Development initiatives considerations on priority at CEL, NITTTR Bhopal for 2023-24

1. **Dimensional Metrology teaching aids**: I any automation what we achieve is always controlled by precision of dimensions measurement during machining. We know that best control signals are electrical inputs and therefore mechanical dimensional parameter needs to be translated as electrical signals and hence encoders based on basic electrical parameters like resistance, capacitance and inductance comes into play. Although such studies are very primitive measurements techniques but we can't expect a good engineering without exploring its merits and limitation during learning. Thus an breadboard model based on channels and riders capable of mounting the resistive , capacitive and inductive components with provision of giving linear and angular displacement and calibrating changes in R,C or L parameters in terms of physical parameters of linear and angular displacement gives actual feel to learner. This set up can be motorized and improved but essentially provide its limitations leading to find alternative technologies for commercial linear and rotary encoders based on magnetic and optical properties. Ultimate target for this kind of exercise will be development of lab model for coordinate measuring machine and understanding importance of metrology in automation.
   https://www2.mitutoyo.co.jp/eng/pdf/E4329_QuickGuide.pdf
2. **Laser Triangulation Sensor Lab**: Laser triangulation sensors belong to the non-contact group of standard measurement techniques. The principle is based on a simple geometrical relationship. A laser diode transmits the laser beam onto the measurement object. A lens focuses the reflected rays onto a CCD/CMOS array. The distance to the measurement object can be determined by the three-point relationship between the laser diode, the measuring point on the target object, and the projection on the array. The measurement resolution can achieve a fraction of a micrometre. The intensity of the reflected beam depends on the surface of the measurement object. Depending on the design, the optical principle supports measuring distances between a few millimetres to over one metre. Depending on the requirements, small and high precision, as well as large and accurate measuring ranges can be achieved. Sensors with digital interfaces are configured via an external PC. Compact sensor models with integrated controller can be installed even in restricted design spaces. The Blue Laser

technology enables absolute precision sensing and reliable measurement results on red-hot glowing metals and glowing silicon. The blue-violet laser offers decisive advantages. Even in the case of measurements being carried out on organic materials such as veneers, wood or skin, the blue laser makes an important contribution with regard to precision. While allowing higher stability, the blue laser light does not penetrate the measurement object due to the shorter wavelength blue-violet laser.

Laser triangulators with a small laser line are ideally suited to precision displacement and distance measurements on brilliant and porous as well as on rough surfaces. A rough surface causes interferences in the laser point and complicates distance measurements on metal. Laser sensors with a laser line bypass this effect. The laser point is extended to a short line using special optics. A special algorithm calculates the average via the length of the line. The interferences that occur are effectively filtered out so that the distance to the metal can be determined accurately.

Laser line sensors

As well as determining one-dimensional sizes (material thickness, vibrations and distance), processed multi-dimensional quality controls (profile and contour measurement) may also be required during the production process, where optical non-contact metrology is ideal due to its high precision, measurement speed and flexibility with respect to the surface of the measurement object. Laser scanners carry out complex 2D/3D measurement tasks. Here, the laser line triangulation principle takes effect (light intersection method). The point-shaped laser beam is extended to a line via special lenses. Together with the distance information (z-axis), the integrated controller calculates the position of the measurement point along the laser line (x-axis) and outputs both values as 2D coordinates. If the measurement object or the sensor is moved, a 3D image of the object is provided. The laser scanners owe their compact design to an integrated controller. Laser scanners are equipped with an integrated, highly sensitive receiving matrix that enables measurements on almost all industrial materials, largely independent of the surface reflexion. The Blue Laser technology is also used with laser profile sensors. The sensors are based on the laser line triangulation. The innovative aspect of the sensors is their use of a short wavelength of 405 nm. The special characteristics of this wavelength range enable the sensors to be used in conditions where measurements have not been practicable to date. The sensors even operate on reflective or transparent surfaces, where it is not possible to use optical measurement methods. The blue laser profile sensors are particularly suitable for red-hot glowing metals as well as for (semi-) transparent and organic materials.

Reference : Laser triangulation, Mohammed A Isa, Samanta Piano and Richard Leach , CHAPTER 3 Advances in Optical Form and Coordinate Metrology © IOP Publishing Ltd 2020 https://iopscience.iop.org/book/edit/978-0-7503-2524-0/chapter/bk978-0-7503-2524-0ch3.pdf

3. **Laser Beam Profiling**: Lasers are now widely used not only in education, medicine and entertainment but are used in precision machining where quality of machining depends on beam quality and hence there is need to learn this topics seriously. With the availability of VISION technology in imaging it can be learned with ease. A teaching aid where students can learns modes and Gaussian beam profile of Lasers are essential however most of them hardly get a chance to visualize and experiment with the same. Thus a teaching aid based on CCD/CMOS sensors and imaging interfaces some simple set up should be developed for a common purpose. A general purpose cost effective image acquisition using USB camera and processing with some general purpose microprocessors like Arduino/Raspberri can be exciting prospects enabling it to find information related to beam qualities like profile which do have modal information as well.

   Ref: https://laser.physics.sunysb.edu/_chriszaprianov/BeamProfiling.pdf

4. **Spectrophotometers/Optical Spectrum Analysers**: Diffraction grating happens to be key components for various spectral analysis equipments and encoders. Gratings are one of the most versatile optical components and so great subject to be studied by scientists and engineers. Design and fabrications of gratings are a subject least addressed in India and mostly we are dependent on foreign grating suppliers. Thus study on this topic necessitate some distinguished development activities as under:
   a. Fabrications of amplitude and phase gratings masters and replication technology using rulings, holographic techniques as well as photolithography are great interdisciplinary development area needs to be explored. This

activity will address mask making technology to make an amplitude grating which will start with a typical pattern printing and reduction using photolithographic set up. This will expose trainees basic technology of graticulation and photolithography. It gives a further improvement in technology with availability of powerful laser as Direct Laser Writers which uses typical CNC machining where Laser Spot does the pattern generation creating a highly precise mask as amplitude gratings. To create phase gratings on hard substrate like quartz reactive ion etching are required. Therefore this activity will have ultimate aim to develop cost effective technology for direct laser writing and reactive ion etching (Dry Etching) with indigenous components resources and automation technology being mastered at our centre of excellence.

b. Spectrophotometers a widely used spectral analysis equipment are manufactured everywhere including our country but still lot of development keeps on emerging. However it is also a must to be studied topics for every scientists and engineers. Its development having two steps 1. Development of Monochromatic and 2. Development of Signal Processing Unit. Monochromator do have options to use scanning grating if signal processing are done with fixed detector or now with availability of array detectors gratings and detectors are held fixed and even compactness are far improved. Design of such spectrophotometers with reduced cost components and longer dynamic range always fascinates developers but in any case a teaching aid which can give better understanding are always welcome

c. With availability of linear and area CCD/CMOS detectors spectrum analysis with visualization and processing opens opportunities innovating on spectrum analysis using machine vision features. Such spectrum analysers are in high demand for throughout spectral range of electromagnetic waves right from radio waves to ultraviolet waves.

https://www.agilent.com/cs/library/primers/public/primer-uv-vis-basics-5980-1397en-agilent.pdf https://www.nature.com/articles/nphoton.2009.250

Reactive ion beam etching of multilayer diffraction gratings with SiO_2 as the top layer **DOI:10.1117/12.758011**