Temporal coherence of a femtosecond optical frequency comb and applied quantity metrology applications

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Measurements of lengths are strongly demanded for not only science purposes but also industry requirements. Due to their improved frequency-stability and very broad frequency-band, there is considerable interest in the development of novel optical measurement techniques based on the characteristics of femtosecond optical frequency combs (FOFC).And the FOFCs have led to the application of these devices in several precision metrology application areas such as precision optical frequency metrology, high-precision spectroscopy, and distance measurements.

In 2009, the FOFC was specified for a new specified standard instrument of length in Japan. In the rear future, the FOFC is expected as a new standard tool of the unit system of "Length" and "frequency", how to perform displacement metrology which directly linked to a frequency standard is a new challenge.

Most of the works have been done on FOFC-based applied metrology, but there are few reports on the temporal coherence function (TCF) of an FOFC, which is important for interference phenomenon. We had analyzed the temporal coherence function of the FOFC. As a result, it has been understood that the coherence peak exists during the time which is equal to the repetitions interval in the traveling direction of the FOFC [1]. Based on this new understanding, new applications can be proposed fairly readily [2-6].

For example, we demonstrated a modified Michelson interferometer to simultaneously observe "overlapped" high temporal coherence between different pairs of pulse trains from an FOFC for a long length measurement to less than an optical fringe [6]. This is, to the best of our knowledge, the first demonstration of simultaneous observation of overlapped high temporal coherence peaks between two pairs of pulse trains with different relative delays. From a different perspective, our results show that this technique can be used as direct link between the FOFC and length measurement. Fortunately, this new approach to high-accuracy length metrology, by combining an ordinary Michelson interferometer and an unbalanced optical-path reversed-phase interferometer, has its own advantages. First, as shown below, this technique maintains the simplicity of the equipment. Second, the displacement metrology can be achieved without fringe analysis which typically restricted the measurement speed in an ordinary Michelson interferometer scheme.

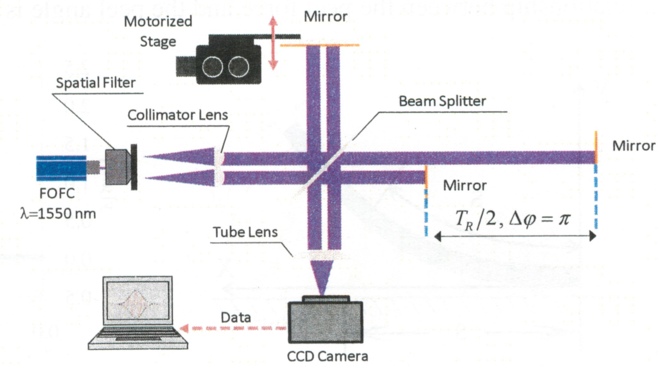

Fig. 1. Optocal layout.

References:

[1] D. Wei et al., Opt. Express **17**, 7011-7018 (2009)

[2] D. Wei et al., Jpn. J. Appl. Phys. **48**, 070211 (2009)

[3] D. Wei et al., J. Europ. Opt. Soc. Rap. Public. 09043 Vol 4 (2009)

[4] D. Wei et al., Opt. Lett. **34**, 2775-2777 (2009).

[5] D. Wei et al., in *Eighth Japan-Finland Joint Symposium on Optics in Engineering*, Tokyo, Japan, 31-32, (2009).

[6] D. Wei et al., in *3rd International Conference of Asian Society for Precision Engineering and Nanotechnology* (ASPEN), Kitakyushu, Japan, 1D13, (2009).