Optical Anisotropy and Depolarization of Healthy Brain White Matter for Intraoperative Delineation of Brain Tumors

Meishu WANG [1,2], Sooyong CHAE [1], Theotim LUCAS [1], Omar Rodríguez-Núñez [3], Eléa GROS [4], Christopher HAHNE [5], Theoni MARAGKOU [4], Richard MCKINLEY [6], Philippe SCHUCHT [3], Tatiana NOVIKOVA [1,7, *]

[1] *LPICM, CNRS, Ecole polytechnique, IP Paris, Palaiseau, France*
[2] *MOE Key Laboratory of Optoelectronic Imaging Technology and System, Beijing Institute of Technology, Beijing 100081, China*
[3] *Department of Neurosurgery, Inselspital, Bern, Switzerland*
[4] *Institute of Tissue Medicine and Pathology, University of Bern, Bern, Switzerland*
[5] *Department of BioMedical Research, University of Bern, Bern, Switzerland*
[6] *Support Center for Advanced Neuroimaging, University Institute of Diagnostic and Interventional Neuroradiology, University of Bern, Inselspital, Bern, Switzerland*
[7] *Department of Biomedical Engineering, Florida International University, Miami, FL, USA*
tatiana.novikova@polytechnique.edu

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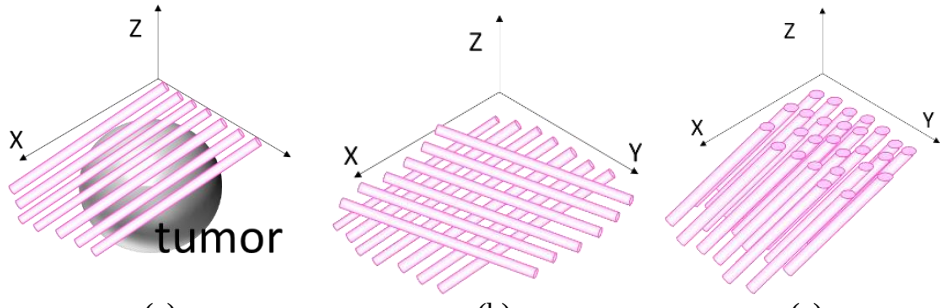
During brain tumor surgery, the identification of precise location of tumor boundary is very important, as it can help neurosurgeons to remove tumor zone completely and reduce the probability of tumor recurrence without excessively damaging normal tissues. It will also preserve neurological functions to the greatest extent after surgery. Pre-operative magnetic resonance imaging (MRI) is commonly used to determine the presence and boundaries of a tumor, but detecting glioma and glioblastoma tumor borders in vivo remains one of main challenges of modern neurosurgery
Our proof-of-concept studies demonstrated that wide-field imaging Mueller polarimetry is sensitive to the anisotropy of refractive index of white matter of healthy brain related to the presence of densely packed brain fibers [1], which are destroyed by brain tumor. It suggests using birefringence of healthy brain white matter as an optical marker for delineation of tumor border. However, the loss of retardance can not only be observed in the tumor zone (Fig. 1a), but also in the zones of brain fiber crossing and inclination (see Fig.1b and 1c).



(a) (b) (c)

Figure 1. Schematic representation of optical phantom models used in Monte Carlo simulation of backscattered Mueller matrices of brain tissue that includes the zones of: (a) tumor; (b) fiber crossing; (c) fiber inclination

Therefore, for differentiating the polarimetric images of brain tissue with complex 3D fiber distribution from the images of brain tumor we used the Monte Carlo modeling of interaction of polarized light with the optical models shown in Fig.1. Statistical analysis of the trends of depolarization, retardance and azimuth of optical axis in each model will be shown and discussed.

[1] P. Schucht et al., "Visualization of White Matter Fiber Tracts of Brain Tissue Sections with Wide-Field Imaging Mueller Polarimetry," IEEE Transactions on Medical Imaging, vol. 39, no. 12, pp. 4376-4382, 2020