III Interferometers for Precision Measurement in Metrology

Applications

① Interferometer-based techniques are used in all types of systems requiring precision measurement of position, velocity, angle, straightness, and many other parameters. These are part of a class of what are called "metrology" applications. Examples include semiconductor wafer steppers in photolithography systems, hard drive and CD/DVD/Blu-ray disc mastering, optical diamound turning and other high performance CNC machines, general machine tool calibration, and many more. Measurements can be made over 10s of meters with resolution down to nanometers using the wavelength of a known wavelength of laser light as the meter (or yard) stick. Before discussing systems using two-frequency lasers, we need to back up.

Note that all the techniques being discussed are for measuring displacement (or position change), not absolute position. Absolute measurements using interferometers are possible using lasers but require additional techniques that are beyond the scope of this discussion.

There are two classes of measurement interferometers called "homodyne" and "heterodyne". They have much in common including the general configuration and use of similar or identical optics. However, the lasers and detection electronics differ substantially and each method has it benefits and drawbacks. Most, if not all, utilize optical configurations that are variations on the Michelson interferometer. See Basic Michelson Interferometer. In short, a laser beam is split into two parts which are bounced off of a pair of reflectors and recombined at a detector. Any change in the relative path lengths of the two "arms" formed by the reflectors results in a phase shift between the waves in the two beams, which can be measured and converted to displacement (change in position) down to nanometer precision.

These techniques generally require a high quality specular reflector like a planar mirror, cube-corner (trihedral prism, also called a retro-reflector), "cat's eye" lens system, or something similar that returns a beam with a high signal-to-noise ratio. They will not work with diffuse reflectors or multi-level reflectors in the beam or where the beam may move over abrupt changes in the position of the reflective surface relative to the interferometer. At least not without much more effort. So forget about measuring plant growth unless it is possible to hang a cube corner on one of the stems. ;-)