STUDY GROUP
ON OPTICAL FIBER LINKS FOR UTC
UNDER THE CCTF WG ATFT

Davide Calonico, INRIM
SG chair

The SGOF focuses on

- **the developments and achievements in the field of frequency and time transfer using optical fibers,**
- **aiming at the comparison of atomic clocks, the comparison of timescale, the dissemination of T&F standards and of UTC to users.**

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Optical Fiber Links: a worldwide snapshot

1 Fiber Link in use

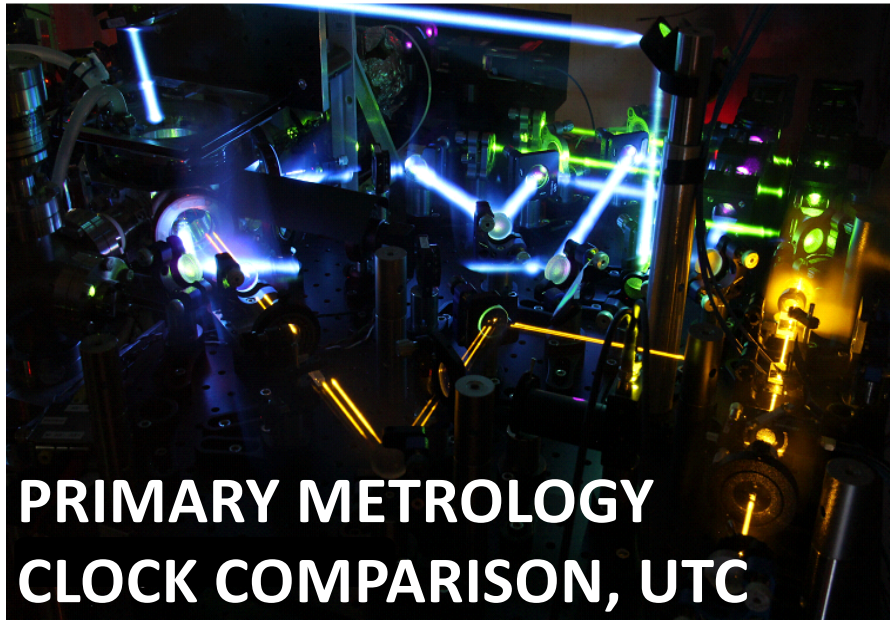
Ongoing projects

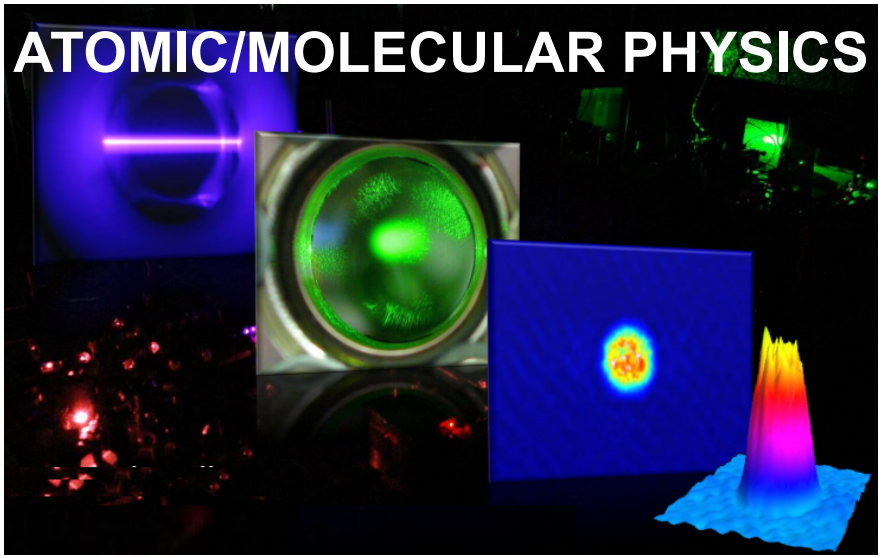
Optical Fiber Links: realized long hauls

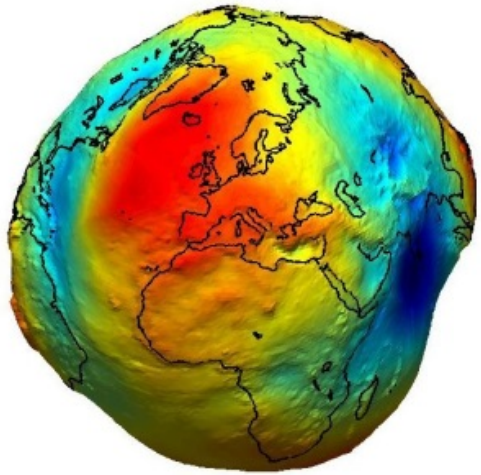
Location	Length	Performance (*)
Check Rep/Austria	550 km	TT, evaluating accuracy 30 ps/20s
China	50 km	FT $20\times10^{-15}/\tau$
Finland	900 km	TT 1 ns
France-Germany	1400 km	FT $1\times10^{-16}/\tau$
France-UK	800 km	FT $\times10^{-15}/\tau$
Italy	1284 km	FT $0.2\times10^{-15}/\tau$
Japan	120 km	FT $0.8\times10^{-15}/\tau$
Poland	420 km	TT 70 ps - FT $35\times10^{-15}/\tau$

(*) accuracy for Time Transfer (TT)
Allan deviation for frequency Transfer (FT), extrapolated to 100 km (scaling law $L^{3/2}$). [*adapted from D. Calonico et al., European Phys Lett, 110 40001 (2015)]*

FL: Primary Metrology and Science



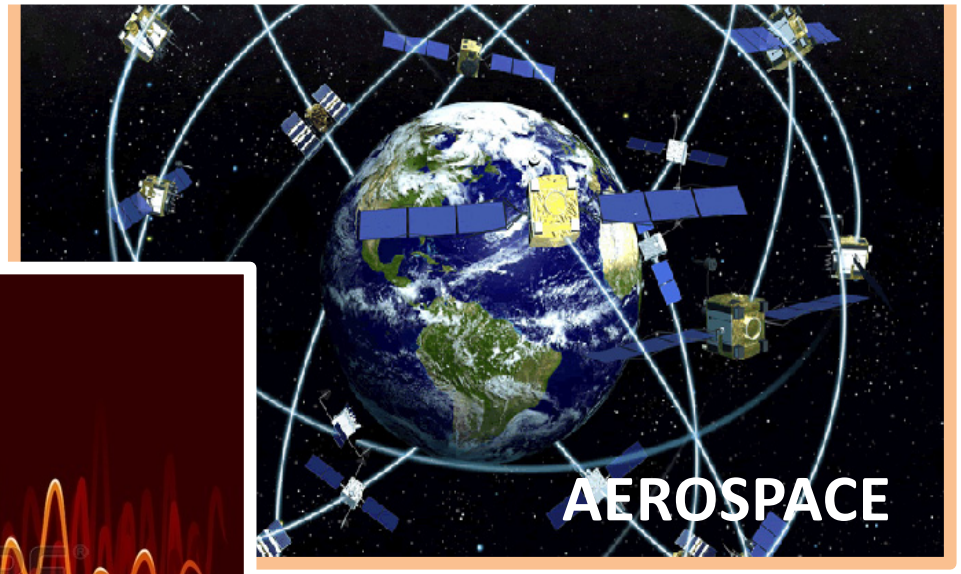




RELATIVISTIC GEODESY

FL: Industry


TELECOM


AEROSPACE

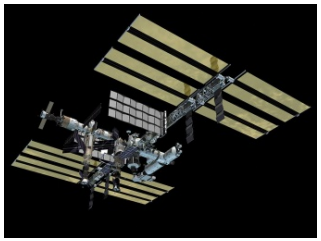

CALIBRATION


NORTH AMERICA
EUROPE
AFRICA
Pacific Ocean
SOUTH AMERICA
Atlantic Ocean
Indian Ocean
AUSTRALIA
NUMBER OF JOURNEYS
>5,000
2,000
1,000
500
200
100
50
20
<10
FINANCE


POWER SMART GRID

Optical Fiber Link European Network

Optical Fibre Links in Japan



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NMIJ

RIKEN

Sr, Hg, Yb lattice

Sr lattice

Yb, Sr lattice

?

U. Tokyo

NICT
headquarter

NICT
Ohtemachi office

Sr lattice, Ca^+, In^+

ACES Ground
Terminal

The link between NICT & NMIJ will be established either by fiber link or Two-way carrier phase (TWCP)

Courtesy of T. Ido

T/F Fibre Link: Primary Metrology

- **REMOTE COMPARISON OF OPTICAL FREQUENCY STANDARDS**
  - Japan, Coherent Link, unc 6e-18
  - Germany/France
  - France/UK

- **CONTRIBUTIONS TO BIPM**
  - Poland, Elstab technique
  - Czech Republic

- **HIGH ACCURACY TIME TRANSFER**
  - Finland

T/F Fibre Link: Scientific users

- **RADIOASTRONOMY**
  - Spain/SKA: White Rabbit Technique
  - Italy: Coherent and WR
  - Poland: Elstab Technique
  - Finland forthcoming WR
  - Japan
- **REMOTE SI TRACEABILITY FOR ATOMIC AND MOLECULAR SPECTROSCOPY**
  - Italy, Coherent Link
  - France, Coherent Link
- **CHRONOMETRIC (RELATIVISTIC) GEODESY**
  - Japan
  - Italy/Germany
  - France/Germany

New IAG WG
Relativistic geodesy: First steps towards a new geodetic technique

Chair: Jacob Flury/Gerard Petit

- Under the auspices of IAG Commission 2 (Gravity Field)
  - Joint with Sub--Commission 1--2 on Global Reference Frames

The objectives of the Working Group are to:

- Act as interface between groups in geodesy (gravity fields, reference frames...) and in time and frequency metrology (clock development, clock comparisons ...);
- Provide a platform to promote the further development and application of relativistic geodesy, e.g. in physics, astronomy and other fields of geodesy and metrology;
- Foster the geodetic interests in the realization of the concept of relativistic geodesy;
- Develop an optimal strategy for the installation and analysis of clock networks and for the combination of clock data with classical geodetic data (e.g. for height systems);
- Advocate the implementation of a clock network of sufficient capability to obtain data products essential for geodetic applications;
- Study the use of clock networks in space;
- Provide relevant information for the geodetic community including key contacts and links;
- Organize meetings and sessions on relativistic geodesy;
- Prepare a document on the perspectives and applications of relativistic geodesy.

T/F Fibre Link: Industrial users

- **FINANCE SECTOR INDUSTRY**
  - UK: PTP/White Rabbit
  - Italy: White Rabbit

- **TELECOM**
  - Germany: Elstab technique

- **AEROSPACE/GALILEO:**
  - Italy: White Rabbit

Conclusions/1

The OFL techniques have grown fast. Over thousands of kilometres, a coherent fibre link can compare clocks with an uncertainty of few parts in 1e18 in 1000-10000 s.

Also time transfer over fibre reports large advances, and today it can offer a sub-ns inaccuracy.

Nonetheless, only one laboratory in Europe regularly reports data to BIPM connecting a remote atomic clock. The implementation of fibre links reporting data to BIPM shall be encouraged and pursued more carefully in the past to take benefit of a widespread optical fibre network.

Conclusions/2

Fibre links comparisons demonstrated to be the only suitable means to compare remote optical frequency standards. More comparisons shall now be realized in order to achieve the identified in the roadmap for the possible redefinition of the SI second, collecting more and more comparison of optical frequency standards with an uncertainty of parts in 1e18.

Nonetheless, there is not any project for an intercontinental fibre link. In the next years, the remote intercontinental comparison of optical frequency standard will become an issue. Intercontinental fibre links could be a possibility, but probably the use of advanced satellite techniques shall be investigated and pursued to compare optical frequency standards at the right level of inaccuracy and instability.

Conclusions/3

Fibre links demonstrated to be beneficial not only for primary metrology and NMI. Scientific communities and industry to use optical fibre links.
In particular, few companies for stock exchanges timestamping, radio-astronomical and particle physics facilities (e.g. CERN, NIKHEF, KM3NeT, SKA project).
Optical fibre links enabled new scientific possibilities, and in particular we report here the demonstration of chronometric geodesy,

The engagement of the T/F community with those stakeholders shall be strengthened.

Thank you.