




Laboratory Techniques and Metrology

Module

Experimental investigations are key to testing of theoretical models and for gaining new insight into physical processes not yet described by sufficient models at all. In addition, they allow for optimization loops in development processes of materials, devices and highly complex systems and enable fast and secure control and monitoring of industrial fabrication processes from food to cars.

Hence, requirements for experimental investigations range from extremely high accuracy and resolution in basic research (where measurement time is of low importance) up to extremely fast but yet highly reproducible measurements in production environments e.g. for quality or process control.

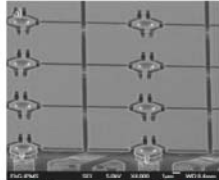
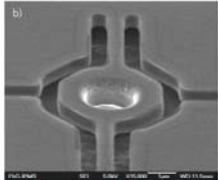
High resolution or high throughput?

<p>Research resolution: extremely important reproducibility: required measurement time: no criterion throughput: no criterion</p>	 <p style="text-align: right;"><i>Bruker</i> FT-IR spectrometer State University New York (Astronomy) resolution: 0.0035 cm⁻¹</p>
<p>Development resolution: less important reproducibility: important measurement time: important throughput: important</p>	 <p style="text-align: right;"><i>Polytec</i> Laser Vibrometer (car body development)</p>
<p>Quality control resolution: as low as required reproducibility: crucial measurement time: crucial throughput: crucial</p>	 <p style="text-align: right;"><i>Foss</i> MilkoScan (dairy) fat, protein, sugar,...</p>

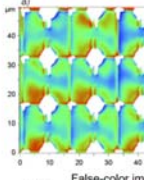
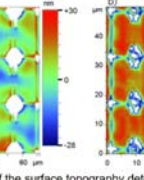
In all cases, experimental investigations require a **solid understanding of the underlying measurement principles**, their application scope and their potential as well as their **physical and technical limits**. Further, before any conclusions from experimental obtained data are drawn, **systematic and random errors** of measurement set-ups need analyzing, possibly minimizing and consideration.

The lecture provides detailed insight into the physics of modern metrology, details the measurement concepts and their technical instrumentation. The spectrum ranges from optical instruments and metrology (e.g. microscopy, spectroscopy, ellipsometry) to electron microscopy up to non-optical surface characterization (e.g. nanoindentation). Additionally, noise sources and techniques to minimize noise in measurements by means of modulation/demodulation techniques are presented. The lecture closes with a discussion of measurement errors and error propagation.

PSI examples: Micro mirror arrays

Detailed SEM images. a) Chip surface in the mirror area. The mirrors in the lower part of the image were removed so that the electrodes are visible. b) Detail of a post with torsional springs.

False-color image of the surface topography determined by interferometry
a) Micro mirrors on photoresist sacrificial layer. b) Micro mirrors on polyimide sacrificial layer.

As a major part of the lecture focuses on optical measurement techniques, optical principles in ray tracing and wave optics are repeated in the beginning and complemented by Fourier-optical concepts like e.g. the modulation transfer function (MTF).