Coupled Optical & Thermal Model of a Silicon Microprobe

Cs. Ö. Boros[1], Sz. Beleznai[1], P. Koppa[1], Z. Fekete[2], Á. Cs. Horváth[3]

[1]Department of Atomic Physics, Budapest University of Technology and Economics, Budapest, Hungary
[2]MTA EK NAP B Research Group for Implantable Microsystems, Budapest, Hungary
[3]Óbuda University Doctoral School of Material Science & Technology, Budapest, Hungary

Abstract

The topic of my work is modeling of a multimodal waveguide microprobe which is suitable for deep brain infrared stimulation. The goal of the research is the investigation of the therapeutic effect of optical IR excitation on biological active substances. In the physical model I investigated the transmission, in- and out coupling, scattering and absorption of the exciting light in the brain. I developed the optical-thermal coupled FEM model of the device, which calculates the temperature distribution of brain tissues around the microprobe.

Our model was developed using ray optics and heat transfer in solids physics. We assumed that the surfaces have no geometry with characteristic widths of the wavelength. The model has three main part: an optical fiber, a silicon microprobe and a water bulk. The λ=1.55μm wavelength rays come from a point source, with conical distribution, and have 10mW total power. The fiber has a=25μm core radius - so according to the analytic estimation it is strongly multimodal - and NA=0.3 numerical aperture. The fiber coupled to the microprobe with a focusing lens, which has ρ=558μm radius. The microprobe has a 3780μm x 3534μm body, and a 5000μm length, 400μm wide shaft. Due to the high silicon-air refractive index ratio, the shaft functions as a waveguide. At the lens and at the end of the shaft the rays reflect on the air-silicon boundary, so we have backwards scattered rays. We placed detectors around the device to measure the power distribution around. The result shows that the 53% of power go to the front, 35% to back and 12% to the sides. The efficiency is in good agreement with the analytic estimation of the efficiency using only normal rays and Fresnel coefficients of the surfaces.

The material of the brain is modeled as water. To calculate the heat effect of rays we used the Ray Heat Source multiphysics feature, with Bidirectional Coupled Ray tracing Study. The front of the shaft is inserted to the brain, so the microprobe is in thermal interaction with it. We calculated the temperature distribution in the brain around the shaft, which has key role in the deep brain infrared stimulation. The results show us that using 10mW laser diode power we can reach 1-2°C temperature rise within 4mm radius area around the device.

Figures used in the abstract

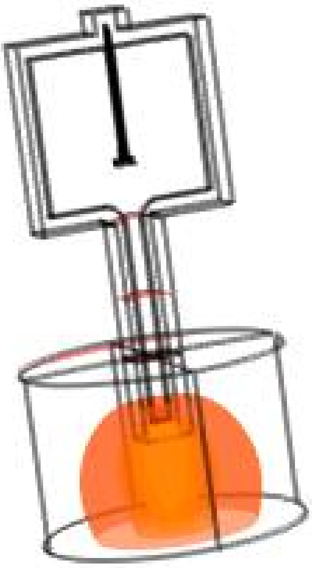

Figure 1: Isothermal contours around the microprobe.