

Photonics Tools for Biomedical Applications: Direct Laser Treatment of Cancer

E.U. Rafailov

Optoelectronics and Biomedical Photonics Group

Aston Institute of Photonics Technologies

**Aston University
Birmingham
UK**

1 September 2026, Belgrade

Outline

- Motivation
- Photo therapy
- Photodynamic Therapy (PDT) and Direct Laser Treatment (DLT)
- Transmission properties of bio tissues
- DLT suppresses GBM progression
- 3D tissues development for research
- Conclusions

Cardiovascular Diseases, Cancer and Diabetes Mortality Prognosis

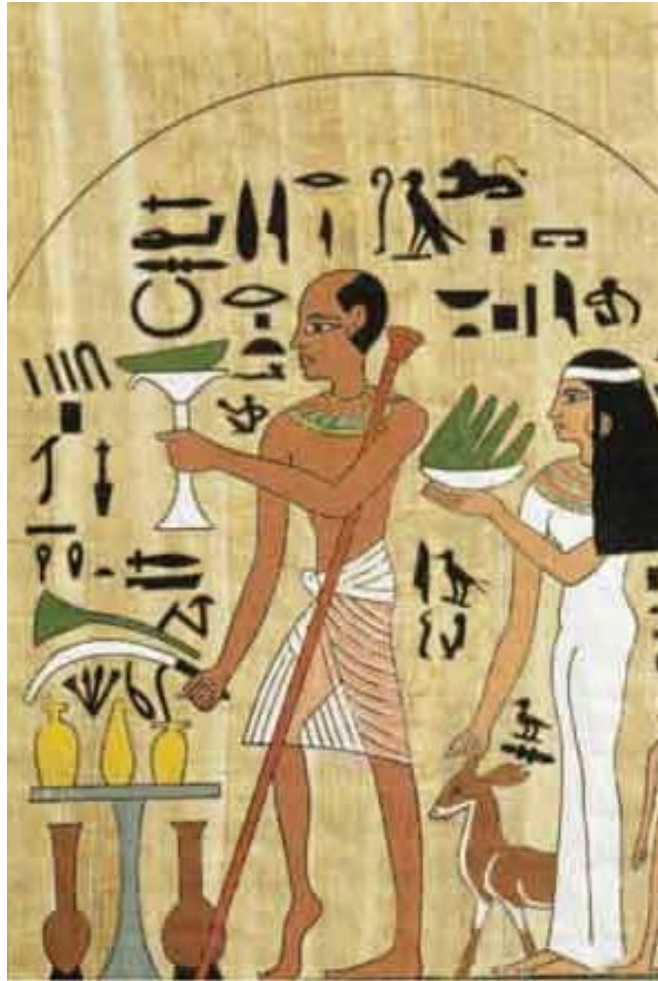
17.3 million died from CVDs in 2008. More than **23.3 million** will die annually from CVDs by 2030

7.6 million deaths from cancer (13% of all deaths) in 2008
Expecting Deaths **13.1 million** in 2030

The expected deaths for diabetes mellitus for 2030 is **13.1 million**. The disease itself has grown to pandemic proportions. A number of people affected worldwide expected to rise in prevalence to **344 million** by 2030

These figures all point towards the pressing need for the development of effective early diagnostics and treatments

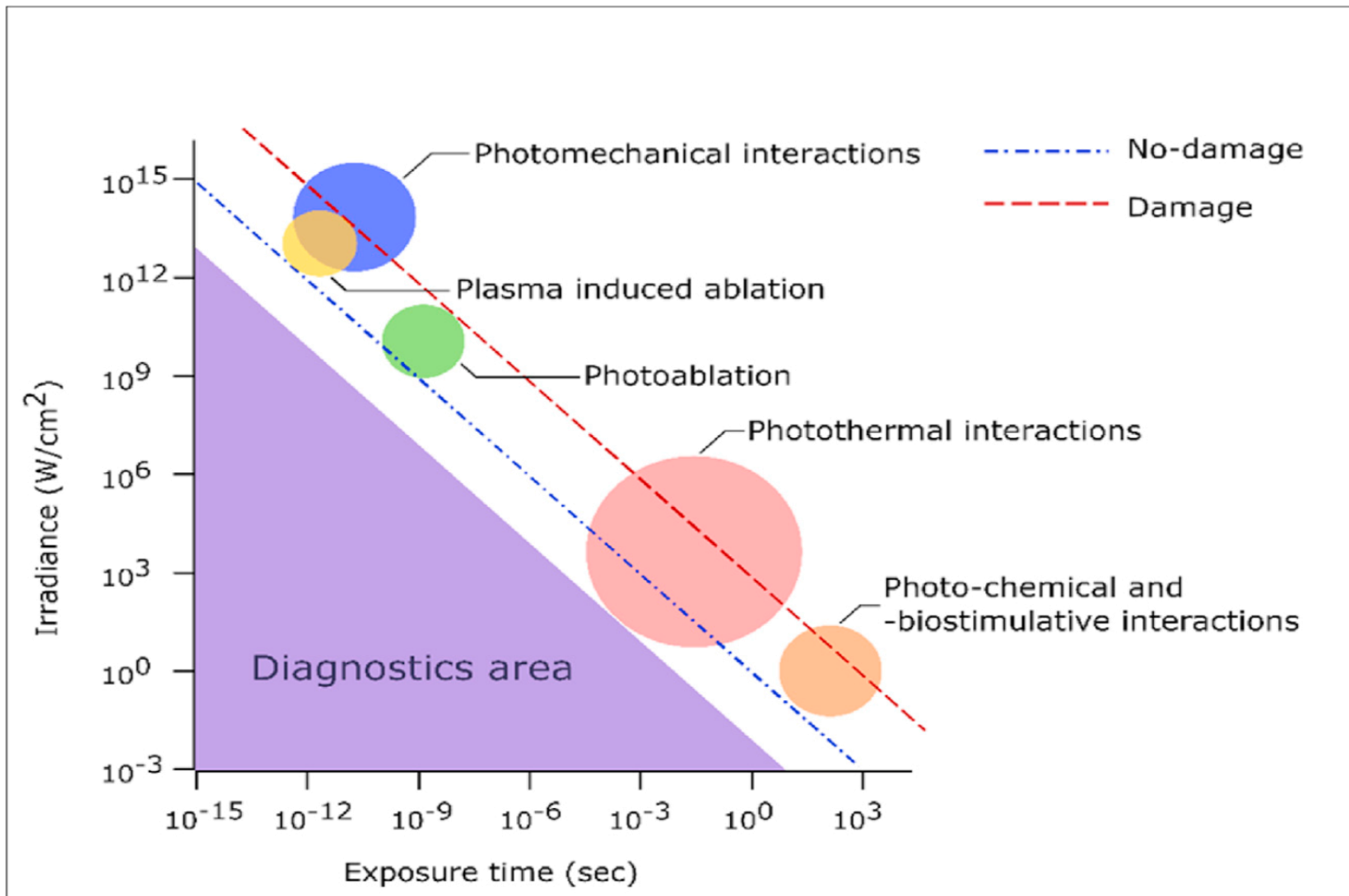
Ancient Egyptian and St John's Wort



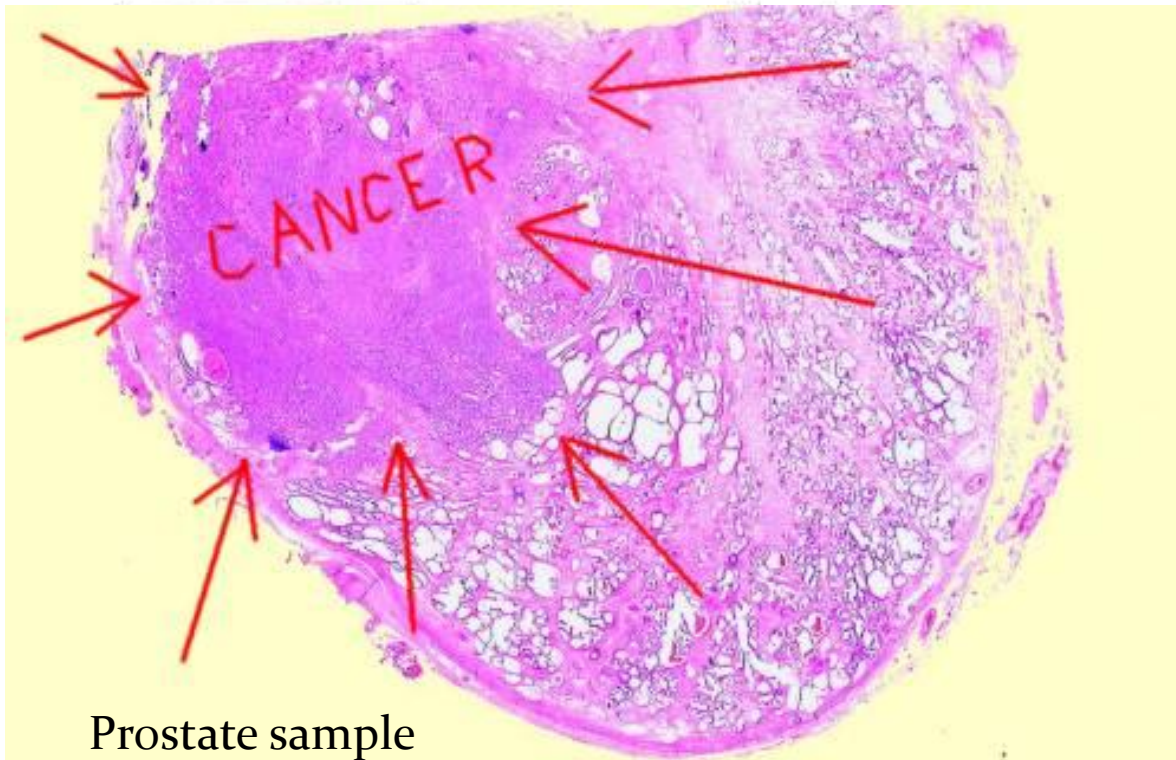
Hypericum aegypticum

Hypericin used as antidepressant, St John's wort is also a photosensitiser suitable for PDT, wound healing, lesions removing, etc

Solar radiation and light-tissue interaction

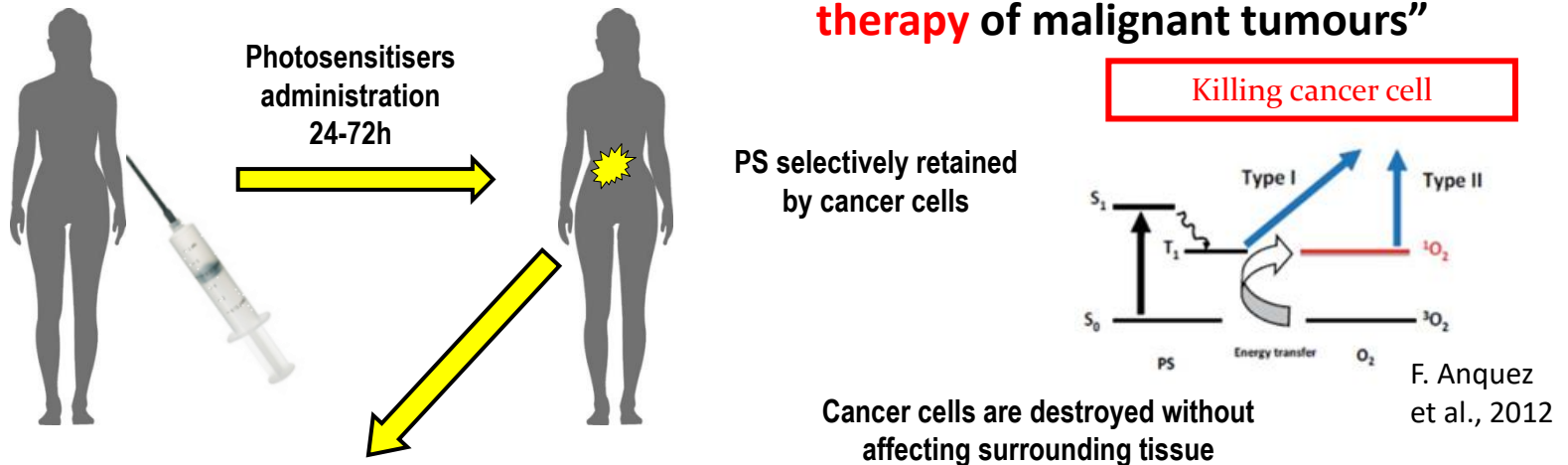


Golden Standard Biopsy



Conventional PhotoDynamic Therapy

In 1972 Diamond with co-authors published in *Lancet* “**Photodynamic therapy** of malignant tumours”



- Requires long administration
- Accumulated by cutaneous tissues
- Phototoxicity for up to 30 days
- 630 nm light has got low penetration rate
- It is expensive

Absorption peaks triplet oxygen ($^3\text{O}_2$)

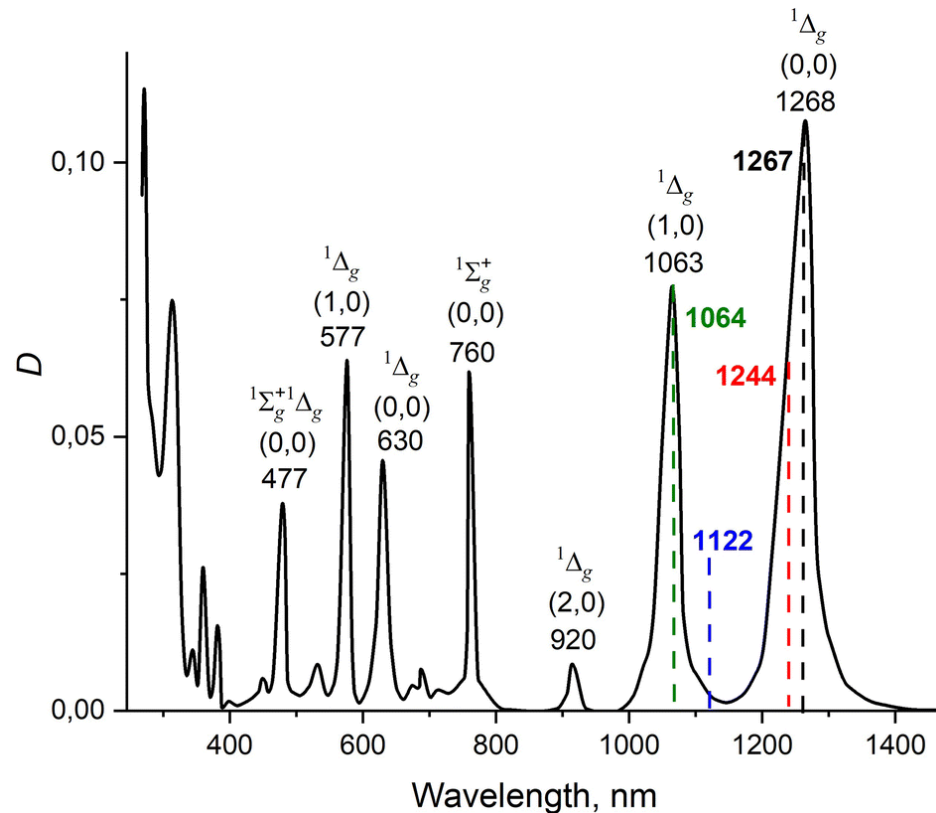
Wavelengths proved affect
CCO activity during PBM

665nm is near 630 nm of the
 $^3\text{O}_2$ excitation

730nm is the same for $^3\text{O}_2$
excitation

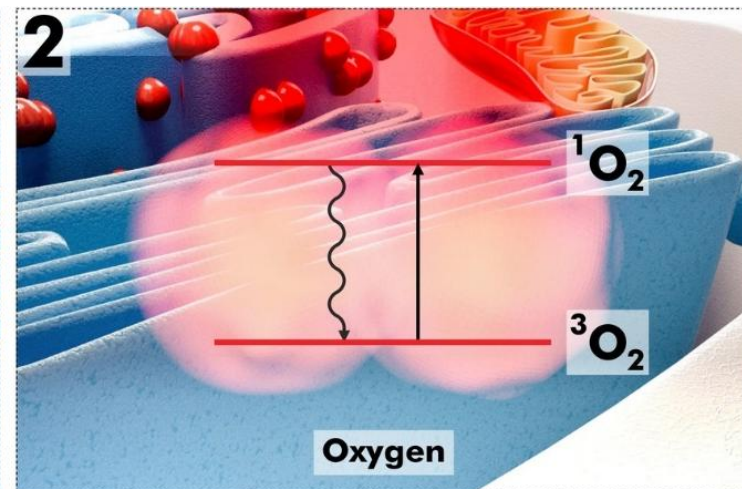
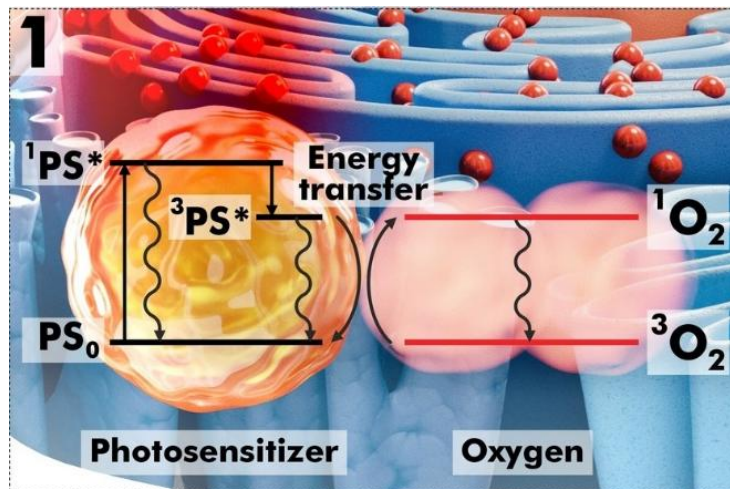
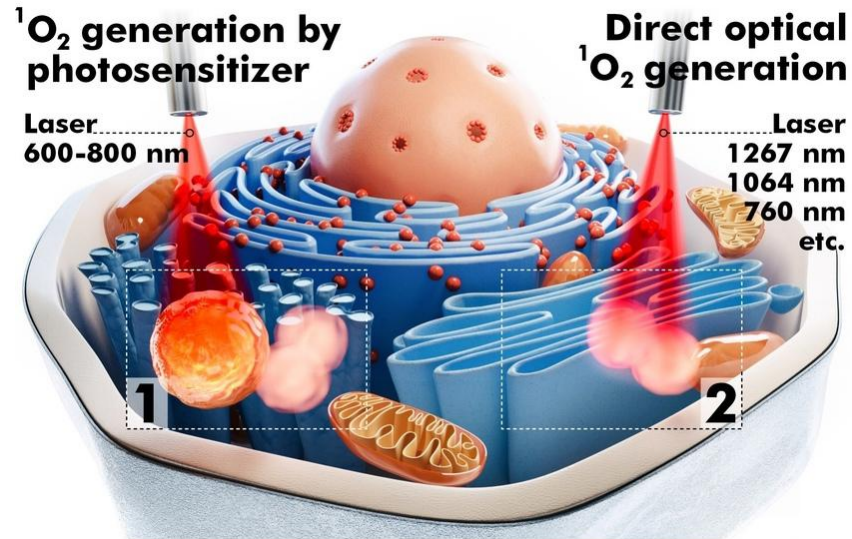
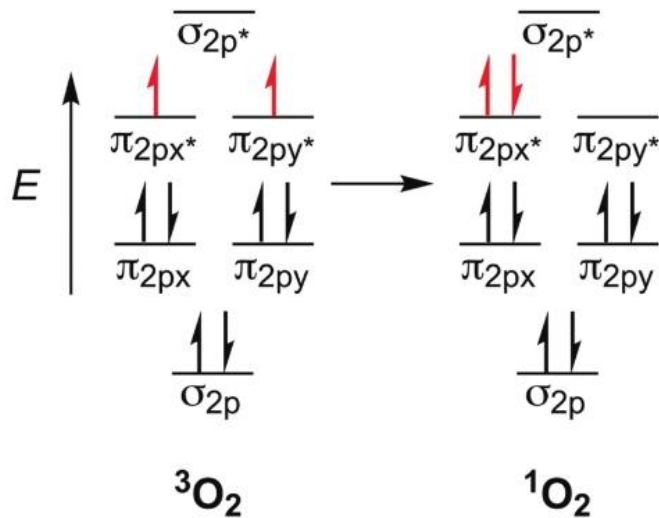
810 and 980 nm are unique for
CCO activation

At least **1064nm** and **1267 nm**
are seemingly unique for $^3\text{O}_2$
excitation



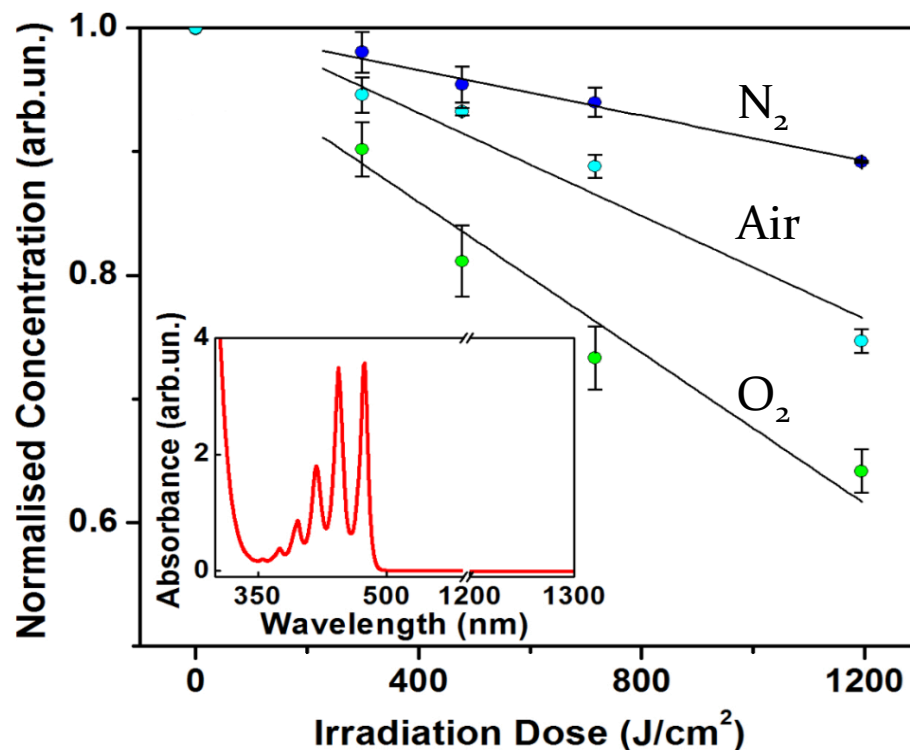
S.D. Zakharov, *Quantum Electronics* (1999), *Biophysics* (2005)

Mechanisms of generation and physiological effect of $^1\text{O}_2$



Dremin et al, Opt. Express, 30(13), 23078 (2022)

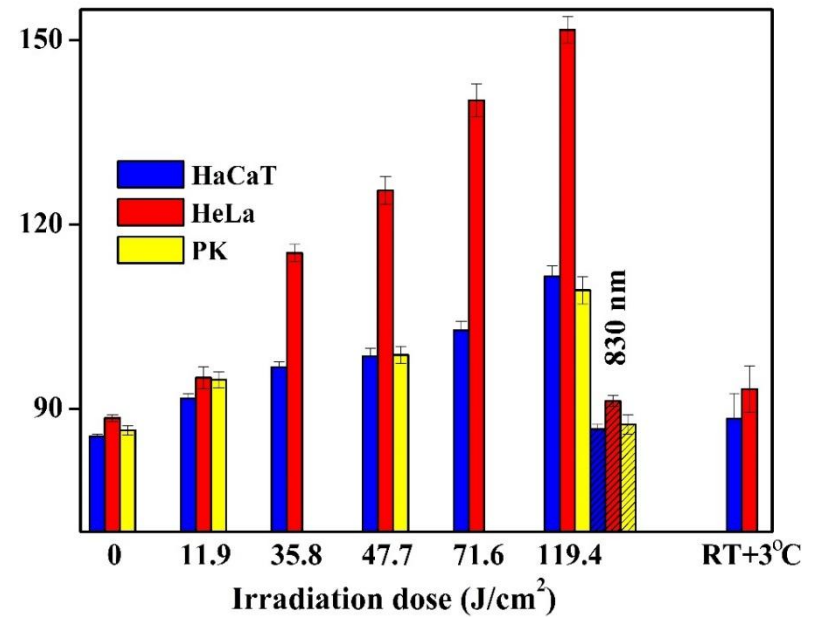
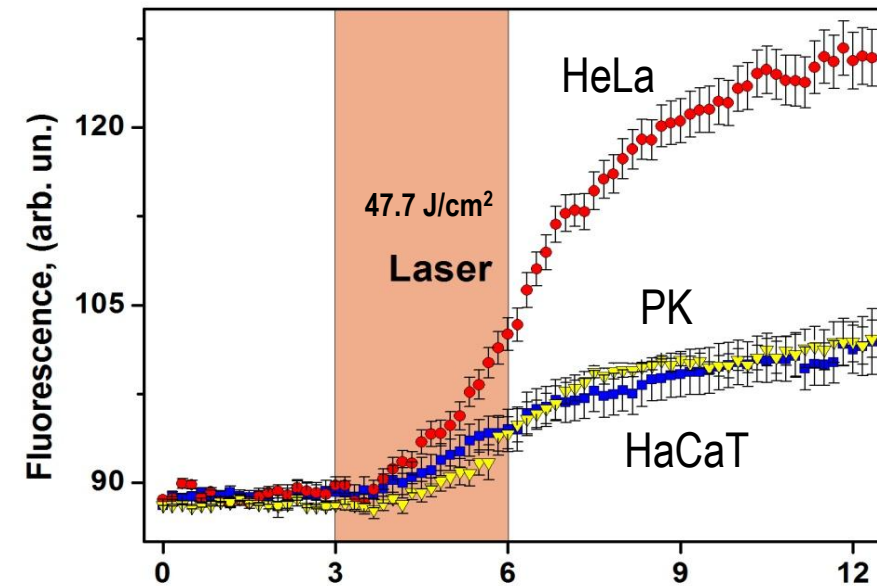
Singlet oxygen generation



Ability of **Naphthacene** (115 μM) to be specifically bleached with $^1\text{O}_2$ was used to assay 1270 nm laser-induced singlet oxygen production in CCl_4 solution.

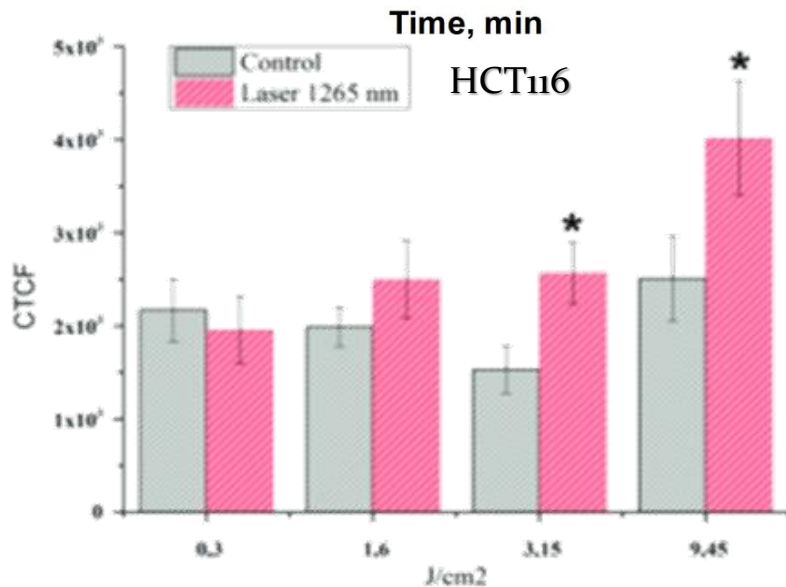
Sokolovski et al, Sci.Reps. 2013

Sensitivity of deferent cell types



Dose-dependant effect

S.G. Sokolovski et al Sci. Rep., 3, 3484 (2013)



Khokhlova et al. IEEE JSTQE, 2018

Near-IR laser treatment of Glioblastoma in rats

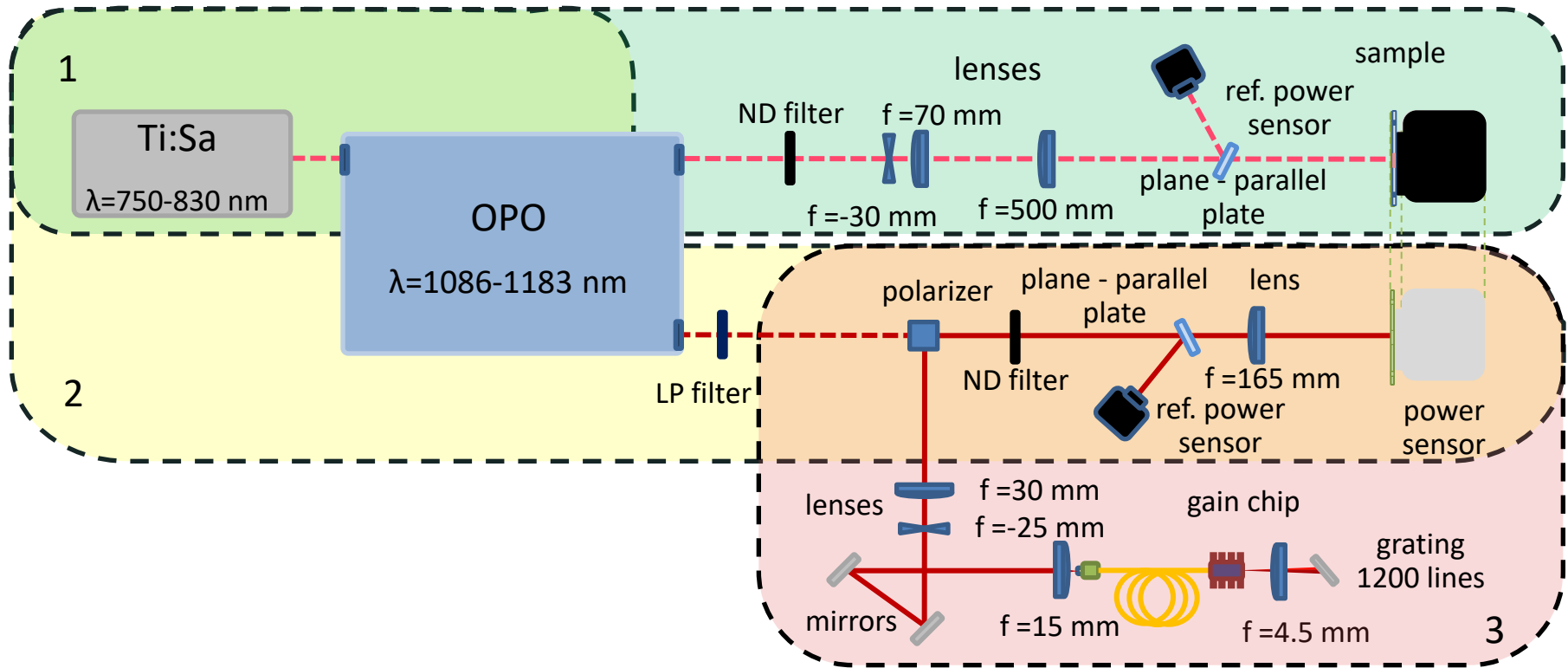


MRI assessment of the GBM size and rat survival

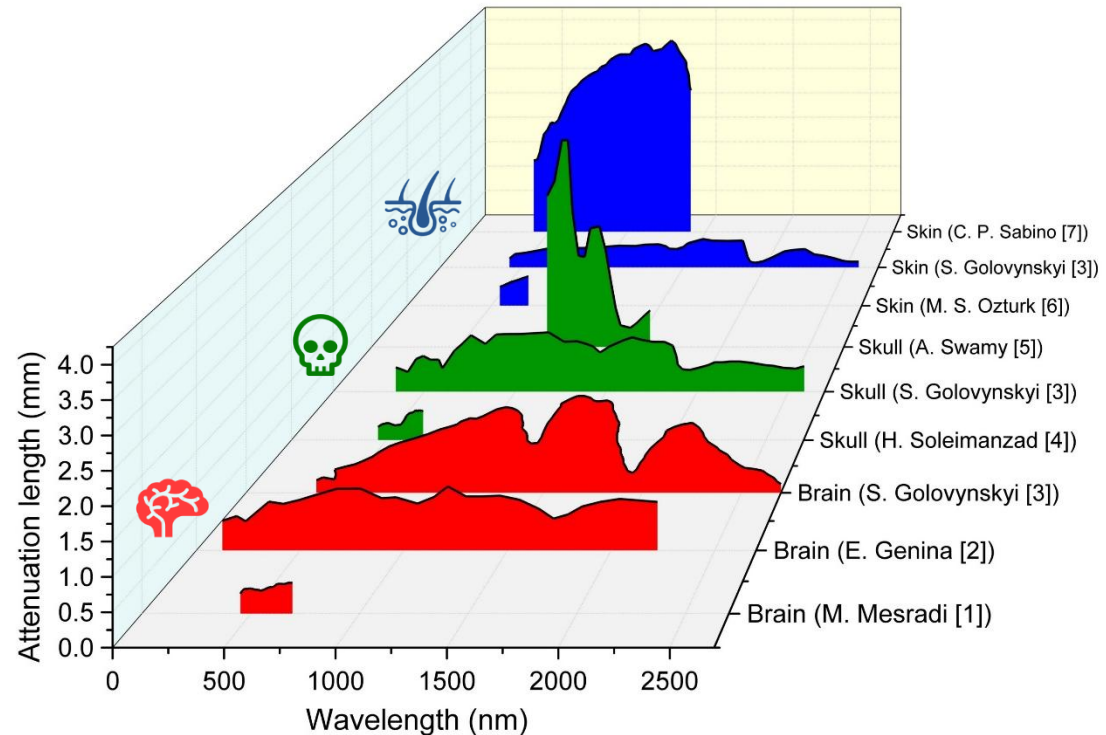
Apoptosis and vacuole formation in GBM cell culture and brain tissue

NIR-laser activation of brain drainage and lymphatics

Spectrophotometry - Experimental setup

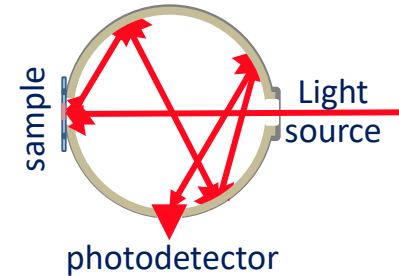
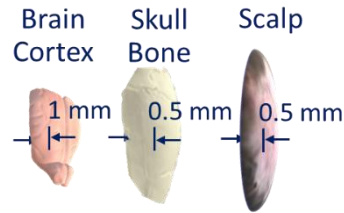
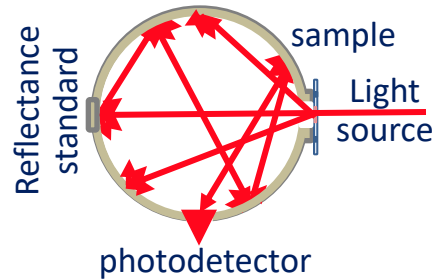


Spectrophotometry

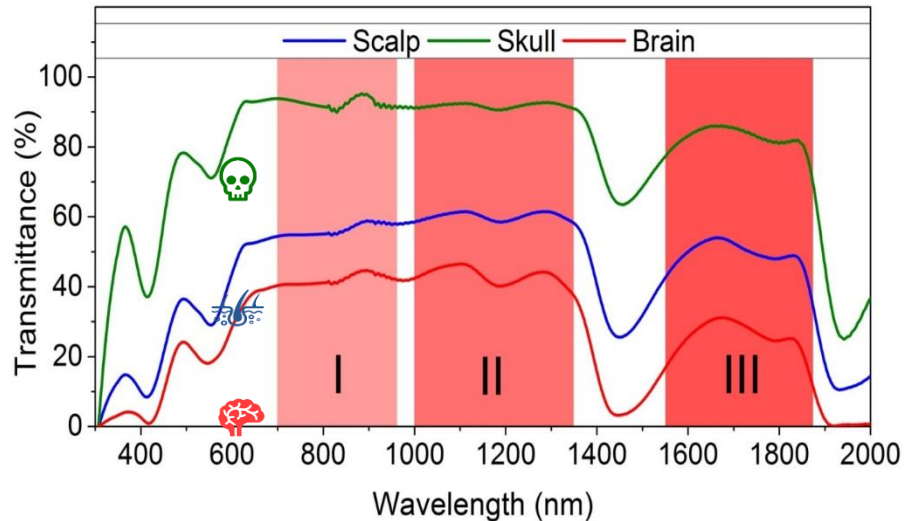


[1] M. S. Mesradi, et al., Journal of biomedical optics 18.11 (2013): 117010. [2] E. A. Genina, et al., Biomedical Optics Express 10.10 (2019): 5182-5197. [3] S. Golovynskiy, et al., J. of Biophotonics 11.12 (2018): e201800141. [4] H. Soleimanzad, et al., J. of Biomedical Optics 22.1 (2017): [5] A. Swamy, et al., J. of Biomedical Optics 24.1 (2019); [6] M. S. Ozturk, et al. bioRxiv (2020). [7] C. P. Sabino, Caetano P., et al. J. of Photochemistry and Photobiology B: Biology 160 (2016): 72-78.

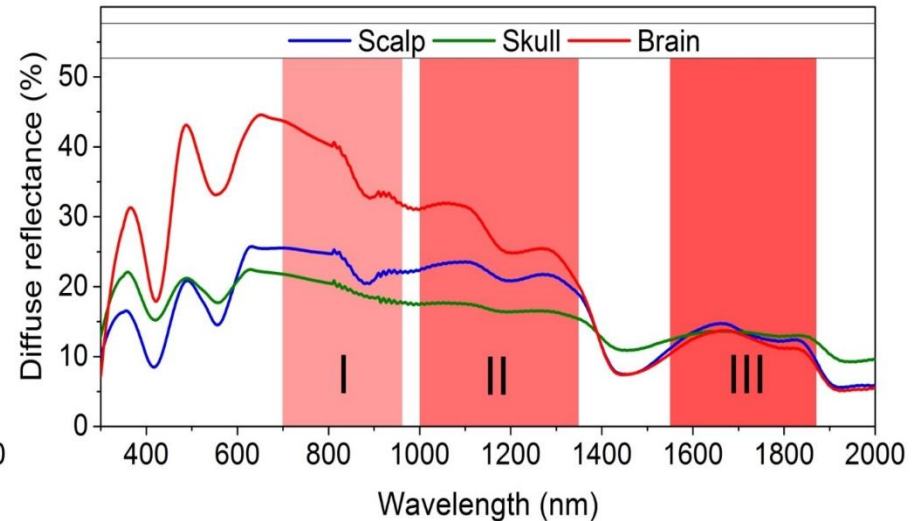
Spectrophotometry



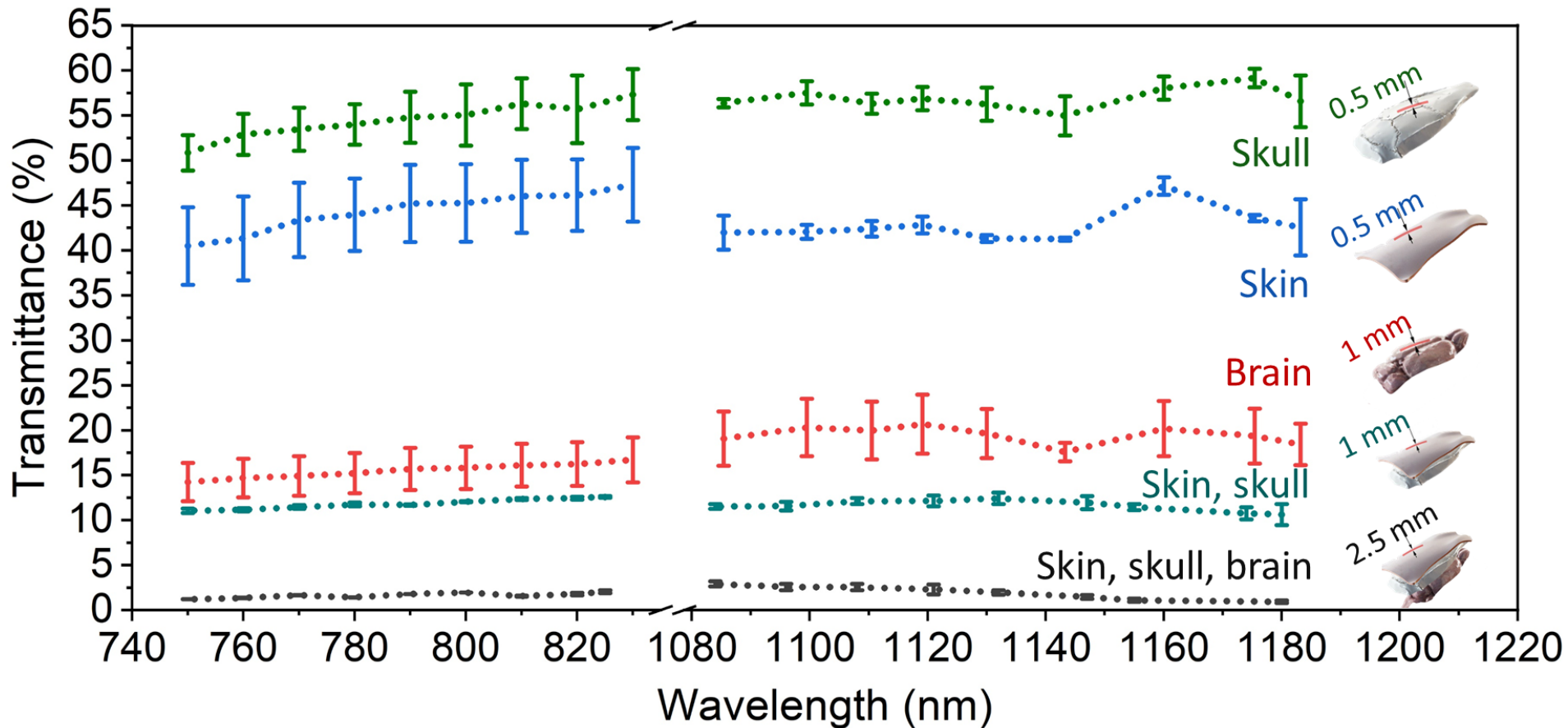
Transmittance



Reflectance

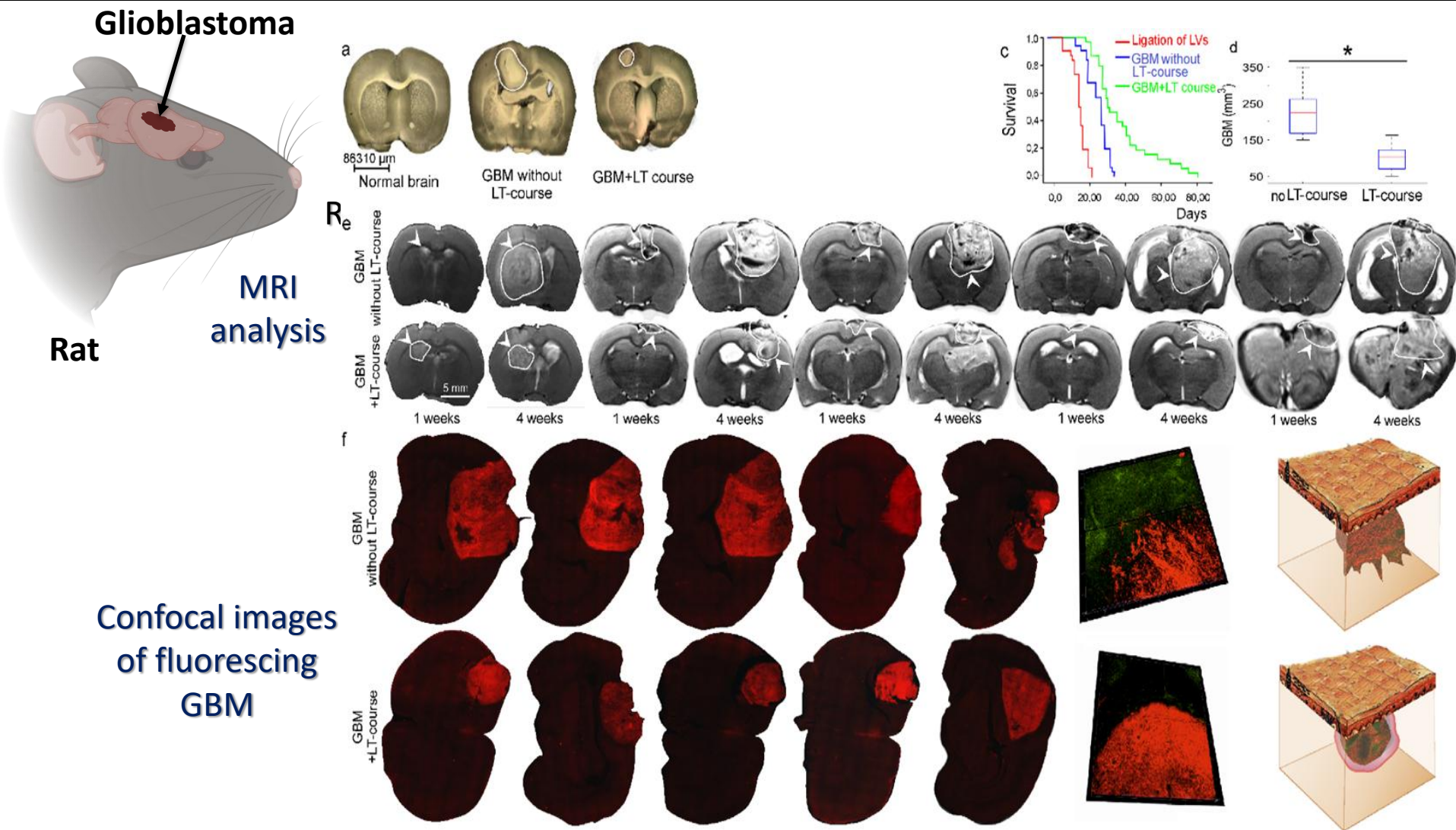


Light penetration



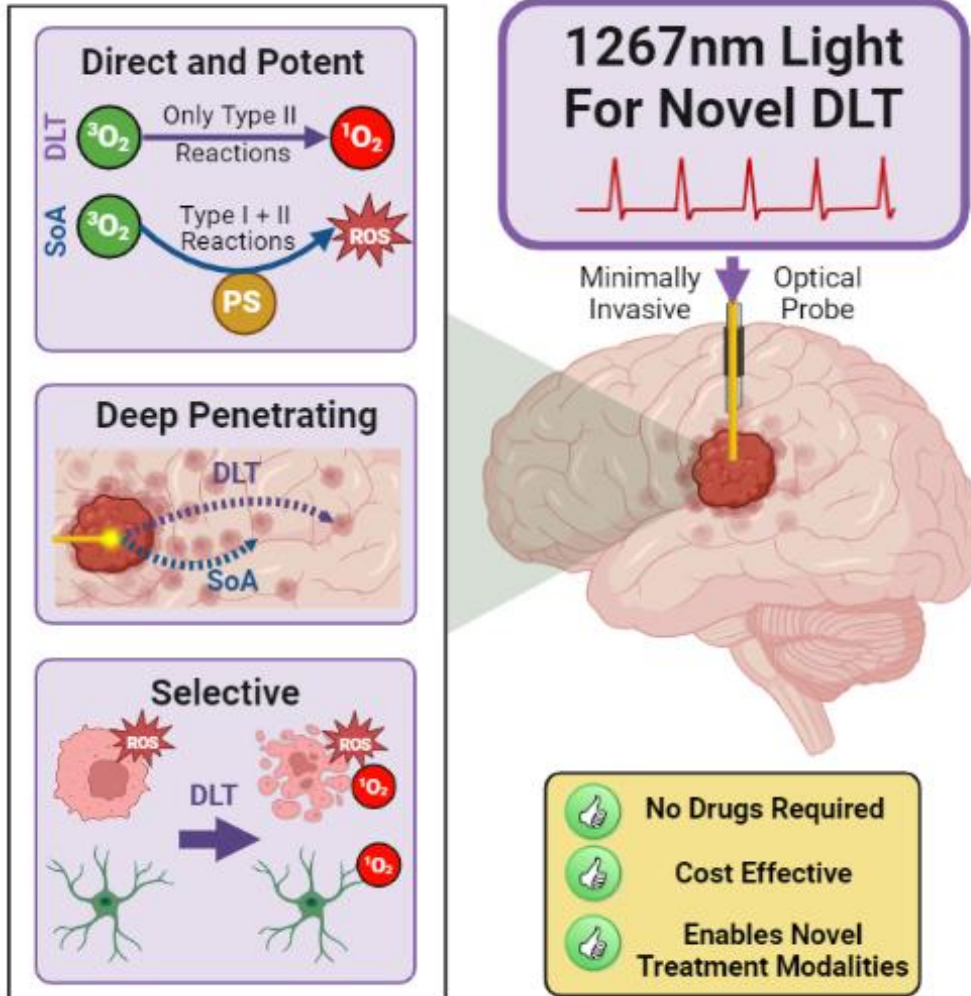
Galiakhmetova, D. et al. IEEE JSTQE, Biophotonics, 29.4, 1-11, 2022.

NIR-LT suppresses GBM progression and increases rat survival rate

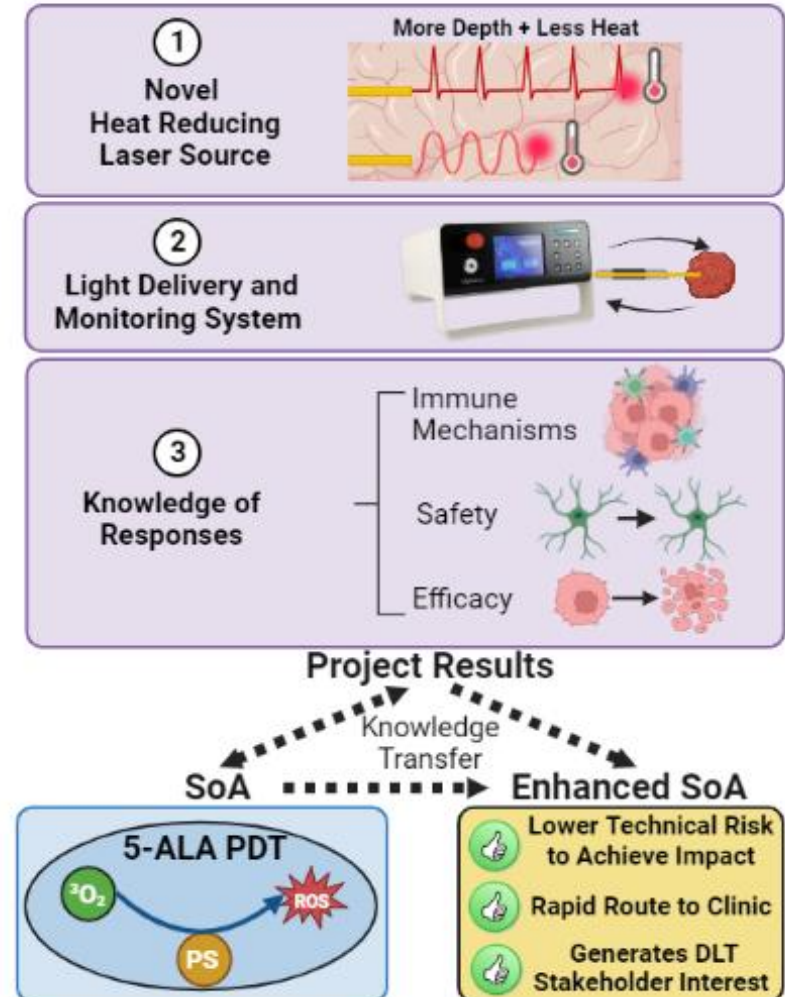


Pathfinder GlioLight project

Long-Term Vision



Project Results

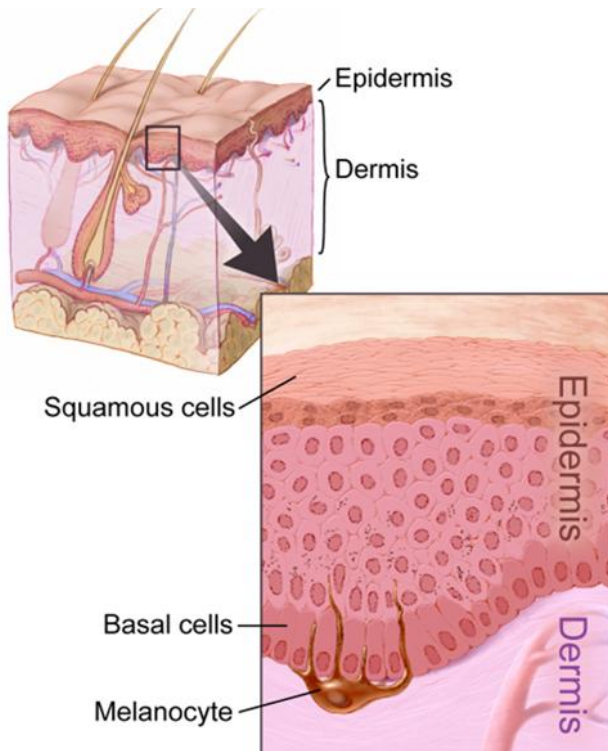


Motivation to work with melanoma

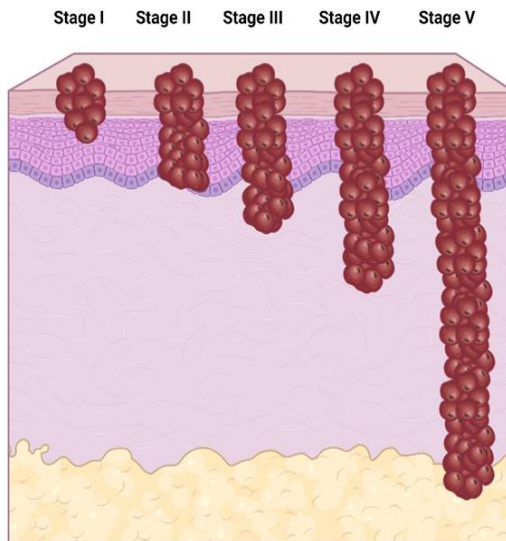
- Reduction of laboratory animal used as in pre-clinical studies
- Developing technology for cancer treatment without photosensitizer
- Deep tissue penetration
- Resolving high melanin absorption issue
- Optimising dosage for apoptosis and necrosis of melanoma cells



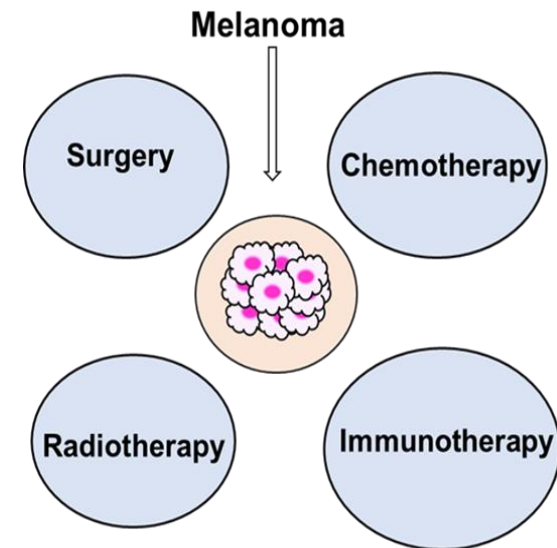
Introduction to melanoma



Stages of melanoma

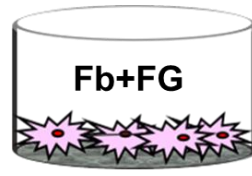
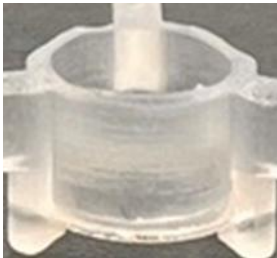
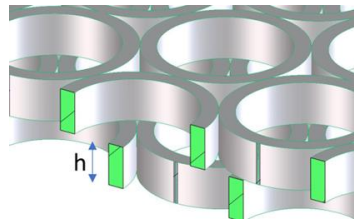


Conventional treatments

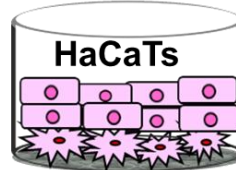


Development of FSE and Melanoma-FSE on two photon printed 3D scaffolds

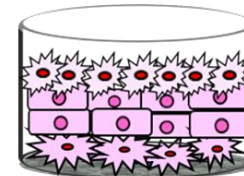
Scaffold



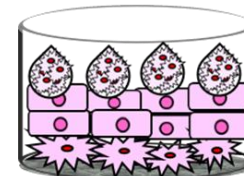
D-0



D-4

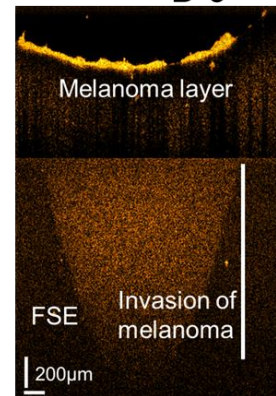
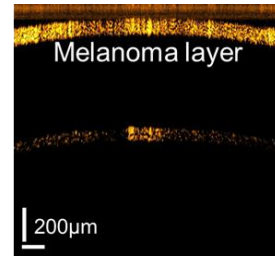


D-5

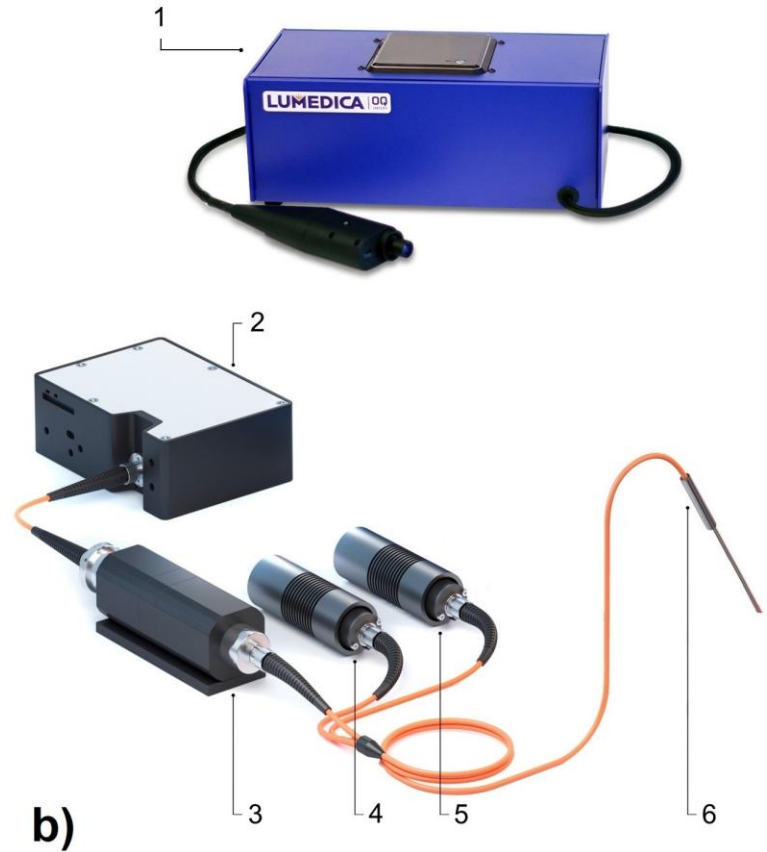
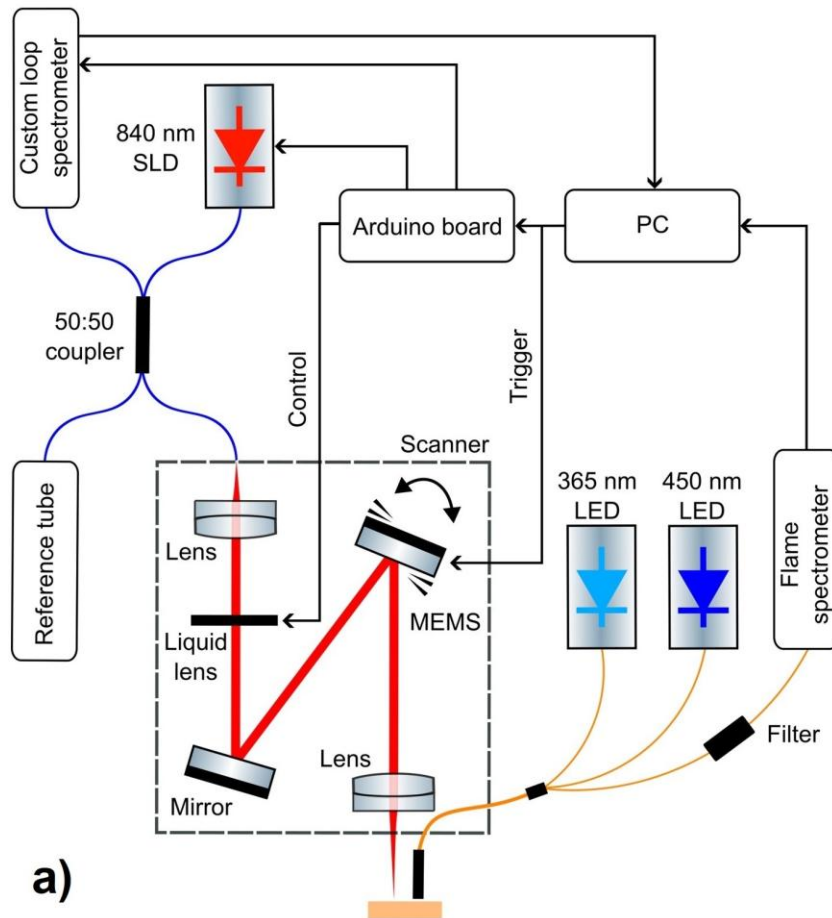


D-9

-  Melanoma
-  HaCaT cells
-  Fibroblasts



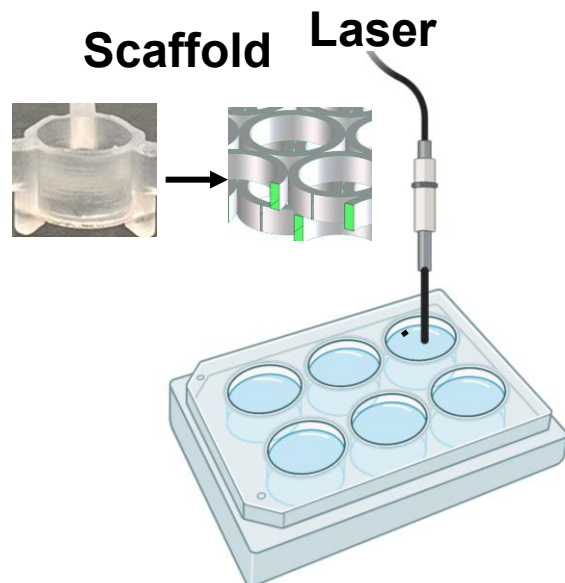
Multimodal OCT and fluorescence spectroscopy system



The experimental setup: 1- OCT system, 2 - spectrometer, 3 - filter holder with long-pass filters, 4 - LED 365nm 5- LED 450 nm, 6 - optical probe

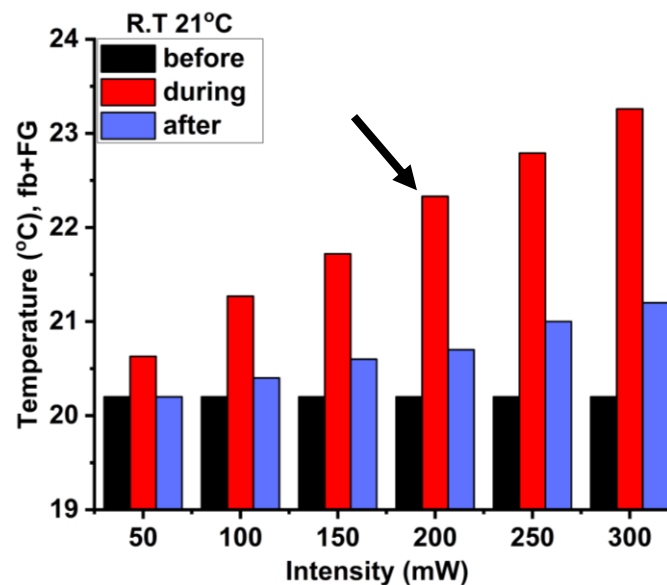
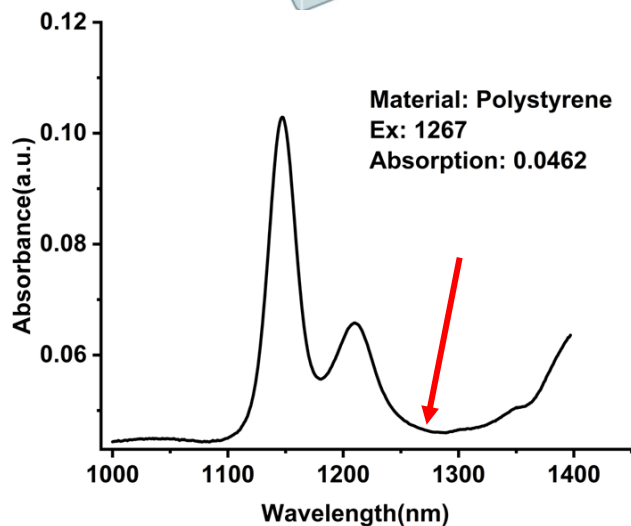
Arooj et al, Biomedical Optics Express, v.15(11), p.6299, 2024

Development of FSE and Melanoma-FSE on two photon printed 3D scaffolds



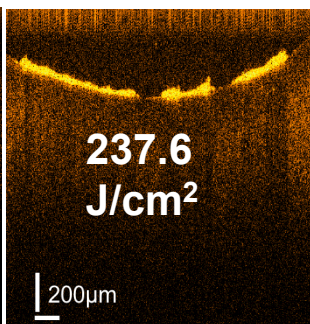
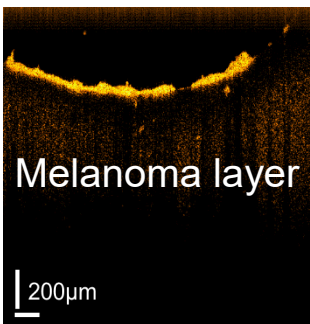
Accumulated doses

Samples	Sample 1	Sample 2	Sample 3
Exposure time	2-mins	4-mins	6-mins
Dose	237.6 J/cm ²	475.3 J/cm ²	712.9 J/cm ²

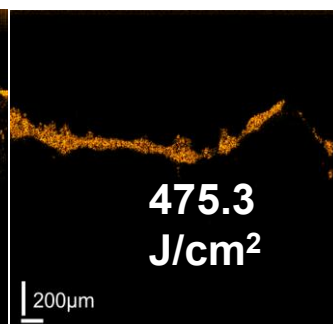
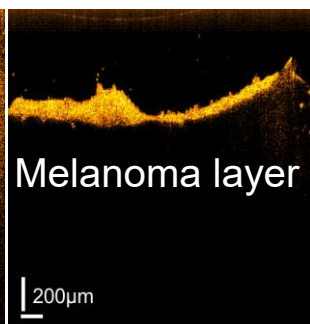


Metabolic and morphological evaluation of 9-days Melanoma-FSE after NIR 200mW laser irradiation

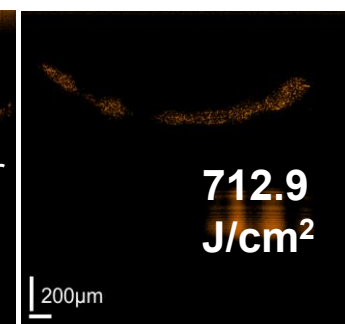
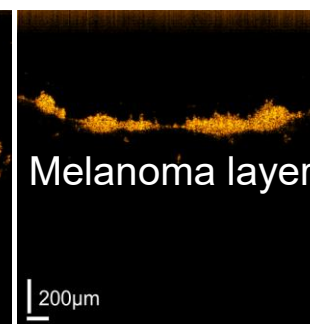
Sample 1 - 2min



Sample 2 – 4min



Sample 3 – 6min



Before laser

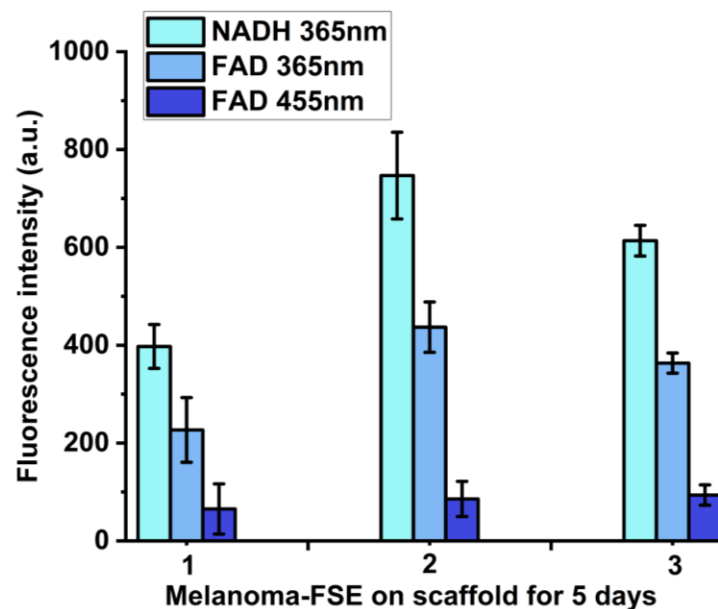
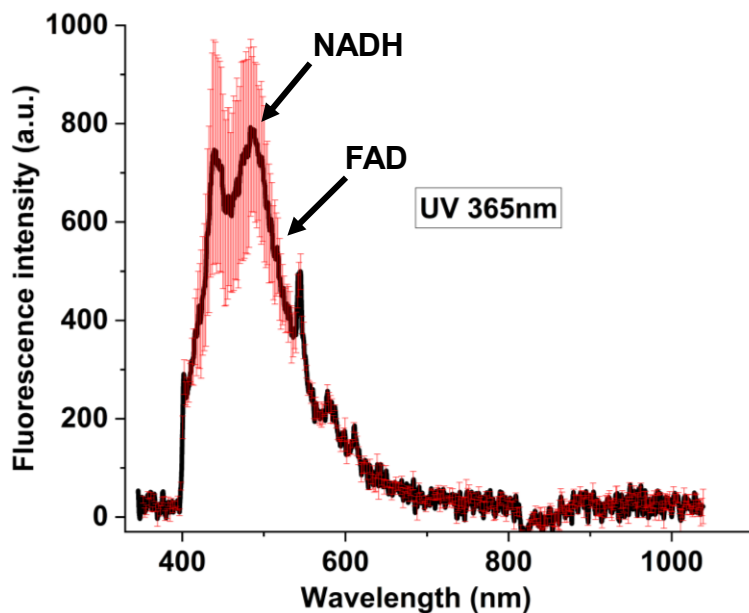
After laser

Before laser

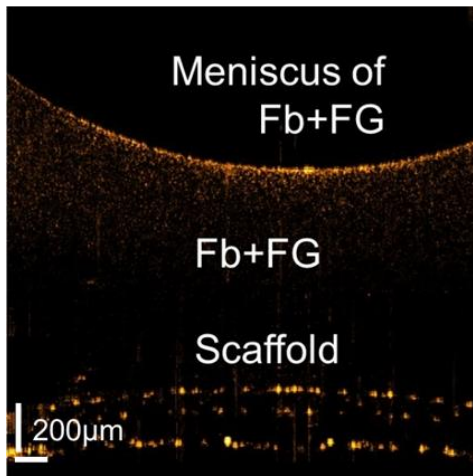
After laser

Before laser

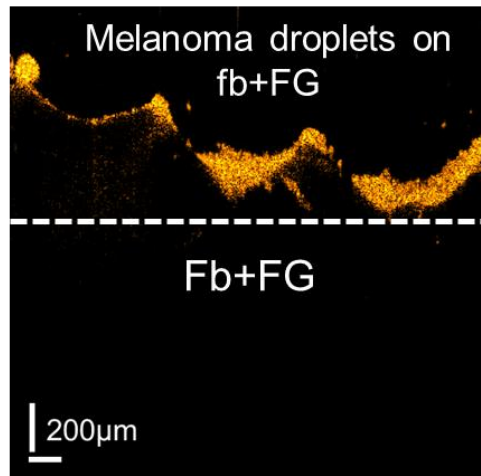
After laser



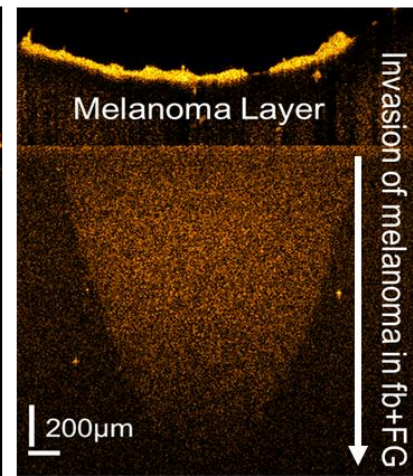
Evolution of Melanoma-FSE and its suppression after NIR laser irradiation



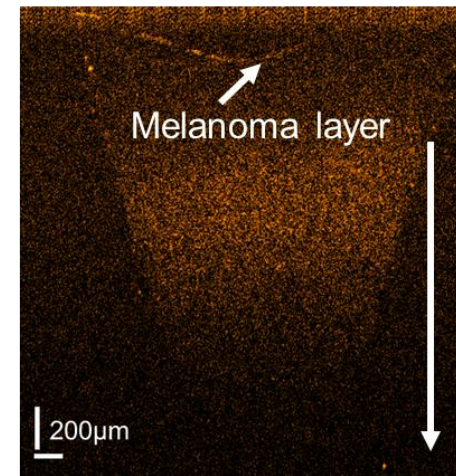
Fb+FG on scaffold for 4 days



Melanoma on Fb+FG at 5th day



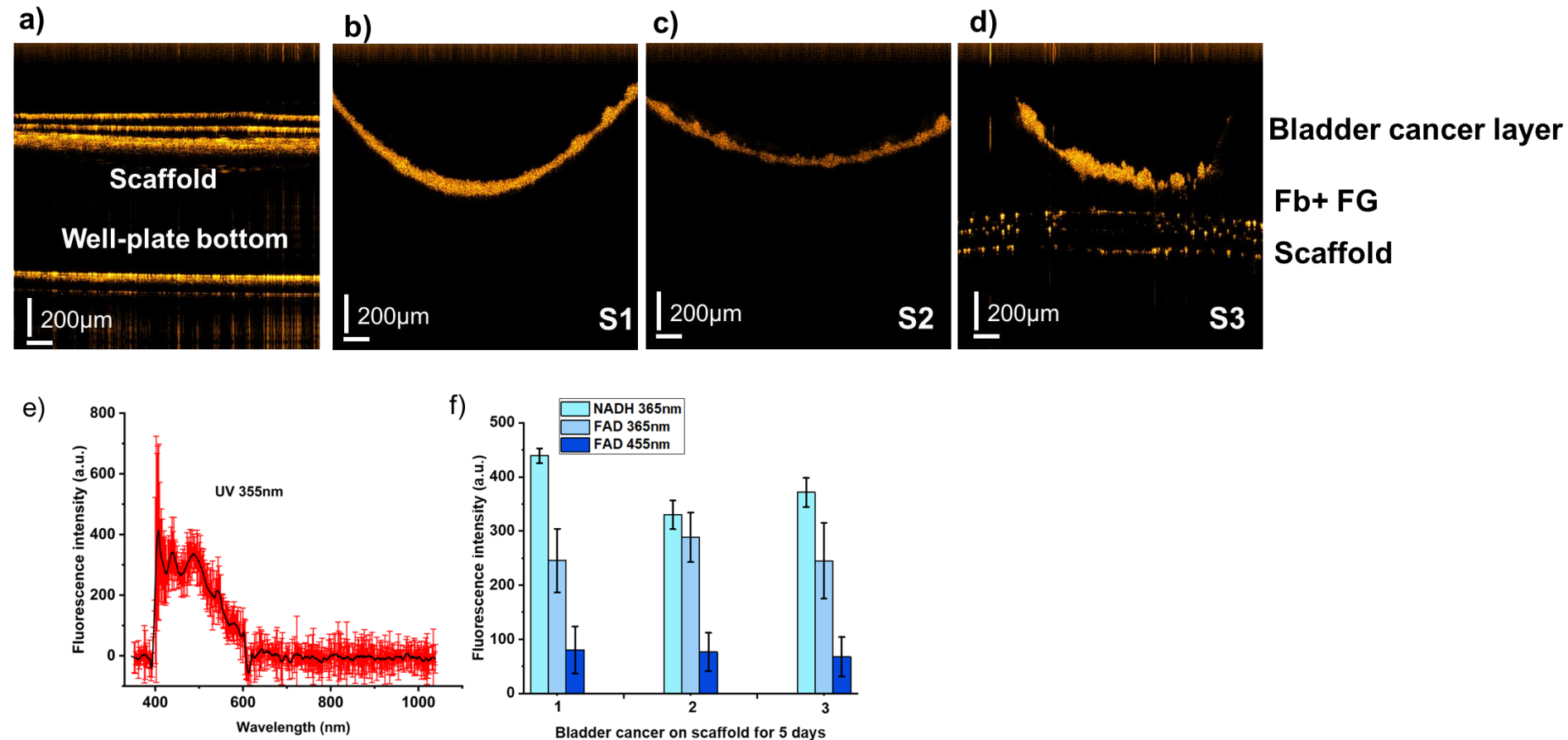
Melanoma layer and invasion in Fb+FG after 9 days (before laser interaction)



After laser treatment for 2 mins

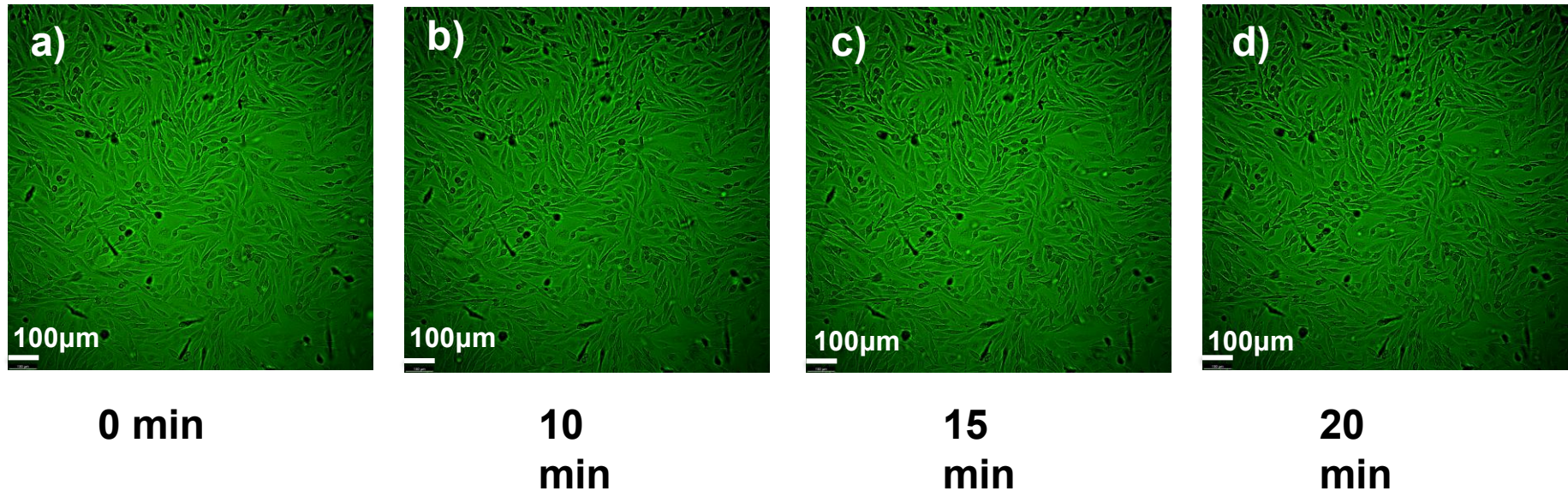
Arooj Khalid, et al, Photonics West, San Francisco, US, 13299-19, 2025

Metabolic and morphological evaluation of 9-days non-muscle invasive bladder cancer (NMIBC) models by FS-OCT system



Metabolic and morphological evaluation of bladder cancer (RT4), non-muscle invasive cancer cells in Fb+FG for 5 days of culturing. (a) Representative OCT image of scaffold in air, (b-d) Representative OCT images of bladder cancer (S1,S2,S3). Scale bar: 200 μm . (e) Fluorescence spectra of 5 days of culturing of RT4 Bladder cancer for UV excitation. (f) Maximum fluorescence intensity of 5 days of culturing of Fb + FG at 365 nm and 455 nm excitation wavelengths. Data are presented as mean $\pm$ SD (n = 3, 3D samples).

Detection of apoptosis and necrosis in NCH-82 cells by Annexin V/PI after 1267nm laser irradiation



Representative fluorescence images of 2D cell culture of **NCH-82** illustrating the effect of **1267nm** (CW), **4 min cumulative irradiation** (2 min irradiation + 2 min rest+ 2 min irradiation) at **200mW**, laser-induced apoptosis and necrosis, stained with Annexin V-FITC and Propidium Iodide a) after laser illumination and incubation with Annexin V/PI b) after 10 minutes, c) after 15 minutes, d) after 20 minutes of laser irradiation

Concluding remarks

We have demonstrated direct glioblastoma suppression by 1267nm laser irradiation

1267nm laser irradiation can induce apoptosis in melanoma but not in non-melanoma cancer cells

3D Human melanoma-FSE for lab testing represents significant advancement in cancer research

Treatment of Melanoma-FSE by 1267 nm can aid in optimisation of therapeutic dosage

Non-invasive photonic based diagnostics is a useful tool to monitor 3D tissue growth

Acknowledgments

- **HE Pathfinder GlioLight project**
- **H2020 AMPLITUDE project**
- **EPSRC**
- **H2020 FETOPEN NEUROPA project**
- **COST TETRA project**
- **H2020 FETOPEN MESO-BRAIN project**
- **H2020 FET PROACTIV PLATFORMA project**
- **FP7 IP FAST-DOT project**



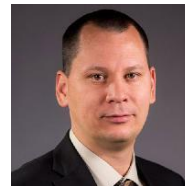
Acknowledgments



All GLIOLIGHT consortium



Prof Oxana V. Semyachkina-Glushkovskaya
Saratov State University, RF



Denis Bragin
Department of Neurosurgery,
University of New Mexico, USA



A. Fotiadi
I. Zolotovskii
Y. Saenko
A. Khokhlova
D. Stoliarov



Prof E. Rafailov



Dr. S. Sokolovski



Dr. N. Bazieva



Dr. A. Yadav



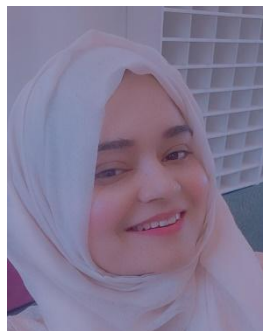
Dr. V. Dremin



Dr. D. Stoliarov



Dr Diana Galiakhmetova



Dr Arooj Khalid



Dr Nguen Minh Ngoc



Ms. N. Mohamed