Application of Optical Coherence Tomography in Micrometric Industrial Inspection

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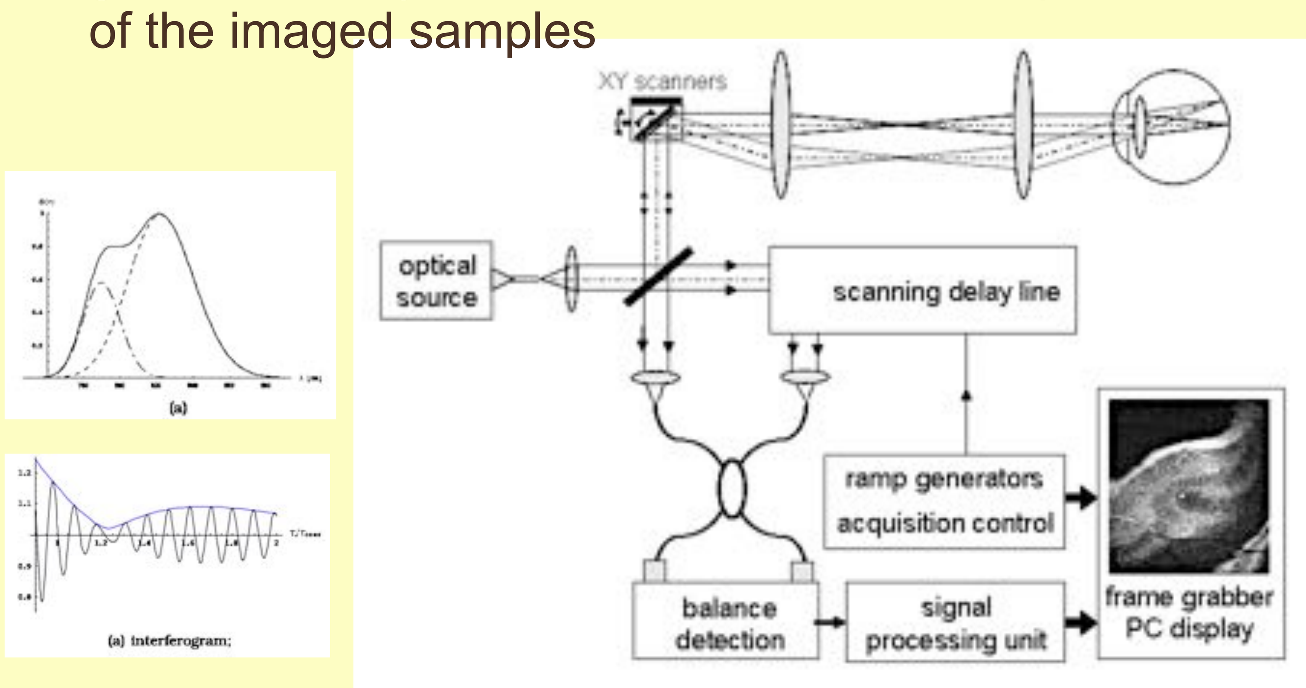
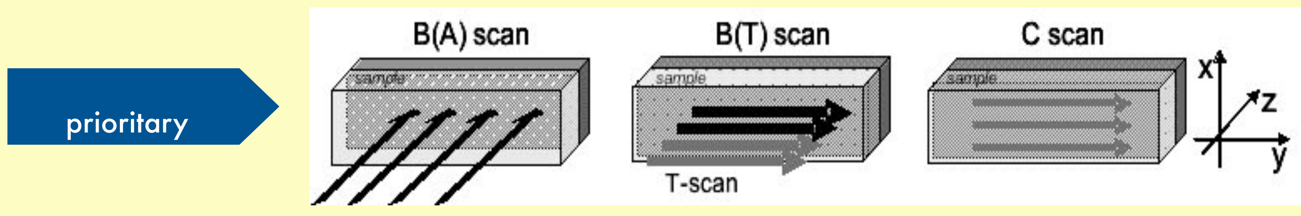
Optical Coherence Tomography (OCT)

- based on **white light interferometry** [1]
  - **high spatial resolution imaging** technique
  - low-coherence optical sources
    - depth selectivity $\Delta z = c\tau = \frac{4\ln 2}{\pi}\frac{\lambda^2}{\Delta\lambda}$
  - generates very narrow and well resolved optical sections of the imaged samples



$$I(\tau_r) = \text{Const} + 2I_0\sum_n \sqrt{a_r a_n}|\gamma(\tau_n)|\cos(\omega\tau_n)$$

- depth scanning capabilities of OCT

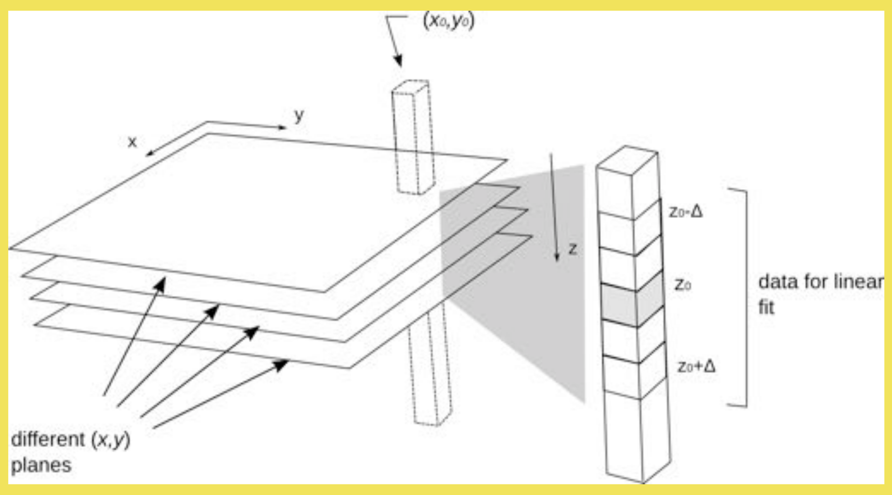


Micrometric voxel resolved extinction coefficients algorithm

Beer-Lambert's law + medium where both absorption and scattering occur [2]:

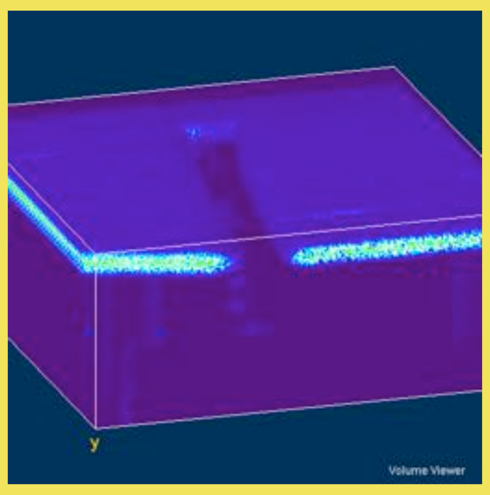
$$I(z) = I_0 \exp\left(-\int_0^z \mu(z')\,dz'\right)$$

$\mu(z)$ is the extinction coefficient, which depends on the medium properties.

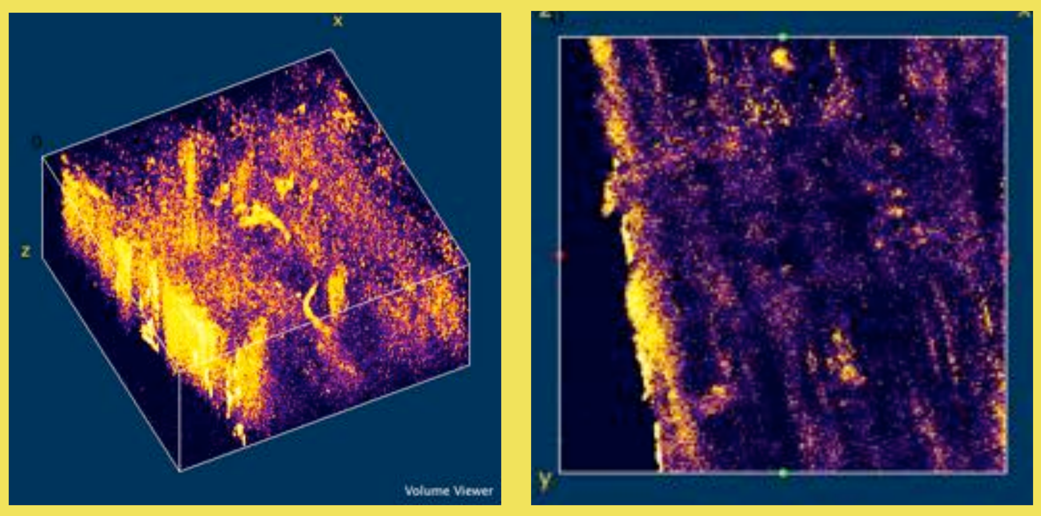


Processing algorithm:
- natural logarithm of the data
- iteratively performing linear fits
- allows:
  - determination of $\mu(z)$ with micrometric voxel resolution.
  - efficient (but costly) signal averaging

laser microfabricated structures
- stack of 100 C-scans
- total depth 0.2 mm (in air)
- chanel widht: 100micorns

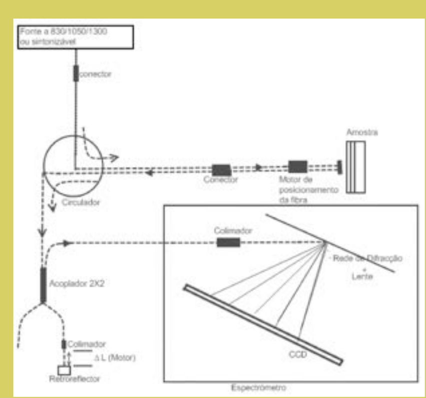


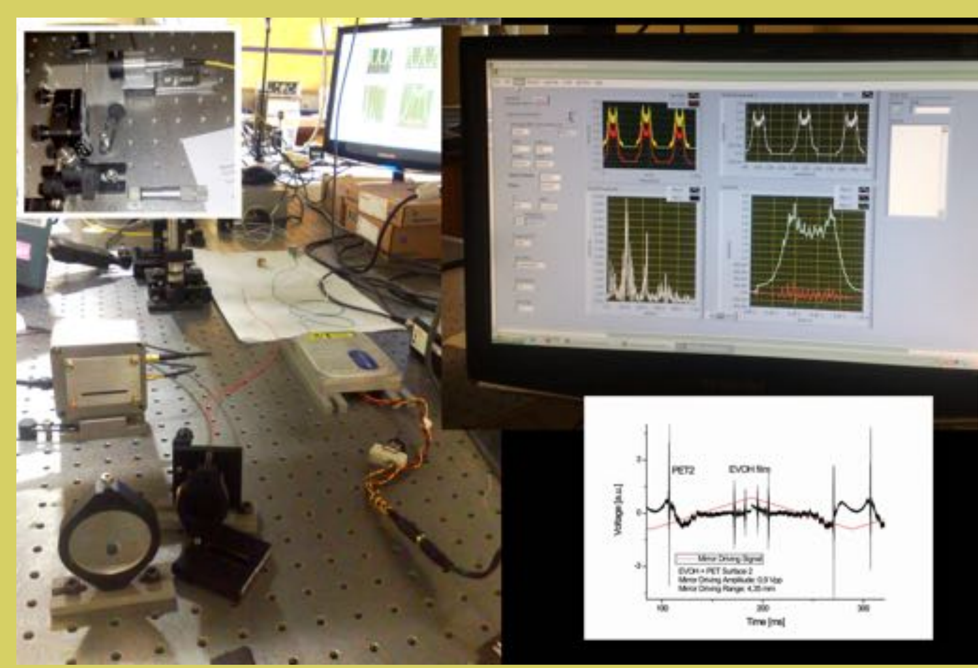
dry wood samples
- stack of 100 C-scans
- total depth 1-2mm (in air)
- slice thickness: 10-20 micron (in air)



spectral domain in-fiber system developed for point measurements of micrometric thicknesses films, embedded in transparent materials

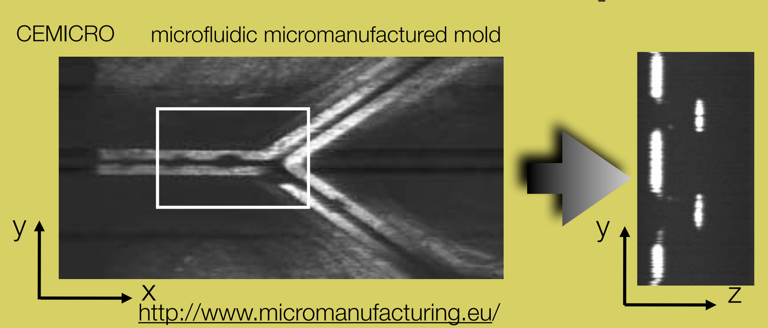
- local interferometer, with generation of an interferometric reference near the sample
  - demanding mechanical and temperature industrial environments
- depth reflectivity profiles
  - acquired channeled spectra are numerically processed by Vandermonde's algorithms
  - standard hardware/software requirements
    - LabVIEW (National Instruments, USA),
    - one CPU controls the measuring setup, acquisition and signal processing





Results

3D inspection



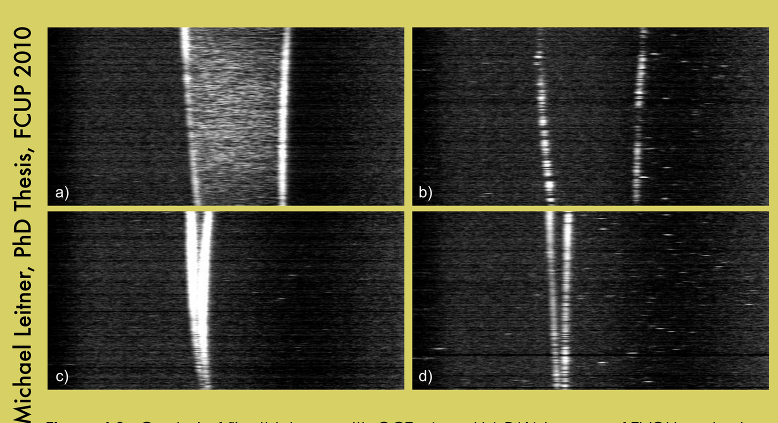
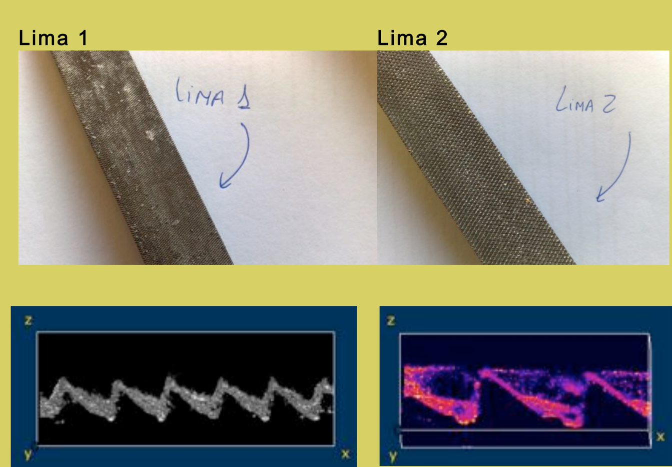


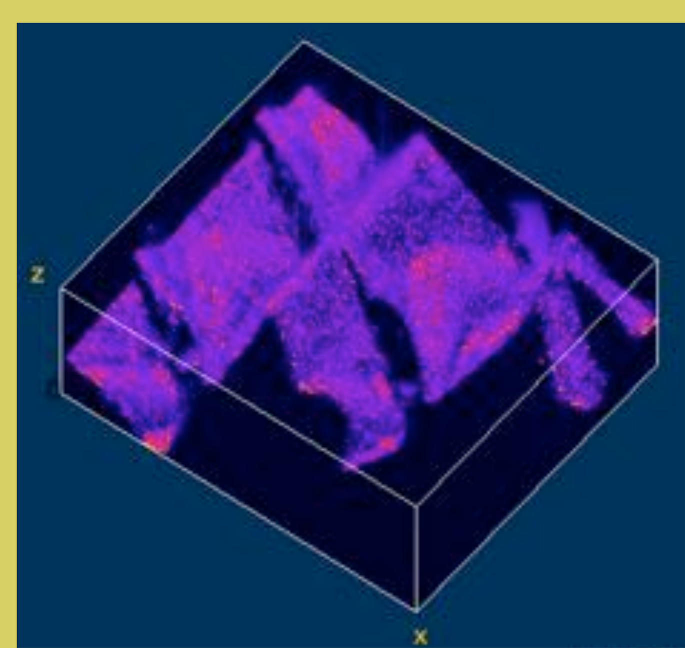
Figure 4.3.: Control of film thickness with OCT. a) and b) B(A) images of EVOH and nylon in PET, respectively, acquired in the region of line 1 in figure 4.1; c) and d) B(A) images of the same samples, obtained in the region of line 2 in figure 4.1. Image size $Y \times Z$ 2.5 × 0.75 (in air) mm².

OCT (time/spectral domain) probing

- depth resolution
  - function of optical source spectra
  - decoupled from diffraction limit
  - tipical values: 1- 20 μm
- transverse resolution
  - diffraction limited
- excelent signal dynamic range
- non-invasive
- contactless technique
  - depth imaging of biological samples in vivo and in real time



Micrometric Perfilometry



References
[1] Schmitt J M 1999 Optical coherence tomography (OCT): A review IEEE Journal of Selected Topics in Quantum Electronics 5 1205–1215
[2] Markolf H Niemz 1996 Laser-Tissue Interactions Springer
[3] Sherif S S, Flueraru C, Mao Y and Change S 2008 Swept Source Optical Coherence Tomography with Nonuniform Frequency Domain Sampling Biomedical Optics, OSA Technical Digest (CD) BMD86

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