Absolute long distance measurement in air

EURAMET
European Association of National Metrology Institutes

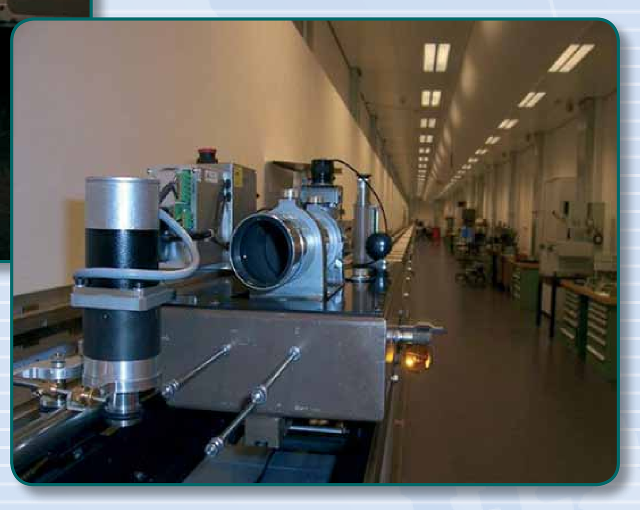
The need for the project

Large scale production, in particular in aerospace, global monitoring (geodesy) and waste management, all require the measurement of dimensions to levels of accuracy currently unachievable over long distances (over 10 m).

To date, the best instrument for long range distance measurement achieved an accuracy of approximately 5 x 10^{-7} when atmospheric parameters were sufficiently stable – but this instrument is no longer commercially available and required highly skilled operators.

This project aimed to improve the current state of the art in long range distance measurements in air to produce a relative accuracy of 10^{-7}. It also aimed to improve current techniques for the measurement of air refractive indices and develop and refine synthetic wavelength interferometers.

PTB scientist preparing the prototype for baseline measurement.



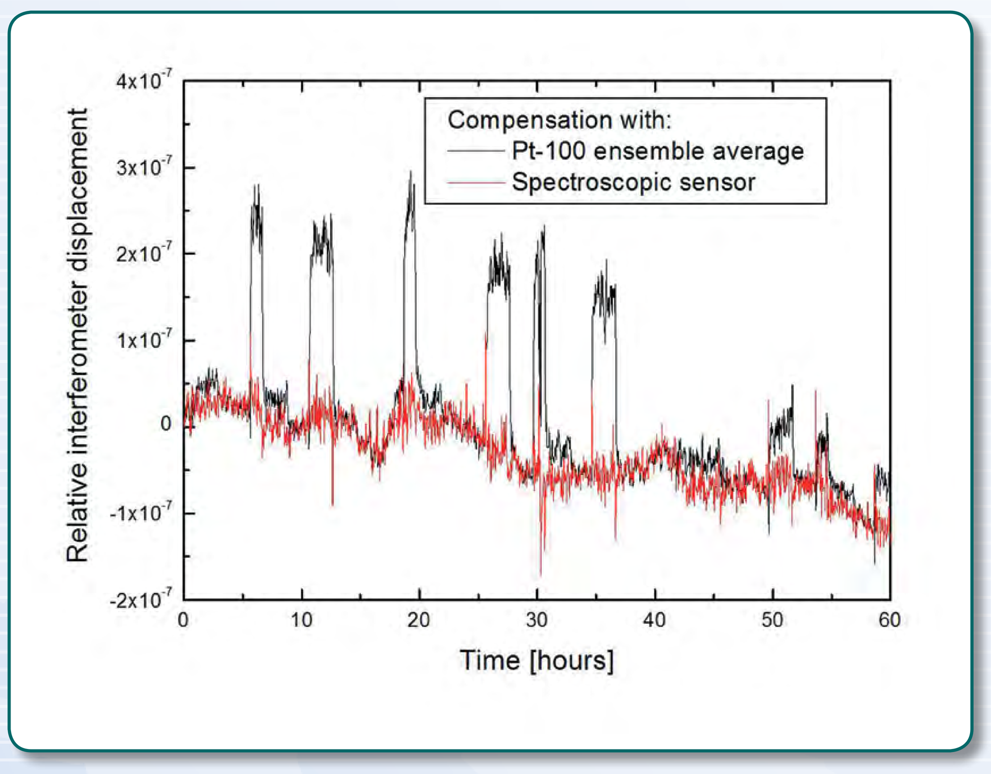
VSL laser interferometer used for validation of pulse to pulse interferometry and femtosecond based telemeter.

Technical achievements

Spectroscopic sensors were built, enabling measurement of temperature and humidity along a given optical path. A resolution of 10 mK and an uncertainty better than 0.1 K was demonstrated for temperature measurement. An improvement of air index compensation compared to a classical thermometer was also demonstrated and relative humidity was measured with an uncertainty of less than 4%. The spectroscopic sensors were used successfully outdoors up to 72 m for humidity and up to 200 m for temperature.

Three new types of transportable telemeters were produced; two based on synthetic wavelength interferometry and one on time of flight techniques using femtosecond lasers. The best resolution obtained with synthetic wavelength interferometry systems was less than 1 mm with an uncertainty of less than 10 mm indoors for absolute measurement. Similar results were found with time of flight techniques up to 100 m.

Pulse to pulse interferometry was implemented for distance measurements up to 50 m (100 m propagation through air). A comparison with laser interferometry demonstrated measurement agreement within 2 mm for this distance (4 x 10^{-8} uncertainty). Dispersive interferometry methods were also compared and showed measurement agreement within 0.5 mm at 50 m (relative uncertainty $<10^{-8}$) compared to the counting laser interferometer.



Evidence of improvement of air index compensation. A comparison of distance measurements (30 m) with a classical thermometer and spectroscopic thermometer. The distance variations in black are due to uncompensated temperature variations that are compensated with the spectroscopic thermometer in red.

Improved long distance measurement

The project developed:

- a transportable spectroscopic thermometer
- transportable spectroscopic hygrometers
- a transportable distance metre with no air index compensation for indoor and outdoor application
- a transportable distance metre with air index compensation
- a distance metre based on femtosecond lasers for indoor application
- a distance meter based on femtosecond lasers for indoor and outdoor application

After further advancement to make them more compact and robust, these prototypes could support the metrological, geodesic and surveying communities.

Commercialisation

Initial contact has been made with measuring instrument manufacturers (e.g. LEICA, SIOS) and laser systems manufacturers (e.g. Toptica, Menlo systems).

The prototype spectroscopic thermometer has been used in the development of a commercial oxygen analyser by Gasmet Technologies Inc.

Guidelines

Produced guidelines for the use of the new techniques and prototypes for measuring absolute distances, which will be available to all interested stakeholders and long distance measurement end-users.

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