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
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 ===