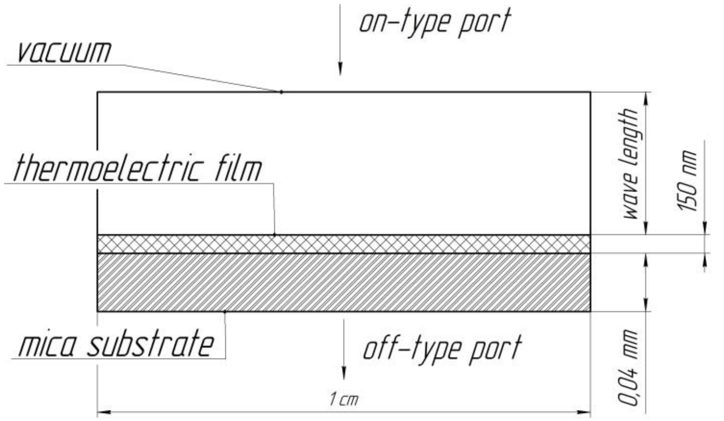
Heating Of Thermoelectric $Bi_{88}Sb_{12}$ Thin Film Due To THz Irradiation Absorption

A.Tukmakova[1], A.Asach[1], A.Novotelnova[1], I.Tkhorzhevskiy[1], N.Kablukova[1], P.Demchenko[2], A.Zaitsev[2], M.Khodzitsky[2]

1. Faculty of Cryogenic Engineering, ITMO University, Saint Petersburg, Russia
2. International Scientific and Research Institute of Bioengineering, ITMO University, Saint-Petersburg, Russia
3. Department of Physics, St. Petersburg State University of Industrial Technologies and Design, St. Petersburg, Russia
4. Terahertz Biomedicine Laboratory, ITMO University, Saint Petersburg, Russia

OBJECT UNDER THE STUDY: Structure based on $Bi_{88}Sb_{12}$ thin 150 nm film on the dielectric 40 μm mica substrate. The structure is placed in vacuum and is exposed to irradiation (0,14 THz; 30 mW).



Cross-section of the simulated object

	$Bi_{88}Sb_{12}$	mica
ϵ'	-28091.8	11.9
ϵ''	79432.1	4.3
σ[S/m]	881338.6	0.0008
$\kappa_{\parallel}$ [$Wm^{-1}K^{-1}$]	13.2	5.1
$\kappa_{\perp}$[$Wm^{-1}K^{-1}$]	5.1	0.5
c_p [$J\cdot kg^{-1}K^{-1}$]	124.4	880

$Bi_{88}Sb_{12}$ is expected to have a thermal response due to the irradiation absorption that can cause a thermoelectric effect (thermoEMF production).

COMPUTATIONAL METHODS:
The model is based on 2 general interfaces: radio frequency and heat transfer in solids:

$$\nabla \times 1\,\mu_r\,(\nabla \times \boldsymbol{E}) - k_0^2\,(\epsilon_r - j\sigma/\omega\epsilon_0)\,\boldsymbol{E} = 0,$$
$$\epsilon_r = \epsilon' - j\epsilon'',$$
$$\boldsymbol{q} = -\kappa\nabla T.$$

Electromagnetic heating is described with the following:

$$Q_e = Q_{rh} + Q_{ml} = \frac{1}{2}Re(\boldsymbol{J}\cdot\boldsymbol{E}^*) + \frac{1}{2}Re(i\omega\boldsymbol{B}\cdot\boldsymbol{H}^*).$$

Thin film is described using two interfaces: "thin layer" for solving the heat transfer problem:

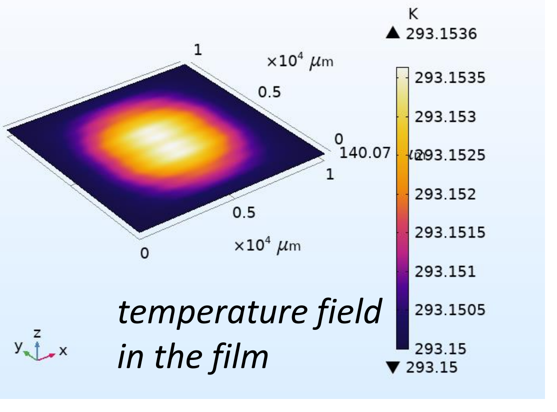
$$\nabla_t q_s = d_s Q_s + q_0,$$
$$q_s = -d_s\kappa\nabla_t T$$

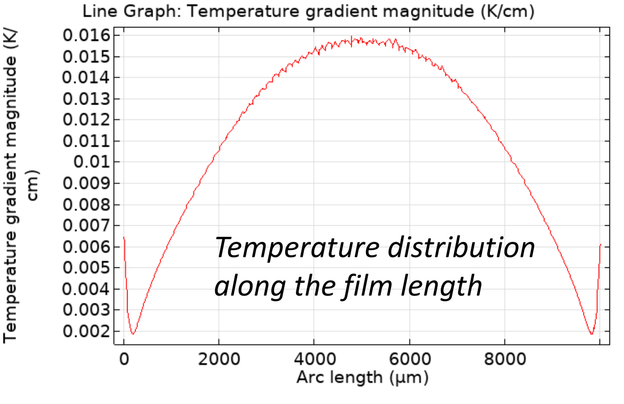
and "transition boundary condition" for solving the electromagnetic problem:

$$J_{s.up} = \frac{Z_s\boldsymbol{E}_{t.up} - Z_t\boldsymbol{E}_{t.down}}{Z_s^2 - Z_t^2}$$
$$J_{s.down} = \frac{Z_s\boldsymbol{E}_{t.down} - Z_t\boldsymbol{E}_{t.up}}{Z_s^2 - Z_t^2}$$

The solver type is frequency domain. The mesh is built based on free tetrahedral elements.

RESULTS:





CONCLUSIONS: Simulation shows the possibility of $Bi_{88}Sb_{12}$ films heating under the THz radiation. The simulated temperature gradient in the film is from 2 to 16 mK/cm.

astukmakova@itmo.ru