Nanostructured MIR Optical Filters
Product Requirements Document
Nano Group

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Document Number 01

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Authentication Block

Nanostructured MIR Optical Filters Product Requirement Document
(for OPE Senior Design)

Rev	Description	Date	Authorization
A	Initial PRD	28 October 15	AK
B	Updated Project Scope	10 November 15	PF
C	Final Edits	02 December 15	PF
D	Added Appendices	10 December 15	ALL

Table of Contents

The Nanostructured MIR Optical Filters project is an internally driven project. As such, its design inputs were derived from our interactions with our industry partner, Materion, as well as interactions with our faculty advisors, Professors Nick Vamivakas and Brian McIntyre.

Team Member Responsibilities:

All – use the program FDTD Solutions to design and characterize MIR filters as specified by the customer

Peter – coordinate the project, keep everyone on task, keep the team working together so that we may accomplish as much as possible

Ty – contact with the customer, keeping all parties up to date on the team's progress, coordinating budget and resources with customer

Andy – document handling, making sure all documents and permissions are in place for use of UR Nano facilities

Guntis – record keeping, documentation of designs, documentation of the team's progress

Vision:

The project team shall produce methods for designing and manufacturing nanostructures with optical properties that selectively transmit or reflect certain bandwidths of electromagnetic radiation, relying on the physics of diffraction and not interference.

Environment:

No application has been given that would require a specific environment

Temperature

32-100 °F - meets specifications

Relative Humidity

Non-condensing – meets specifications

In general, the filters should be able to survive in any lab environment without degrading.

Regulatory Issues:

N/A

Fitness for use:

The team must produce:

- High wavelength pass filter
    - 200mm 0.6 mm thick (SEMI standard) silicon substrates
    - Any size for proof of principle
    - Transmits 80-90% from 8-12 um
    - Transmits <1% from 1-7 um
- Design Study for high wavelength pass filters
    - What geometric patterns affect how smooth the passband is
    - What geometric patterns affect the location of the 50% transmission point
    - What geometric patterns affect the steepness of the switch
    - What geometric patterns affect the attenuation
    - What are the cost dependencies and trade offs of these features

It is desirable that the team produces:

- Design study for other types of filters
    - Low wavelength pass
    - Band pass
    - Band stop
    - Same geometric questions as above
- Manufacturing plan
    - How can these be mass produced
    - Cost and speed of production considerations
    - 3 to 10 mm rectangle filters
    - Trade offs between performance and manufacturing cost

Schedule:

fall semester:

December-

Get comfortable with design software.
Meet with Vamivakas and McIntyre to figure out manufacturing capabilities.

spring semester:

January-

Focus on getting the one specific spectrum asked for.
Get access to all materials and modes of manufacturing we will need.

February-

Start expanding from one design to try and find the variables that affect performance
Schedule time on the necessary fab/metrology equipment

March-

Continue figuring out design parameters that are relevant
Start producing proof of concept filters
Figure out manufacturing tolerances on relevant design parameters
Tweak designs based on measured vs. expected results and fabrication limitations

April-

Continue design study, expand to other types of filters if possible
Produce final filters
Take all necessary pictures and measurements
Put together final presentation
Present to school and Materion

Project Scope:

We are responsible for a design study of long-wavelength pass MIR optical filters. This includes both a design that meets the specifications above, and an explanation as to what different design factors there are and how they affect filter performance.

We are not responsible for any sort of manufacturing plan, or any devices on a larger scale than necessary for proof of concept.

Budget:

This project has an estimated production cost of $5000. This is expected to be provided by Materion, but that depends on us producing a working design that is reasonable to manufacture. Until then, we are purely design run, which is free.

Appendix A:

Patent No.: US 8,879,152 B2

Date of Patent: Nov. 4, 2014

OPTICAL BANDPASS FILTER SYSTEM, IN PARTICULAR FOR MULTICHANNEL SPECTRAL-SELECTIVE MEASUREMENTS

ABSTRACT

The present invention relates to an optical bandpass filter system that has at least one combination of a bandpass filter that provides a first nanostructured metallic layer (4) and a bandstop filter comprising a second nanostructured metallic layer (7), which are arranged one behind the other, and the layer thicknesses of which are different. The bandstop filter is tuned to the bandpass filter in such a way that it blocks a contiguous wavelength range that partially overlaps a pass band width of the bandpass filter. With the suggested optical filter system it is possible to create various filter characteristics side by side in a small space with a small pass-band width.

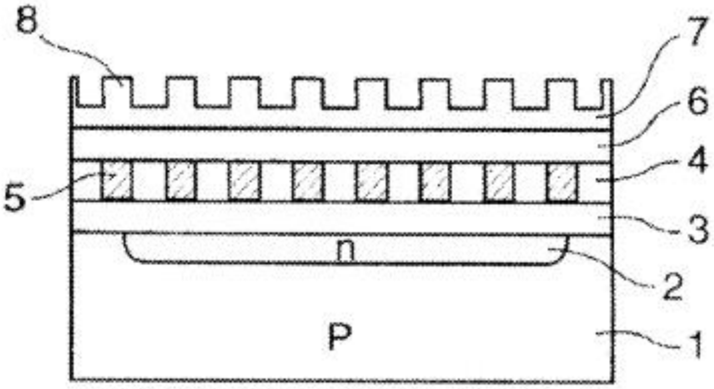

Fig 01
1 p-doped semiconductor substrate
2 n-doped well
3 dielectric intermediate layer
4 first metallic layer for bandpass filter
5 nanoapertures
6 dielectric intermediate layer
7 second metallic layer for bandstop filter
8 cylindrical or cuboid nanostructures

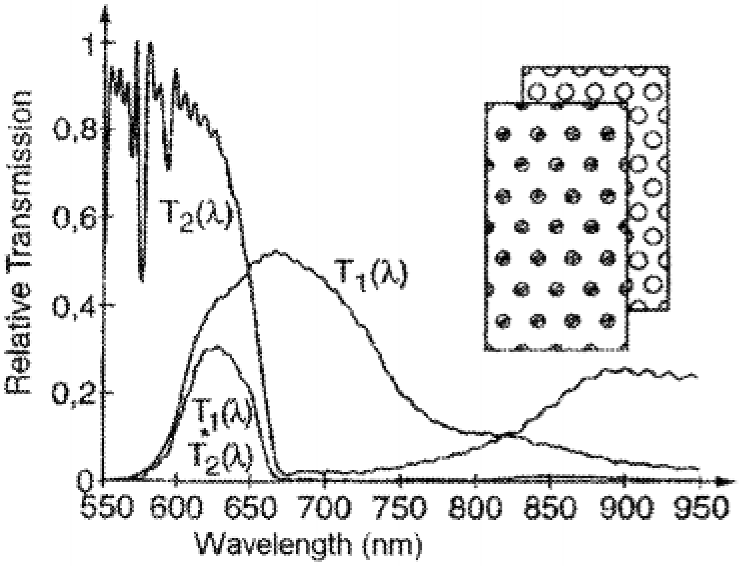

Fig 02: Relative transmission vs wavelength for the nanostructures (8 in Fig 01) labeled T_1, for the nanoapertures (5 in Fig 01) labeled T_2, and the convolution of $T_1 \circ T_2$ that creates the multilayer filter.

In relation to our product:

This patent can be considered the inspiration for the product we are designing. As opposed to other examples of nanostructures and nanoapertures being used for wavefront modification, this patent deals specifically with transmission and reflectance. This patent proves that the concepts are able to be produced in a laboratory, which gives our team hope that this is something we can design and manufacture (although for now just a proof of concept). Designing a product with a similar structure is something we are hoping to accomplish in practice and describe in this document.

Appendix B:

The following images are taken from simulations run on our personal computers using Lumerical's FDTD Solutions software. No useful design information was obtained from these simulations.

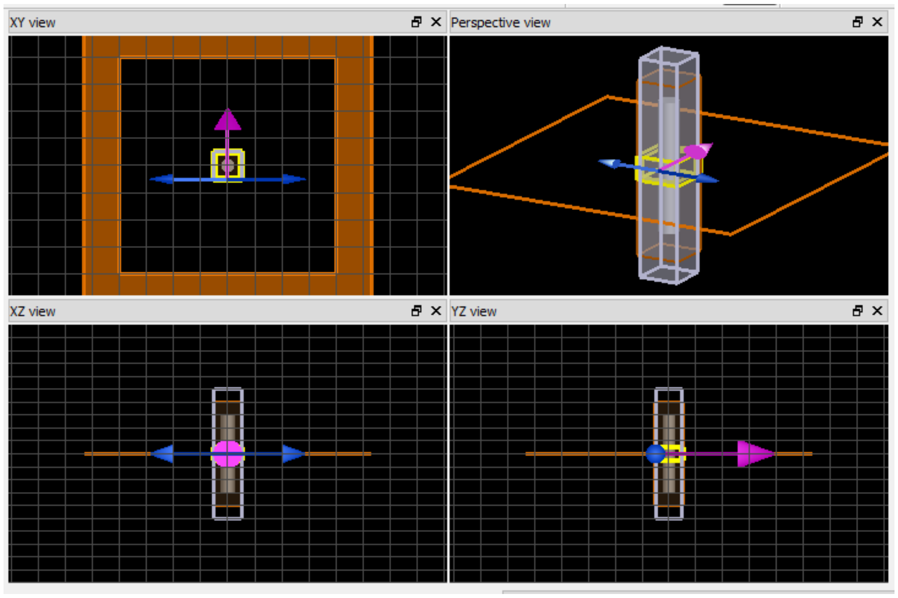

Figure 03: Test rendering of a nano-scale wire using Lumerical FDTD Solutions Software. This followed a simple tutorial put out by Lumerical.

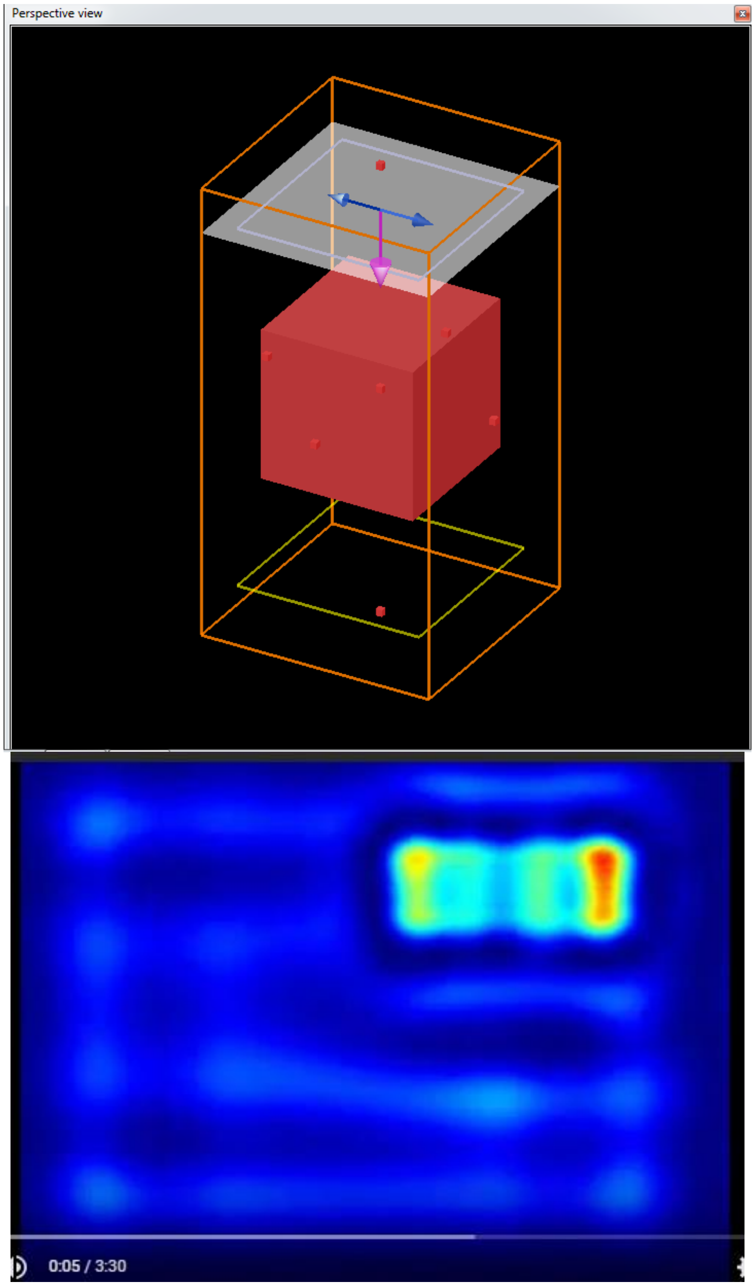

Figure 03: (top) Rendering of a single, 50nm tall, gold pillar placed on top of a silicon substrate. (bottom) Screenshot from the simulation video of electromagnetic interactions with the nanoscale construct.

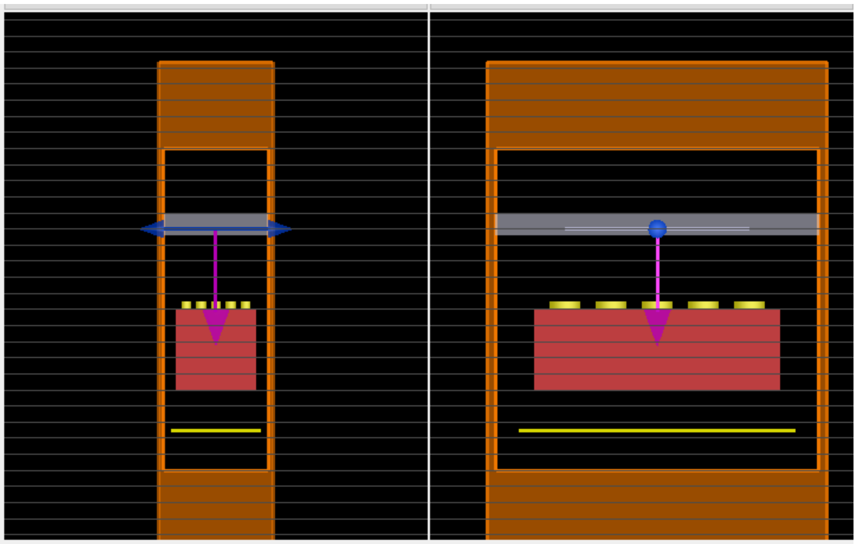

Figure 04: Array of 50nm tall gold pillars nested on top of a silicon substrate using Lumerical FDTD Solutions. This was too complex of a simulation to run, but the computers in the Hopkins Center will be able to run it.

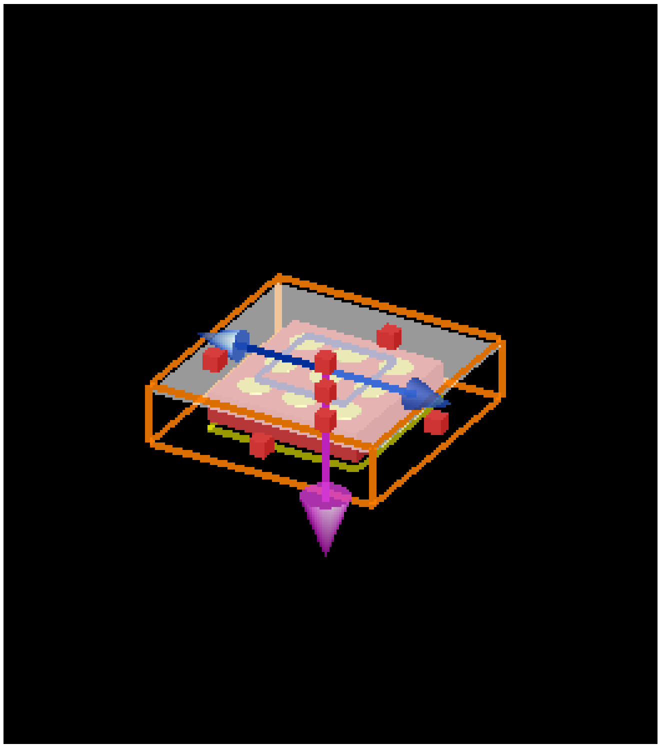

Figure 05: The most complex simulation run. It only worked on the lowest accuracy setting, and the results didn't tell us anything.