Optoelectronic Transducer with an Optical Fiber Transmission Used for Current Measurement

Jacek Gołębiowski, Lodz University of Technology, Department of Semiconductor and Optoelectronics Devices
211/215 Wolczanska Street , 90-924 Lodz, Poland

Introduction: The transducer's construction used for current measurement in medium voltage power lines for current values kA is shown (fig. 1). The transducer involves magnetic circuit with a gap in which a MEMS structure with a movable cantilever is placed. The beam is made of silicon with a NiFe layer (fig. 2). The beam with the ferromagnetic layer is deflected due to effecting magnetic field [1]. The deflection of the beam is measured by the optical fibre sensor [2,3].

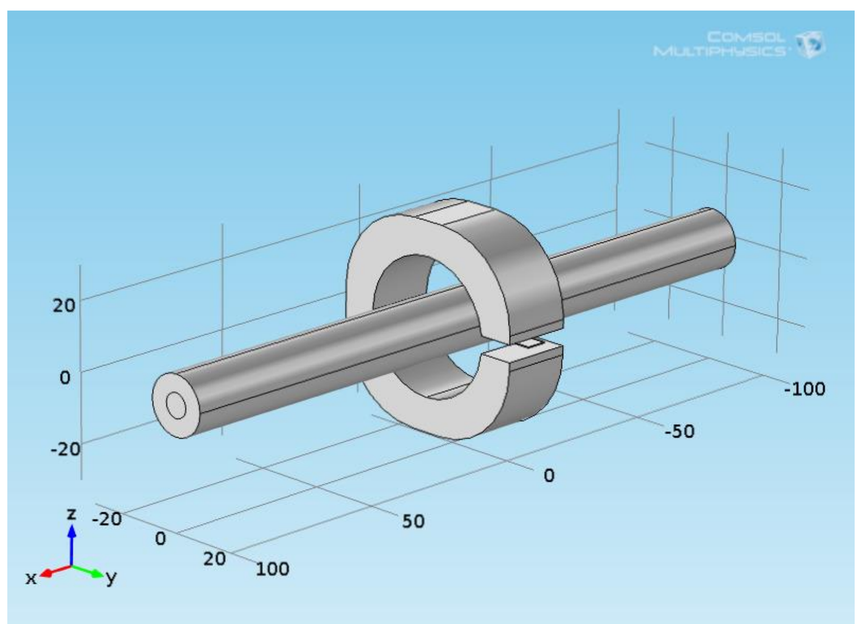

Figure 1. Construction of the current transducer

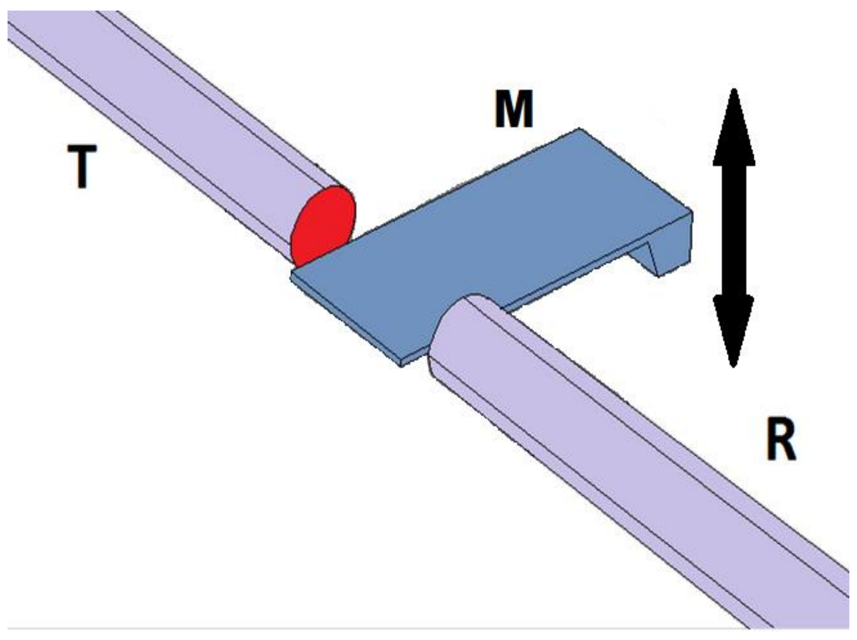

Figure 2. . Construction of the silicon M beam-through fibre-optic transducer T – transmitting fibre, R – receiving fibre

Numerical Models: The numerical models were prepared and computed in Comsol Multiphysics. Magnetic field module and stationary analysis were used. The line, for simplification of the model, consisted of two cylinders. The inner one material was steel; the outer one was made of aluminum (the diameter of the external 10mm, internal steel 3.5mm. The ferromagnetic core geometry was made by a work plane, basic figures and extrude operation. The simulations considered an influence of material's anisotropy and placing a silicon beam with a NiFe film in the air-gap.

The basic material properties were:

Steel – electrical conductivity σ= 4.032 [MS/m];
Aluminum σ=3.774 [MS/m]; **Permalloy** σ=1.74 [MS/m], relative permeability μ=1e6; **NiFe** – density 7860 [kg/m^3], E= 152[GPa], poisson's ratio v= 0.27;
Si <100> density 2329 [kg/m^3], E=160e9[GPa], v =0.28.

Free tetrahedral, predefined (fine) mesh was used. A solution time for single model, considering all current steps, was about few minutes. The number of degrees of freedom for different models from 70 to 130 thousand.

Was studied magnetic field distribution in the air gap of various parameters of the magnetic circuit (fig. 3,4). Beam deflection was tested in a magnetic field [3,4].

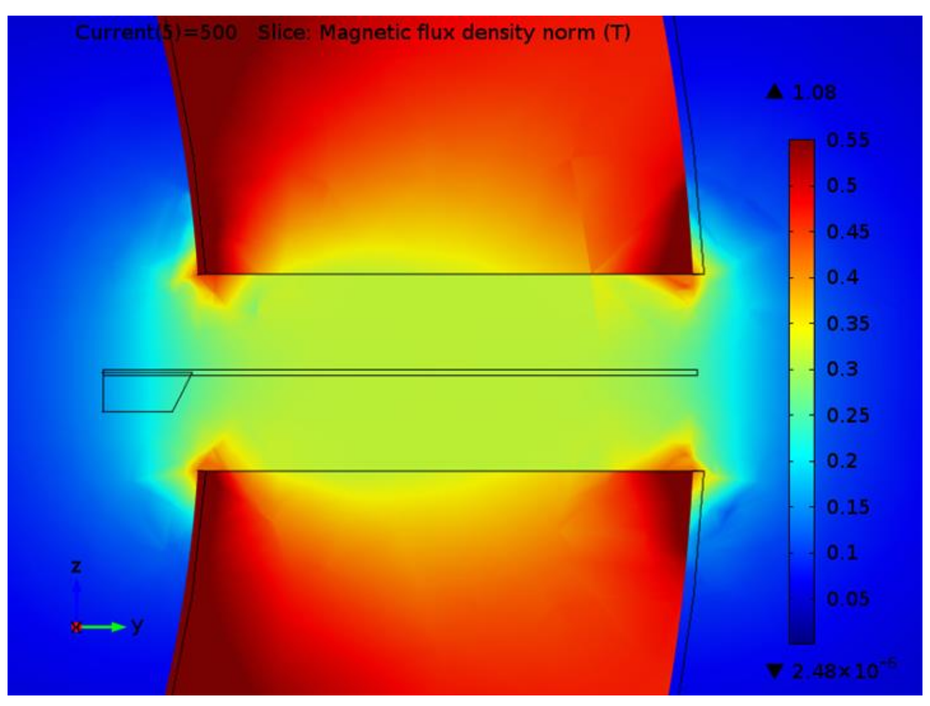

Figure 3. Magnetic flux density in the air-gap

Results: Results show distribution of magnetic flux density for the different values of current supplying the line, for heights of the air-gap from 2 mm to 4 mm (the diameter of the external 25 mm, internal 18mm, width 12 mm of the ferromagnetic toroidal core) (fig. 5).The silicon beam was 50μm thick (width 2mm, length 4 mm), Ni50%Fe50% was 10μm.

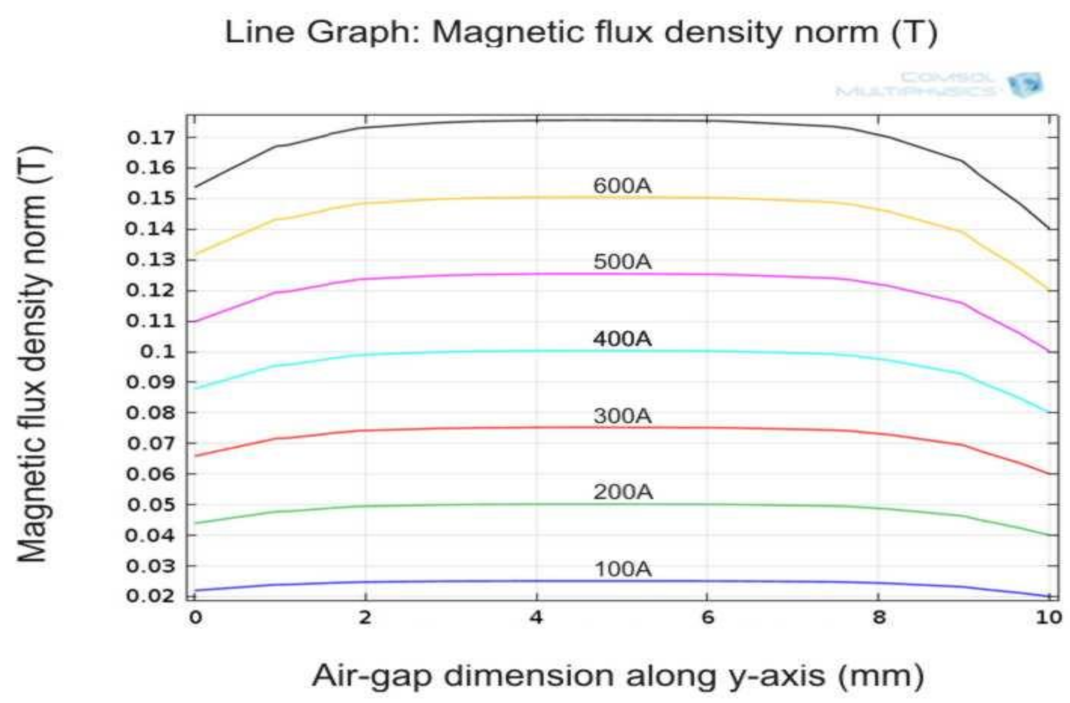

Figure 4. The distribution of magnetic field along the air-gap (width 4mm)

Simulation were computed for the different current values from 100 A to 700 A, typical for power lines.

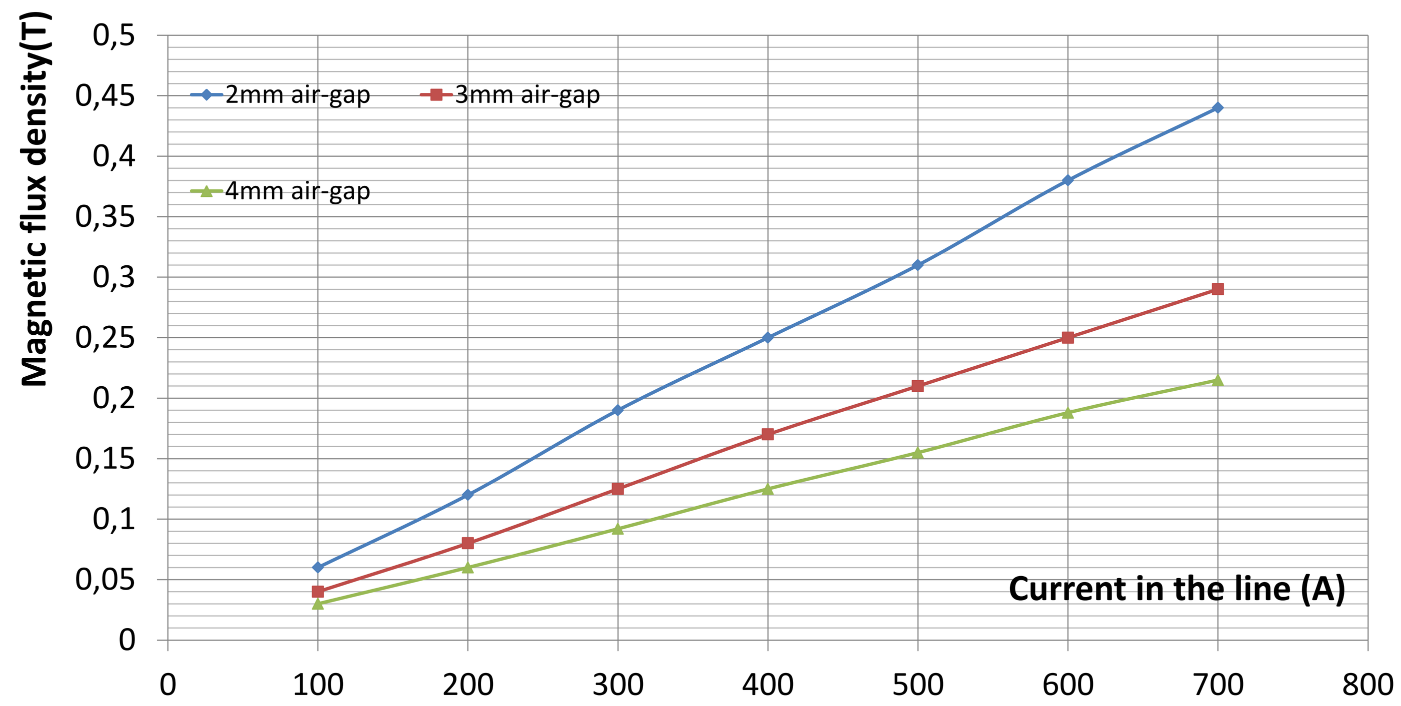

Figure 5. Magnetic flux density in the air-gap in function current supplying the line

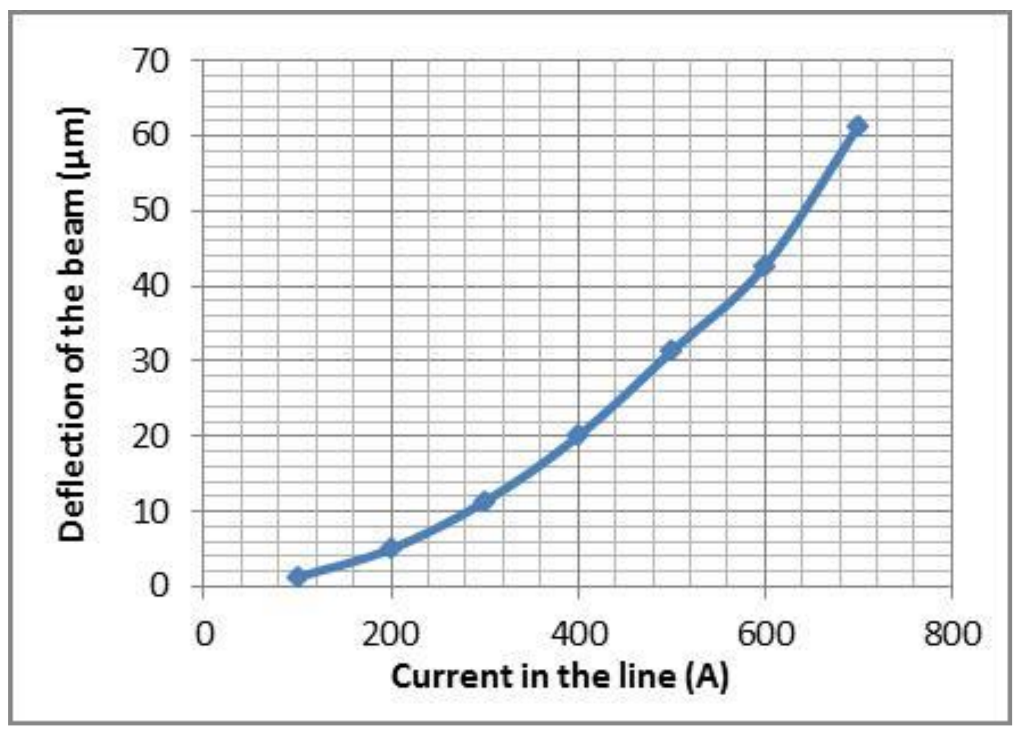

Figure 6. The beam's deflection in function of current in the power line, air-gap 2 mm

Conclusion: The study shows simulation results of the construction of the current transducer used in power lines measurements. The use of Comsol Multiphysics and AC/DC Module helped to determine the values of magnetic flux in the air-gap of the toroidal ferromagnetic core. The study showed that magnetic flux in the air-gap grows linearly with the value of the current in the power line. As for the air-gap, increase of the height of the air-gap from 2mm to 4mm resulted in 50% decrease of the magnetic flux in the air-gap. However, a dependency between the height of the air-gap and the magnetic flux is not linear. The study proves that the use of optoelectronic transducer is appropriate. The construction of sensor consisting of two plastic optical fibres (980/1000 μm– core/ cladding, NA = 0.5) placed opposite each other [5] , emitted optical power was P = 0.3 mW. For a range of changes to 100 μm were obtained changing the optical power of about 5 μW.

References:

[1] J.W.Judy, R.S.Muller, Magnetically actuated addressable microstructures, Journal of Microelectromechanical Systems, vol. 6, no. 3, pp 249-256, 1997
[2] S.Binu, V.P. Mahadevan Pillai, N.Chandrasekaran, Fibre optic target reflectivity sensor, Opt Quant Electron, 39 , pp 747-752, 2007
[3] J.Golebiowski, Microelectromechanical transducer with optical readout for magnetic flux density measurements, Electrical Review, no. 5, pp 22-26, 2012
[4] J.Golebiowski, S.Milcarz, Numerical Modeling of MEMS Sensor with Planar Coil for Magnetic Flux Density Measurements, Proc. Comsol Confer., Milan, 2012
[5] S.Milcarz,J.Golebiowski,, Transmission fibre-optic transducer used for a silicon structure's displacement measurement, Electrical Review, no.11, pp 120-122, 2014