Undulator gap monitoring using FSI

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The LCLS-II is a proposed extension to the SLAC FEL facilities, providing two additional beamlines. Both will use variable-gap undulator magnets [1]. In August 2011 the AMULET group was invited to SLAC to measure and monitor the gap of a variable-gap undulator, on loan from Argonne National Laboratory, using Frequency Scanning Interferometry (FSI). These measurements revealed the magnets deformations at various gap sizes as well as the long term motion of the magnet.

Frequency Scanning Interferometry

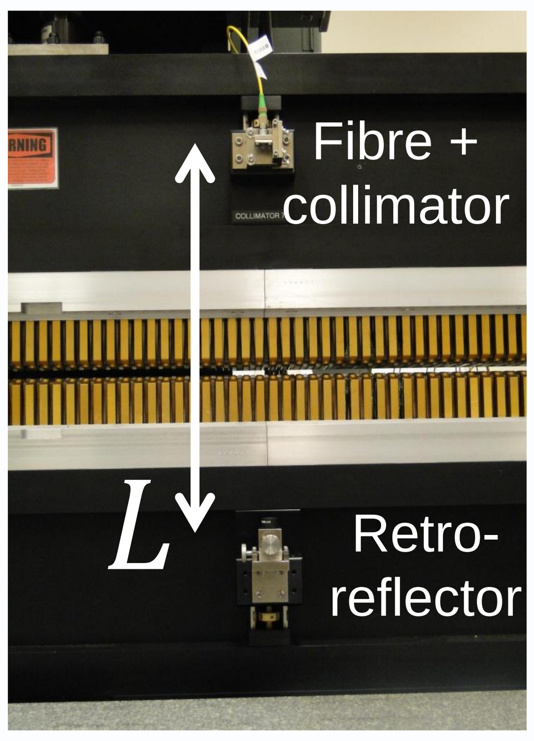
Frequency Scanning Interferometry is a technique to measure absolute distance using lasers [2,3]. Changing the optical frequency of the light changes the phase of the interference pattern in proportion to the path length difference, and so provides a measure of the optical path difference between the two arms. Recent developments at Oxford [4,5] allow the technique to measure the length every time the intensity of the interference pattern is sampled. These measurements are limited to the period it takes for the lasers to complete a frequency scan. They must then be reset and the measurement process is repeated. The technique achieves sub micron per metre accuracy, and is traceable to the definition of the metre.

Fizzeau Interferometer

The interferometers used were Fizzeau interferometers, where the short arm reflection is taken from the end of the optical fibre used to illuminate and read out the interferometer. The phase of the interferometer is given by:

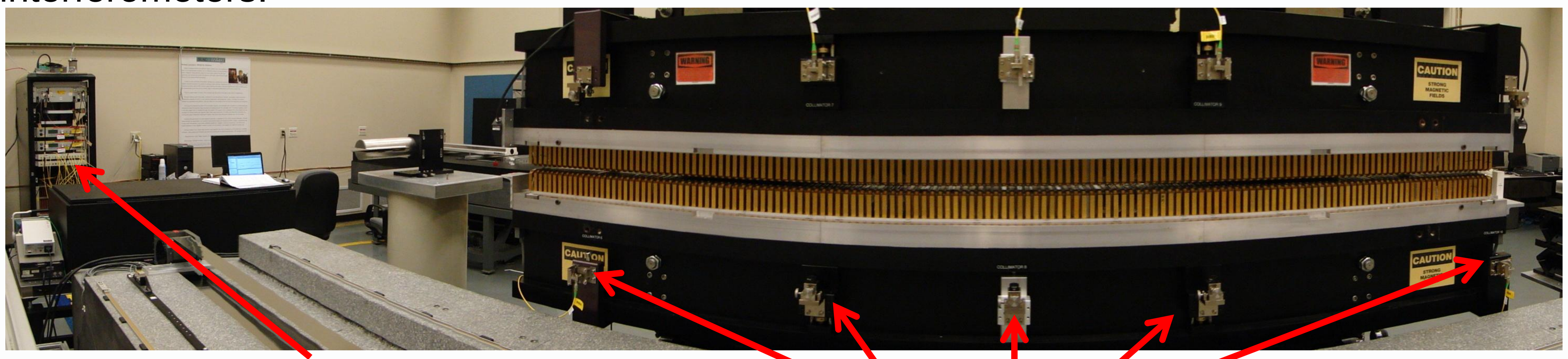
$$\phi = \frac{2\pi}{c}\nu\times(2L)$$

where ν is the frequency of the laser.



FSI on an undulator

10 FSI lines were fixed to the undulator, 5 on each side. The mounts and optical components were all made from non-magnetic materials to avoid affects on the undulators magnetic field. The main laser system was set up away from the magnet and light distributed using long optical fibres. The system could have supplied up to 100 interferometers.



Main laser and DAQ system

Interferometers

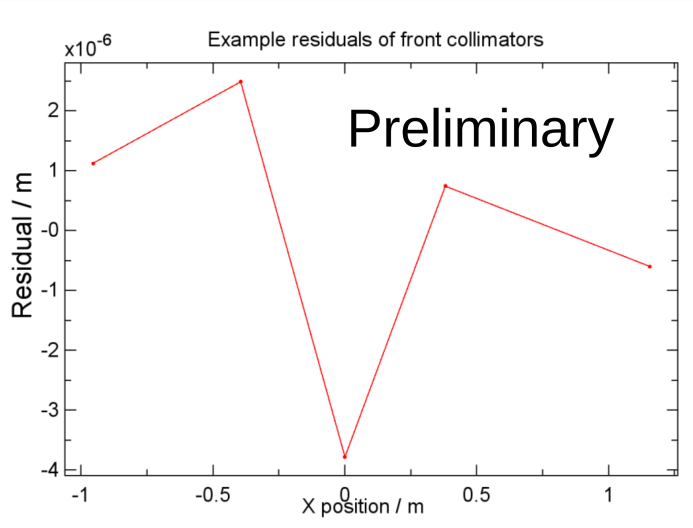
Procedure

The gap was measured, using all 10 interferometers simultaneously, at various gap settings. An experiment consisted of a series of gap measurements. Once the data for an experiment was collected measurements from one of the gaps were taken as the baseline, and the difference between it and the other gap data was calculated. A plane was then fitted to the difference data using non-linear least squares [6], and residuals calculated. The plane gives the relative orientation of the undulator jaws.

For some measurements one interferometer was setup to monitor the position of the top jaw with respect to a granite table. This interferometer was positioned in the middle of the front of the undulator.

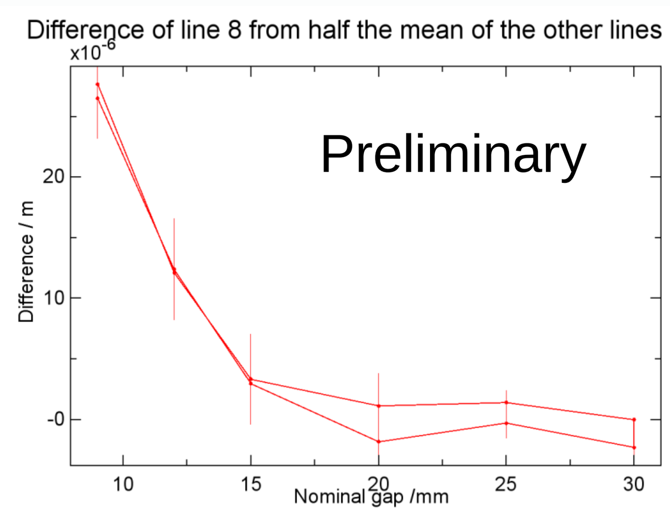
Undulator deformation

The residuals from the plane fit show that the magnet does not retain it's shape as the gap is varied. It can clearly be seen that the undulator takes on an increasingly "M-like" shape as it is moved away from the baseline gap. It is thought that this is caused by areas of the undulator away from the supports being pulled towards the other jaw more than those near to the supports



Motion of the upper and lower jaws

When one collimator was fixed to a granite table it was possible to compare the motion of the top jaw with the relative motion of the jaws with respect to each other. It can clearly be seen that the top jaw moves up to 25µm further than the bottom jaw, which will affect the position of the magnetic axis of the undulator with respect to the ground.

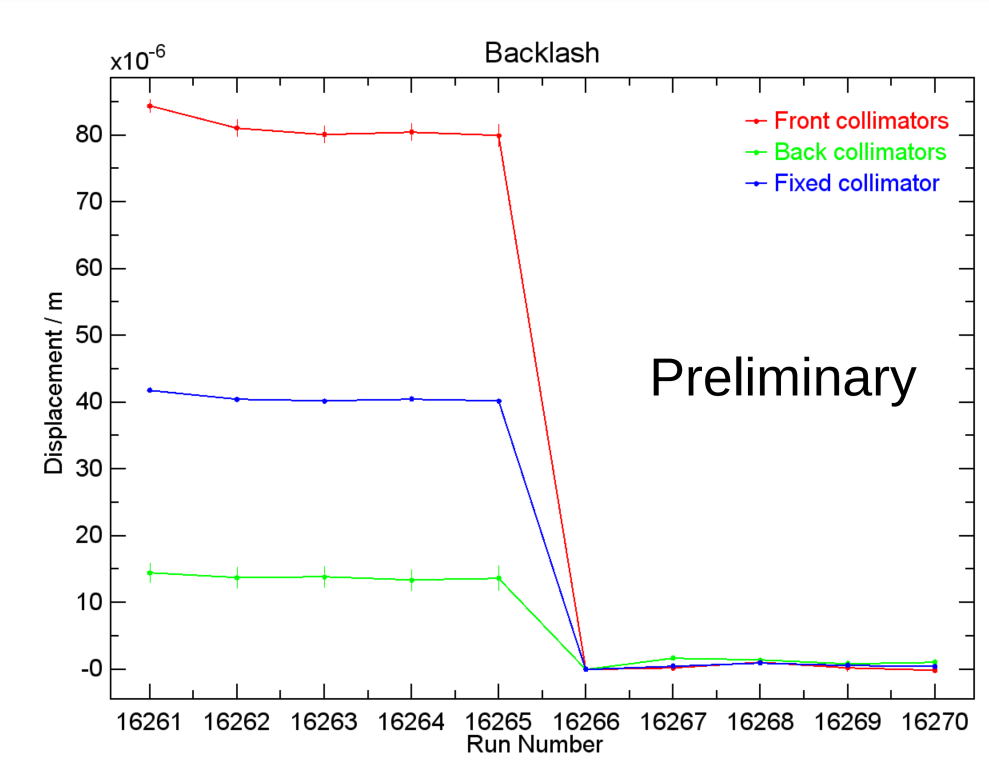


FSI could be used in both the undulator beamlines and Magnetic Measuring Facility for LCLS-II.

Repeatability of positioning

The magnet gap was set to 12mm 10 times. The first 5 times it was approached by opening the magnet, and the second 5 by closing it. It can clearly be seen that there is a backlash of order 80µm for the front of the magnet and 15µm for the back of the magnet. This also implies a change in the tilt of the magnet jaws with respect each other depending on the direction of motion.

The backlash does seem to be consistent when the gap is set from the same direction.



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