STSM report

STSM Application number: COST-STSM-BM1205-26647

STSM Grantee: Dr. Alexander Bykov

STSM title: Characterization of cancerous and non-cancerous biotissues with polarized light

Home Institution: University of Oulu, Finland

Host Institution: Ecole polytechnique, Palaiseau, France

STSM period: 10.05.2015 to 16.05.2015

STSM purpose: To perform characterization of biotissues and biotissue phantoms with multispectral Mueller polarimetric imaging setup

Description of the work carried out during the STSM:

In optoelectronics and Measurement techniques laboratory of the University of Oulu we develop a method for noninvasive diagnostic characterization of cancerous and non-cancerous biotissues with circularly polarized light. An alternative approach of using polarized light for cancer detection is based on the Muller matrix formalism. This approach is under development in Dr. Tatiana Novikova's research group at the Ecole Polytechnique (France).

Prior to the visit, a set of biotissue phantoms with different scattering properties were fabricated. The phantoms were characterized with spectrophotometer setup and their optical properties were retrieved from the measured diffuse transmittance/reflectance and collimated transmittance.

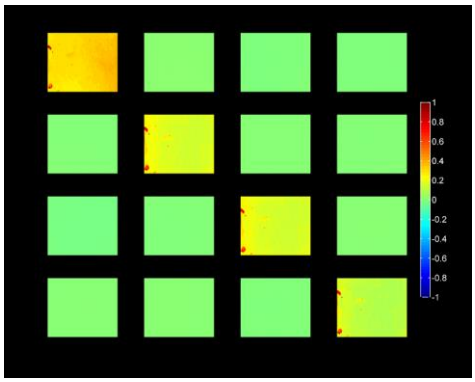
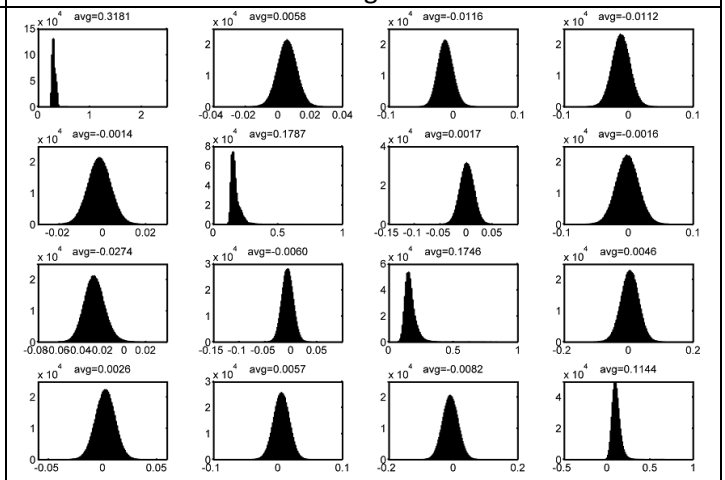
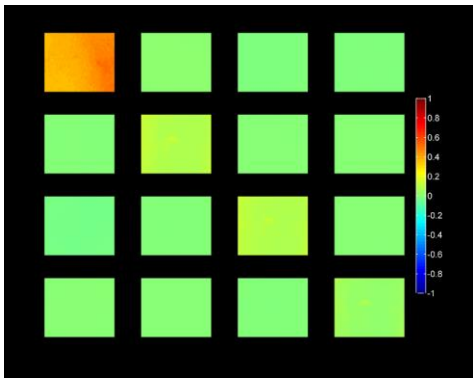
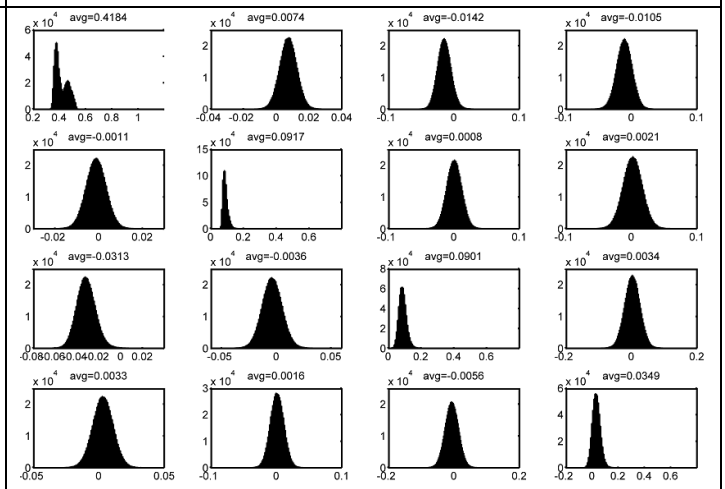
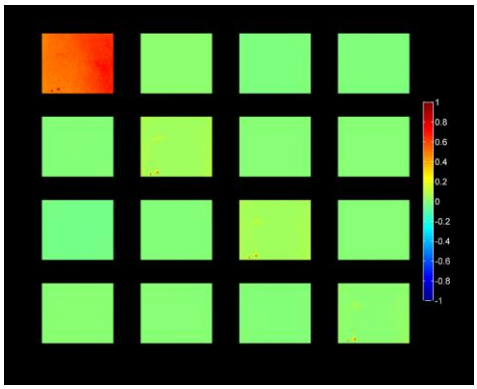
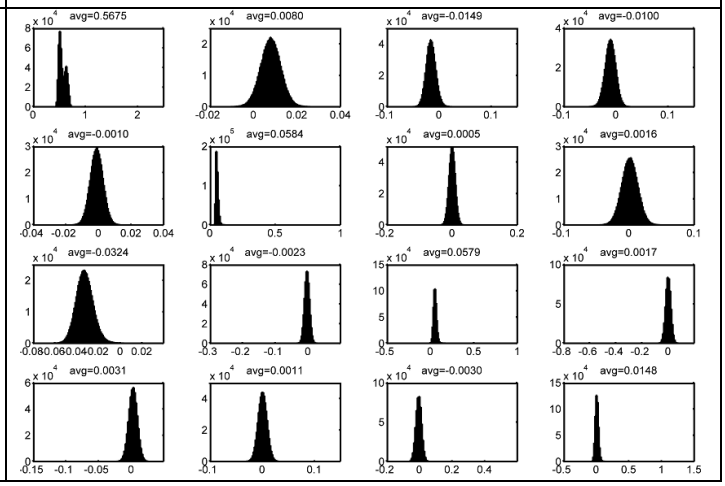
During the visit the polarization properties of fabricated phantoms as well as the biotissue samples were characterized using a set of Mueller polarimeters available at the host laboratory. In particular, Mueller matrices of the considered samples were measured with the multispectral Mueller polarimetric imaging setup. Additionally, all the samples were characterized with angular-resolved Mueller polarimeter and transmission mode Mueller polarimeter.

Thus, the characterized samples will be used for calibration and comparison of the performance of the setup for noninvasive diagnostic characterization of cancerous and non-cancerous biotissues with circularly polarized light which is currently under development in the Optoelectronics and Measurement Techniques Laboratory of the University of Oulu.

Description of the main results obtained:

The samples described above were characterized with the multispectral Mueller polarimetric imaging setup. Some results of the measurement are summarized the tables bellow. Table 1 shows the measured Mueller matrices and histograms of corresponding matrix elements for the biotissue phantoms with different scattering coefficients (namely 2.5, 5 and 10 mm^{-1}) obtained for the wavelength of 550 nm.

Table 1. Mueller matrices and histograms of corresponding matrix elements for the biotissue phantom with different scattering coefficient (λ = 550 nm).

Scattering	Mueller matrix	Histogram
2.5 mm^{-1}		
5 mm^{-1}		
10 mm^{-1}		

It is clearly seen that the manufactured phantoms have diagonal Mueller matrices showing that the considered phantoms represent pure depolarizer and do not show any significant diattenuation and retardance properties. It is also seen that the increase of the scattering coefficient causes the increase in the value of first element of Mueller matrix. At the same time, the values of (2,2), (3,3) and (4,4) elements are

decreasing that indicates that the Mueller matrix approaching the shape of the Mueller matrix of ideal depolarizer.

Further, two paraffin-embedded tissue samples (normal and tumorous) were analyzed with the same setup. The Mueller matrices of the corresponding samples obtained for the wavelength of 550 nm are shown on the fig. 1.

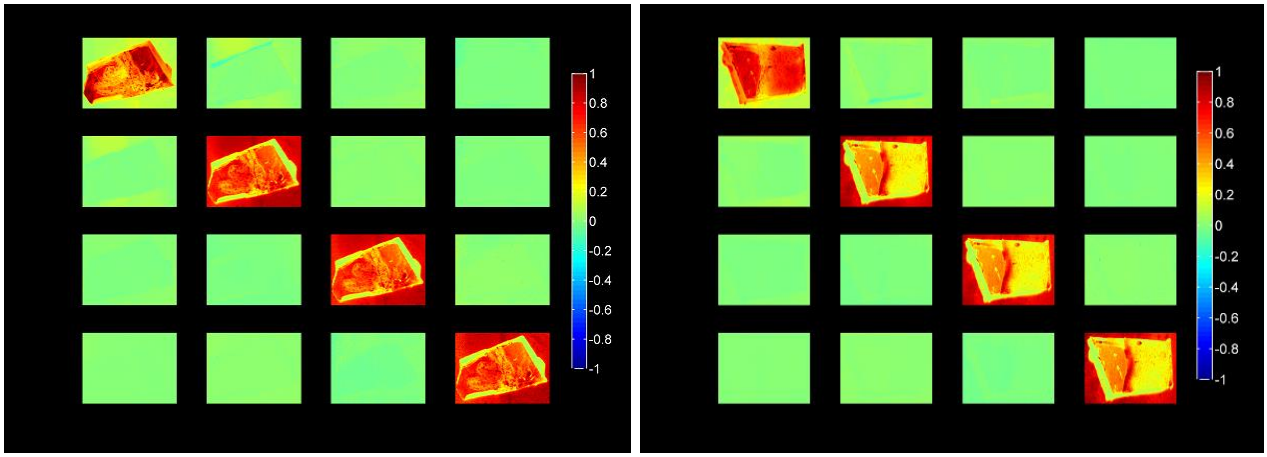


Fig.1. Mueller matrices of the paraffin-embedded normal (left) and tumorous (right) tissue samples obtained with multispectral Mueller polarimetric imaging setup.

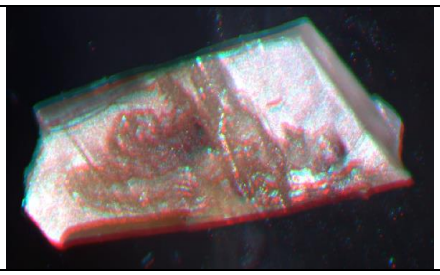
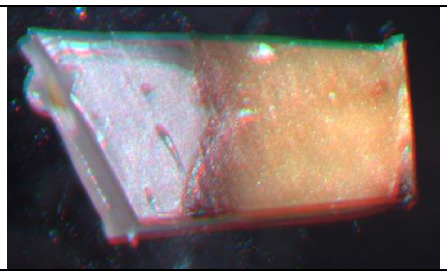
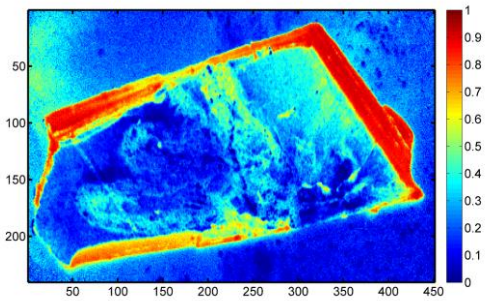
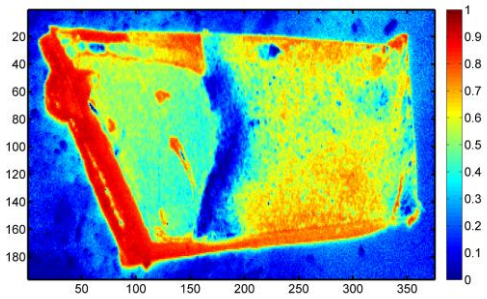
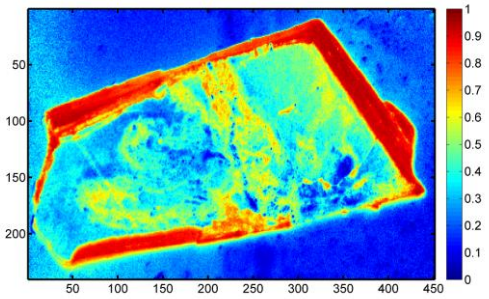
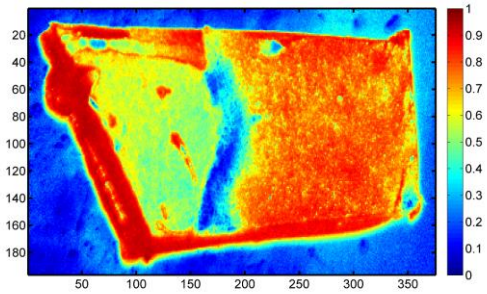
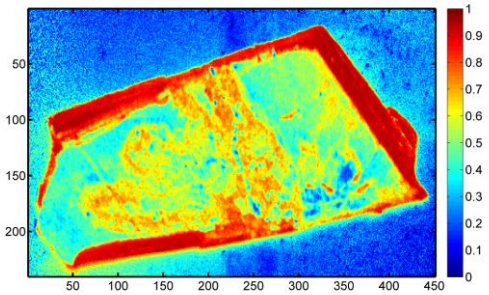
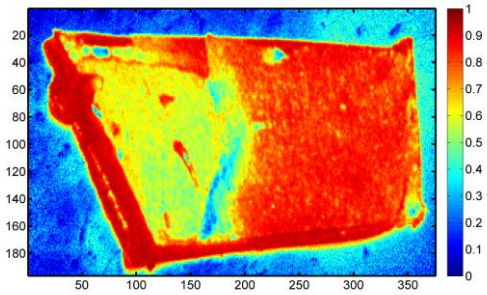
From fig. 1 it is seen that the obtained Mueller matrices also have diagonal form as in the case of tissue phantoms. Thus, we can also conclude that the considered samples represent pure depolarizers and do not exhibit any significant diattenuation and retardance. In this case, depolarization parameter (degree of depolarization) Δ can be calculated according to the formula:

$$\Delta = 1 - \frac{|a|+|b|+|c|}{3},$$

where a, b , c are (2,2) (3,3) and (4,4) elements of Mueller matrix.

Depolarization coefficient Δ for both samples and for different wavelength are shown in the Table 2. From these images one can conclude that depolarization coefficient increases with the increasing wavelength for both samples. This fact can be explained by increased penetration depth and larger contribution of diffused photons to the reflected signals. It is also seen that tumorous sample has higher degree of depolarization than the normal one. However, the direct comparison may be somehow hindered by nonequal contribution of the specularly reflected photons preserving the polarization due to the difference in sample surface alignment.

Table 2. Images and depolarization coefficient derived from the Mueller matrices for the normal and tumorous samples for different wavelengths.

	normal	tumorous
Image		
450 nm		
550 nm		
650 nm		

Mutual benefits for the Home and Host institutions:

The benefits for both Home and Host institutions are obvious. First of all, the collaboration between the laboratories increases the knowledge in the field of polarization imaging. Host institution got acquainted with the state-of-the-art capabilities for biotissue phantoms manufacturing of the Home institution. The Home institution acquired state-of-the-art knowledge in Mueller polarimetry from the Host institution leading in this field.

Future collaboration with the Host institution (if applicable): During the visit, mutual interest for joint research was expressed. We believe that this visit will serve as a stepping stone for further collaboration resulted in joint publication and projects including H2020.

Foreseen journal publications or conference presentations expected to result from the STSM: During this short visit, a lot of measurement data from the biotissues and biotissue phantoms were obtained. These data should be analyzed and properly interpreted. Depending on the analysis, additional measurements might be needed. Thus, journal/conference article may be prepared upon completion of the data analysis.

STSM outcome form

STSM application number	Home institution & country	Host institution & country	BM1205 WG	Objective of the collaboration	Results of the collaboration
COST-STSM-BM1205-26647	University of Oulu, Finland	Ecole polytechnique, France	WG4	Characterization of biotissues and biotissue phantoms with multispectral Mueller polarimetric imaging setup	Polarization properties of biotissues and biotissue phantoms were characterized

Confirmation

Hereby I confirm that the described short term scientific mission (STSM) performed by Dr. Alexander Bykov was successfully completed. Within the frame of this mission, he worked at Ecole Polytechnique during the period of 10th - 16th of May 2015 and has achieved all the planned goals.

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27/05/2015