UNIVERSITÀ DI SIENA 1240

Light-scattering methods for tissue diagnosis

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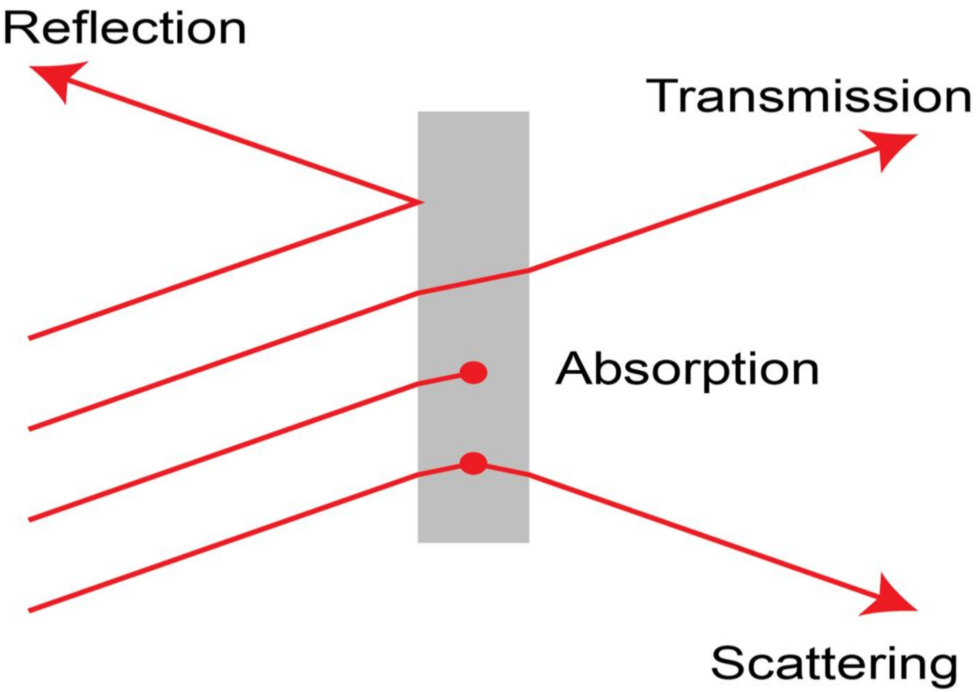
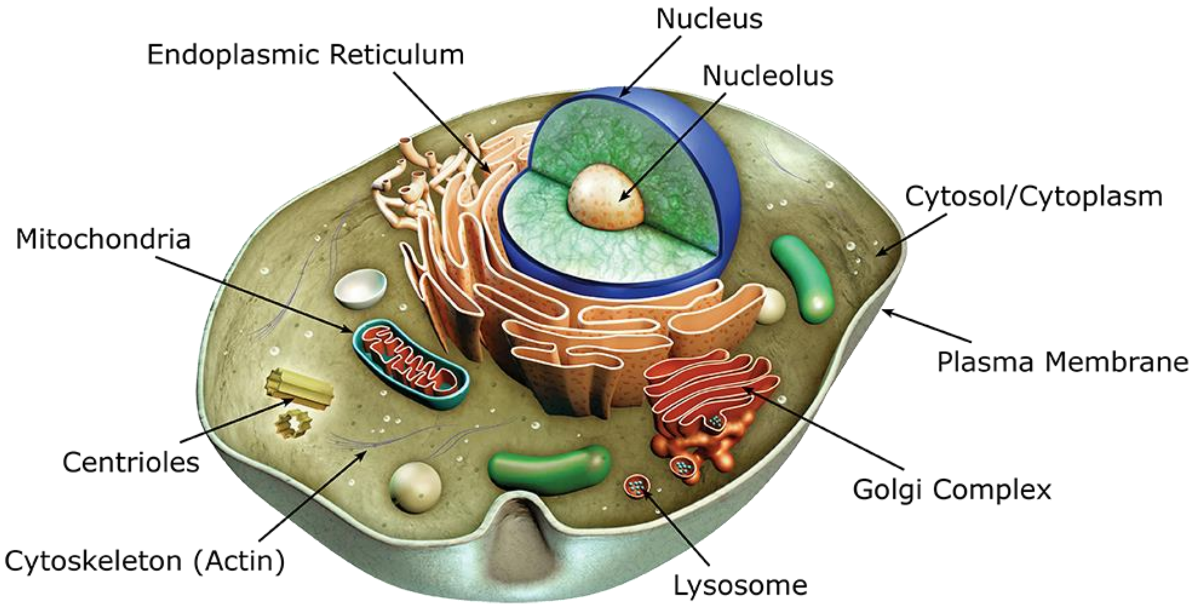
High Energy Seminar-16.11.2023

Interaction of light with medium:

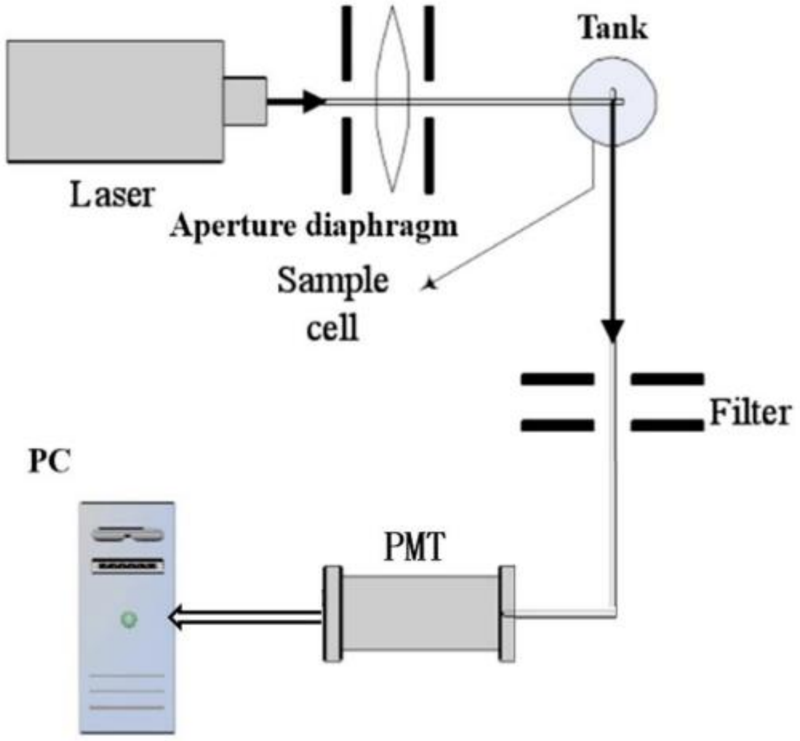




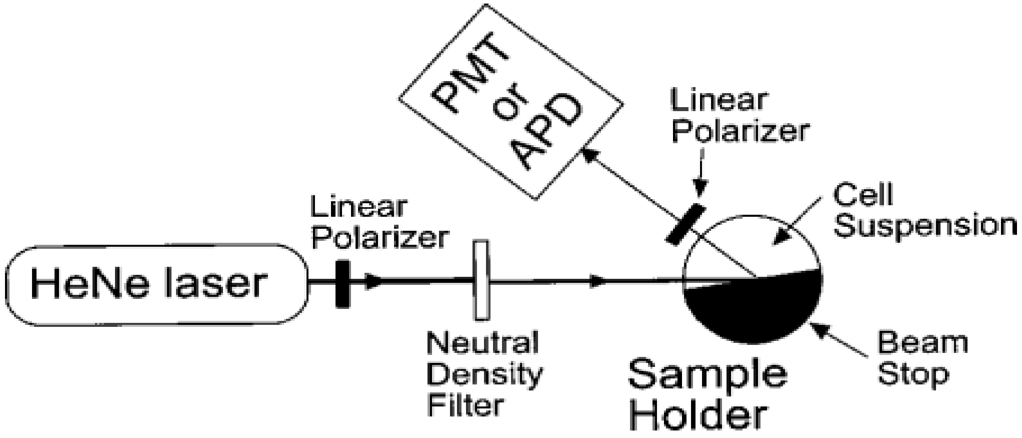
ANGLE-RESOLVED LIGHT SCATTERING

- Goniometric Measurements
- Finite-Difference Time-Domain Method
- Four-Dimensional Elastic Light-Scattering Fingerprinting
- Angle-Resolved Low-Coherence Interferometry

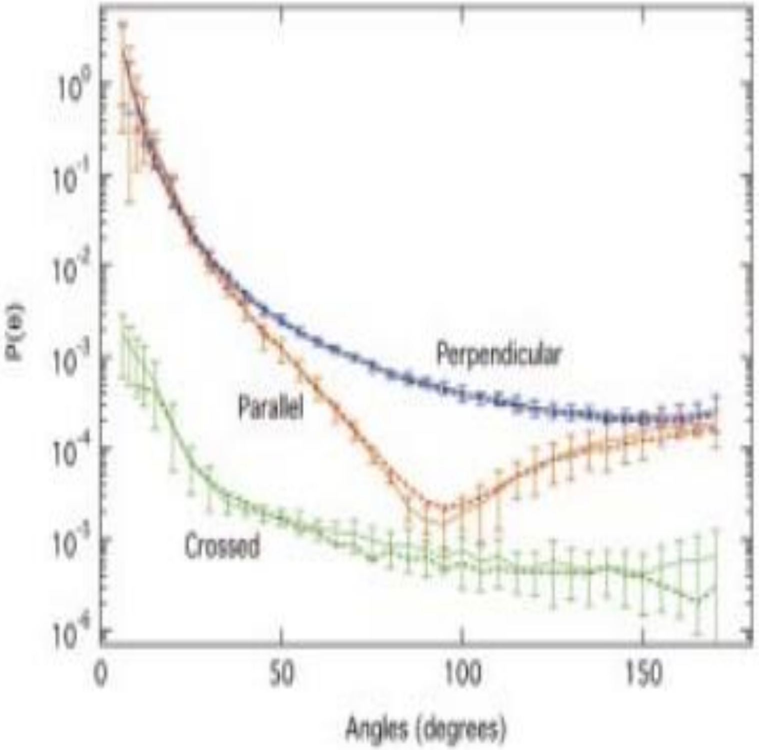
Goniometric Measurements

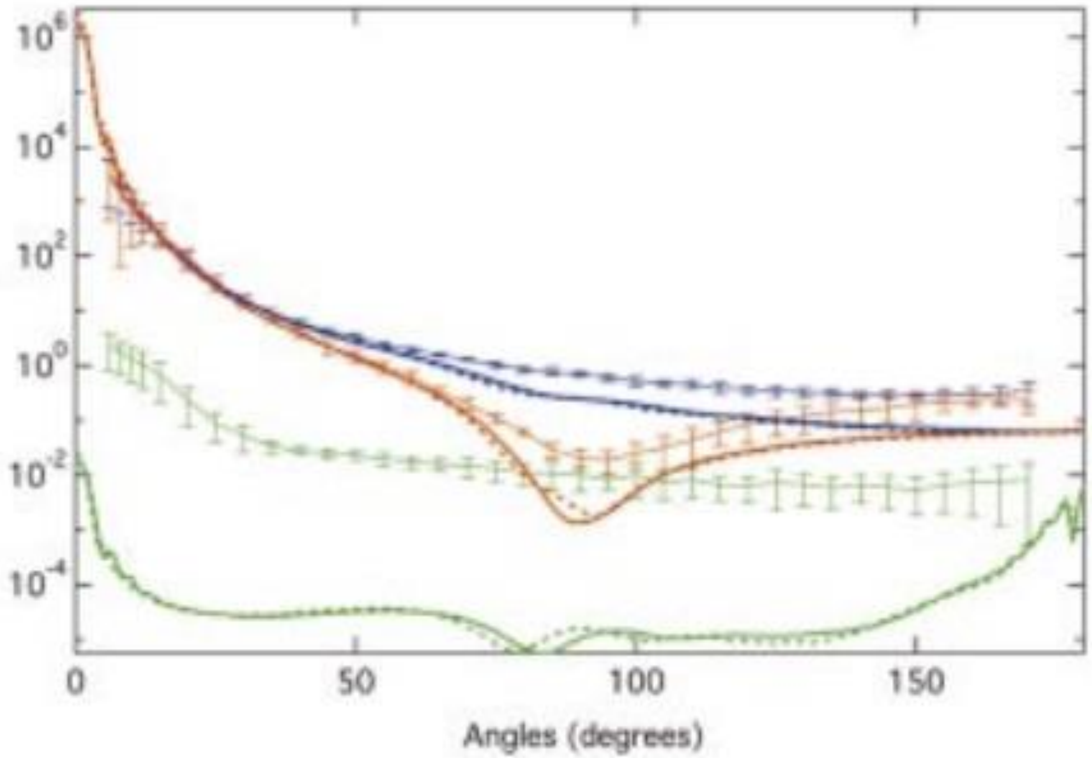


1. A laser with a wavelength of 532 nm was used, and it was unpolarized.
2. The setup included an aperture diaphragm with a radius of 200 µm to control the light beam's size.
3. A filter was used to eliminate stray light.
4. A photomultiplier tube was rotated aroun the sample to measure light intensity.



Goniometric Measurements





Applications:

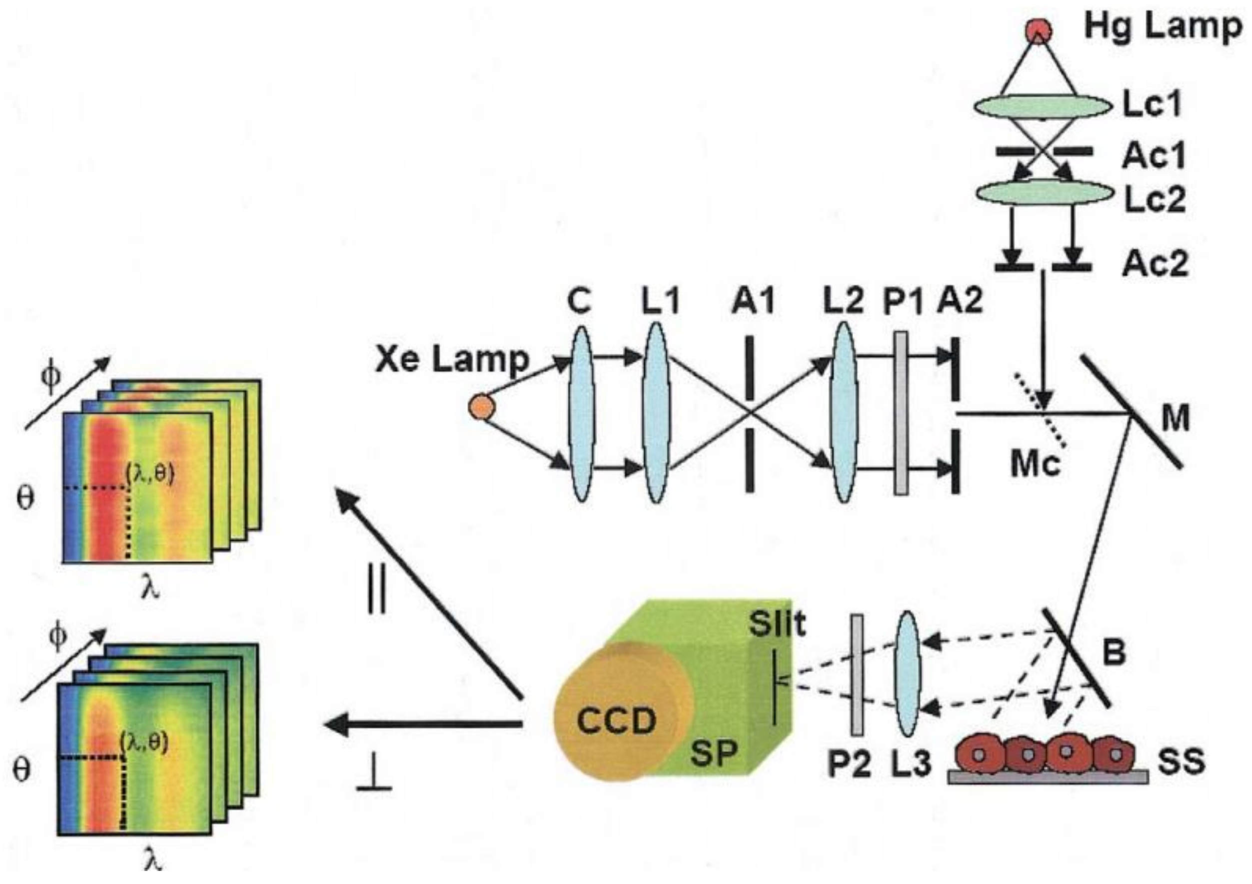
- Skin Cancer Diagnosis,
- Laser Surgery
- Photocoagulation
- Drug Interaction Studies
- Intravascular Optical Coherence Tomography (OCT)
- Flow Cytometry

Finite-Difference Time-Domain Method

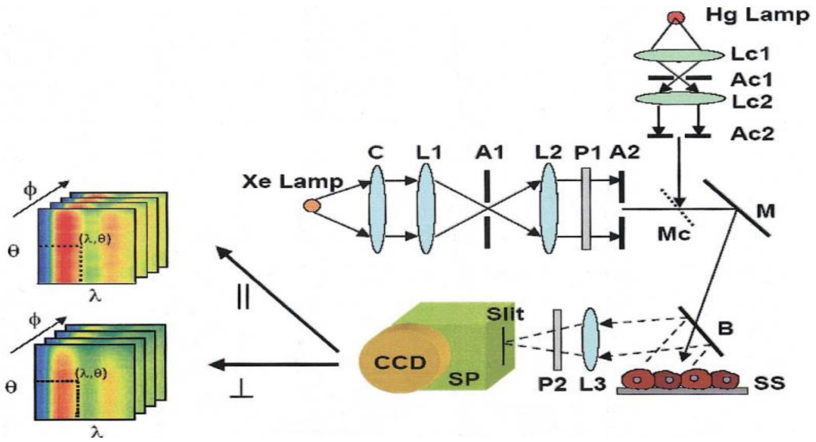
The Finite-Difference Time-Domain (FDTD) method is commonly employed in the field of computational electromagnetics, including in simulations related to light scattering. When applied to light scattering problems, FDTD allows researchers to model the interaction of electromagnetic waves (such as light) with objects or structures, providing insights into scattering patterns, reflection, and transmission.

- Maxwell's Equations
- Discretization of Space and Time
- Initial Conditions
- Update Equations
- Material Properties
- Scattering Objects
- Boundary Conditions
- Simulation Time Steps
- Data Collection
- Analysis and Visualization

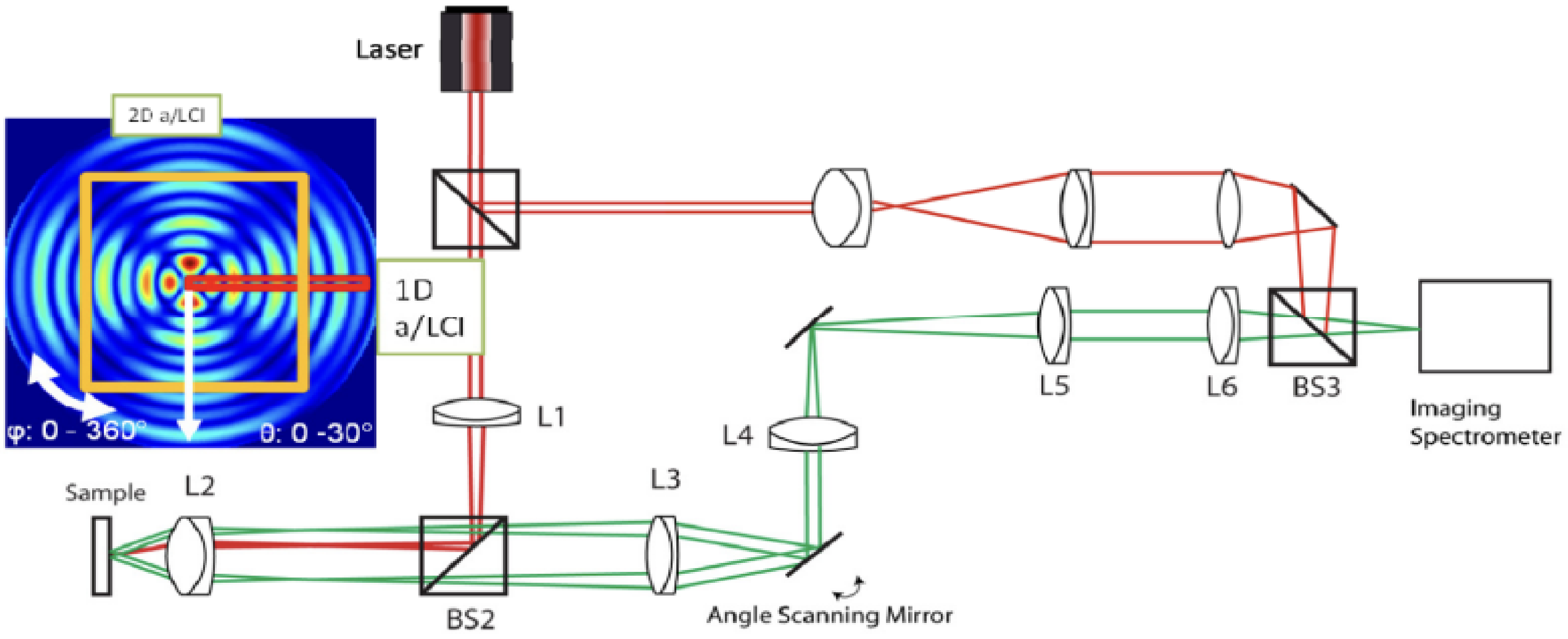
Four-Dimensional Elastic Light-Scattering Fingerprinting



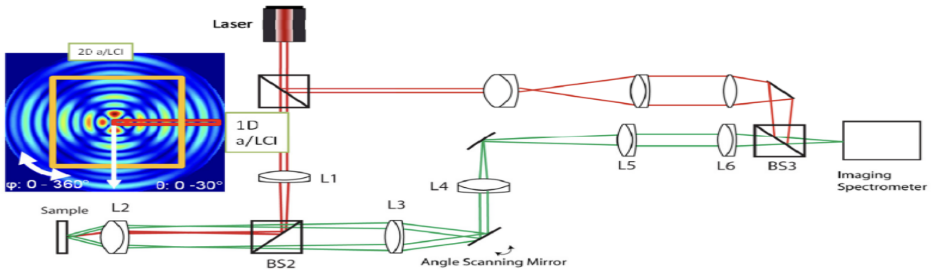
- **Wavelength of Light (Dimension 1):** This dimension involves the analysis of scattered light as a function of its wavelength. Different molecules absorb light at specific wavelengths, and by examining the wavelength, you can identify the presence of these molecules in the tissue.
- **Scattering Angle (Dimension 2):** This dimension refers to the angle between the direction of the scattered light and the backward direction relative to the propagation of scattered light. It provides information about the direction in which light scatters within the tissue.
- **Azimuthal Angle of Scattering (Dimension 3):** This dimension concerns the angle between the incident light's polarization and the projection of the direction of the scattered light's propagation onto the plane in which the incident electric field oscillates. It gives insights into the orientation and polarization of the scattered light.
- **Polarization of Scattered Light (Dimension 4):** This dimension involves analyzing the polarization of the scattered light. It provides information about the alignment of the electric field vectors of the scattered light.



Angle-Resolved Low-Coherence Interferometry



1. **Interference of Light:** Low-coherence interferometry relies on the interference of light waves. It uses a beam of light that has low temporal coherence, meaning that the light consists of a broad spectrum of wavelengths and has a short coherence length. This light is directed onto the sample of interest.
2. **Splitting the Light:** The incoming beam of low-coherence light is typically split into two arms: a reference arm and a sample arm.
3. **Sample Interaction:** In the sample arm, the low-coherence light interacts with the sample. This interaction can be with reflective or scattering surfaces within the sample. The light is either reflected off the sample or scattered back toward the interferometer.
4. **Reference Arm:** In the reference arm, the light travels a known distance before it is reflected back. This reference arm sets up a reference path length against which the light returning from the sample is compared.
5. **Interference:** The light returning from the sample arm and the light from the reference arm are combined, and their interference is detected. The interference pattern is a result of the phase difference between the two light beams.
6. **Depth or Thickness Measurement:** By analyzing the interference pattern, it is possible to measure the time delay or phase difference between the reference and sample arms. This information can be used to determine the thickness, depth, or optical path length of the sample. In medical applications, this can be used for imaging biological tissues, and in material science, it can be used to analyze the thickness of thin films and coatings.
7. **High Resolution:** Low-coherence interferometry provides high axial (depth) resolution because it can distinguish between reflections from different depths within the sample. This makes it particularly useful for imaging structures with fine details.



Application:

Technique	Contrast Mechanism	Representative Applications in Tissue
Goniometric measurements	Angle-resolved	Morphological structure of organelles [59–61]; Multicellular spheroids [62,63]; DNA content [64].
Finite-difference time-domain (FDTD) methods	Angle-resolved	Nuclear size and refractive index [74,75]; Collagen fiber networks [76]; Epithelial depth [77];
Four-dimensional elastic light-scattering fingerprinting (4D-ELF)	Spectral, Angle-resolved, Azimuthal, Polarization	Colon carcinogenesis (rat model) [65,78]; Early carcinogenesis of the rectal mucosa [79].
Angle-resolved low-coherence interferometry (a/LCI)	Angle-resolved, Depth-resolved (Interferometric)	Esophageal dysplasia [83,84]; Intestinal dysplasia [85]; Cervical dysplasia [66,86]; Grading of esophageal neoplasia (rat model) [82]; Esophageal adenocarcinoma (rat model) and retinal degradation (mouse model) [88];
Fourier transform light scattering (FTLS)	Fourier-domain, Angle-resolved	Identification of bacterial species [94,95]; Neural transport and growth dynamics [96]; Alzheimer's disease (mouse model) [100].
Spatial frequency-domain imaging (SFDI)	Fourier-domain, Spectral	Blood oxygenation [102]; Burn severity [103]; Pressure ulcer risk assessment [104]; Cancer risk of actinic skin lesions [105]; Skin cancer [106]; Breast tissue classification [107]; Alzheimer's disease (mouse model) [108]; Brain damage from cardiac arrest (mouse model) [110].

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Thanks for your time