Trends and development in laser based dimensional metrology

from 29 May 2017 through 02 June 2017

- *Focus of the first three days is on instrumentation and the second part of the workshop on refractivity compensation and turbulence*
- *One major outcome of this workshop is to come to research strategies for the next decade; it is developed in various steps each day.*
- *Discussion groups are continuously mixed*

Monday 29 05 2017

- *Instrumentation I: Survey of instrumentation developments/practical realizations*
- *Identification of success/evaluation criteria of an instrument development*

09.30 – 10.00 **Registration**

10:00 – 10:10 **Welcome by organizing committee**
S. van den Berg, N. Bhattacharya, F. Pollinger, J.-P. Wallerand

10:10 – 10:30 **Purpose and organizational specifics of this Lorentz Workshop**
Lorentz Center representative and N. Bhattacharya, TU Delft, Netherlands

Introductory Session
(chair: Steven)

10:30 – 11.15 **Introduction of participants (plenary)**

11:15 – 12:00 **Distance metrology as fast evolving field: driven by application and / or technology?**
Seung-Woo Kim, KAIST, Korea
This will be a survey and preparatory talk on the whole field; preparing the discussion groups below.

12.00 – 12:30 **Plenary summary** *on technologies and possible success criteria (introduction of moderators for discussion groups)*

12.30 – 13.30 **Lunch (including meeting of moderators and scientific committee)**

Measurement principles survey

(chair: Florian)

13.30 – 14:15 **Interferometry with low coherence diode lasers**
Yves Salvadé, HE-ARC, Switzerland

14.15 – 14:45 **Coffee break** – private discussions

14:45 – 16.05 **Short presentations**: *various measurement approaches and practical realizations.*

14.45 **Development of a new long range telemeter**
Jean-Pierre Wallerand, CNAM, France

15:05 **NPL OPTIMUM – A Prototype Real-time Optical Coordinate Measurement System**
Michael Campbell, NPL, UK

15.25: **Absolute distance interferometry based on synthetic wavelength for space applications**
Massimo Zucco INRIM, Italy

15:45: **Differential plane mirror interferometer with negligible periodic nonlinearities**
Christoph Weichert, PTB, Germany

16:05 – 17:00 **Break out into 3 discussion groups***:*
discussion with presenters of previous sessions against success criteria catalogue (approx. 10 minutes per presenter per group)

17:00 – 17:15 **Plenary presentation** of discussion group results;

Poster session and ice breaker party

17:15 – 19.00 **Wine & Cheese party** combined with poster session

Tuesday 30 05 2017

- *Instrumentation II: Length measurement technologies based on properties of frequency combs based techniques*

Frequency comb based length measurement techniques I
(chair: Nandini)

09.30 – 10.15 **Overview of femto second laser based technology for distance measurements**
Kaoru Minoshima, UEC, Japan

10:15 – 10.45 **Coffee break** – public and private discussions

10.45 – 11.30 **Heterodyne Techniques for Frequency Comb Based Ranging**
Ian Coddington, NIST, USA

11:30 – 12.10 **Short presentations***:*

11.30 **Frequency-comb-referenced high-precision surface profile and refractive index measurement**
Young Jin Kim, NTU, Singapore

11.50 **A frequency comb based single frequency optical synthesizer**
Felix Rohde, Toptica Photonics, Germany

12:15 – 13:15 Lunch

Frequency comb based length measurement techniques II
(chair: Steven)

13:15 – 13:55 **Short presentations**:

13:15: **Femtosecond Laser frequency comb tracking measurement technology**
Weihu Zhou, Chinese Academy of Science, China

13:35: **Absolute laser ranging and its application in large-scale metrology**
Fumin Zhang, Tianjin University, China

13:55– 14:30 **Coffee break** – private discussions/posters

Frequency comb based length measurement techniques III

(chair: Jean-Pierre)

14:30 – 15:15 **Frequency comb interferometry for distance determination: from time to frequency domain measurements**
Steven van den Berg, VSL, Netherlands

15:15 – 15:35 **Short presentations:**

15:15: **Heterodyne absolute distance interferometry with dual combs**
Ruitao Yang, HIT, China

15:35 **Towards flexible multiwavelength ranging using the intermode beats of a fs-laser supercontinuum**
David Salido Monzú, ETH Zurich, Switzerland

15:35 – 16:35 **Break out into 3 discussion groups**: *moderated discussion on technology perspectives of day 2 (optical sources length measurement); preparation of this part of technology roadmap*

16:35 – 16:50 **Plenary of discussion group results and summary of day 2**; sketch of technology survey and anticipated evolution

16:50 – 17:50 **Poster session and strategy document meeting I**

Wednesday 31 05 2017

- *Instrumentation III: Instrumentation and Data Acquisition for optical distance metrology*

Novel Instrumental possibilities

(chair: Florian)

09.30 – 10.15	**Real-time, scalability, and customisation: the power of micro-TCA.4 data acquisition systems for fast multi-channel interferometry** Armin Reichold, University of Oxford, UK
10:15 – 10.45	**Coffee break** – public and private discussions
10:45 – 11:15	**Frequency comb based metrology in space: Design considerations, recent experiments, and future applications** Matthias Lezius, Menlo Systems GmbH, Germany
11.15 – 12:00	**Break out into 3 discussion groups***: discussion with presenters of previous session; open questions/challenges/status*
12:00 – 12:15	**Plenary summary** and implementation into strategic research document
12.15 – 13:30	**Lunch**
13:30 – 14:10	**Short presentations:** with focus on technological developments 13:30 **Dynamic measurement using Frequency sweep interferometry** Zhongwen Deng, Xi'an Jiaotong University Xi'an, China 13:50 **High resolution wave front measurements** Susanne Quabis, PTB, Germany
14.10 – 15:00	**Break out into 3 discussion groups***: discussion with presenters of previous session; open questions/challenges/status*
15:00– 15:15	**Plenary summary** and implementation into strategic research document
15:15 – 15:30	**Coffee break** / discussions

Interferometry at its limits I

(chair: Nandini)

15:30 – 16:15	**Listening to the 'sound' of colliding black holes with atto-meter level laser interferometry** Bas Swinkels, EGO, Italy

Social event

16.30	Departure bus to conference dinner
17.00	Boat trip on the Kaag Lakes with dinner on board
21.00	Departure bus back to Lorentz Center and hotel

Thursday 01 06 2017

- *Absolute refractometry*
- *Turbulence effects and distance measurements*

Environmental influences I: turbulence

(chair: Jean-Pierre)

09:30 – 10.15 **Turbulence impact on long-range laser beam and image propagation.**
Mikhail Vorontsov, University of Dayton, USA

10.15 – 10.35 **Multiscale modeling of atmospheric refraction and turbulence**
Sukanta Basu, TU Delft, Netherlands

10:35 – 11:00 **Coffee break** – public and private discussions

11.00 – 11.45 **Satellite laser ranging (SLR): accuracy and environmental limitations**
Clément Courde, OCA, France

11:45 –12.15 **discussion group** on turbulence effects

12:15 – 12:30 **Plenary discussion** group results on turbulence effects

12.30 – 13:30 Lunch

Environmental influences II: refractometry

(chair: Florian)

13:30 – 14:15 **Refractometry at 10^-10: more than a compensation?**
Patrick F. Egan, NIST, USA

14.15 – 14.45 **Coffee break** and private discussion

14:45 – 15:45 **Short presentations:** *refractivity and applications*

14:45: **Characterization of FP cavity for refractivity applications**
Jean-Pierre Wallerand, CNAM, France

15:05: **Influence of He on Spacer Materials - Starting Investigations with the PPC (partial pressure measurement standard for characterizing partial pressure analyzers and measuring outgassing rates)**

Tom Rubin, PTB, Germany

15:25: **The refractive index of air measurements based on the single-frequency, tunable, and mode-locked lasers**
Ondrej Čip, ISI Brno, Czech Republic

15:45 – 16:30 **Break out into 3 discussion groups***: discussion with presenters of previous sessions; brainstorm on status and limitations of technology*

16:30– 17:00 **Plenary discussion** on *limitations of current models; open questions in refractometry*

Interferometry at its limits II

(chair: Nandini)

17:00 – 17:45 **Quantum limits in space time positioning, and how to go beyond**
Claude Fabre, Laboratoire Kastler Brossel, Sorbonne Université Pierre et Marie Curie, Paris

17:45 – 18:45 **Poster session and strategy document meeting II**

Friday 02 06 2017

- *Inline refractivity compensation*

Environmental influences III: inline compensation

(chair: Steven)

09.30 – 10.15 **Refractivity compensation in realistic conditions: case studies from surveying and industrial applications**
Florian Pollinger, PTB, Germany

10.15 – 11:15 **Short presentations**: *inline refractivity compensation*

10:15: **Absolute distance measurements by two-colour systems: progress in the realization of the CNAM telemeter**
Joffray Guillory, CNAM, France

10:35: **Spectroscopic air thermometry**
Thomas Fordell, MIKES, Finland

10:55 **An acoustic thermometer for air refractive index estimation in long distance interferometric measurements**
Massimo Zucco, INRIM, Italy

11.15 – 11:45 **Coffee break**

11:45 – 12:15 **Break out into 2-3 discussion groups*:*** *discussion on status, potential, open questions and limitations of refractivity compensation including turbulence*

12:15 – 12:30 **Plenary summary of discussion group**: draft of refractivity compensation and turbulence status (day 4 and 5)

12.30 – 13.30 **Lunch** / **Strategy document meeting** at 13:00

13:30 – 14.30 **Plenary discussion on the research strategies developed during the workshop & conclusions**
S. van den Berg, N. Bhattacharya, F. Pollinger, J.-P. Wallerand

=== end of workshop ===