Frequency scanning fibre interferometer for absolute distance measurements over a large target area

Yanmei Han, Armin Reichold, Colin Perry, Richard Bingham

John Adam Institute and Physics Department, University of Oxford

Abstract

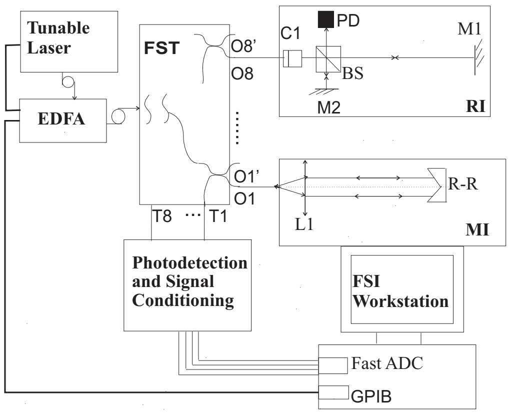
The Linear Collider Alignment and Survey (LiCAS) project aims to establish the reference survey network of the ILC (International Linear Collider) by measuring the relative positions of survey reference markers, located in a regular sequence along the tunnel walls of the ILC. A fibre distance sensor has been developed by the Oxford LiCAS group to measure the co-ordinates of the tunnel markers. It exploits the frequency scanning interferometry (FSI) technique, supplying a reference interferometer and multiple measurement interferometers from one shared frequency scanning laser source. In the measurement interferometer a fibre tip without any optic is used to launch and receive light to perform absolute distance measurements over a large target area. In this paper, calculations based on the Gaussian field distribution are presented, which predict the efficiency of the reflected light from the tunnel marker coupled back to the launching fibre. The high gain and low noise photo-detection unit is described. Preliminary measurement results are reported.

Principle of FSI

FSI is a precise absolute distance measurement technique capable for simultaneous multiple measurements. Light from a tunable laser illuminates a reference interferometer (RI) with a known optical path difference (OPD) L and a measurement interferometer (MI) with an unknown OPD D. The ratio of the phase changes in the MI and RI as the laser frequency is scanned is equal to the ratio of interferometer lengths. A length measurement is made by finding the ratio of phase changes.

Laboratory FSI system for LiCAS

Here a telecom tunable laser (Agilent 81640A) is exploited. An Erbium Doped Fibre Amplifier (EDFA) is used to amplify the light from the laser. The output light of the EDFA is sent to a fibre splitter tree (FST) which splits the light into many output channels, allowing simultaneous length measurements to be made. Single mode fibre Corning SMF-28 is used.

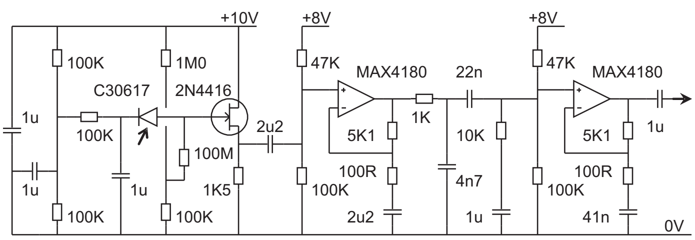


FST: fibre splitter tree; O1, O1'…O8, O8': 16 output channels of the FST;
T1…T8: 8 feedback channels of the FST.
RI, reference interferometer; C1: collimation optics; BS: beam splitter;
PD: Photodiode; M1, M2, reflecting mirrors.
MI: measurement interferometer; L1: collimation lens; R-R: retro-reflector.

Calculation results

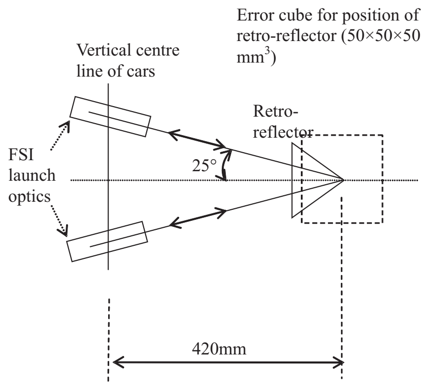
When the R-R is set 420mm away from the fibre tip, the coupling efficiency of the reflected light from R-R back to the launching fibre is $10^{-7.8}$ to 10^{-9} if the off-axis distance of R-R varies from 0 to 35mm. Then the return light is 16pW to 1pW when the output power of the fibre is 1mW.

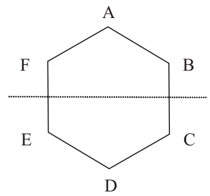
Photo-detection unit



The detector is an InGaAs PIN photodiode, Perkin-Elmer type C30617, with an ST optical fibre connector. The maximum optical input power of this unit is 25nW.

Requirements of the external short lines



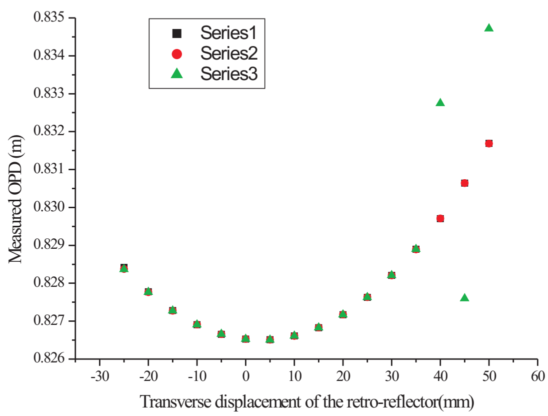


Orientation of hexagonal array of external lines, viewing towards the retro-reflector

Measurement of the x, y, z co-ordinates of the tunnel markers in respect of the measuring car is performed by a set of 6 FSI distance measurements in the form of a cone. The combination of the 6 lines can over-determine the 3D co-ordinates. The tunnel markers are sphere mounted retro-reflectors of 1 inch clear aperture. The distance between the car and the retro-reflector is 400mm ~ 500mm, and the retro-reflector roams in a 50×50×50mm³ cube. At a measurement distance of 420mm, the retro-reflector can be about 33mm off-axis. Then the crucial requirement for the external FSI is to cover a large area of ~ 70mm diameter.

Solution: a fibre tip without any optic was chosen for the external short line measurement due to its simplicity, low cost and vanishing chromatic aberration.

Preliminary measurement results



The OPD measurement results indicate that the single mode fibre tip without any optic can cover a large measurement area of ~ 75mm diameter.