STSM report

STSM Application number: COST-STSM-BM1205-29380

STSM Grantee: Prof. Igor Meglinski

STSM title: Cancer screening using quantitative polarimetry

Home Institution: University of Oulu, Finland

Host Institution: Ecole polytechnique, Palaiseau, France

STSM period: 25.07.2015 to 30.07.2015

STSM purpose: To compare the results of studies obtained independently and to prepare a joint scientific publication.

Description of the work carried out during the STSM:

In Optoelectronics and Measurement Techniques Laboratory of the University of Oulu a new method for non-invasive diagnostic of cancerous and non-cancerous tissue samples by using circularly polarized light has been developed. An alternative approach of using polarized light for cancer detection is based on the Muller matrix formalism is available in Dr. Tatiana Novikova's research team at the Ecole Polytechnique (France).

During the visit the results obtained at the tissue phantoms with different scattering properties were analysed and compared quantitatively.

Based on the analysis of the results a joint publication has been prepared (see enclosed). The results of the joint collaboration are presented in paper (currently submitted to the Opticsl Letters with the acknowledgements to the COST action).

Mutual benefits for the Home and Host institutions:

The tissue samples mentioned above were characterized wih both experimental systems and the results cross-validated.

Both Host and Home institutions agree to continue collaboration. More phantoms will be developed in Oulu and will be tested jointly by two different eperimental systems. Based on these studies we expect a development of a phemenological model that will be able to predict the changes of polarization in cancerous and non-cancerous tissues. Thus, a new technique for quantitative screening of cancer agressivness can be developed.

I confirm that the information above is correct and that this STSM has set the basis of a profitable collaboration between the two groups involved in this research.

Description of the main results obtained:

The turbid media used for comparison of two polarization-based approaches were assembled by use the rutile (TiO2) submicron particles homogeneously embedded, at various concentrations, in a PVC-based transparent host material. The samples appeared in the form of 1-mm-thick plastic sheets. Samples with three concentrations of particles, 1.5, 3.0 and 6.0 mg/ml, were studied. The experimentally determined (by electron microscopy) size distribution histogram of the particles was found to follow the log-normal law with a mean particle size value of 0.530 ±0.010 μm and a standard deviation of 0.446 ± 0.016 μm. Spectrophotometric measurements showed the intrinsic absorption coefficient to be negligible with respect to the scattering coefficients, so that the samples could be considered optically as absorption-free solid scattering media.

To vary experimentally the path-length z, the plastic sheet samples were cut into a number of small (~1 cm × 1 cm) pieces that were piled up compactly on a glass substrate, thus forming stacks of variable number of layers. Every new layer was spread with caution on the previous one so as to minimize the formation of an optical interface between layers. A measurement was performed each time a new layer was added to the stack, starting from the bare substrate (whose Mueller matrix was found to be equal to the identity within the experimental uncertainty).

In parallel with the experimental determination of the Mueller matrices of the stacks of layers, these were also obtained through numerical simulations. For this purpose, the vector integral-differential radiative transfer equation was solved with a Monte Carlo technique (developed by Professor Meglinski) by simulating the random walk of incident “photon packages” within the scattering medium.

Figure below shows the experimental verification of the results obtained in the Ecole polytechnique in comparison with the results obtained by Professor Meglinski’s team.

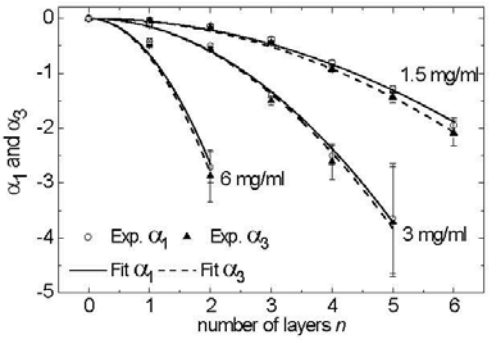

Fig.1. Evolution of the logarithmic depolarizations α1 = α2 and α3 with the number of layers n for the three studied particle concentrations.

For further confirmation of the parabolic behavior, as well as a guard against any experimental bias or possible artefacts present in the data, Table 1 lists the experimental and simulated values of the coefficient A of the parabolic dependence An2 for the two logarithmic depolarizations at the three particle concentrations. These values were obtained by fitting the parabolic law to the experimental and simulated logarithmic depolarizations respectively. Prior to that, the experimental logarithmic depolarizations were simulated by using the scattering coefficient μs as ‘free’ parameter. The μs values thus found were 17.05, 28.4 and 56.8 cm-1 respectively for the three particle concentrations (1.5, 3.0 and 6.0 mg/ml). The average refractive index of the particle material, anisotropic rutile (TiO2), was assumed to be 2.75 and that of the PVC host material, 1.461 (at the wavelength of 550 nm) in all simulations. It is readily seen from the table that the agreement between simulation and experiment

is excellent. The small discrepancies observed are attributable most likely to the variations in the thickness of the layer stacks arising from the pronounced plasticity of the samples and the manual layer-piling process. For the same reasons the average thickness of an individual layer from the stack is expected to be slightly smaller than the one of the plastic sheet (1 mm) before cutting it into pieces, as described in the experimental paragraph. To account for this "effect", a fixed value of 0.95 mm instead of the nominal 1 mm for the average layer thickness was assumed in the simulations

Table 1. Experimental ('exp') and simulated ('sim') values of the parabola coefficient Ai of the fit to the logarithmic depolarization αi (i = 1, 3) for the three studied particle concentrations ('conc.').

conc, mg/ml	1.5	3.0	6.0
$A_{1\,exp}$	−0.0536 ± 0.001	−0.146 ± 0.003	−0.66 ± 0.04
$A_{1\,sim}$	−0.0534	−0.149	−0.662
$A_{3\,exp}$	−0.0576 ± 0.004	−0.153 ± 0.003	−0.70 ± 0.04
$A_{3\,sim}$	−0.0574	−0.153	−0.703

We found that the depolarization of a turbid medium consisting of submicron scattering particles evolves parabolically with the path-length travelled by light through the medium. This experimental observation was backed by numerical simulations, thus ruling out the presence of any significant measurement artefacts. Furthermore, the depolarization being expressed through the variances of the elementary polarization properties within the fluctuating medium differential Mueller matrix picture, the square roots of the variances, i.e. the standard deviations of the properties were found to vary linearly with the concentration of scatterers. This finding represents a remarkable link between the phenomenological and physical descriptors of a turbid medium. The results of this work are expected to be helpful to experimentalists involved in the polarimetric characterization of turbid media and, in particular, to those addressing biomedical applications.

Future collaboration with the Host institution (if applicable):

During the visit two techniques were compared to each other and common interests in terms of research for were found. The participants are going to establish more active research collaboration, publish joint scientific papers and apply for the H2020 programme.

Foreseen journal publications or conference presentations expected to result from the STSM:

Based on the obtained results a joint journal paper has been submitted. Two joint presentations are going to be prepared and presented at the major scientific conferences in 2016.

STSM outcome form

STSM application number	Home institution & country	Host institution & country	BM1205 WG	Objective of the collaboration	Results of the collaboration
COST-STSM-BM1205-29380	University of Oulu, Finland	Ecole polytechnique, France	WG4	Compare two independently developed polarization-based techniques for cancer screening and tissues characterization	The techniques was compared. Based on the results a phenomenological model has been developed. The joint publication was prepared.

Confirmation

Hereby, I am pleased to confirm that Professor Meglinski visited the Ecole Polytechnique in the framework of the short term scientific mission (STSM) during 25 – 30 July 2015. During the visit all the tasks and planned actions were successfully completed.

Should you require addition information please contact me at your convenience.

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29/09/2015