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Morphological characterization of particles by the intensity and polarization of the scattered radiation

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ABSTRACT

Optical techniques are being used more and more, because they have the advantage of being non-destructive, the light scattering by the material provides a framework of prospecting pointed and fast. The elastic and inelastic interaction portion of the light with the matter allows following the assessment of particulate matter including cell nuclei which are the focus of tissue pathologies. Our work focused on the use of this phenomenon to follow the evaluation in size and shape of the nuclei, in order to prevent tumor activity.

1. Introduction

Light scattered by the biological tissue is rather related to its structure, including to the density [1], size [2] and morphology of cells nuclei [3], etc, these important parameters are indications for the pathologist to make differentiate between normal cells (which often have a structured organization), and tumor cells (which present a disorderly structure).

In the present work, the light scattering is used as a tool to characterize this kind of tissue. The advantage of this technique is that it is made without contact with the object studied, non-destructive and non-ionizing. This means that the use of electromagnetic wave information is now the subject of increasing interest in the biomedical field, and the physics of materials [4,5]. The precision on the diagnosis is related to the precision on the measurements of the scattered radiation, the parameters of which extracts may be exploited to study the evolution of the micro particles size and morphology. Various measurements of the scattering intensities, and in particular of its angular, spectral, or polarization dependence, can serve as a diagnostic means.

Our objective is to make help pathological anatomy services. This technique offers valuable assistance by its non-destructive effect and its speed and precision, by varying same optical parameters such as wavelength, polarization state and scattering angle, the information on the evolution of particles sizes and morphology makes it possible to predict directly the existence of pathology.

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2. Biological cells and computation of their light scattering

The morphology of the nucleus is important in the diagnosis of pre-cancerous conditions [6]. In many pre-cancerous epithelial tissues, the nuclei become both enlarged and crowded, and when stained for pathology they take up larger quantities of certain dyes.

We compute a static light scattering from particles comparable with the incident wavelength using the Mie solution, which is an analytical resolution of the problem of the interaction between the electromagnetic wave and the spherical particle [7,8]. From this theory we can deduce the expressions of the extinction and scattering cross sections as well as that of the scattering phase function.

In this work, an appropriate optical assembly of an optoelectronic high angular resolution measurement system is presented to provide non-invasive elastic scattering measurements on slides containing histological sections. Here, via computer calculations and rapid data collection, it is demonstrated that the measurements have the potential to differentiate between cell nuclei sizes as well as its shapes and morphology.

3. The mechanics of light scattering

The amplitude of scattered light at different angles depends not only on complex refraction index of the medium in which the particle exists and the particle size [9], but also on the particle morphology [10,11].

Using the above method for calculation the scattering phase functions, we can examine the effects of particle size, shape, refractive index and particle morphology. We first examine the effects of particle size on the scattering properties. We use the Mie theory to plot the angular scattering distributions for a series of radius from 0.1 μm to 14.0 μm which have been illuminated with several wavelengths of polarized visible light.

Taking into account the polarization we used the complex formulas of scattering [12,13]. They involve two complex functions of scattered amplitude: $S_1(\theta)$ and $S_2(\theta)$.

The electric field is decomposed into two polarizations:

E_r Polarized perpendicular electric field to the scattering plane.

E_t Polarized parallel electric field to the scattering plane.

The expression of the diffusion is:

$$E_r = S_1(\theta)\frac{e^{-ikr+ikz}}{ikr}E_{r0} \tag{01}$$

$$E_t = S_2(\theta)\frac{e^{-ikr+ikz}}{ikr}E_{t0} \tag{02}$$

E_{r0} and E_{t0} are Incident fields.

For an unpolarized incident wave, the intensity is then:

$$I = I_0\frac{1}{2r^2k^2}(i_1 + i_2) \tag{03}$$

If the wave is linearly polarized along Ox:

$$I = I_0\frac{1}{r^2k^2}(i_1 \sin^2(\varphi) + i_2 cos^2(\varphi)) \tag{04}$$

When: $i_1 = |S_1(\theta)|^2$ and $i_2 = |S_2(\theta)|^2$

The amplitude functions S_1 (perpendicular to the scattering plane) and S_2 (parallel to the scattering plane) have the following form:

$$S_1(\theta) = \sum_1^\infty \frac{2n+1}{n(n+1)}[a_n\pi_n(\cos(\theta) + b_n\tau_n(\cos(\theta))] \tag{05}$$

$$S_2(\theta) = \sum_1^\infty \frac{2n(n+1)}{n(n+1)}[b_n\pi_n(\cos(\theta) + a_n\pi_n(\cos(\theta))] \tag{06}$$

The angular factors π_n and τ_n have the following forms:

$$\pi_n(\cos(\theta)) = \frac{1}{\sin(\theta)}P_n^1(\cos(\theta)) \tag{07}$$

$$\tau_n = \frac{d}{d\theta}P_n^1(\cos(\theta)) \tag{08}$$