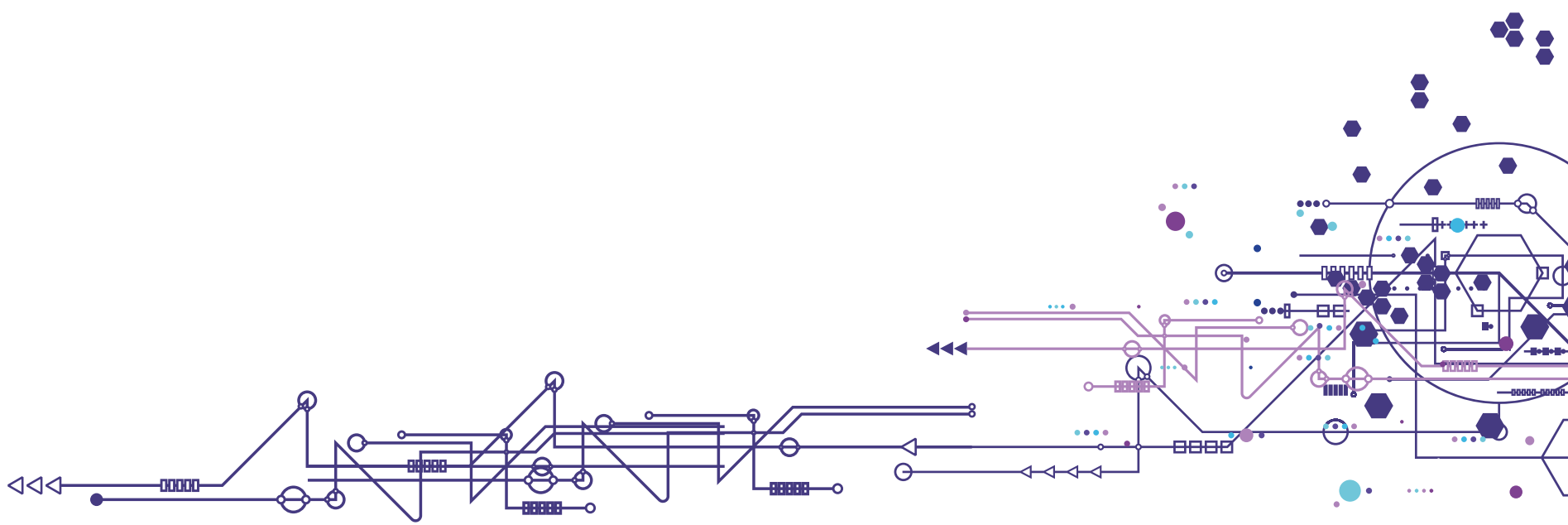
Services over the dark optical spectrum

- Deployed 120+ OADMs for dark spectrum reservation to main and relevant routes, in the past or during CESNET3 upgrade
- Emphasis on minimum attenuation (<1 dB)
- Dual(tri)-band

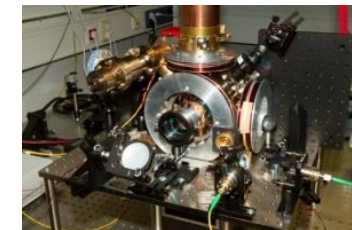




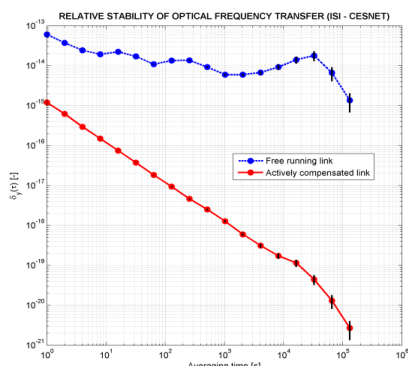
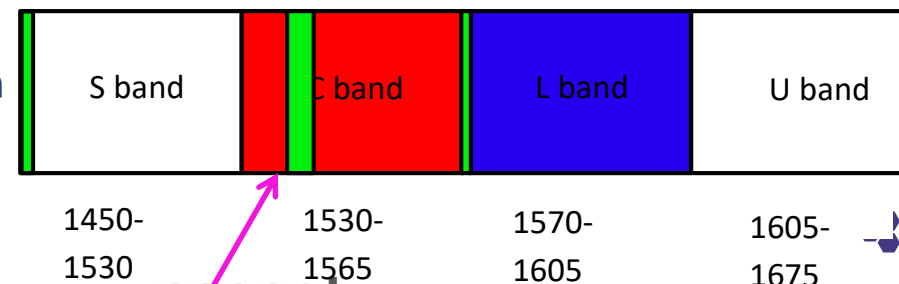
Ultra-stable Transfers – Interconnection of Coherent Optical Frequency Sources



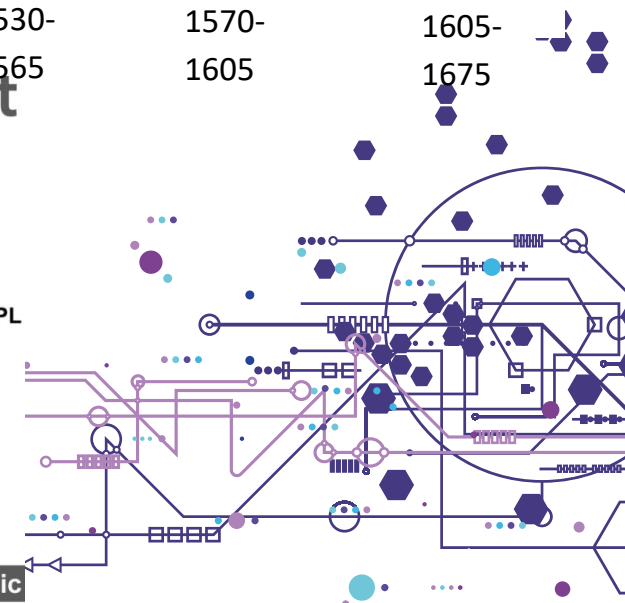
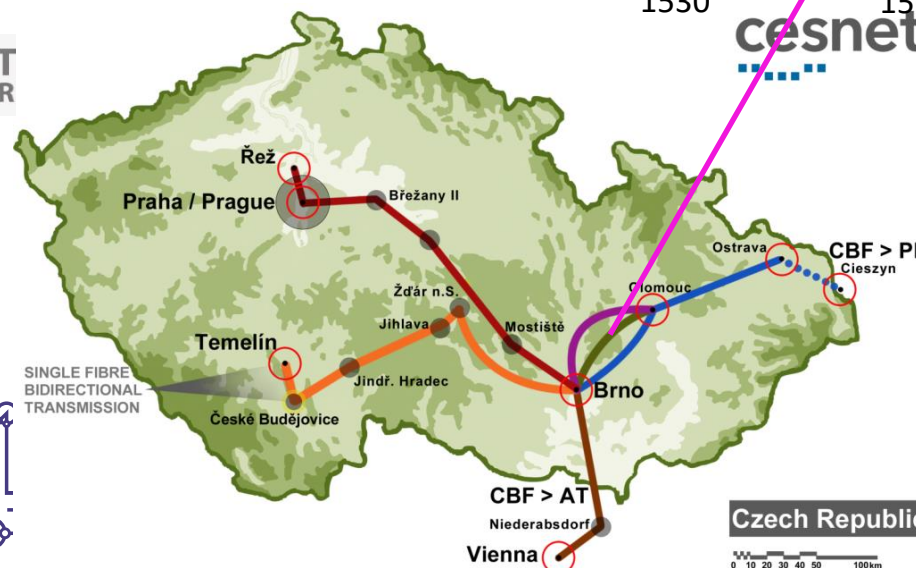
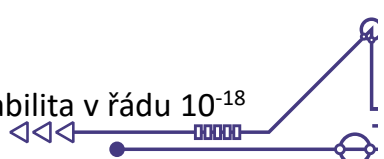
Ultra-stable Coherent Optical Frequency Transfers



- Ultra-stable optical frequency transmissions, from 2015
- Contractual research for UJV Řež (17-19)
- Optical frequency transport to UJV Řež and Temelín for containment stability sensing
- Additional service of e-Infrastructure (20-22)
- Interconnection of optical single clocks based on a single $^{40}\text{Ca}^+$ ion
- For homodyne CV QKD detection, phase fluctuation compensation

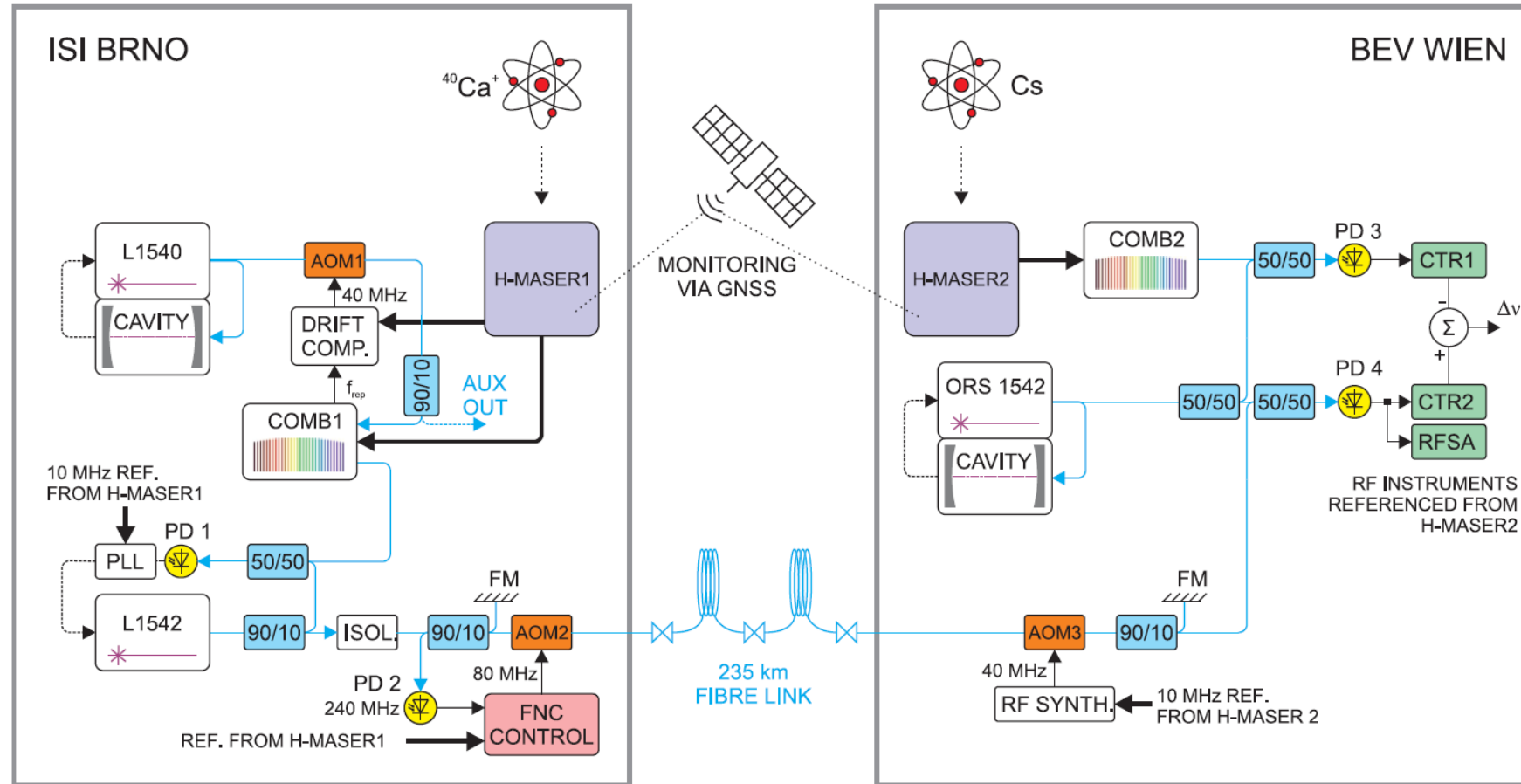


CESNET Praha - UPT Brno 306 km, nestabilita v řádu 10^{-18}

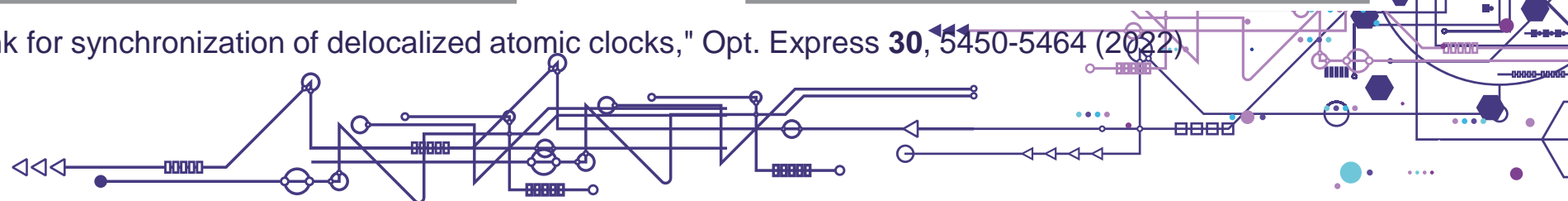


Ultra-stable Transfers

- ORS - cavity locked laser 1540.5 nm in UPT AV ČR

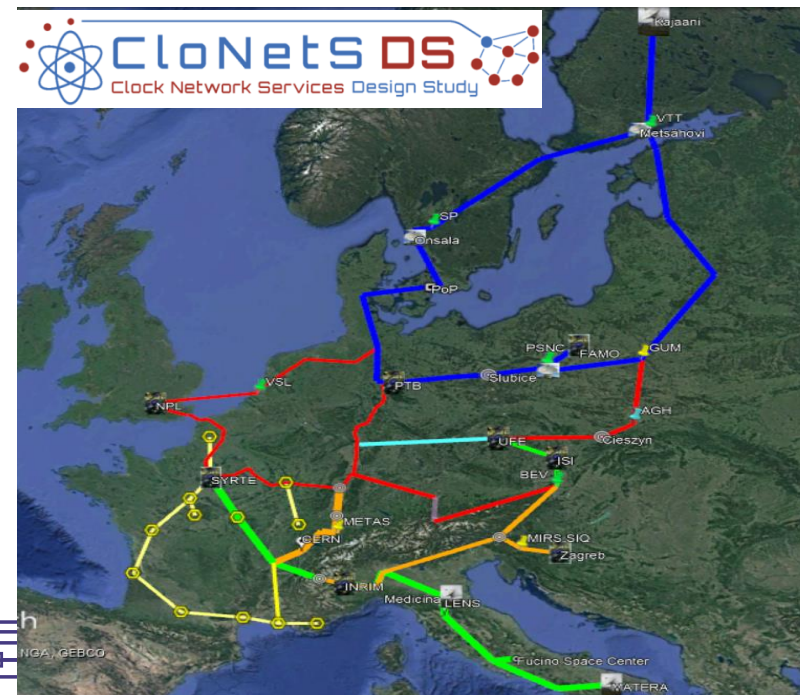
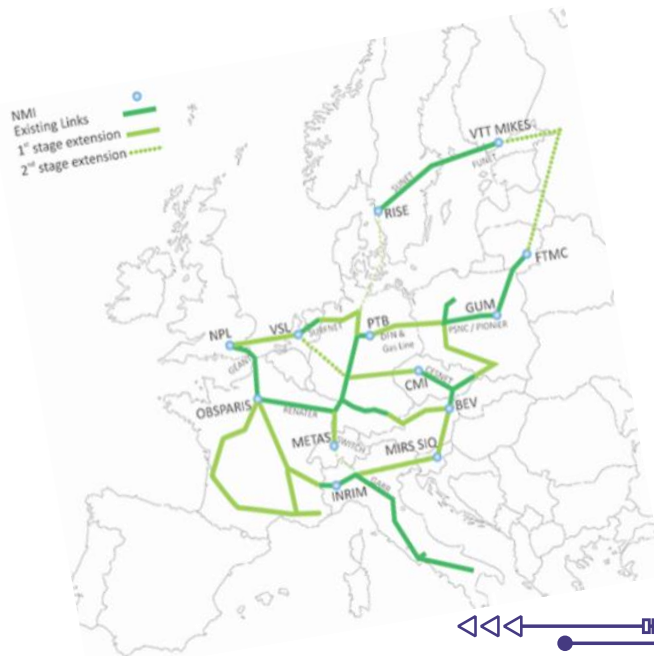


Martin Cizek et. al, "Coherent fibre link for synchronization of delocalized atomic clocks," Opt. Express **30**, 5450-5464 (2022)



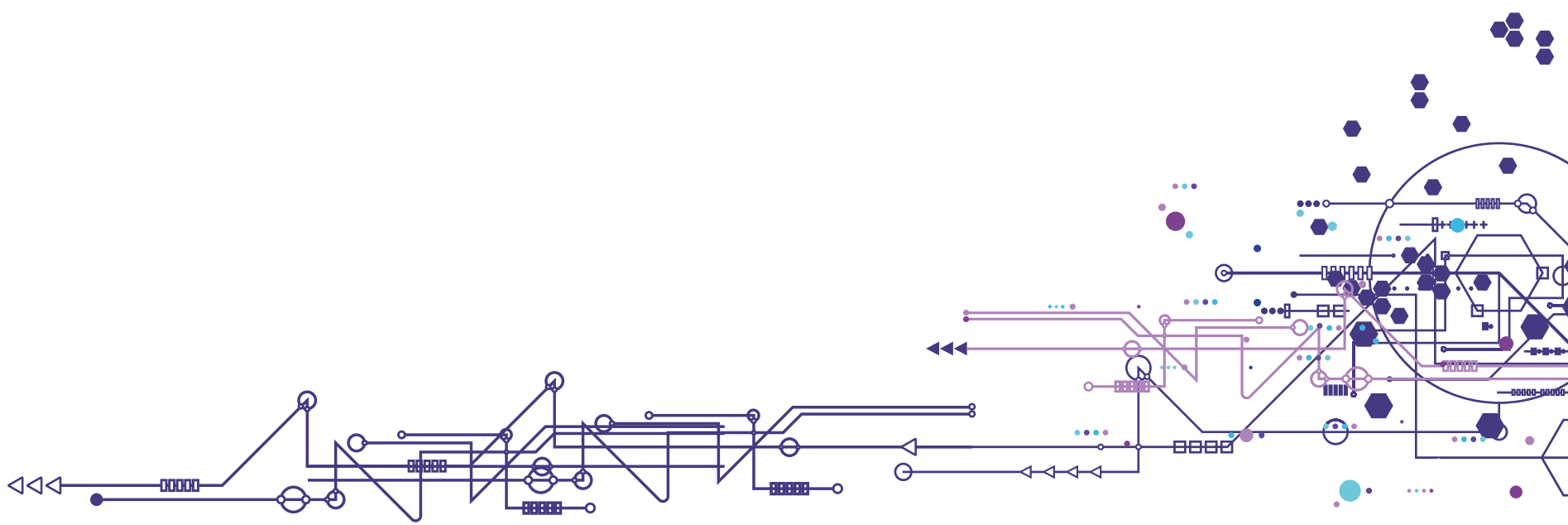
Ultra-stable Transfers

- 2019-2022 H2020 **CLONETS-DS** CLOckNETworkServices - Design Study, coordinated by GEANT)
- We also participate in: the GN4-3 WP6 Optical Time Frequency Network, also in the GN5 project (trial Bra-Vie)
- In both projects, great synergy between QKD and TF





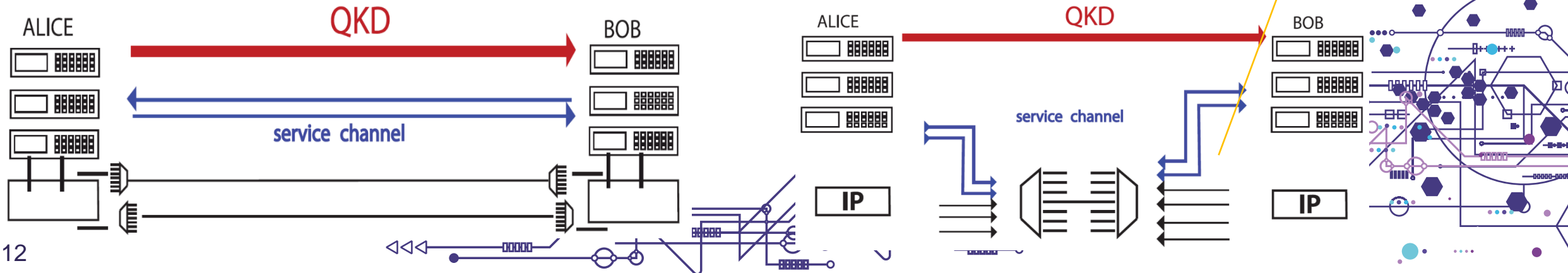
Quantum technologies



QKD

First intercity and international QKD trial v CZ

- Cooperation with VŠB-TUO, PSNC (EU project OpenQKD)
- Ostrava – Cieszyn, 75km, 16 dB
- The QKD system used was not designed for shared fibers, it is "fiber hungry", quantum channel, service channel, 3 fibers in total, offer for additional fibers for this route but not usable
- Solution over single fiber DWDM, proven solution from DWDM network
- Signal detection < -100 dBm, measure, measure, measure, clean, clean and clean
- The link also transmitted very accurate **time and frequency** in parallel



QKD

■ Network Cybersecurity in Post-Quantum Era – NeSPoQ (VUT, VŠB, CESNET)

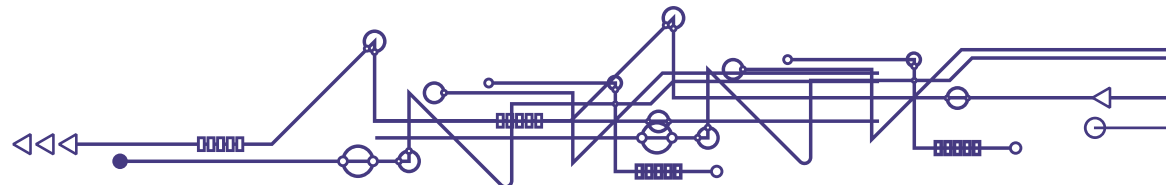
■ 2021-2025, MVČR

■ Practical applicability of QKD for links with 100G+ traffic, PQC (post-quantum cryptography)

■ Application sponsor: **NÚKIB**

■ We are participating **GN4-3 WP6 QKD, continues in GN5**

■ **GN5 PoC 200+km (Twin-field)**



ARTICLE

<https://doi.org/10.1038/s41467-021-27808-1> OPEN



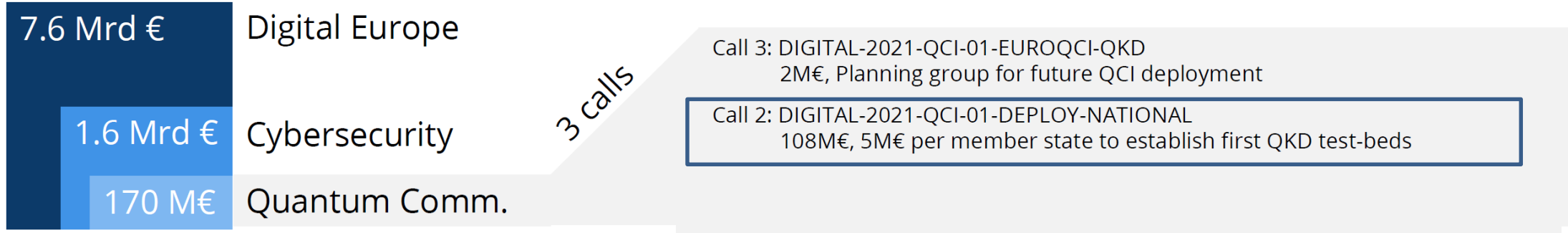
Coherent phase transfer for real-world twin-field quantum key distribution

Cecilia Clivati¹, Alice Meda¹, Simone Donadello¹, Salvatore Virzi¹, Marco Genovese^{1,2}, Filippo Levi¹, Alberto Mura¹, Mirko Pittaluga^{3,4}, Zhiliang Yuan⁵, Andrew J. Shields³, Marco Lucamarini⁶, Ivo Pietro Degiovanni^{1,2} & Davide Calonico¹

Quantum mechanics allows distribution of intrinsically secure encryption keys by optical means. Twin-field quantum key distribution is one of the most promising techniques for its implementation on long-distance fiber networks, but requires stabilizing the optical length of the communication channels between parties. In proof-of-principle experiments based on spooled fibers, this was achieved by interleaving the quantum communication with periodical stabilization frames. In this approach, longer duty cycles for the key streaming come at the cost of a looser control of channel length, and a successful key-transfer using this technique in real world remains a significant challenge. Using interferometry techniques derived from frequency metrology, we develop a solution for the simultaneous key streaming and channel length control, and demonstrate it on a 206 km field-deployed fiber with 65 dB loss. Our technique reduces the quantum-bit-error-rate contributed by channel length variations to <1%, representing an effective solution for real-world quantum communications.

QKD

■ QCI 01- DEPLOY CZ-QCI (expected 1.1.2023)



QKD

■ QCI 01- INDUSTRIAL – SEQRET (begins 1.1.2023)

7.6 Mrd €

Digital Europe

1.6 Mrd €

Cybersecurity

170 M€

Quantum Comm.

3 calls

Call 3: DIGITAL-2021-QCI-01-EUROQCI-QKD
2M€, Planning group for future QCI deployment

~~Call 2: DIGITAL-2021-QCI-01-DEPLOY-NATIONAL
108M€, 5M€ per member state to establish first QKD test-beds~~

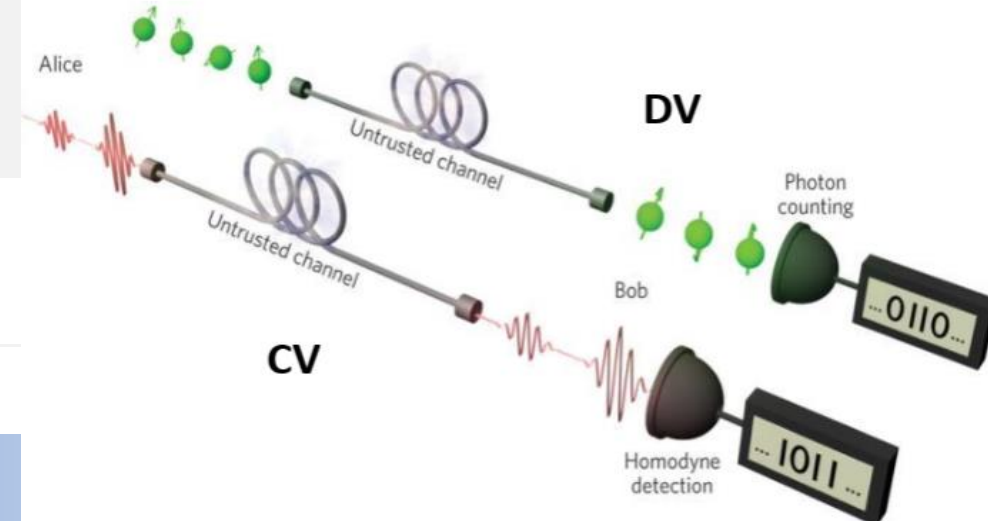
Call 1: DIGITAL-2021-QCI-01-INDUSTRIAL

„Create a European Industrial Ecosystem for Secure QCI technologies and systems“

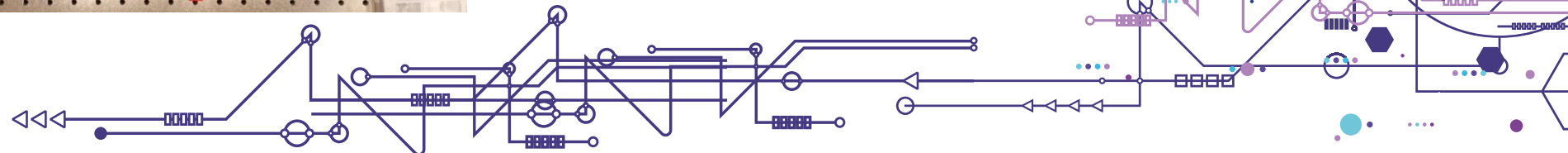
- secure (>EAL4), standardized (ETSI, etc.), industrialized QKD-system at TRL 8-9
- integration in existing telecom networks

■ EU based telecom components

■ Expected price drop 70%

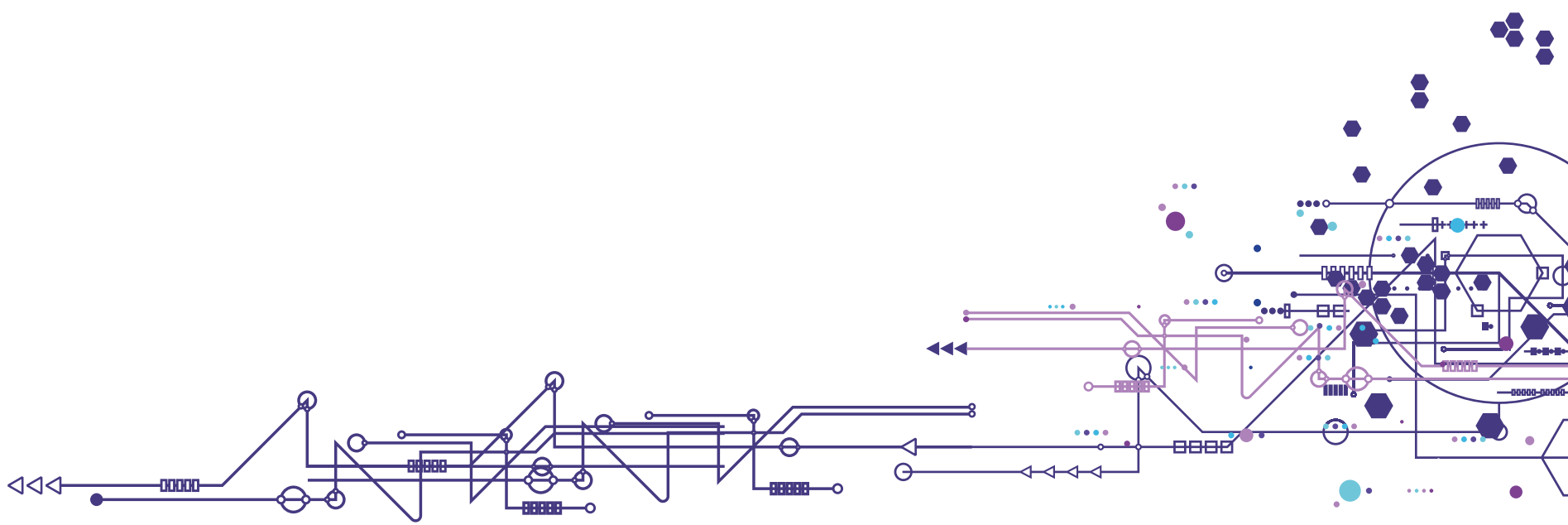


- We verify parallel transmissions and transmission interference
 - Generation of entangled photon pairs
 - Single-photon detection



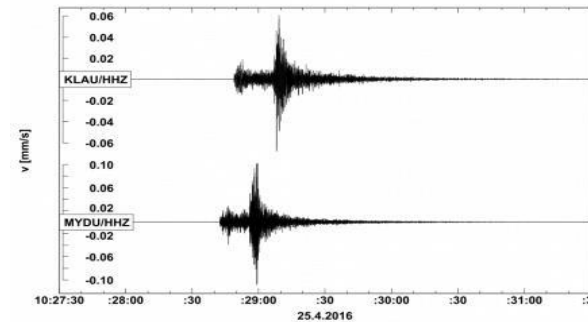
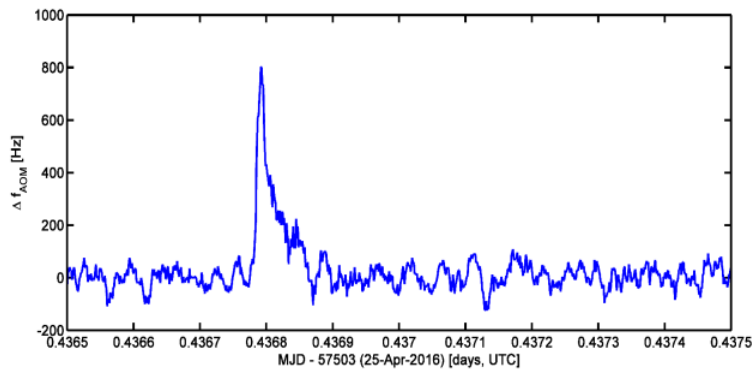


Telecom Fibre Sensing

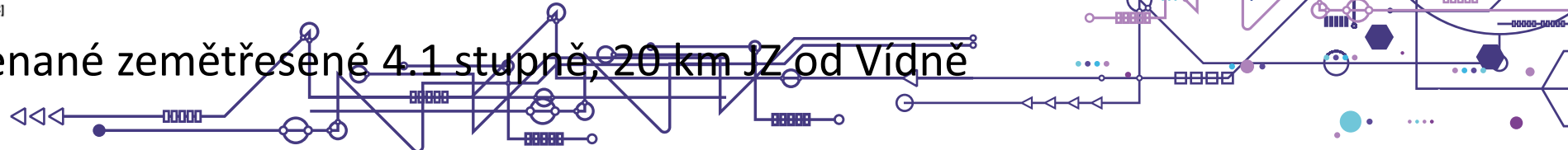


Telecom Fibre Sensing

- Frequency stabilization is very powerful, detect changes in the order of Hz, carrier 192 THz
- Can be used for vibration-tampering/earthquake detection, temperature, lightning strikes,...
- Additional level of transmission security
- We are implementing the results of the successfully completed MVČR DOBI 2015-2020 project
- CESNET consortium member of the SUBMERSE project submitted to the Horizon Europe -TECH 01-01 call

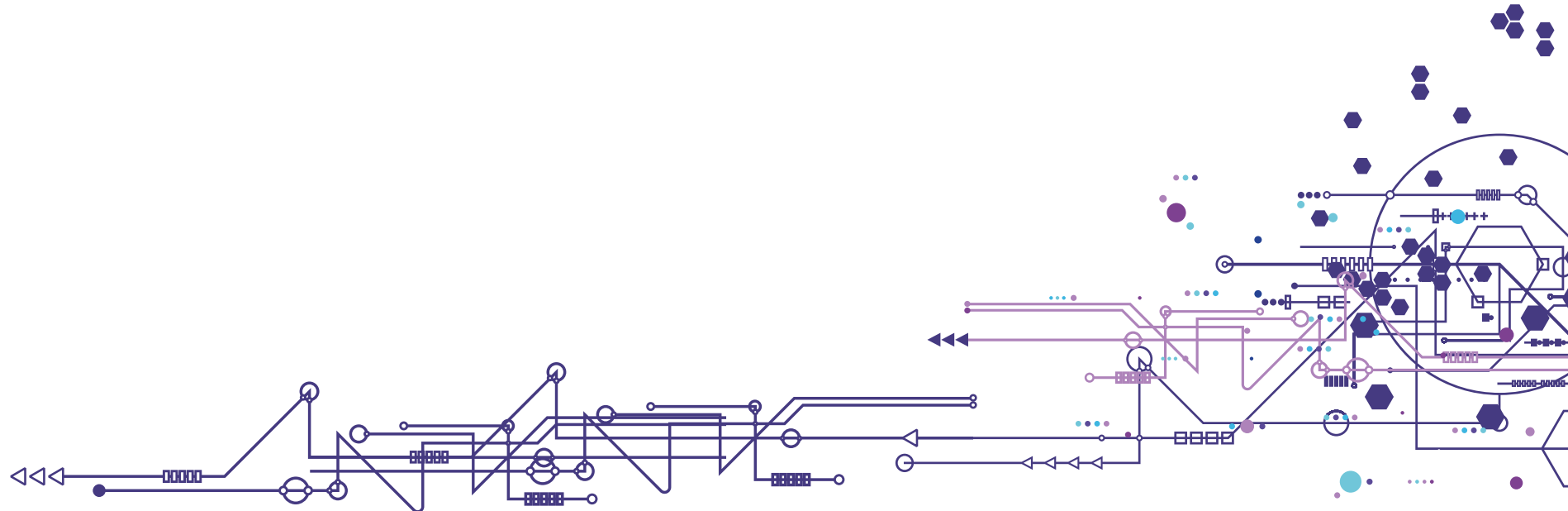


25. dubna 2017 zaznamenané zemětřesené 4.1 stupně, 20 km JZ od Vídně



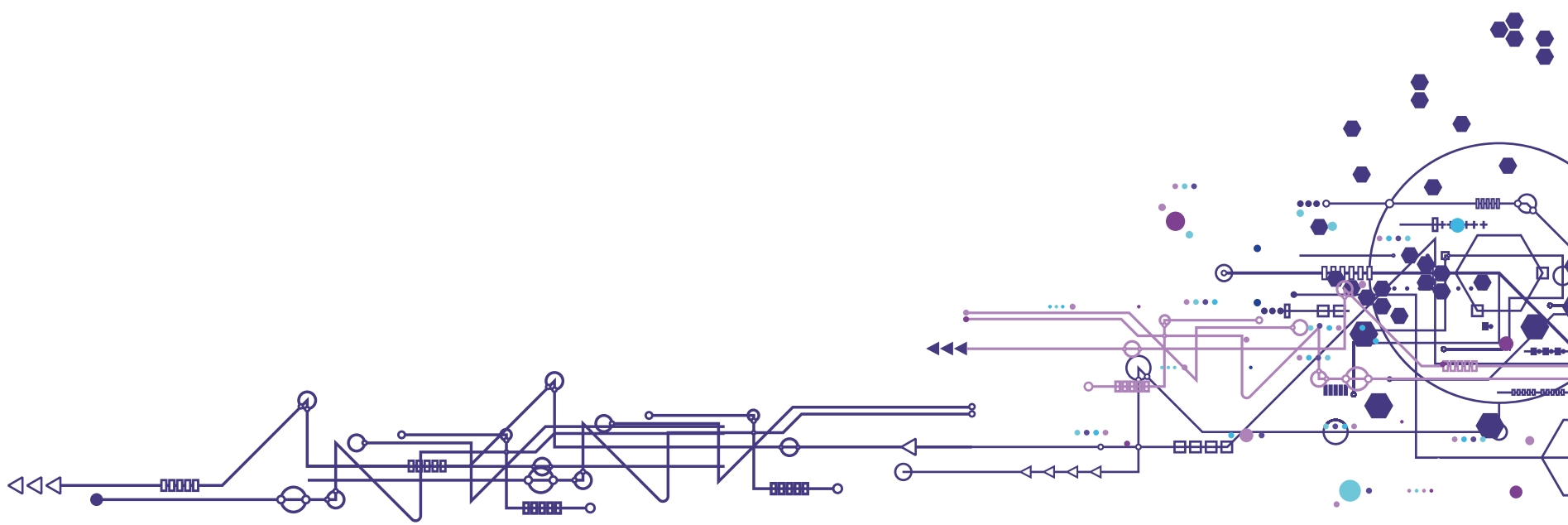
QKD + Sensing

- VK01030193 - Quantum encrypted communication with enhanced physical layer security
- Begins 1.1.2023, led by Institute of Scientific instruments Acad.Sci. CZ



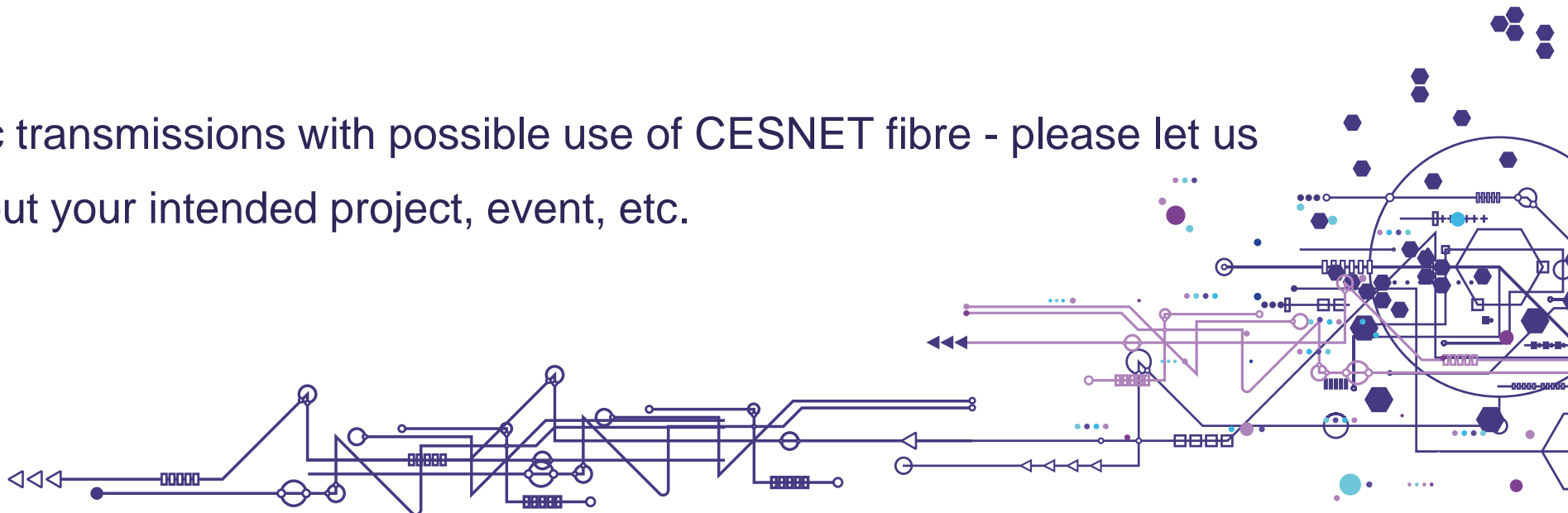


Conclusion



Possible Colaboration

- QKD use cases - very sensitive data of permanent value
- Use cases - ultrastable optical references
- Use cases QKD+sensing - multilayer security
- Sensor data acquisition and processing
- Advanced key distribution and management
-
- In the case of photonic transmissions with possible use of CESNET fibre - please let us know in good time about your intended project, event, etc.





Napište nám

info@e-infra.cz

Thank you very much for attention

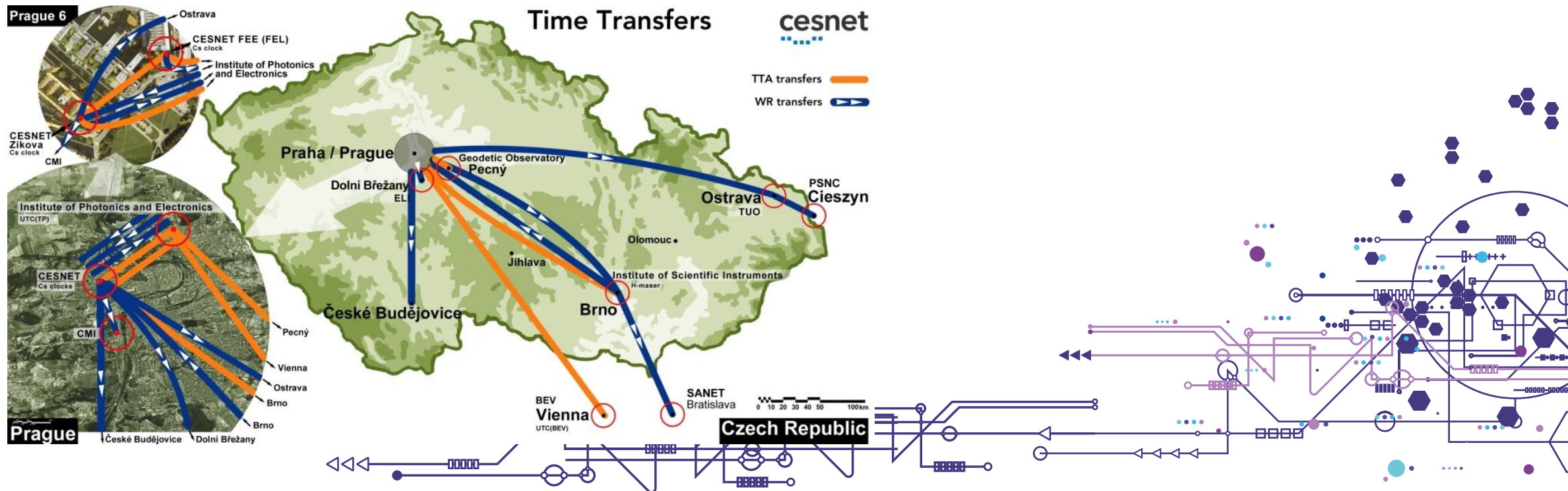
josef.vojtech@cesnet.cz

A large, dark blue circle with a thick outline. Inside the circle, the text 'e-infra.cz' is written in a dark blue, sans-serif font. The circle is partially enclosed by two curved lines on its left and bottom sides, suggesting a stylized 'e' or a partial circle.

e-infra.cz

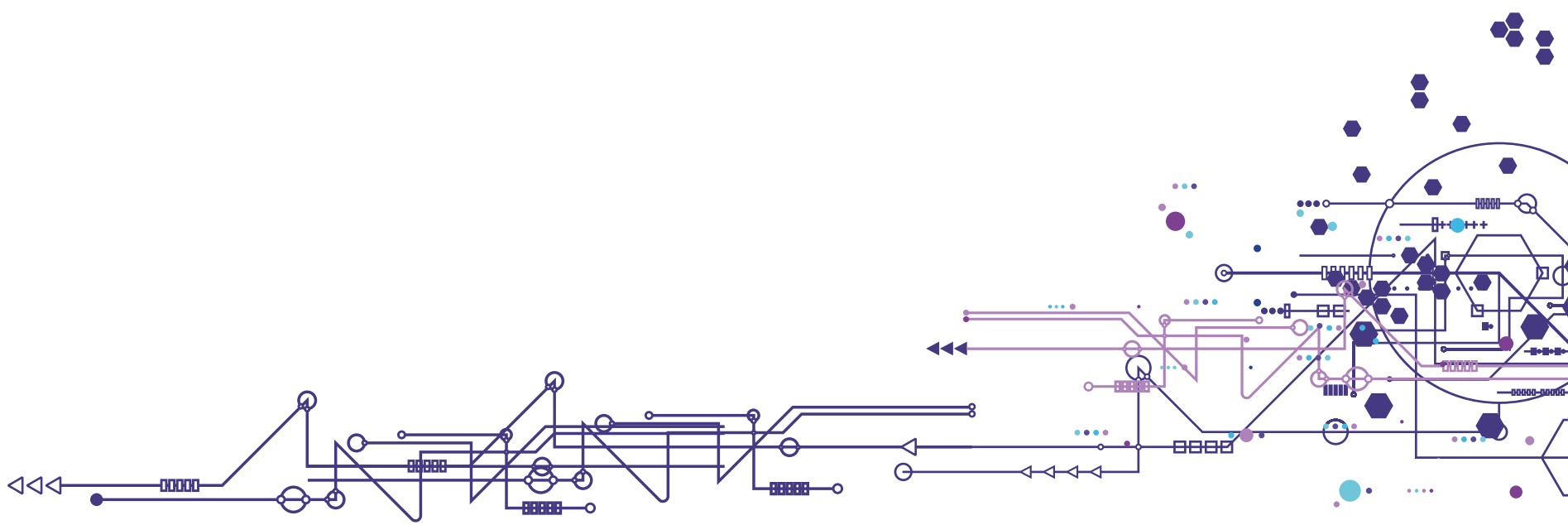
Ultrastabilní přenosy

- Od 2011, dnes přesný čas na 3100+ km a na 1100+ km ultra-stabilní optická frekvence
- Dedikované kanály, preferenčně obousměrné – temné spektrum (kompenzace termálních jevů)
- Zásadní pro DV QKD
- O TF službách podrobně pohovoří kolega Vladimír Smotlacha



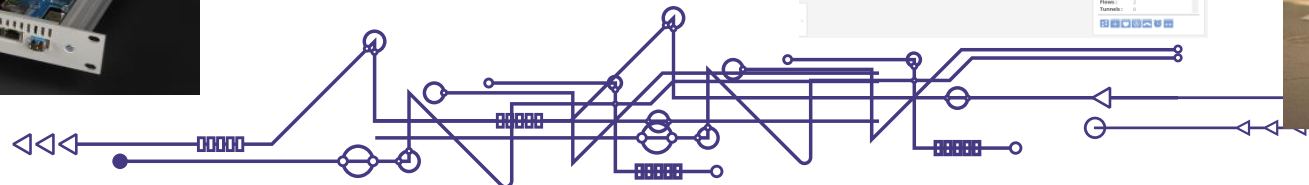
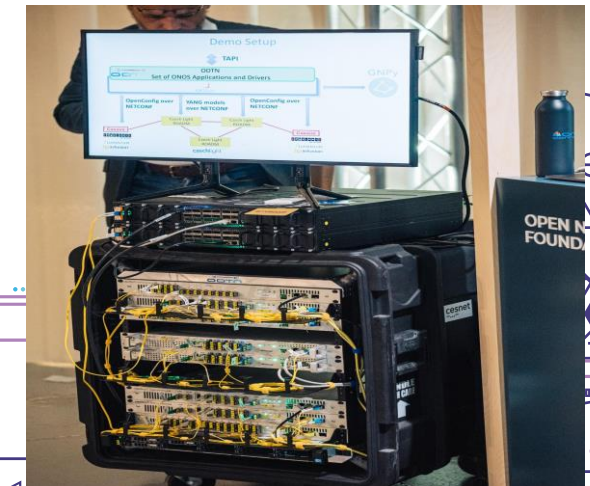
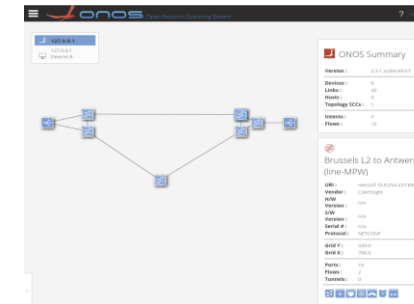
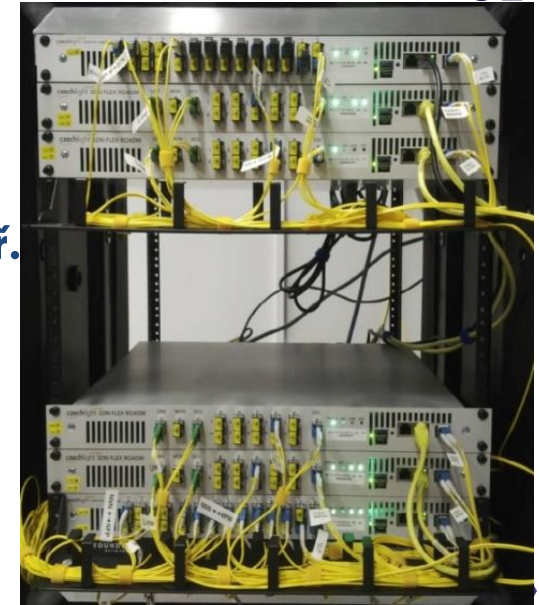


Open Line Systems



Open Line System Czech Light

- Určen pro efektivní využití vláknových kapacit (pásma C a L, obousměrné přenosy)
- Nasazován od roku 2004: „J Vojtech, J. Radil, ‘Czech Light & Czech Light Amplifiers’, 17th TF-NGN, Zurych, 2005“
- Nasazeno více než 130 zařízení rodiny Czech Light v CESNET2 a dalších sítích, např. SWITCH
- Vyžádané demonstrace na předních akcích v oboru: Telecom Infrastructure Project 2018+19, Optical Fibre Conference 2020, European Conference on Optic Communications 2021 + pozvánka na rok 2022



Open Line System Czech Light

- Vše vzdáleně konfigurovatelné
 - NETCONF
 - RESTCONF + YANG - push telemetry
- Vše vzdáleně monitorovatelné
 - OpenMetrics (Prometheus)
 - Grafana
 - Odezva pod 1s (vs telekom standard 15 min)
 - Velmi jemná práce se spektrem pro super rychlé signály:
 - CL SDN ROADM zeleně, telekomunikační OSA černě)
- Výtečná prezentace J. Kundráta:
 - Chatty ROADMs: Streaming Telemetry with Open Source Software and Open Hardware (ECOC 2021)
 - https://www.youtube.com/watch?v=zPdA_GX4rPI

