Terahertz Biomedicine Laboratory

ITMO UNIVERSITY

METAL GRATING TERAHERTZ POLARIZERS ON SUBSTRATE

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Introduction

- Effective terahertz polarizers are needed for controlling polarization of THz sources and conducting polarization-sensitive experiments, such as studies of chiral media, biological samples and other objects
- Most THz sources generate low power which requires polarizers to have low transmission losses along with good extinction of undesired polarization
- Different manufacturing technologies for producing polarizers have different limitations; therefore understanding the dependence of polarizer performance on its dimensions is needed to choose the appropriate design for given requirements

Wire-grid polarizers

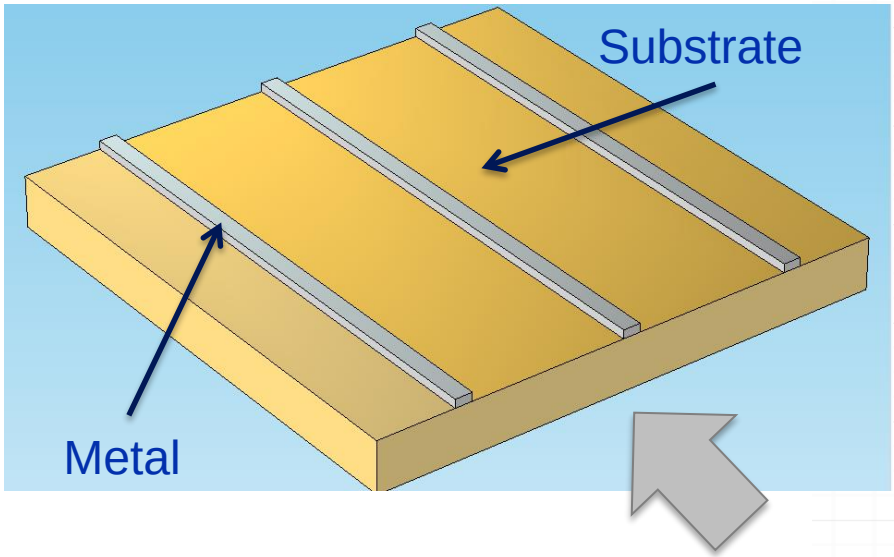
- Wire-grid polarizers have high extinction ratio and low losses
- Free-standing wire-grid polarizers are fragile and hard to manufacture
- Substrate-based wire-grid polarizers are more robust and easy to manufacture but have more losses

Aim of the research:

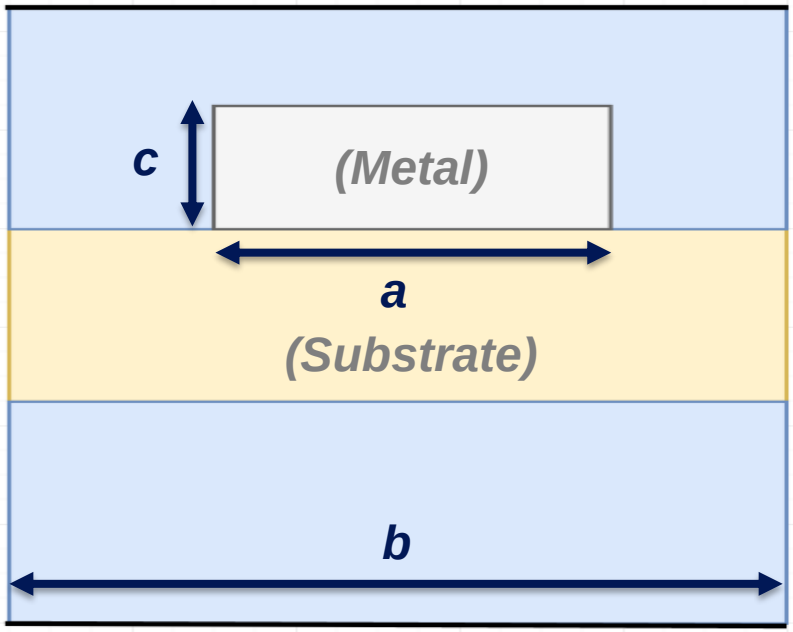
Calculating the dependencies of a substrate-based wire-grid polarizer extinction ratio and transmission losses via finite element method on the wire-grid dimensions (wire-grid period, fill factor and metal wire thickness) in the 0.1–1 THz frequency range

Views of the polarizer structure

General view

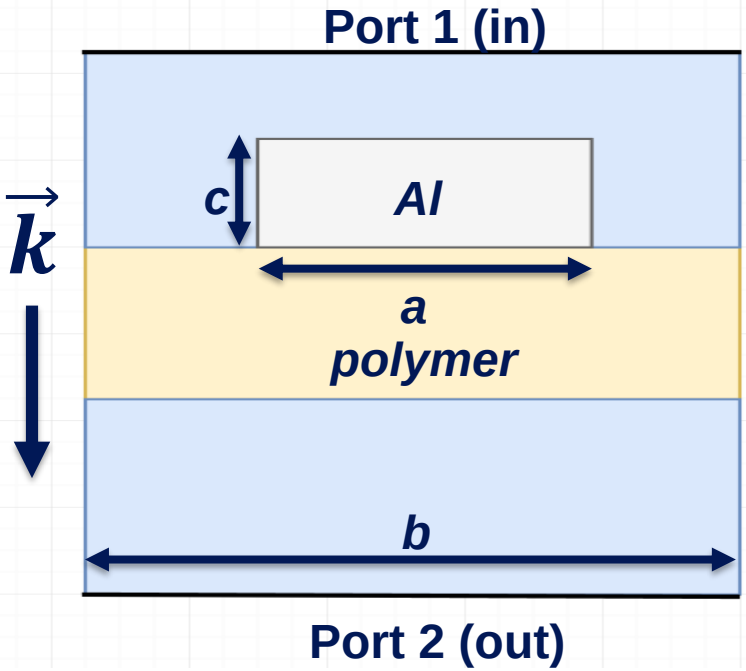


Front view (one wire)



- Variable polarizer parameters:
  - Period ***b***
  - Fill factor ***a/b***
  - Metal thickness ***c***

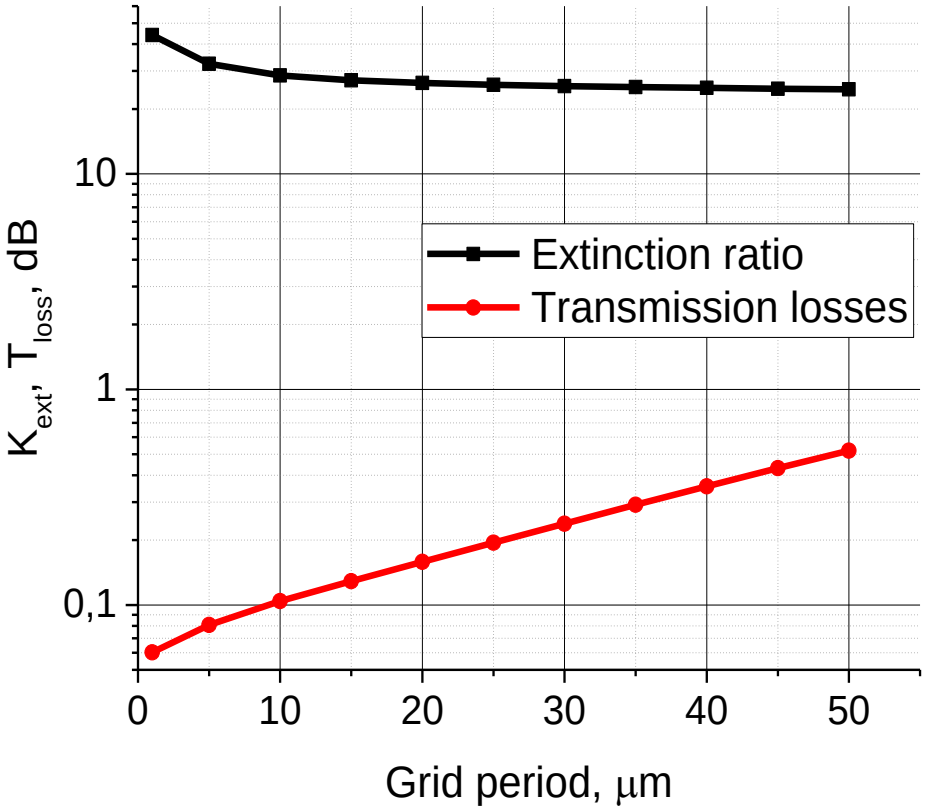
Numerical simulations



- COMSOL Multiphysics
- The cell size is equal to the wire-grid period
- Periodic boundary conditions at the cell boundaries
- Perfect impedance matching at the ports
- THz wave properties:
  - TE or TM plane-polarized
  - Monochromatic
  - 0.1–1 THz sweep with 20 GHz step

TE polarization:	$\vec{E}$ ⊗
TM polarization:	$\vec{E}$ ⟷

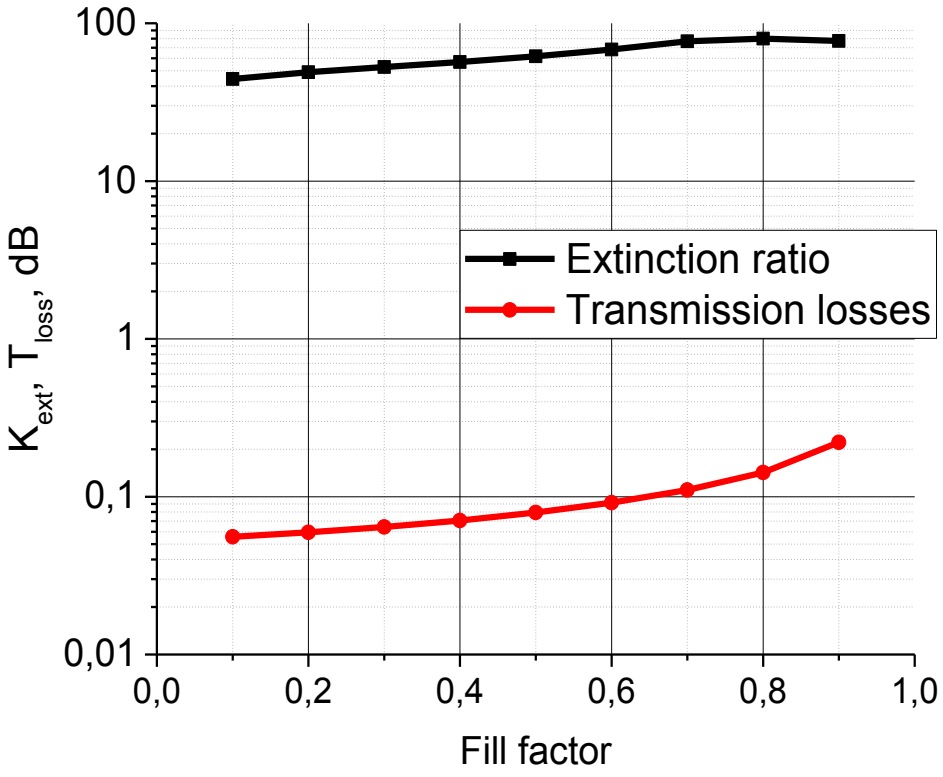
Dependence of the extinction ratio and transmission losses on the wire-grid period



- Clearly, smaller wire-grid period is preferable
- However, physical manufacturing of polarizers with a very short wire-grid period (less than 10–15 μm) can be difficult

Frequency	1 THz
Metal grid thickness	0.3 μm
Fill factor	0.3

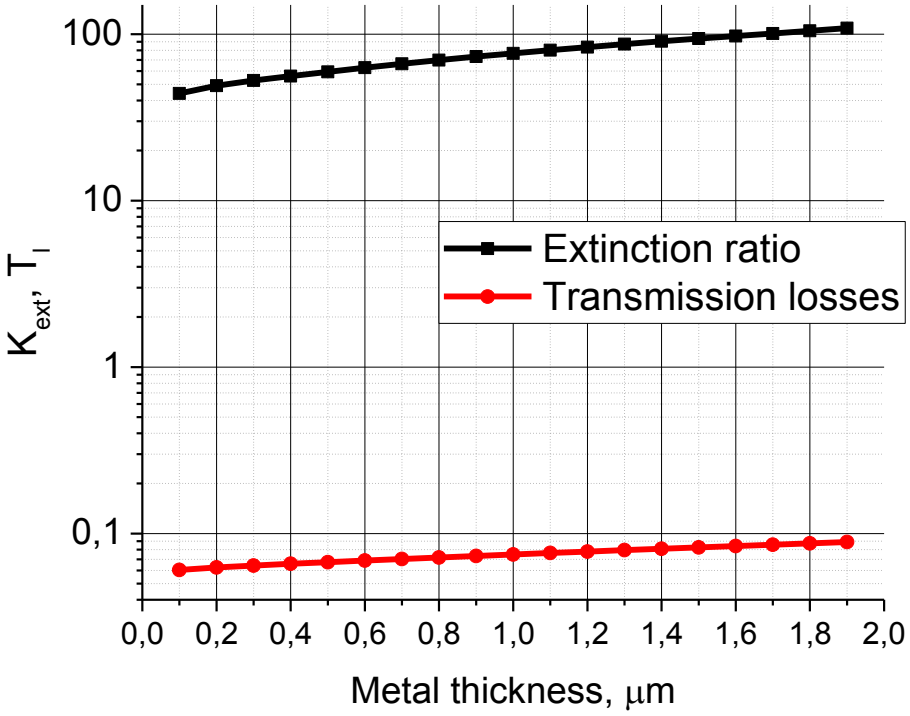
Dependence of the extinction ratio and transmission losses on the fill factor



- Increasing the fill factor improves the extinction ratio but also increases transmission losses
- Therefore choosing the optimal fill factor should take into account demands of the problem at hand

Frequency	1 THz
Metal wire thickness	0.3 μm
Period	1 μm

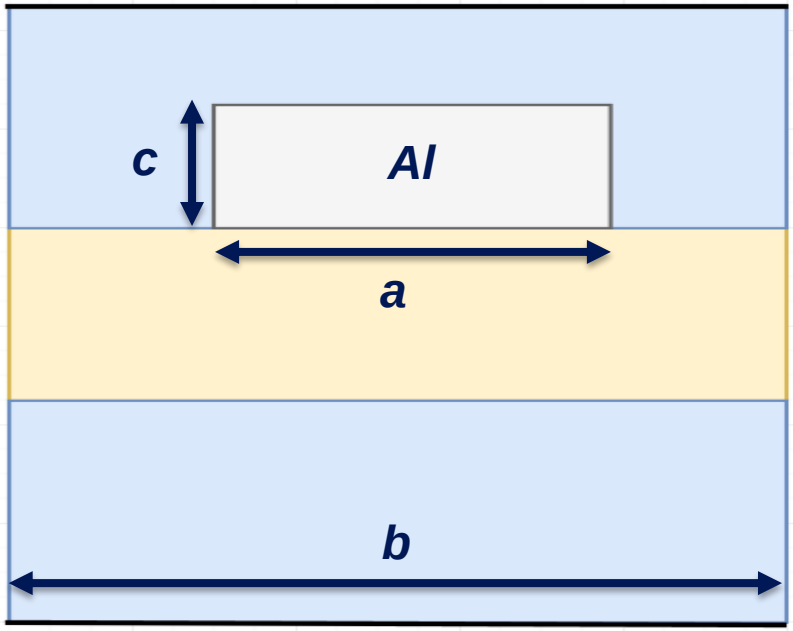
Dependence of the extinction ratio and transmission losses on the metal wire thickness



- As with the fill factor, increasing the thickness of metal wires improves the extinction ratio but also increases transmission losses
- Unlike the fill factor, the increase in losses is relatively small and may be negligible in many cases

Frequency	1 THz
Fill factor	0.3
Period	1 μm

Conclusions from the simulations

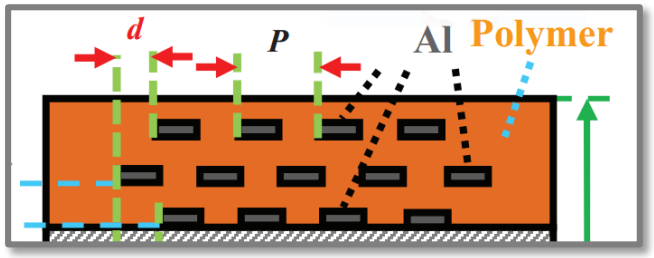


- Influence of wire-grid dimensions on polarizer performance:
  - Lower period ***b*** is preferable
  - Higher metal thickness ***c*** is generally preferable
  - Higher fill factor ***a/b*** is preferable but may result in higher losses

- All of the above dependencies need to be taken into account along with the limitations of the chosen manufacturing process

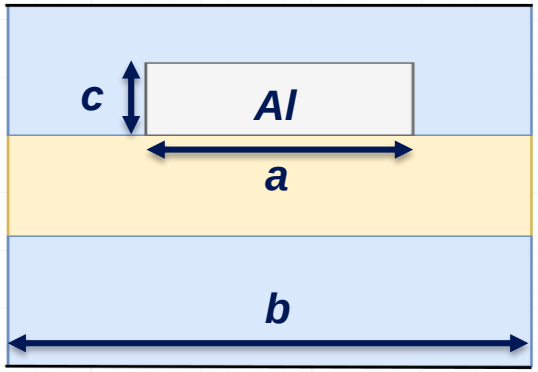
Comparison with another THz polarizer

The 3-layer polarizer*



Period	14 μm
Fill factor	0.5
Ext. ratio at 1 THz	90 dB
Losses at 1 THz	1.4 dB

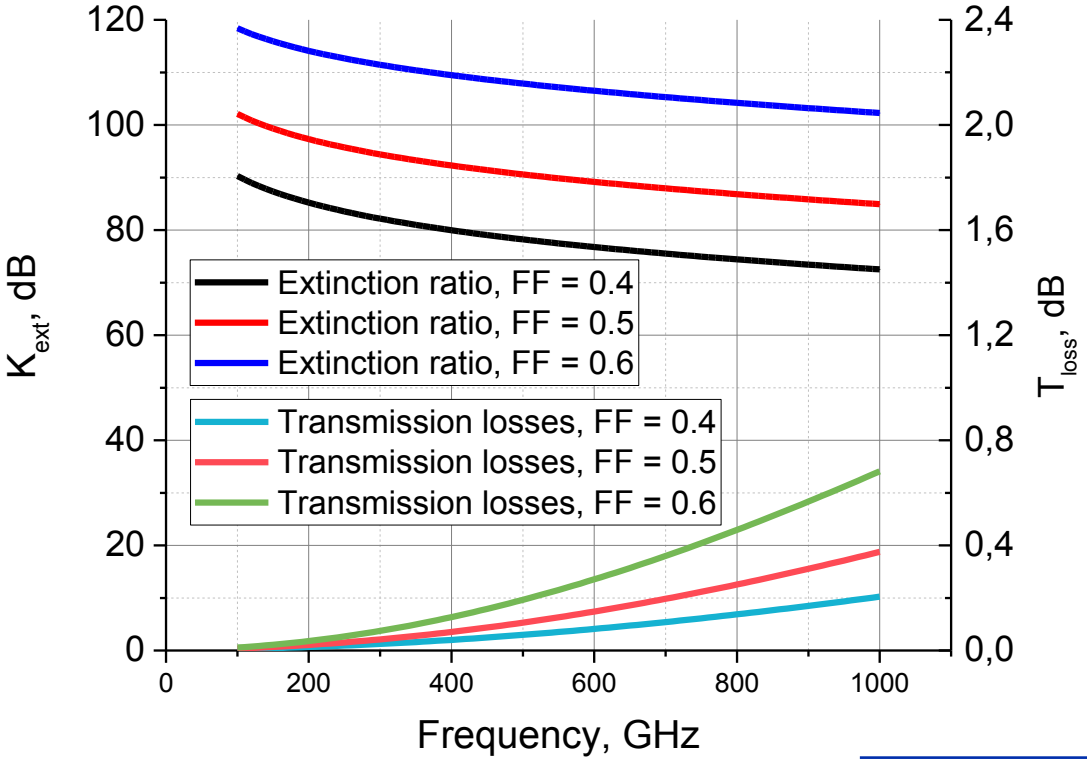
The single-layer wire-grid polarizer with the same period



Period	14 μm
Metal wire thickness	14 μm
Fill factor	0.6
Extinction ratio at 1 THz	100 dB
Losses at 1 THz	0.6 dB

*Huang Z. et al. Ultra-high extinction tri-layer thin-film wire-grid THz polarizer // 40th International Conference on Infrared, Millimeter, and Terahertz waves (IRMMW-THz). IEEE, 2015. P. 1.

The extinction ratio and losses of the sample single-layer polarizer. Variations for different fill factors



- Increasing the fill factor can significantly improve the extinction ratio at a cost of increased transmission losses

Period	14 μm		
Fill factor	0.4	0.5	0.6
Ext. ratio at 1 THz	73 dB	85 dB	100 dB
Losses at 1 THz	0.2 dB	0.4 dB	0.6 dB

Results

- Decreasing the grid period of a wire-grid polarizer leads to an increase in the extinction ratio and a decrease in losses
- Increasing the fill factor or metal grid thickness also improves the extinction ratio but at the same time increases the transmission losses
- An sample one-layer polarizer with period of 14 μm, metal thickness of 14 μm and fill factor of 0.6 has extinction ratio of about 100 dB and losses of less than 1 dB at a frequency of 1 THz

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Thank you for attention!

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