

TC for Time & Frequency: Activities & Highlights 2018-19

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TC-TF Chair

Borås, Sweden
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Agenda



- Introduction to TC-TF
 - Overview
 - Annual meeting
- Research activities
 - TC-TF projects and comparisons
 - EMPIR projects
- T&F participation in EMNs



TC-TF overview



- Current status:
 - 29 contact persons
 - 2 active TC projects, 1 completed early 2019
 - No sub-committees
 - Working group for CMC reviews
 - Current Chair will continue in post for a further 2 years
- TF CMCs:
 - 23 EURAMET members have 342 CMCs (out of 781 globally)
 - Revised CMCs from FR, ES, BH currently in inter-RMO review



TC-TF annual meeting

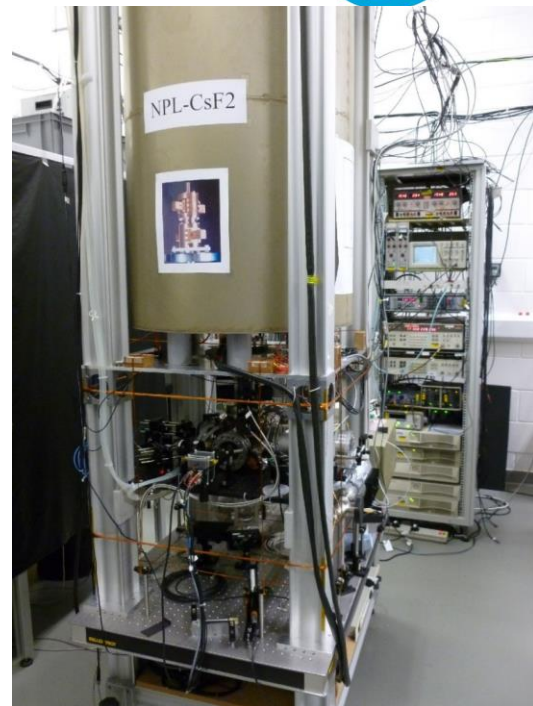


- Held at NPL, UK
 - 7-8 March 2019
- Guest delegates
 - BIPM Time Department
 - GULFMET
 - Taiwan (TL)
- Main topics covered:
 - Updates from EURAMET & BIPM
 - Progress reports on TC, EMPIR, H2020 & other projects
 - CMC changes & reviews
 - TF participation in EMNs



TF comparisons

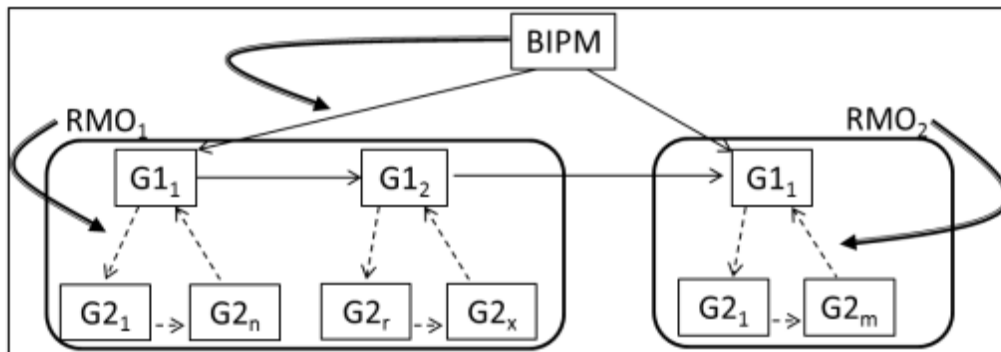
- One KC in TF:
 - CCTF-K001.UTC
 - UTC computation by BIPM, ongoing
- Currently no TC-TF SCs
 - GULFMET.TF-S1
 - Time difference between 2 pulses (2017)
- Much of the work of TC-TF is in support of the KC



Projects supporting GNSS time links



- Project 1152: *GNSS receiver performance monitoring*
- Project 1156: *GPS link calibrations in support of CCTF-K001.UTC*
 - Project coordinates calibrations of Group 2 labs within EURAMET



3 G1 labs in EURAMET:

- ROA (Spain)
- PTB (Germany)
- OP (France)



SC on time interval measurement

- Project 1288: *Time interval comparison Pilot Study*
 - 3 time interval delay standards developed by SIQ/ InLambda (SI)
 - Variable delay standard developed by GUM (PL)
 - All standards characterised by GUM



Project completed

- TC annual meeting approved a new SC based on these standards
 - Technical protocol in preparation
 - First campaign expected to start in the autumn



EMPIR TF project overview



2 projects from 2015 call finishing this year:

- 15SIB03 OC18 - Optical clocks with $1\text{E-}18$ uncertainty
- 15SIB05 OFTEN - Optical frequency transfer – a European network

1 project from 2017 call:

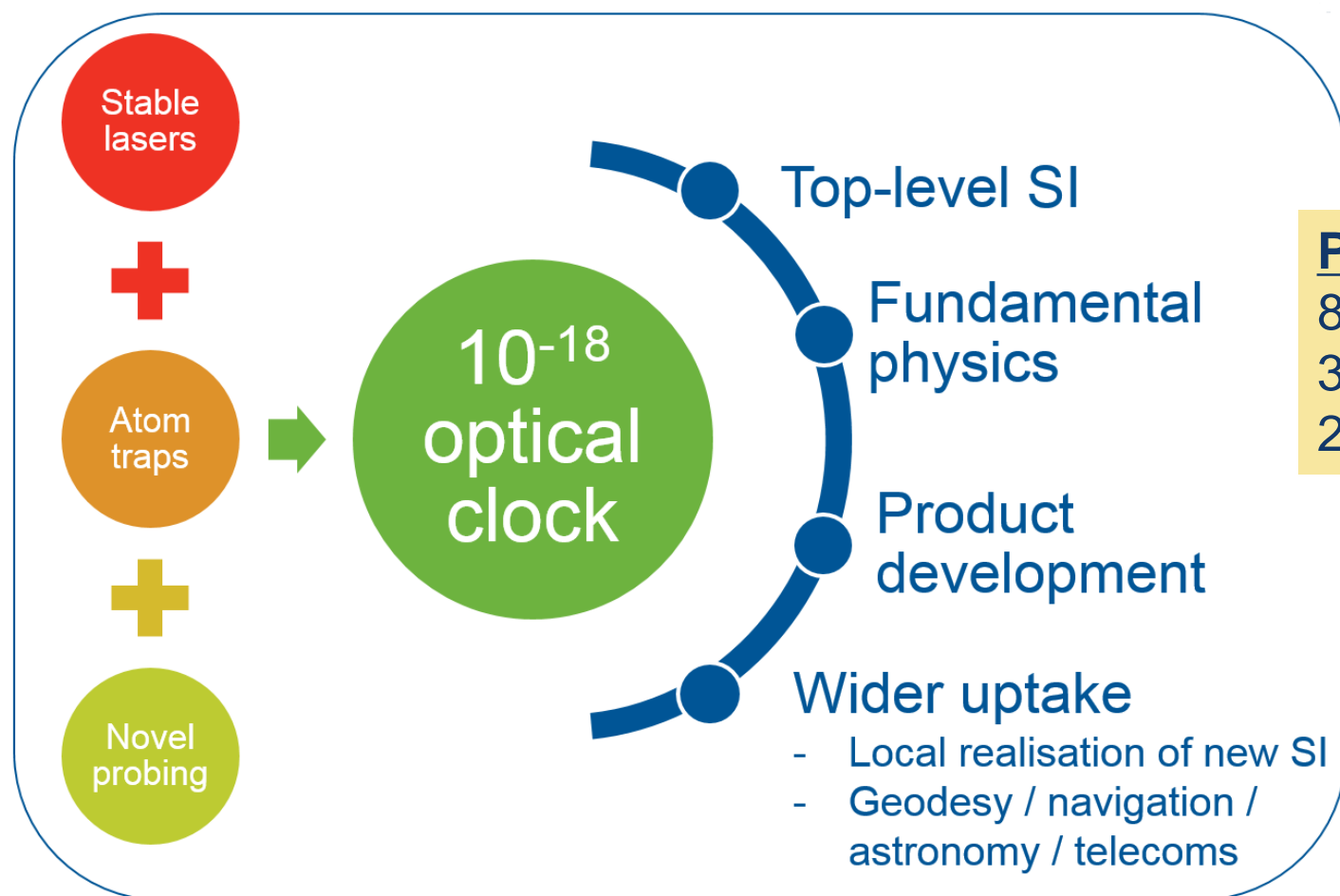
- 17IND14 WRITE - White Rabbit for industrial timing enhancement

2 projects starting in 2019:

- 18SIB05 ROCIT - Robust optical clocks for international timescales
- 18SIB06 TiFOON - Time and frequency over optical networks

15SIB03, Optical clocks with $1\text{E-}18$ uncertainty

- May 2016 – April 2019, coordinated by NPL



Participants

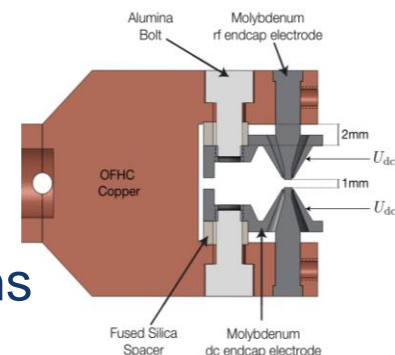
8 internal partners
3 external partners
2 RMGs

EMPIR OC18 highlights



- Demonstrated significant advances in optical clock performance across Europe
- All scientific objectives achieved

2 independent Yb ion clocks compared over several months
Measured agreement with uncertainty of $4.2\text{E-}18$



➔ World-leading result for ion clocks

➔ Ion trap design adopted for German '*Opticlock*' compact optical clock demonstrator



➔ 25 peer-reviewed papers, >100 conference presentations

➔ Guidelines for building optical clocks in preparation

EMPIR OC18 **impact & CB**

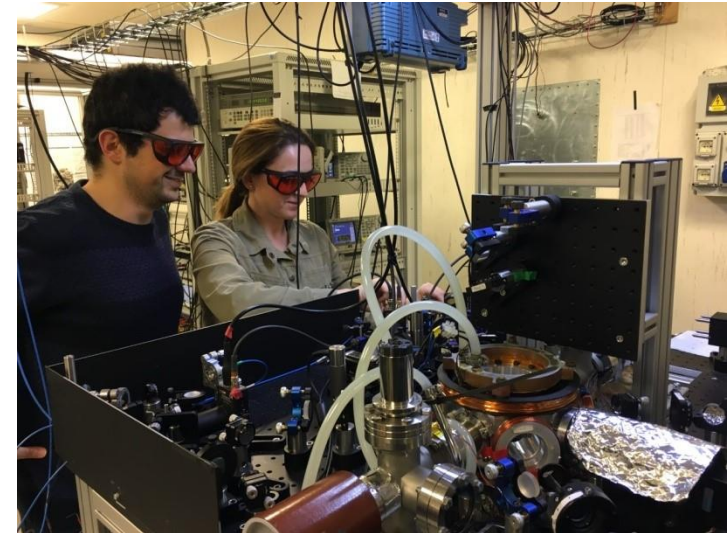


2 very successful RMGs

Researchers from ROA spent 31 months at SYRTE and at INRIM

Summer school

One-week optical clocks school for PhD students held in September 2018



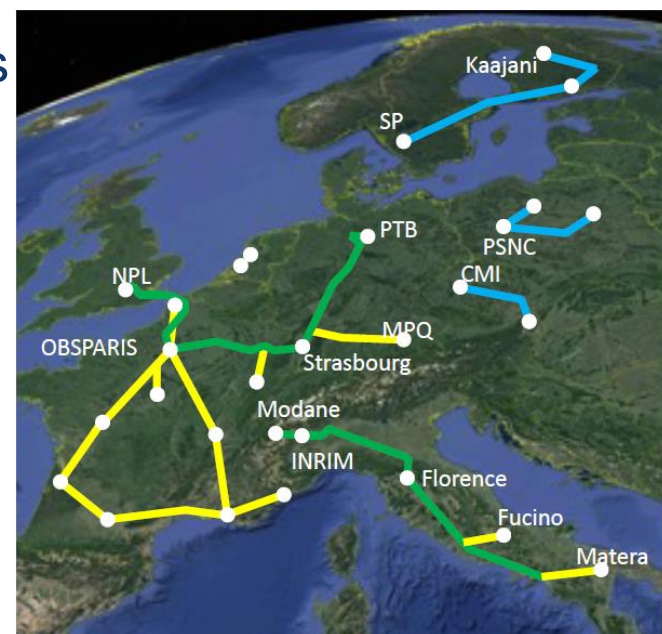
15SIB05, Optical frequency transfer – a European network

- June 2016 – May 2019, coordinated by PTB
- Project aims:
 - To improve fibre T&F transfer methods
 - To compare optical & Cs fountain clocks
 - To support applications for non-NMI users

Participants

7 internal partners
4 external partners

19 peer-reviewed papers
24 conference presentations



EMPIR OFTEN highlights



- Demonstrated first international fibre comparisons of optical clocks



3-way comparisons



Link more stable and accurate than the clocks ($3E-19$)

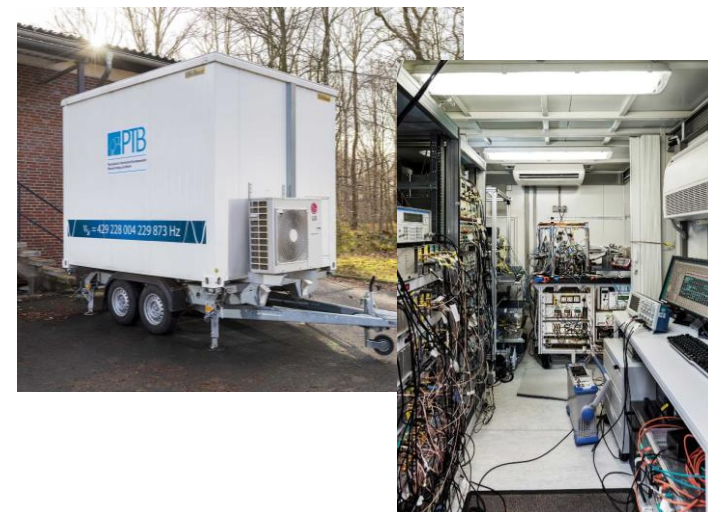
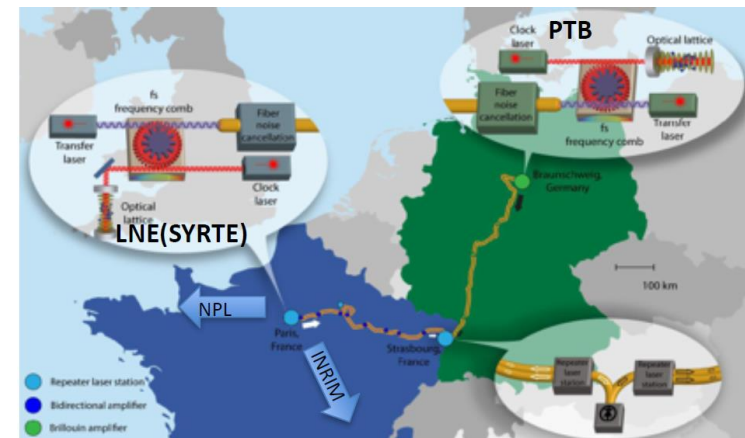


Relativistic levelling demonstrated at the 10 cm level

- References for end users



Provided reference frequencies in: Italy (for VLBI), France (laser lab), Germany (telecoms)



17IND14, White Rabbit for industrial timing enhancement

- June 2018 – May 2021, coordinated by INRIM

White Rabbit (WR) is a method for packet-based T&F transfer through optical fibre networks with ns accuracy and stability. It is a development of the Precision Time Protocol (PTP).

- Project aims:
 - Develop scalable calibration techniques for WR
 - Improve the resilience of WR time transfer
 - Improve the performance of WR equipment
 - Demonstrate time delivery to industrial users



Participants

6 internal partners
5 external partners

TF involvement in EMNs



- 3 EMNs of interest to TC-TF:

EMN-Q (Quantum Technologies)

Includes optical clocks and clock comparisons

EMN-SEG (Smart Electricity Grids)

Includes synchronisation requirements

EMN-PNTG (Position, Navigation, Timing and Geodesy)

Includes time dissemination and comparison by GNSS and optical fibre methods, and clock-based levelling

Other TF ideas for EMNs unlikely to go further

Thank you for your attention!

