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The stabilisation of final focus system

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Abstract. The StaFF (stabilisation of final focus) system will use interferometers to monitor the relative positions and orientations of several key components in the beam-delivery and interaction region. Monitoring the relative positions of the ILC final focus quadrupole magnets will be the most demanding application, where mutual and beam-relative stability will have a direct impact on machine luminosity. Established, laser-based frequency scanning interferometry (FSI) and fixed-frequency interferometry (FFI) offer positional resolution at length scales of the laser wavelength (1500 nm to 1560 nm) and a thousandth of the wavelength, respectively. As part of the ATF at KEK, StaFF will use interferometers to measure lines of a geodetic network to record relative motion between two beam position monitors. Interferometers are being designed and tested in Oxford prior to deployment at the ATF.

Keywords. Absolute distance interferometer; accelerator alignment; accurate distance measurement; international linear collider.

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1. Introduction

The total integrated luminosity of the international linear collider (ILC) will depend strongly on the stability of the key accelerator components. The ILC exacts unprecedented requirements for the machine stability, being the first collider to produce nanometre wide focused beams at 500 GeV (centre of mass). Any movement of magnets in the beam delivery system (final km prior to the collision) including, most critical of all, the final focus magnets, will directly affect beam emittance and direction. Hence systems are required for the stabilisation of magnets and correction of bunches. The latter will be corrected on nanosecond time-scales within a bunch train, whereas the accelerator components need monitoring on time-scales from seconds to hours, or even days. The stabilisation of the final focus (StaFF) project [1] aims to monitor the relative stability of key accelerator components at the ILC, using interferometers. Interferometric measurements are routinely made with nanometre resolution over sub-millimetre dynamic ranges [2]. The aim is to combine displacement interferometry at nanometre precision with long range, micron precision frequency scanning interferometry (FSI) [3–5] in the same fibre-coupled interferometer design. Measurements of transverse motions are required to monitor both positions and rotations. We plan to develop in Oxford, distance meters, for longitudinal measurements and a straightness monitor, for measuring the transverse degrees of freedom. The target system has nanometre resolution, with a dynamic measurement range of several metres and a readout rate between 100 Hz and 1 kHz. Such a system would be ideal for monitoring the relative stability of critical magnets in the beam delivery system (BDS) of the ILC including the highly sensitive final focus.

2. Monitoring BPMs at the KEK ATF

The network shown in figure 1, is a planned set-up for the ATF (accelerator test facility at KEK, Japan). This is a network of distance meters, each consisting of a single interferometer. Each interferometer has a fibre coupled, optical launch/receive head at one end, aimed at a retroreflector at the other end. The network has a floor to ceiling reference triangle in the centre, with nine distance meters from the triangle to each BPM. The reference triangle connects a stable floor node to two points on a ceiling girder. The network performs the role of a conventional straightness monitor [6] detecting transverse motions, without the need for a direct line of sight. Measuring lengths in the network to a nanometre precision will allow the relative vertical motion of two beam position monitors (BPM)s to be monitored with an expected resolution [7] of around 20 nm, based on simulations using the Simulgeo [8] software package.

3. Demonstration system

A single laser system has been set up, which will allow testing of distance meters, for frequency scanning interferometry (FSI) and fixed frequency interferometry (FFI). So far only FSI tests have been performed.

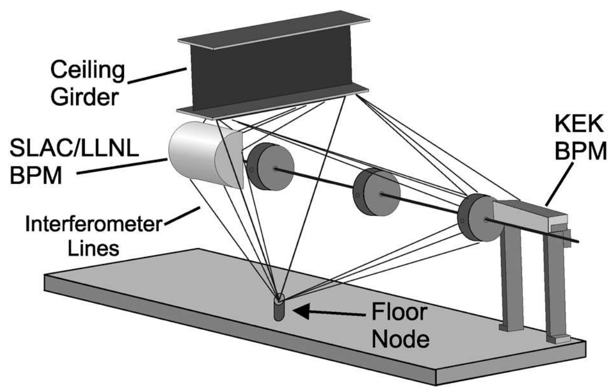

Figure 1. Arrangement of a proposed ATF network, for monitoring relative movement between two sets of beam position monitors (BPM)s. The axial line between the BPMs represents the beam pipe.

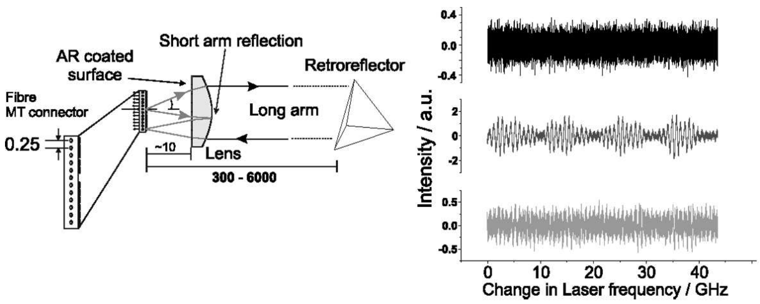

Figure 2. Left: The prototype distance meter under test in the lab at Oxford. Right: Initial FSI signals from three readout channels of the distance meter. Dimensions are in mm.

In FSI, interferometers are coupled to a tunable laser, which is scanned to generate fringes in the interference signals. Since the phase of the fringe pattern at any instant is given by $\Theta = (2\pi/c)\mathcal{D}\nu$ where ν is the laser frequency and $\mathcal{D}$ is the optical path difference (OPD) between the arms of the interferometer, for a given frequency change, the corresponding phase shift in each interferometer is proportional to the interferometer OPD. Hence a set of distance meters may be compared to a common reference interferometer using the same tunable laser. Further details of FSI are given elsewhere [3].

A prototype distance meter was assembled according to the lay-out shown in figure 2. The launch/receive head consisted of a 12-way MT connector held in front of a lens ($f = 25$ mm). The MT connector held a dozen single-mode optical fibres 250 μm apart, in a parallel array. One fibre was used as the launch fibre, with neighbouring receive fibres read out using one photodetector per fibre. The short arm of the interferometer was formed by reflection from the far side of the lens (with the near side anti-reflection coated). The launch head was aimed at a target retroreflector to form the distance meter. With this design each receive fibre can be read out for a separate FSI measurement of the same distance meter, allowing the phase relationships between almost identical optical paths to be exploited.

For these tests, light from a tunable laser (Agilent model 86410A) was amplified in fibre using an erbium-doped fibre amplifier (EDFA) fibre coupled to a reference Michelson interferometer and the distance meter under test. With the laser scanned at approximately 60 GHz/s and the interferometer signals digitised at 10^6 samples/s. Initial signals for three readout fibres are shown in figure 2. Since these early tests, resolutions of around 4 microns using this interferometer design have been demonstrated [7].

4. Conclusions

A network of distance meters is planned for the ATF at KEK. The network will demonstrate nanometre precision absolute distance measurement techniques suitable for stabilisation of the final focus and other critical components of the ILC. Initial prototype distance meters were under test at the time of the LCWS06, and further designs are being studied.

Acknowledgements

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References

[1] Since this presentation at LCWS06 in Bangalore, March 2006, to reflect the wider scope of this work, the project has been renamed MONALISA, Monitoring Alignment and Stabilisation with High Accuracy, http://www-pnp.physics.ox.ac.uk/∼StaFF
[2] N Bobroff, *Meas. Sci. Technol.* **4**, 907 (1993); DOI:10.1088/0957-0233/4/9/001
[3] P A Coe, D F Howell and R B Nickerson, *Meas. Sci. Technol.* **15**, 2175 (2004); DOI:10.1088/0957-0233/15/11/001
[4] J Thiel, T Pfeifer and M Hartmann, *Measurement* **16**, 1 (1995); DOI:10.1016/0263-2241(95)00010-I
[5] G P Barwood, P Gill and W R C Rowley, *Meas. Sci. Technol.* **9**, 1036 (1998); DOI:10.1088/0957-0233/9/7/005
[6] A conventional straightness monitor consists of a collimated laser beam acting as a straight line reference, with respect to which, transverse motions are measured by sensors at locations along the reference line
[7] D Urner, P A Coe and A Reichold, Stabilization of the ILC final focus using interferometers, THPCH090, *EPAC06 Proceedings*, Edinburgh, UK (2006)
[8] L Brunel, SIMULGEO: Simulation and reconstruction software for optogeometrical systems, CERN CMS Note 1998/079