META®
Go Beyond.

Applications of Transparent Metal Mesh Nanostructures

Themos Kallos, Chief Science Officer, Meta Materials Inc.

20th April 2022AD

NASDAQ:MMAT

Forward Looking Statements

This presentation includes forward-looking information or statements within the meaning of Canadian securities laws and within the meaning of Section 27A of the Securities Act of 1933, as amended, Section 21E of the Securities Exchange Act of 1934, as amended, and the Private Securities Litigation Reform Act of 1995, regarding the Company, which may include, but are not limited to, statements with respect to the business strategies, product development, expansion plans and operational activities of the Company . Often but not always, forward-looking information can be identified by the use of words such as “pursuing”, “potential”, “predicts”, “projects”, “seeks”, “plans”, “expect”, “intends”, “anticipated”, “believes” or variations (including negative variations) of such words and phrases, or statements that certain actions, events or results “may”, “could”, “should”, “would” or “will” be taken, occur or be achieved. Such statements are based on the current expectations and views of future events of the management of the Company and are based on assumptions and subject to risks and uncertainties. Although the management of the Company believes that the assumptions underlying these statements are reasonable, they may prove to be incorrect. The forward-looking events and circumstances discussed in this release may not occur and could differ materially as a result of known and unknown risk factors and uncertainties affecting the Company, the capabilities of our facilities and the expansion thereof, research and development projects of the Company, the market potential of the products of the Company , the market position of the Company, the scalability of the Company’s production ability, capacity for new customer engagements, material selection programs timeframes, the ability to reduce production costs, enhance metamaterials manufacturing capabilities and extend market reach into new applications and industries, the ability to accelerate commercialization plans, the possibility of new customer contracts, the continued engagement of our employees, the technology industry, market strategic and operational activities, and management’s ability to manage and to operate the business. More details about these and other risks that may impact the Company’s businesses are described under the heading “Forward-Looking Information” and under the heading “Risk Factors” in the Company’s Form 10-Q filed with the SEC on November 15, 2021, in the Company’s Form 10-K filed with the SEC on March 18, 2021, and in subsequent filings made by Meta Materials with the SEC, which are available on SEC’s website at www.sec.gov. Although the Company has attempted to identify important factors that could cause actual actions, events or results to differ materially from those described in forward-looking statements, there may be other factors that cause actions, events or results to differ from those anticipated, estimated or intended. Accordingly, readers should not place undue reliance on any forward-looking statements or information. No forward-looking statement can be guaranteed. Except as required by applicable securities laws, forward-looking statements speak only as of the date on which they are made and the Company does not undertake any obligation to publicly update or revise any forward-looking statement, whether as a result of new information, future events, or otherwise, except to the extent required by law. Unless otherwise stated, all references to $ herein are to US dollars.

We are Hiring!

metamaterial.com/careers

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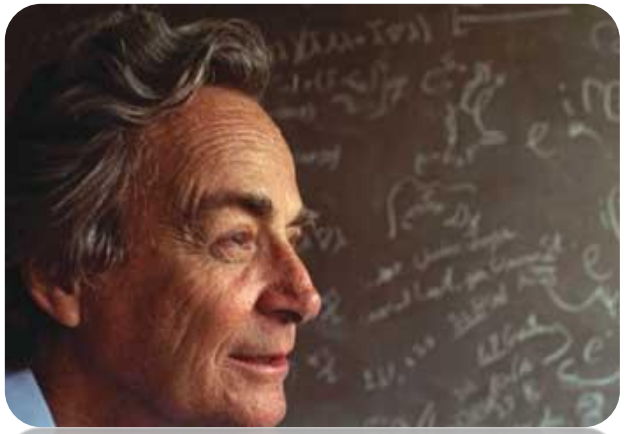
Outline

- About META
- META Applications
- Focus Application: Transparent Redirectors for Communications
  - The Problem
  - Technology: Nanoweb
  - Solution
- Manufacturing at Scale



"I can't see what exactly would happen,

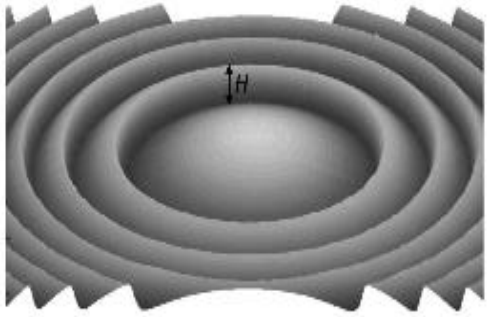
but when we have some control of the arrangement of things in the small scale,

we will get an enormously greater range of possible properties that substances can have."

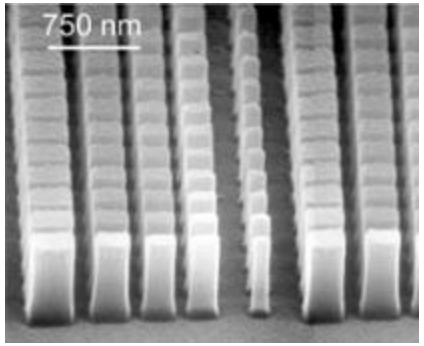
1959

The “Age of Invisible Materials”

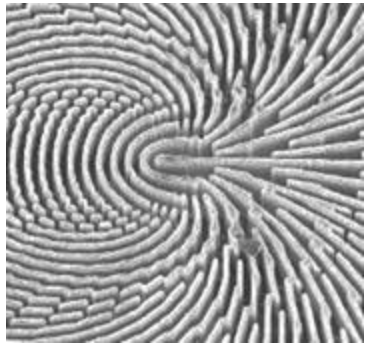
Échelette DOE
(1970’s)



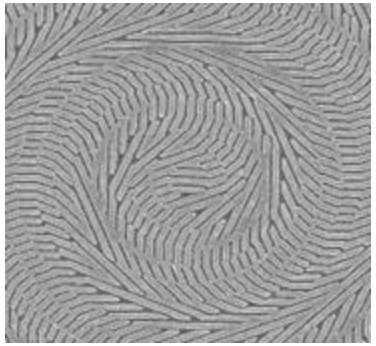
Blazed binary grating
(1998)



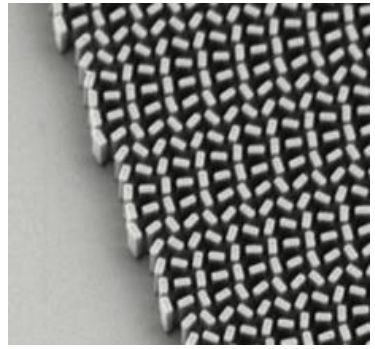
Geometric Phase
(2001)



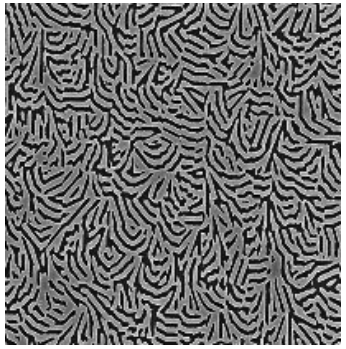
Mie resonators
(2014)



High performance
(2016)



Light field
(2019)



About META

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The META Timeline

2021	1st Metamaterial Company on NASDAQ
2011	META Founded (London, UK)
2000	Negative Refraction Demonstrated
1968	Veselago's Paper
1865	Maxwell's Equations
1492 AD	America Discovered
55 BCE	Romans invade Britain
776 BCE	First Olympiad
3000 BCE	Great Pyramid Built
10,000 BCE	Farming
200,000 BCE	Early Humans

Global Presence

Halifax, Nova Scotia, Canada
Global HQ
R&D and Integrated Applications
Product Dev. & Low vol. mfg.

Boxborough, MA, USA
USA Headquarters

Pleasanton, California, USA
NA Sales
Product Design and R&D

London & Oxford, UK
UK/EU Sales
Research & Development

Burnaby, BC, Canada
Product Design and R&D

Thurso, QC, Canada
Global Manufacturing HQ
High Vol. Manufacturing

Tokyo, Japan
Japan/APAC Sales

Athens, Greece
EU Sales
Product Design and

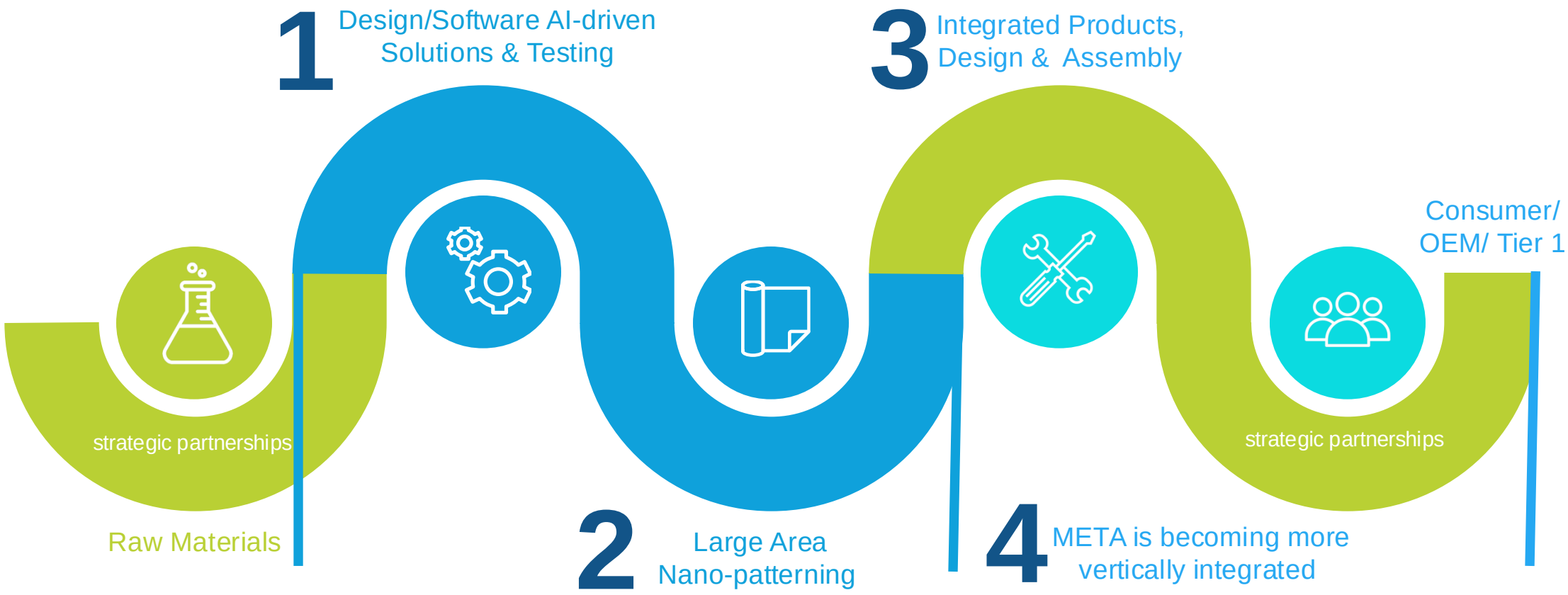
OEM Partners & Customers: Solving Global Challenges Together

META®

Select Targeted Co-Development Partners and Customers in Automotive, Medical, Aerospace & Defense, Consumer Electronics and Energy

SAMSUNG
ThermoFisher SCIENTIFIC
BOEING
Caltech
PPG
mazda
SONY
AIRBUS
Elbit Systems
enel Green Power
AGC
PLASTIC OMNIUM
Panasonic
SATAIR
SEKISUI
SolAero TECHNOLOGIES
covestro
babcock™
DENSO
Midea
CORNES Technologies
Transitions™
UKRI Innovate UK
SUSTAINABLE DEVELOPMENT TECHNOLOGY CANADA
Atlantic Canada Opportunities Agency
LOCKHEED MARTIN

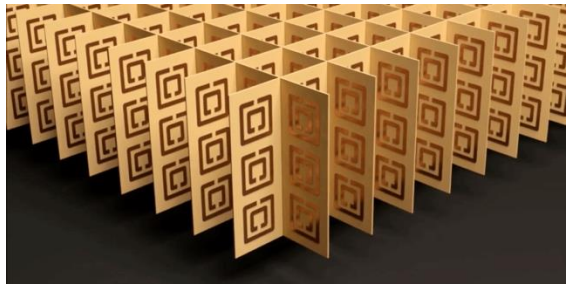
META Solution Provider in the Value Chain



Intellectual Property & Know-How

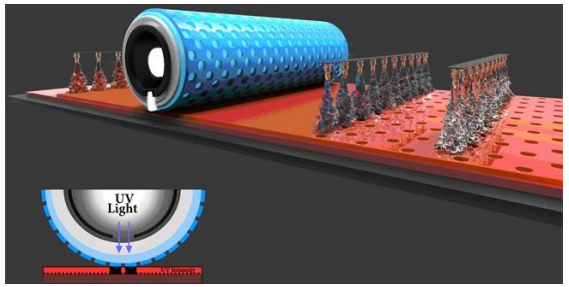
269
active utility and design patent documents

37
issued patents and **26** pending applications in the U.S.



9
registered trademarks

6
design patent applications



UTILITY PATENT DOCUMENTS

164 Devices & Components
65 Scaled Manufacturing
34 Fabrication & Origination

163
utility patents have issued **74** patent families

126
issued patents and **80** pending applications in **24** other countries

Metamaterials 2014

Copenhagen, Denmark

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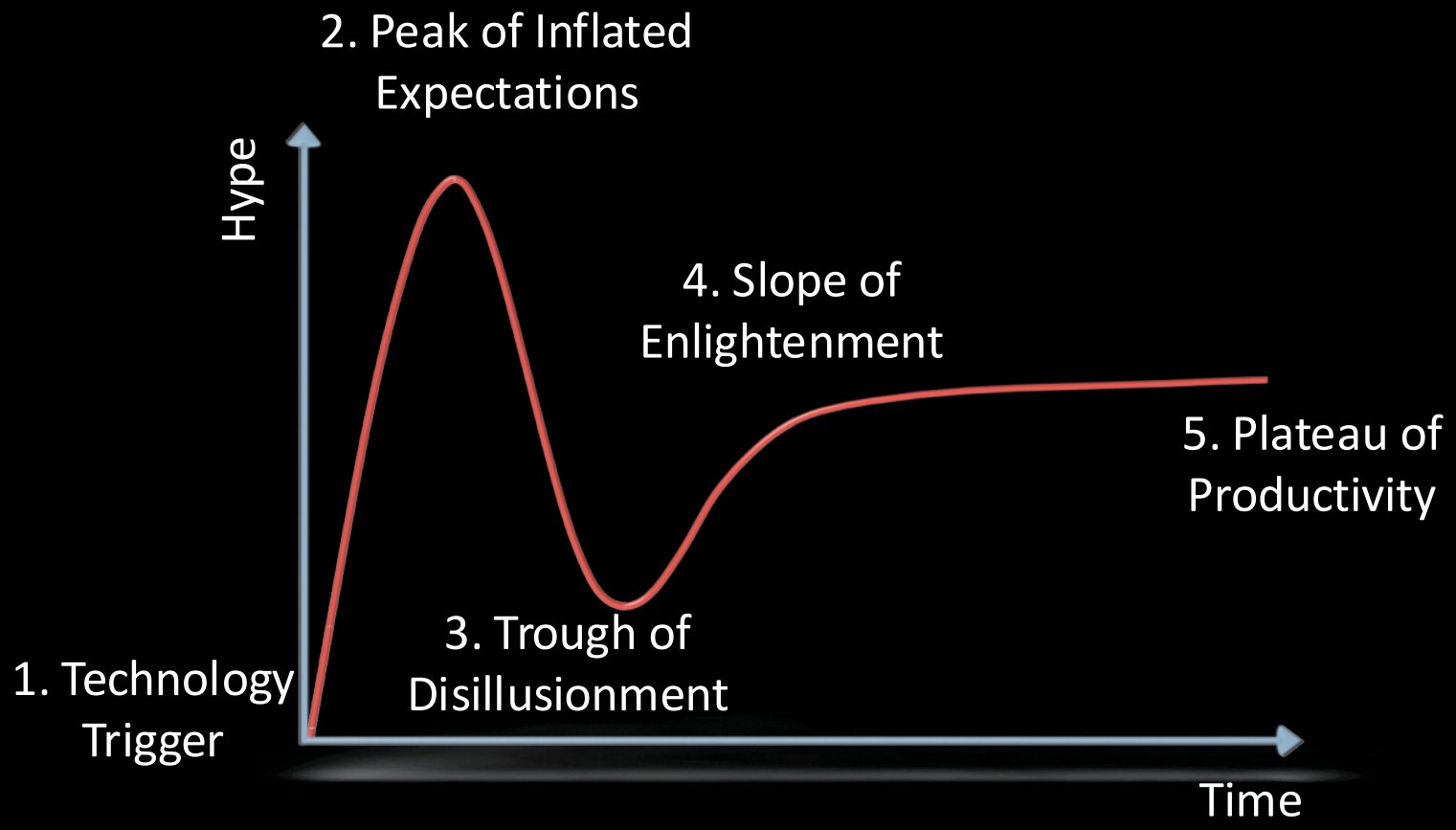
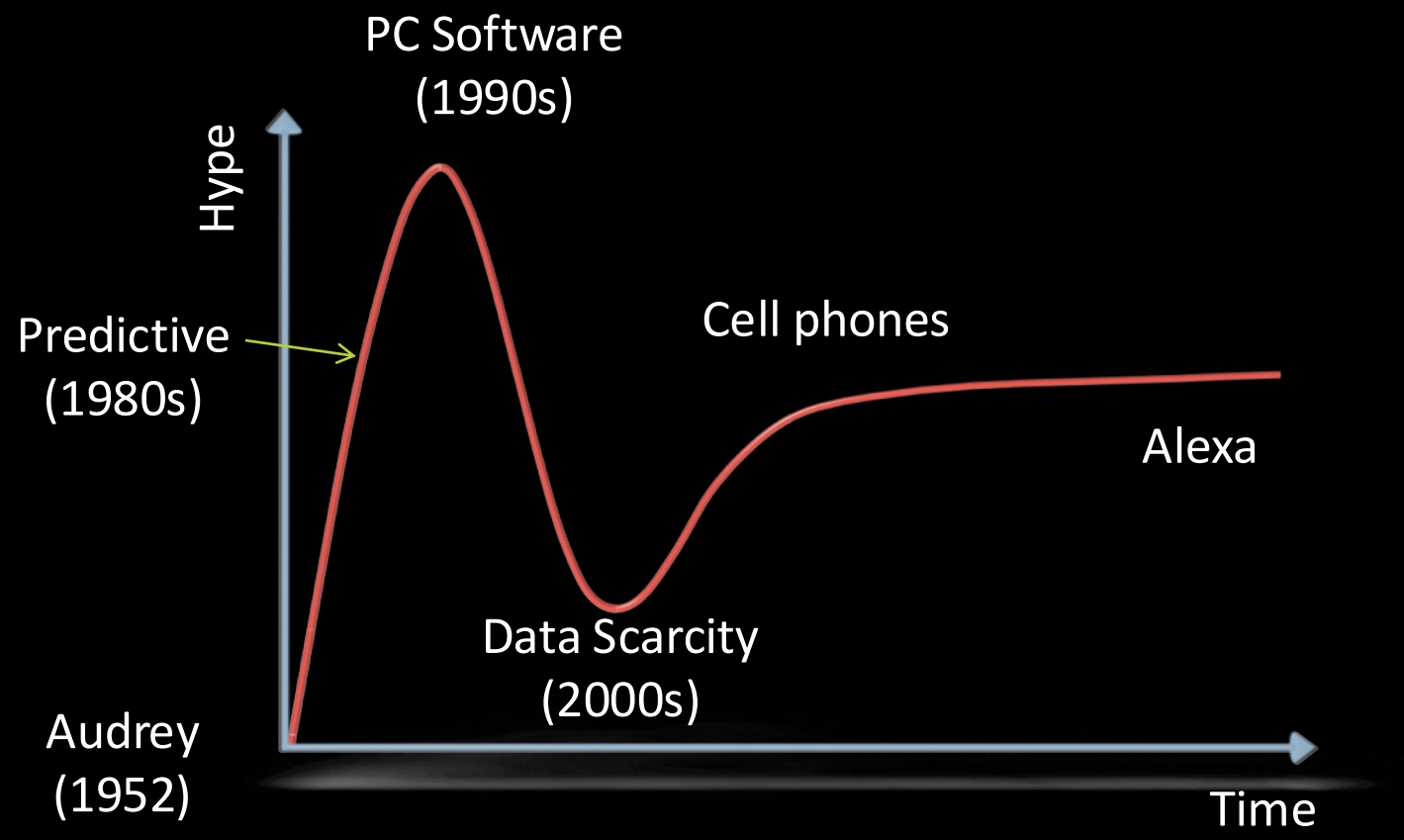
The Gartner Hype Cycle



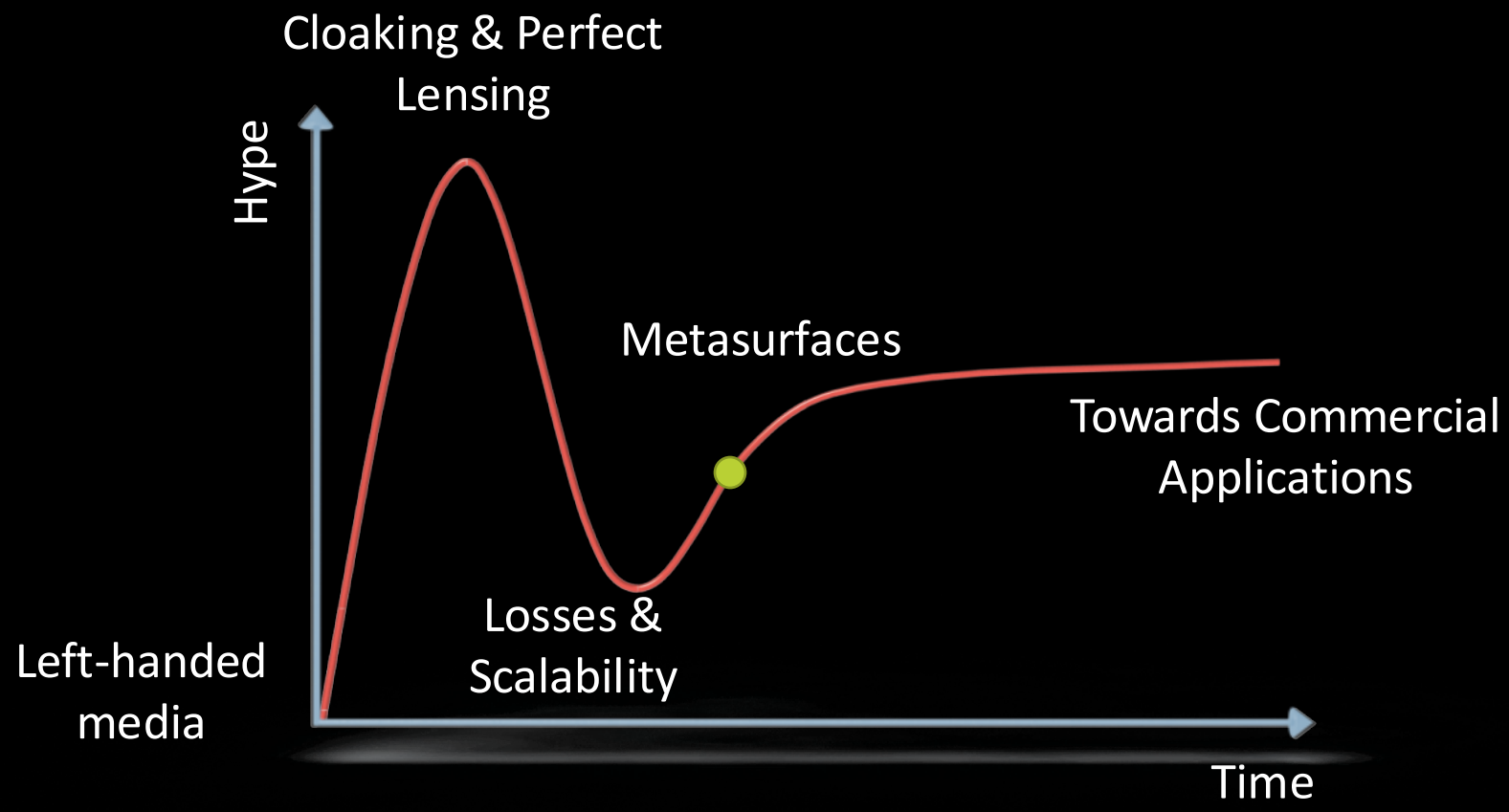
Gartner (2013)

The Hype Cycle – Speech Recognition



Gartner (2013)

The Hype Cycle for Commercial Metamaterials



Gartner (2013)

The Challenges

- Transparency for visible applications
- Large scale nanofabrication
  nm accuracy over meter-long surfaces
- Cost-effective fabrication
  $1-10 per cm^2 on volume production

META Applications

Functional Films for the People

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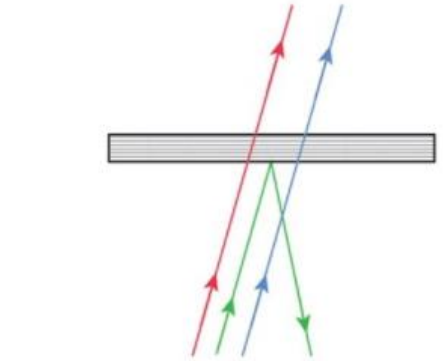
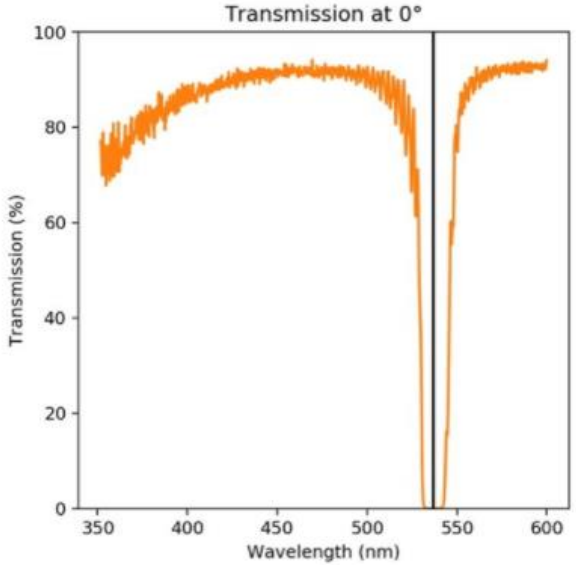
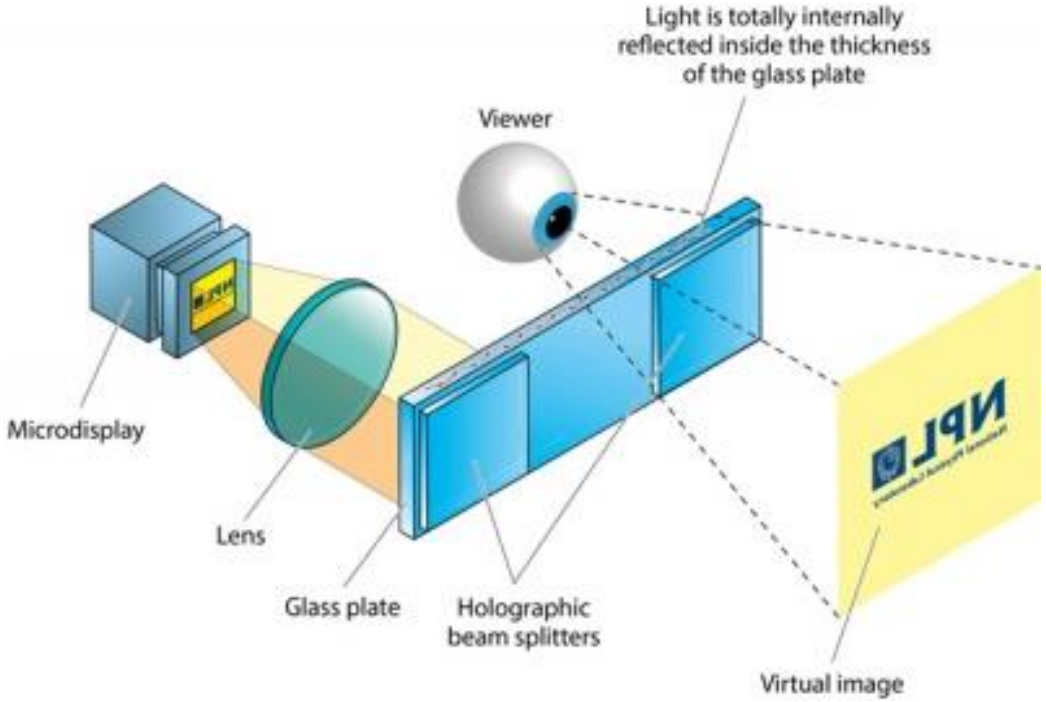
metaAIR® Laser Glare Protection Eyewear



	Notch Center (nm)		
	447	532	635
SBW (nm)	7	13	11
OD (log)	>2	>4	>2

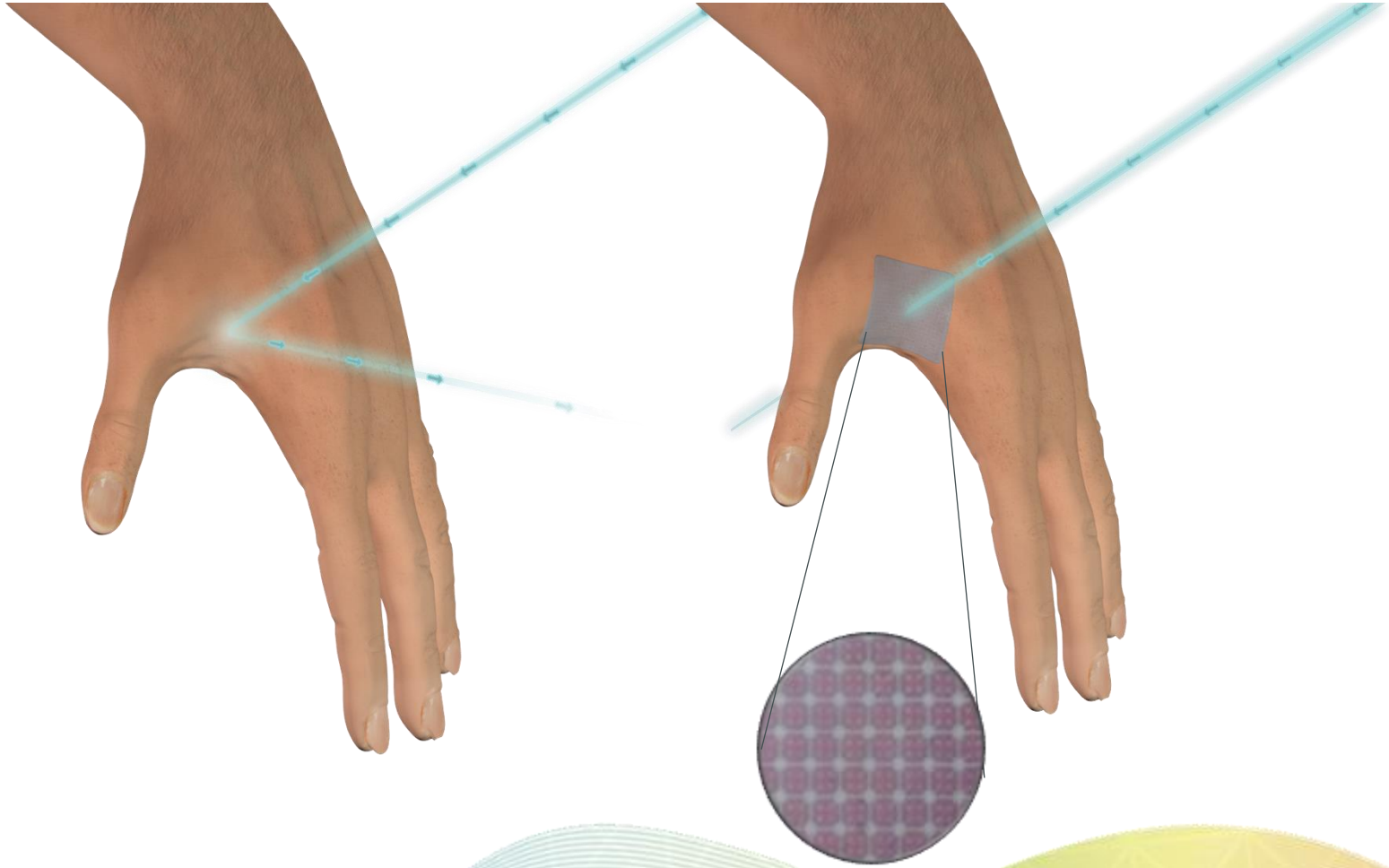


Augmented Reality



Source: NPL

Biosensing w/ Impedance Matching



Wearable Biosensor Vision

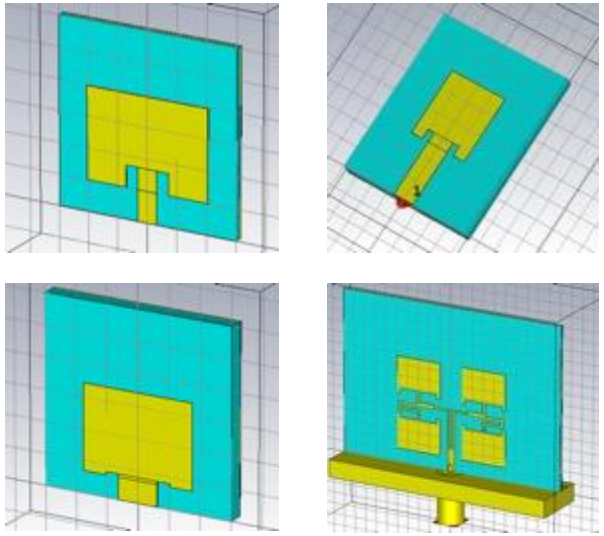
Secure Currency & Brand Protection

- Produce motion, depth and color without inks or dyes.
- Full color, nearly impossible to reproduce.
- Engaging security features with RGB color, 3D images, and movement.
- Developing new security feature for a confidential top-10 central bank.

UEFA Euro Cup Tickets

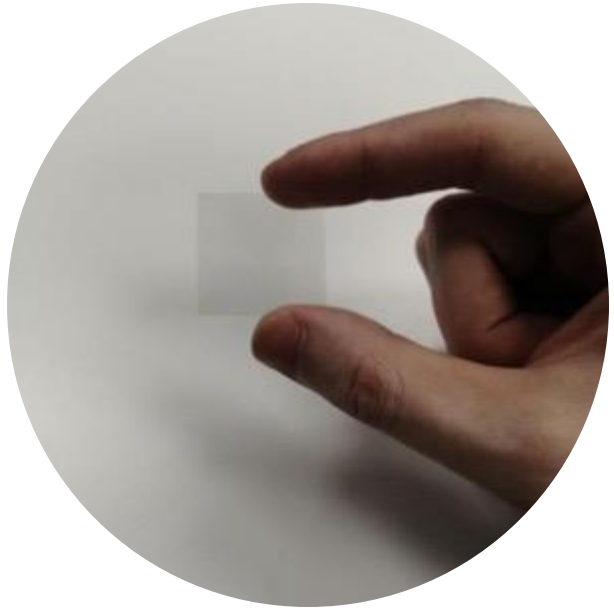
NANOWEB® Antennas

Custom Design & Simulation



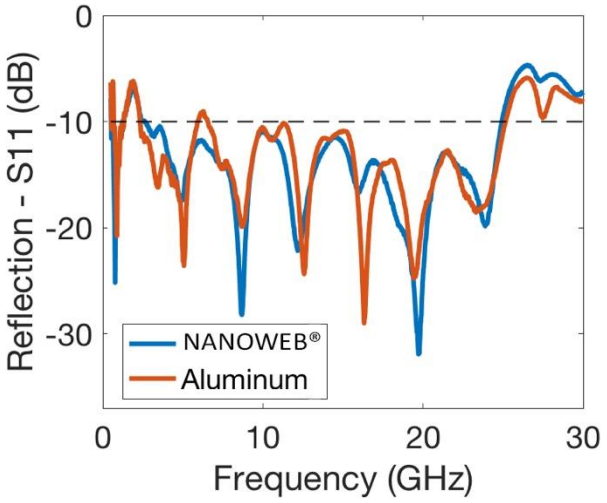
Precision Fabrication

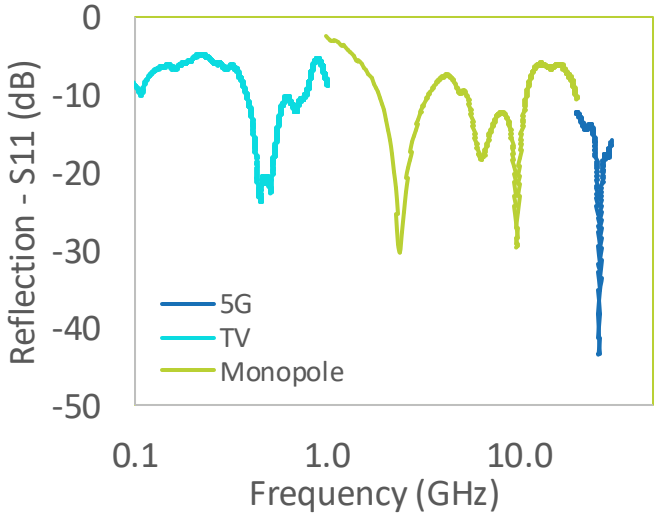
High Performance & Transparency



NANOWEB® Antennas

Integrate high-speed communications functionality while maintaining visibility

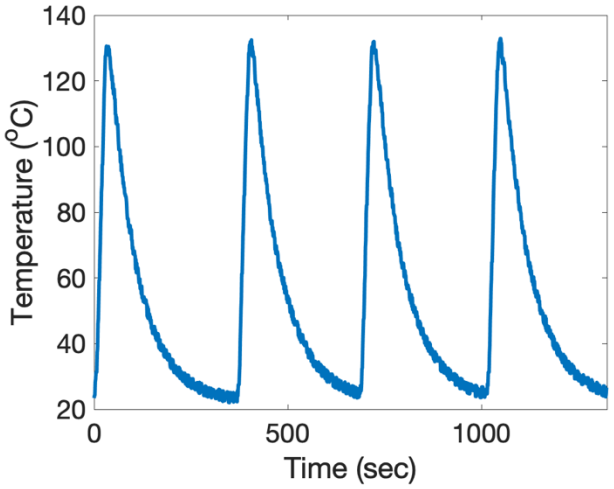


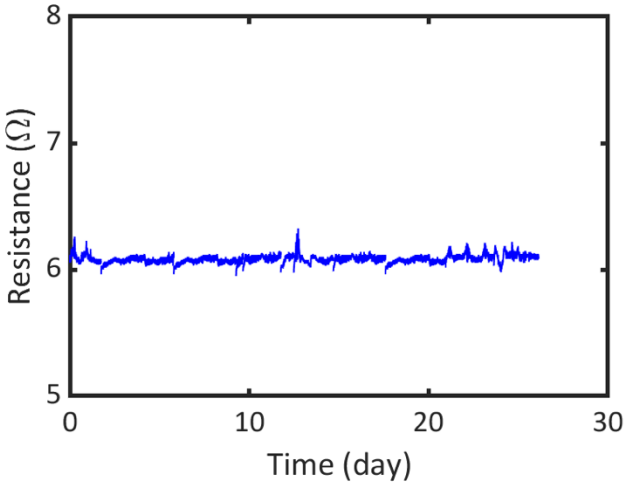


Transparent Microwave Doors

EMI Shielding & Nano-heater to Protect Sensors - Transparent to RADAR and LIDAR Simultaneously

NANOWEB® Temperature Cycling





Heating performance tests using NANOWEB®

Each 25-second-long heating pulse raises the temperature of the 1mm thick glass substrate by 100 ˚C. The test has been conducted in a constant temperature chamber using 95% transparent NANOWEB®.

Focus Application

Transparent Redirectors for Communications

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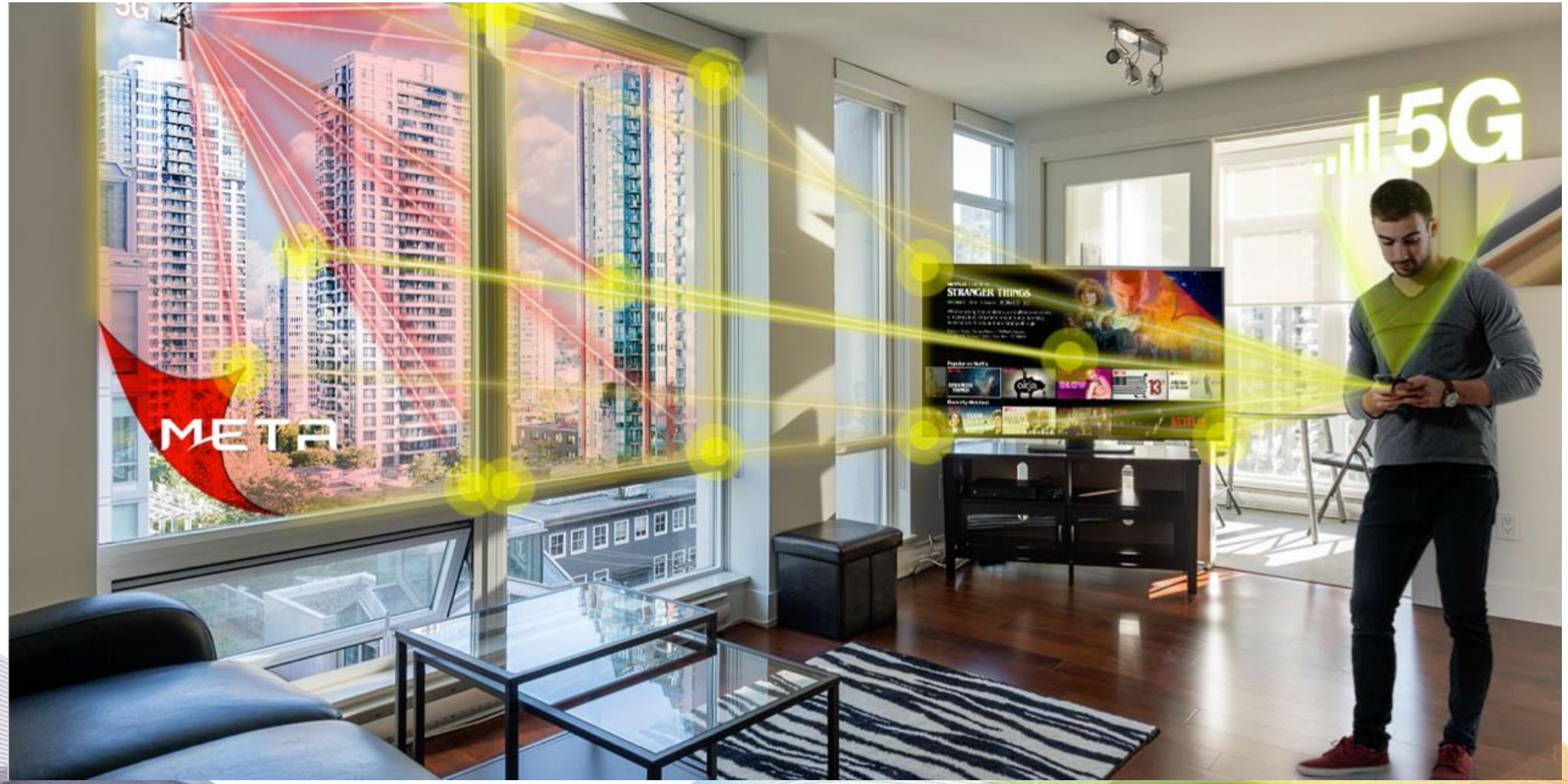
Outdoor 5G Coverage Enhancement

Indoor Coverage Enhancement



Technology

Nanoweb Metal Mesh

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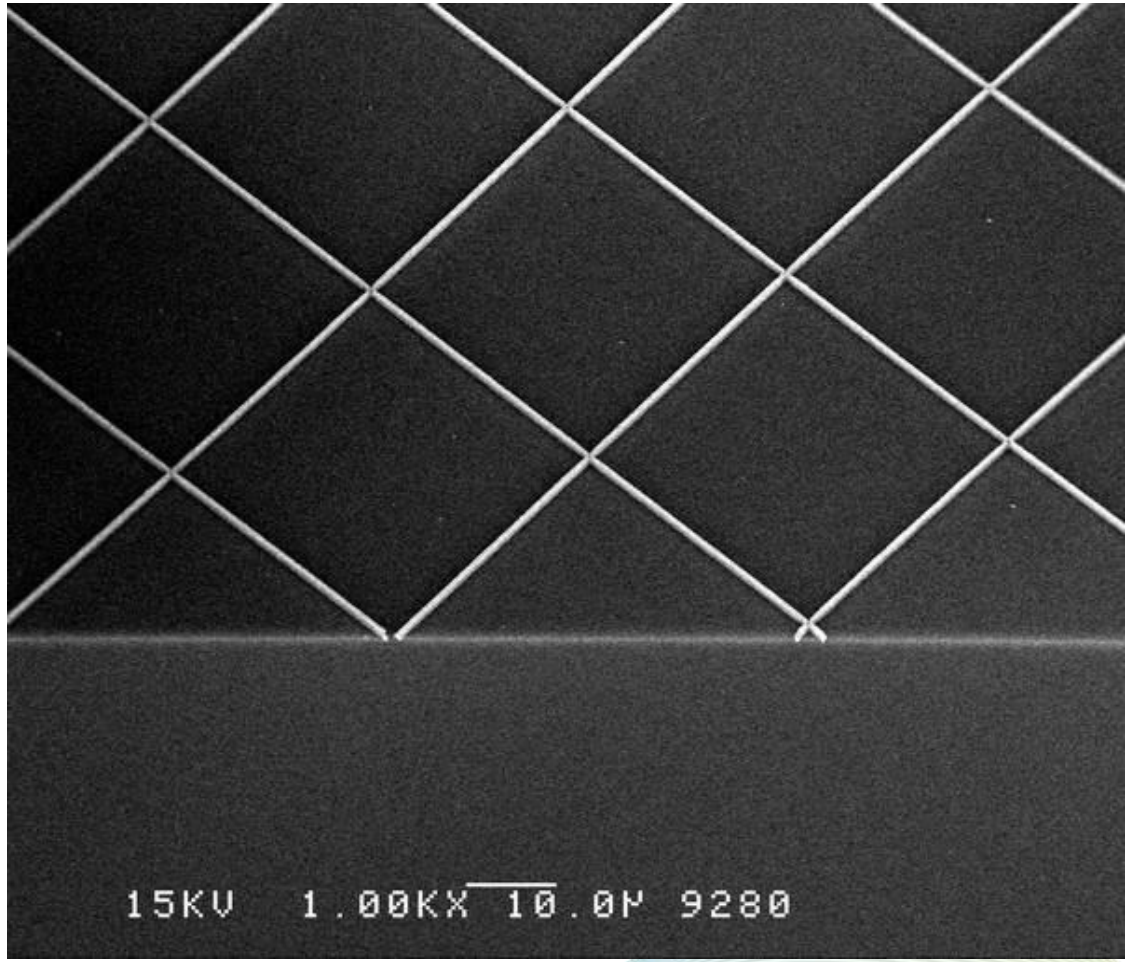
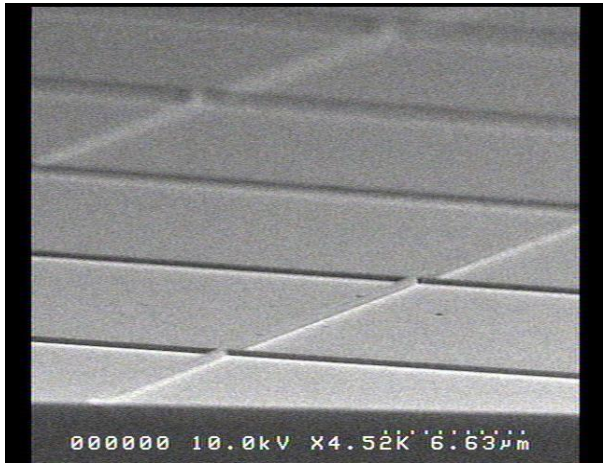
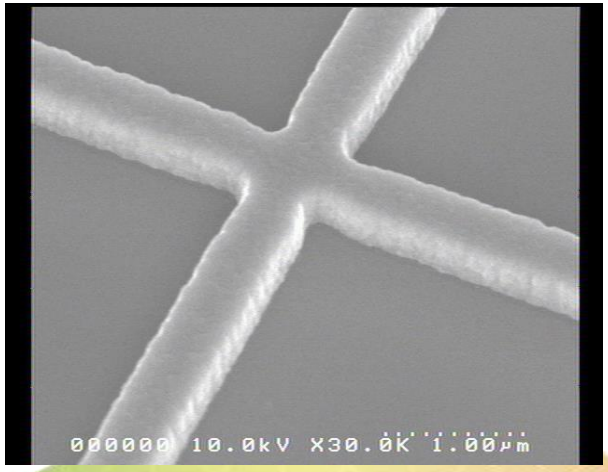
NANOWEB® – Transparent Metal Mesh



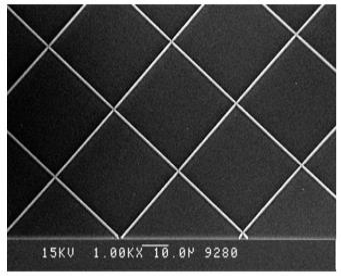


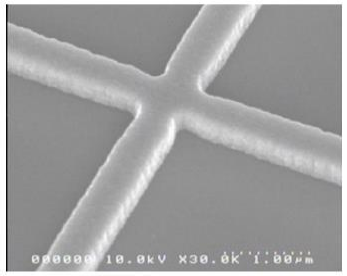


Nanoweb Comparison

Sub-micron, high transparency, super conductive metal mesh

- ✓Higher Transmission >95% Vs. Conductivity 1-20 Ω/sq
- ✓Low Haze 1-2%
- ✓Hi Resolution & Control
- ✓Flexible substrates or directly on Glass, Sapphire

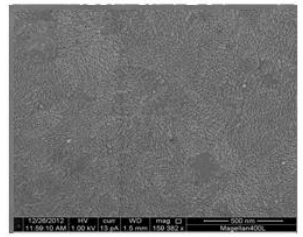




VS.

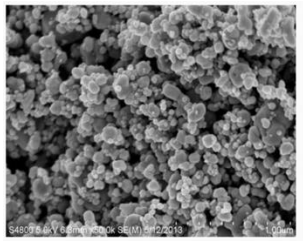
ITO

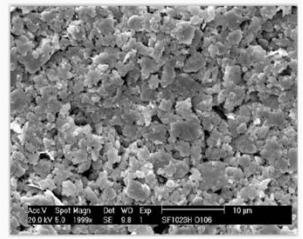
- ✗Lower Transmission Vs. Conductivity
- ✗Not flexible
- ✗Not suitable for large surface areas

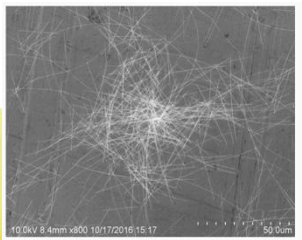


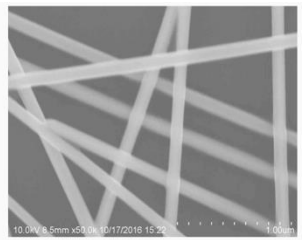
Silver flakes & Nanowires

- ✗High Haze
- ✗Lower Transmission
- ✗Lower Conductivity
- ✗Lower precision







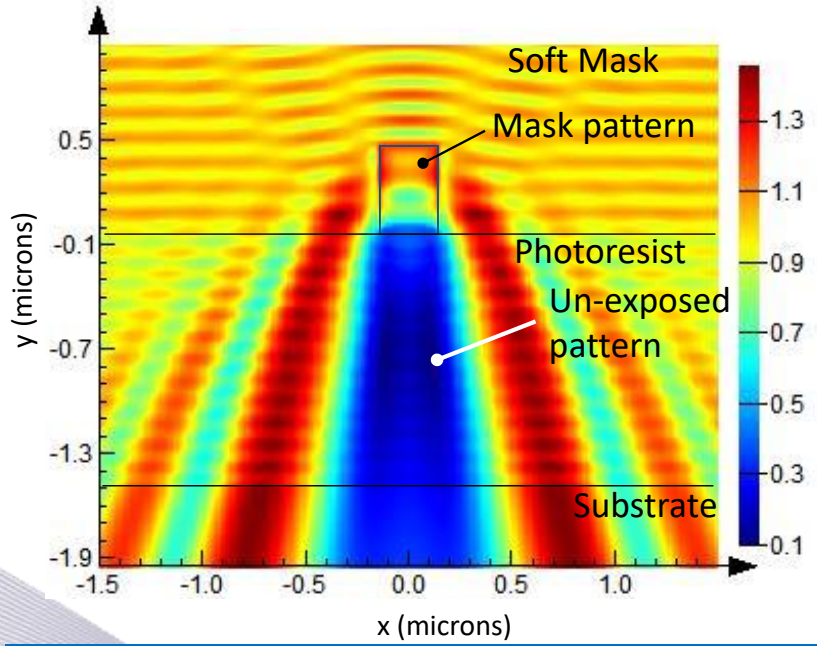


Optimizing NANOWEB®

Translate requirements into designs, develop new masks tailored for optimum performance of target applications.

Linewidth Pattern optimization

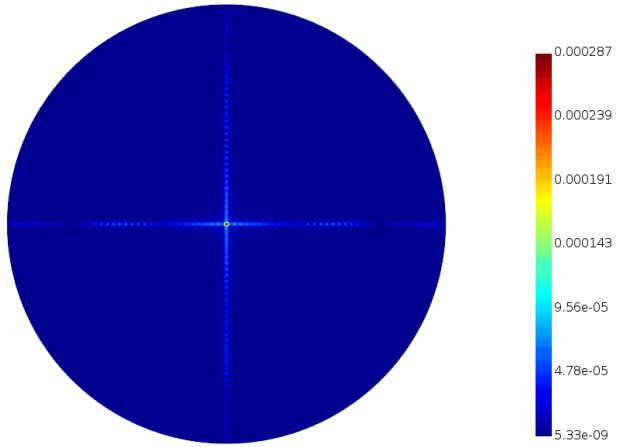
Colormap for the E-Field Distribution



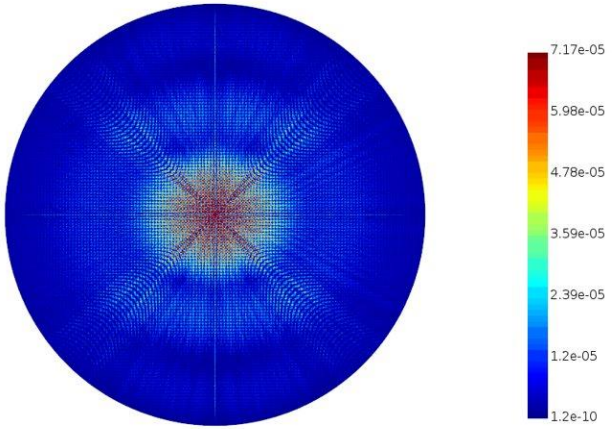
High contrast enables high uniformity and yield

Haze and Transmission optimization

Polar maps for the scattered field



Rectangular mesh

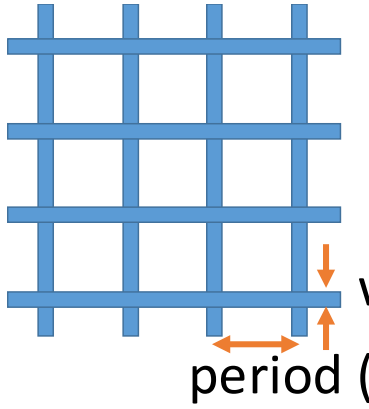


Optimized mesh

Haze, diffraction and transmission can be optimized for each application

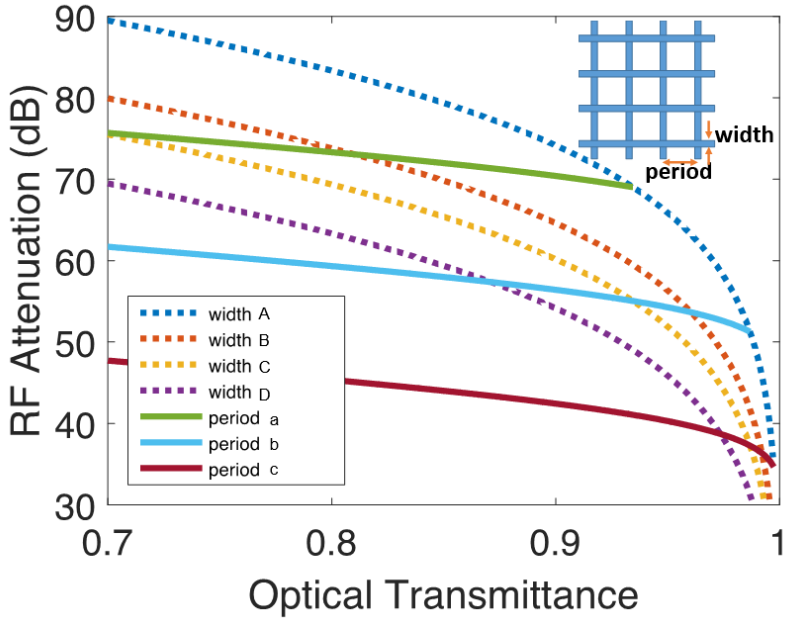
EMI Shielding - Optimum set of design parameters

Analytical Model for the RF Transmission



$$T \cong \frac{4g^2}{\lambda^2}\left[ln\left(\sin\frac{\pi a}{g}\right)\right]^2$$

RF attenuation at 3 GHz vs. Optical Transmittance



Smaller width has higher EMI shielding

GOAL : Finding optimum width, period and thickness of the Nanowires for largest EMI Shielding

Solution

Transparent Metasurface Reflectarrays

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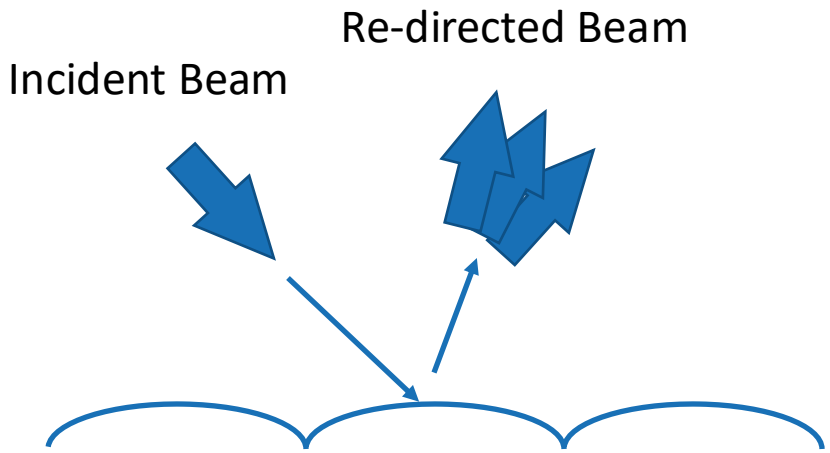
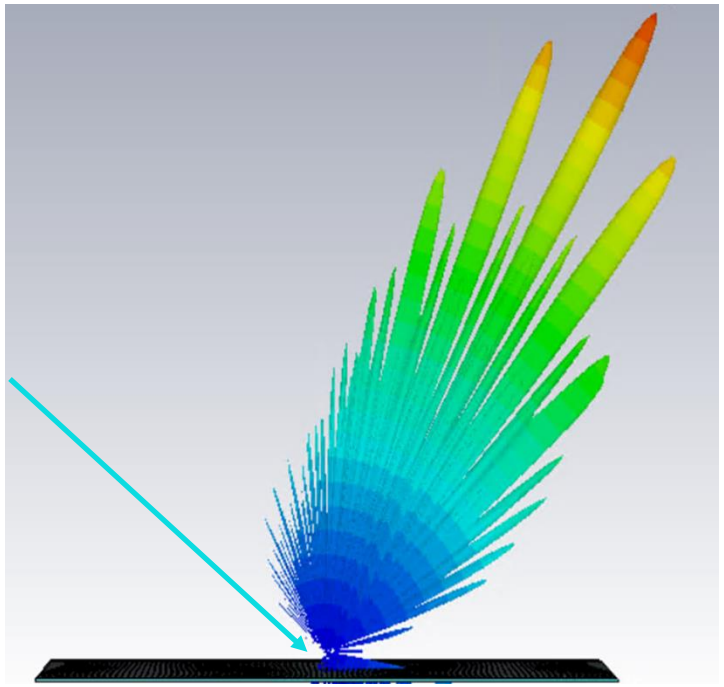
Key idea: Geometric Optic Analogue of a Beam Disperser



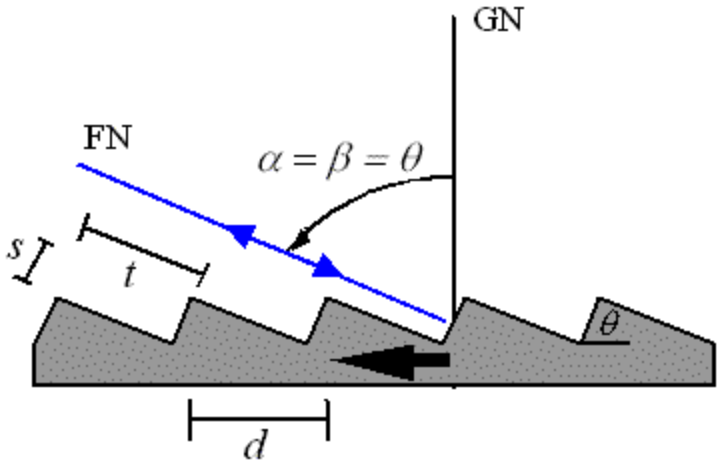
Mirror array Implemented using Transparent Metamaterial



NANOWEB® Reflectarray

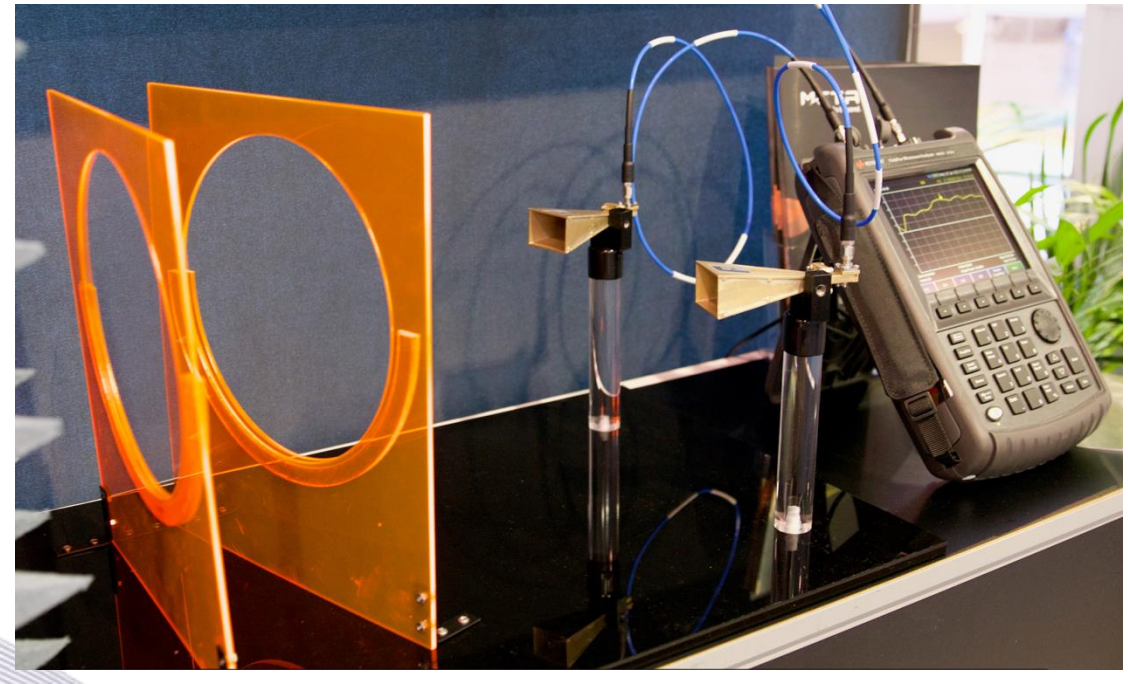
Design Overview

- Reflectarrays based on square patches
  - The localized reflection phase can be controlled by changing patch size
  - Parabolic mirrors and Eschelle grating type surfaces can be implemented
  - Beam broadening or deflection
  - High efficiency (~92%)
  - Polarization Insensitive operation
  - Wideband design

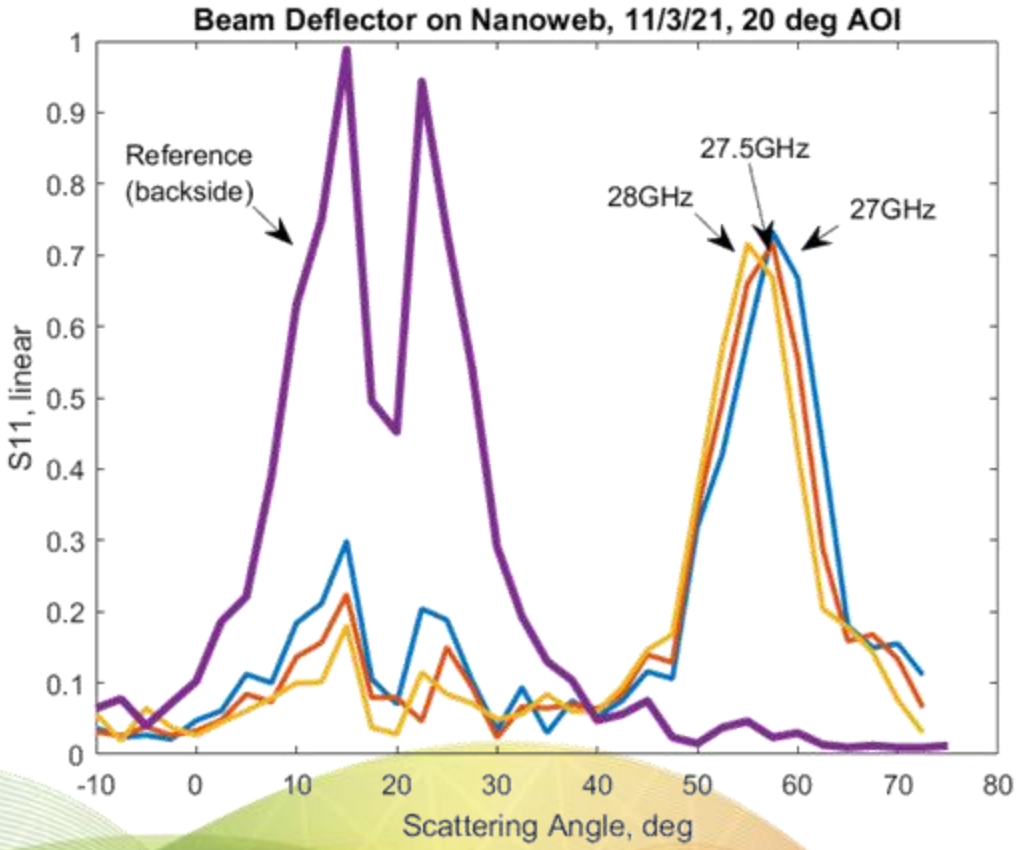


Implementation for Anomalous Reflection

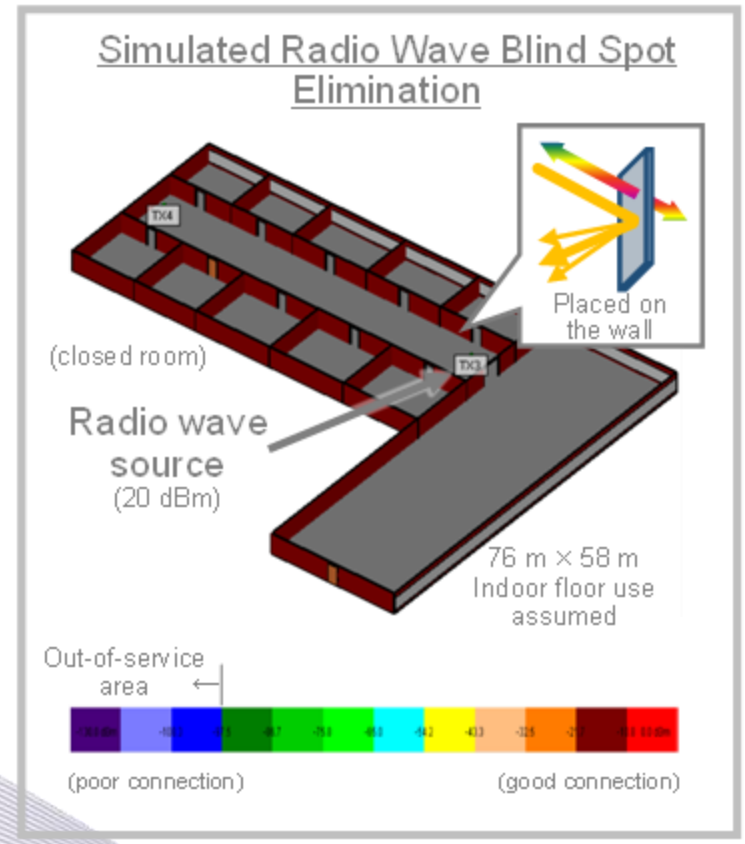
Fabricated Film in Demo Setup



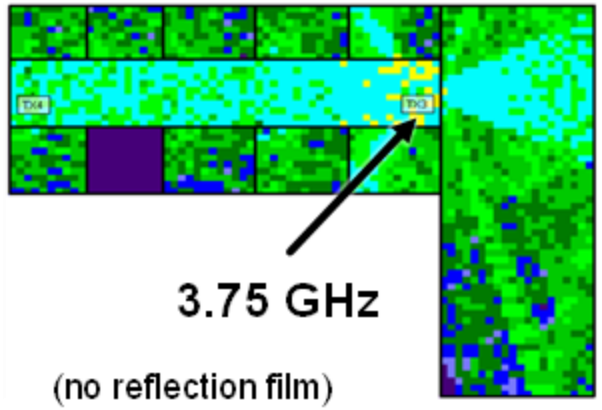
-20 Deg Angle of incidence

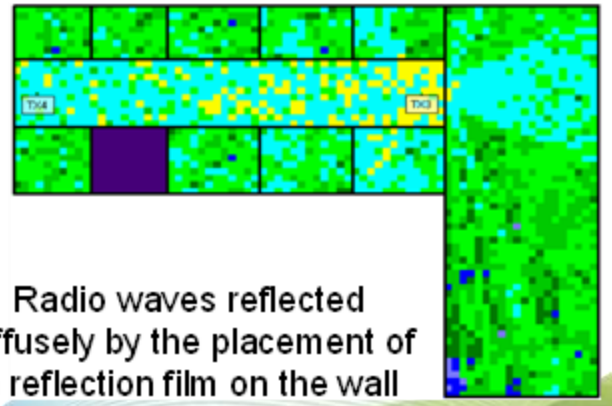


Simulation of Indoor Coverage Enhancement

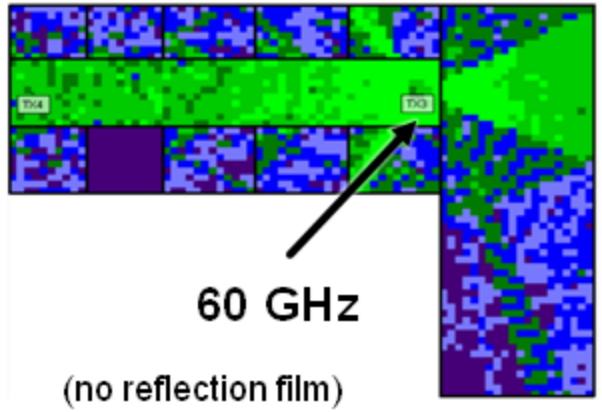


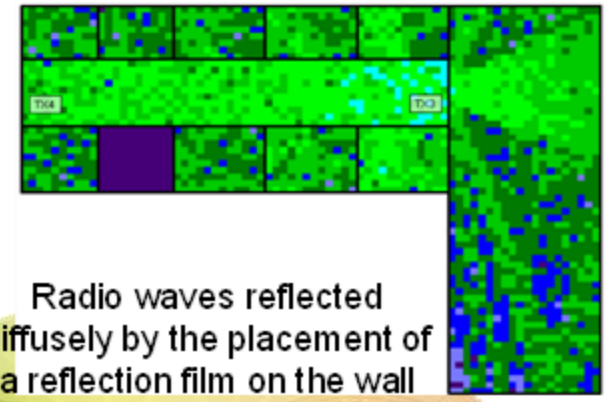
<5G Frequency Range>



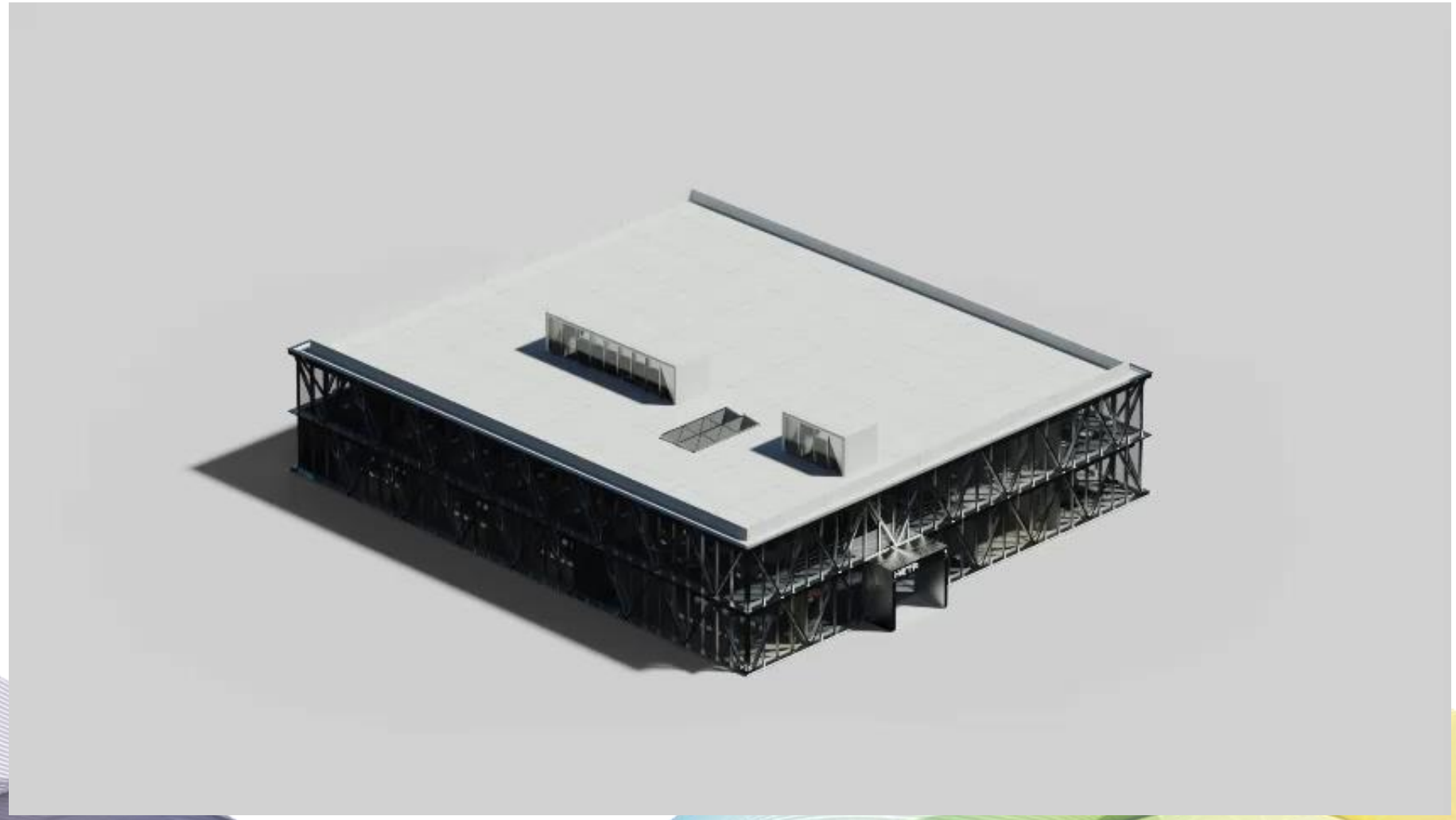


<Prospective Beyond-5G Frequency Range>



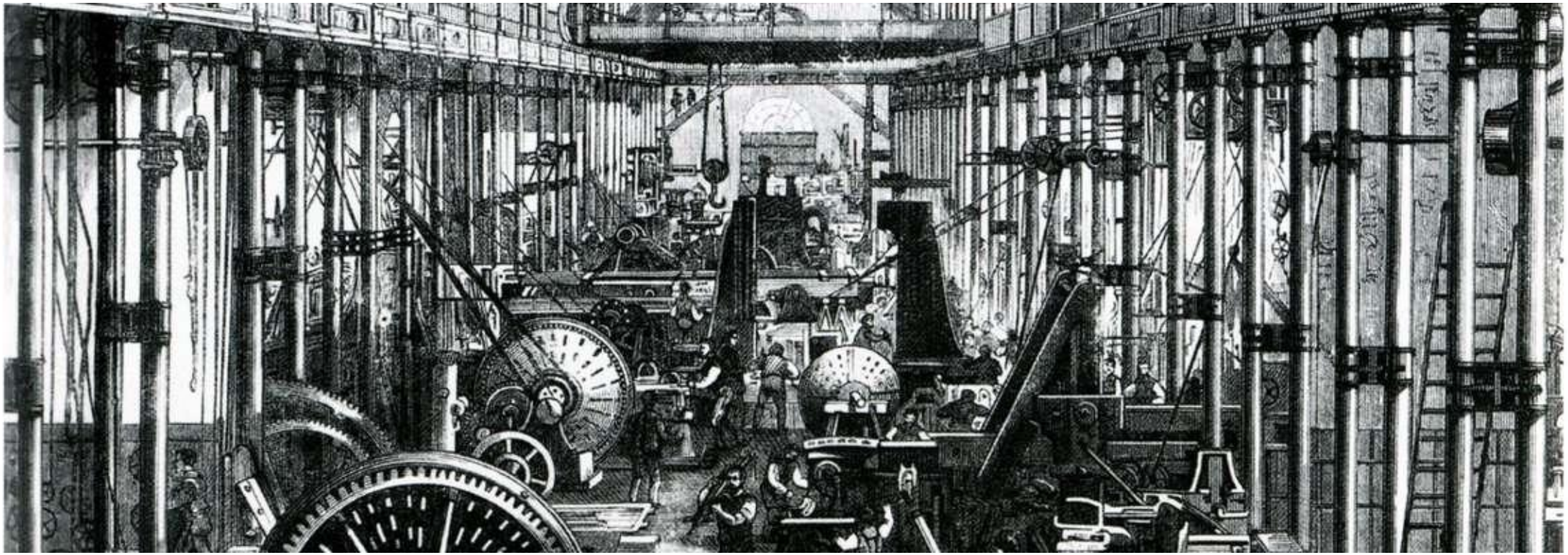


Indoor Coverage Enhancement



Manufacturing at Scale

META®
Go Beyond.



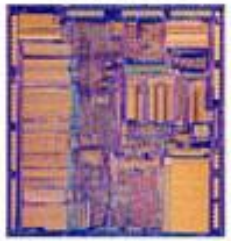
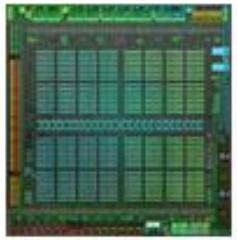
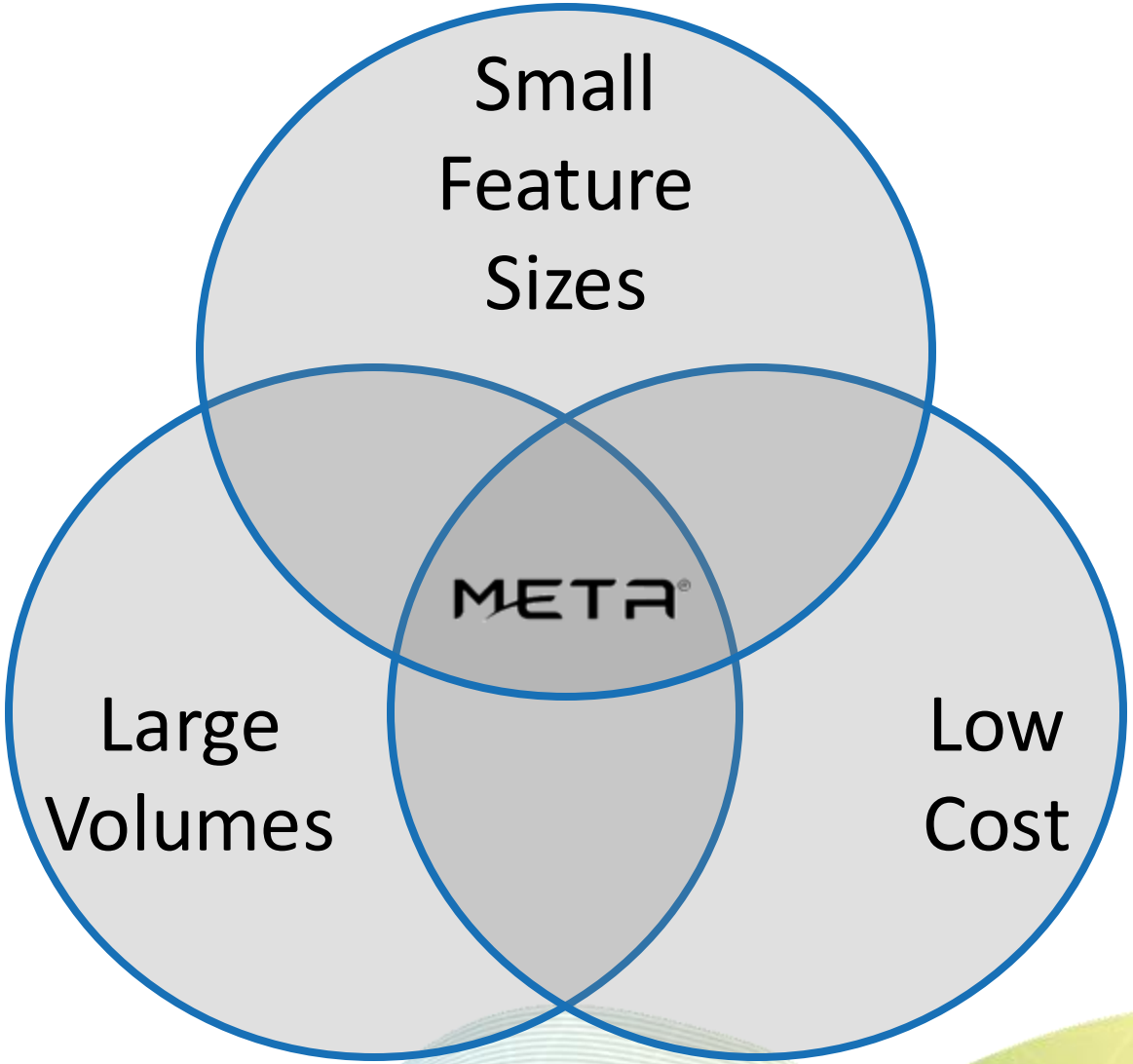
1950s	1960s	1970s	1980s	1990s	2000s	2010s
Silicon Transistor	TTL Quad Gate	8-bit Microprocessor	32-bit Microprocessor	32-bit Microprocessor	64-bit Microprocessor	3072-Core GPU
						
1 Transistor	**16 Transistors**	**4500 Transistors**	**275,000 Transistors**	**3,100,000 Transistors**	**592,000,000 Transistors**	**8,000,000,000 Transistors**

Image Source: Computer History Museum



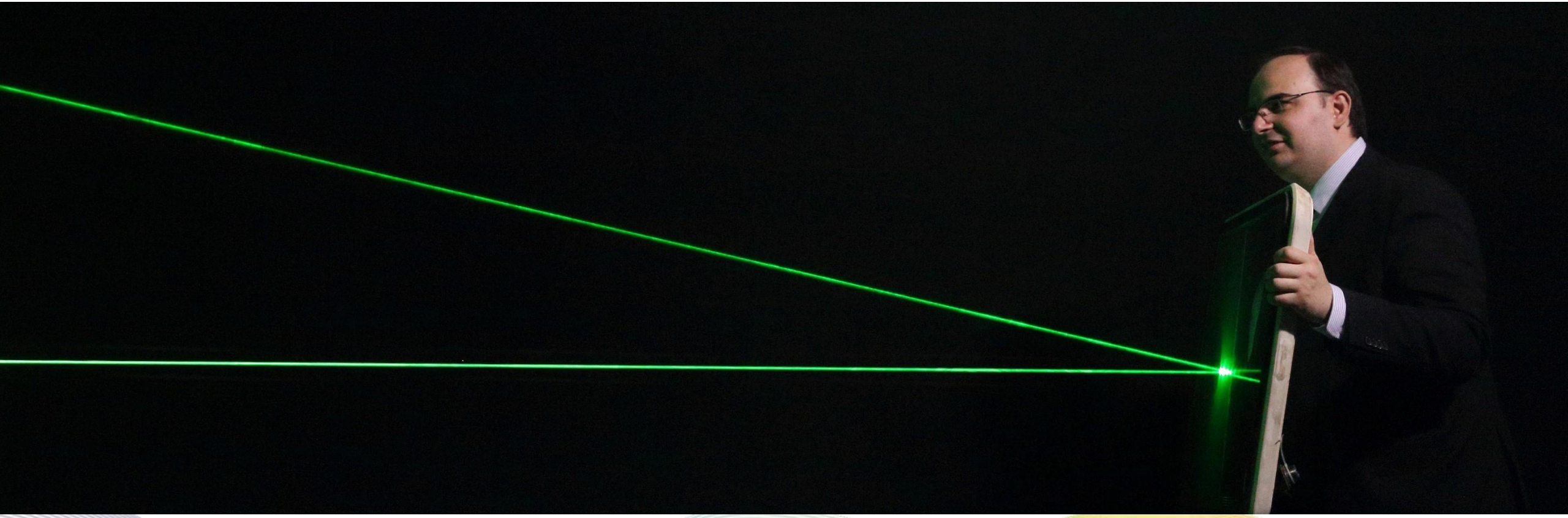
How to Fabricate Fast?

META®
Go Beyond.

Large-Scale Manufacturing Techniques

- Scanning Holography
- Rolling Mask Lithography
- Nanoimprint Lithography

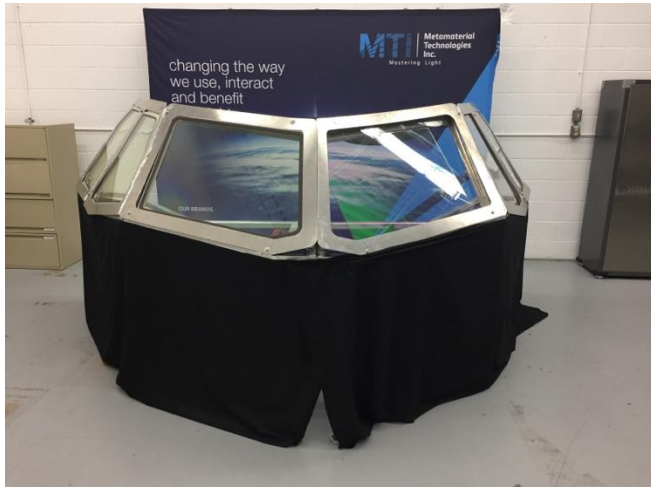
metaAIR®



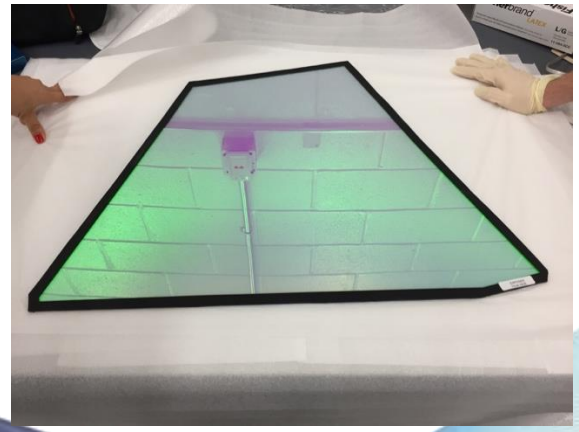
Aircraft Windows

metaAir on sliding window of Airbus A319 (binocular view)

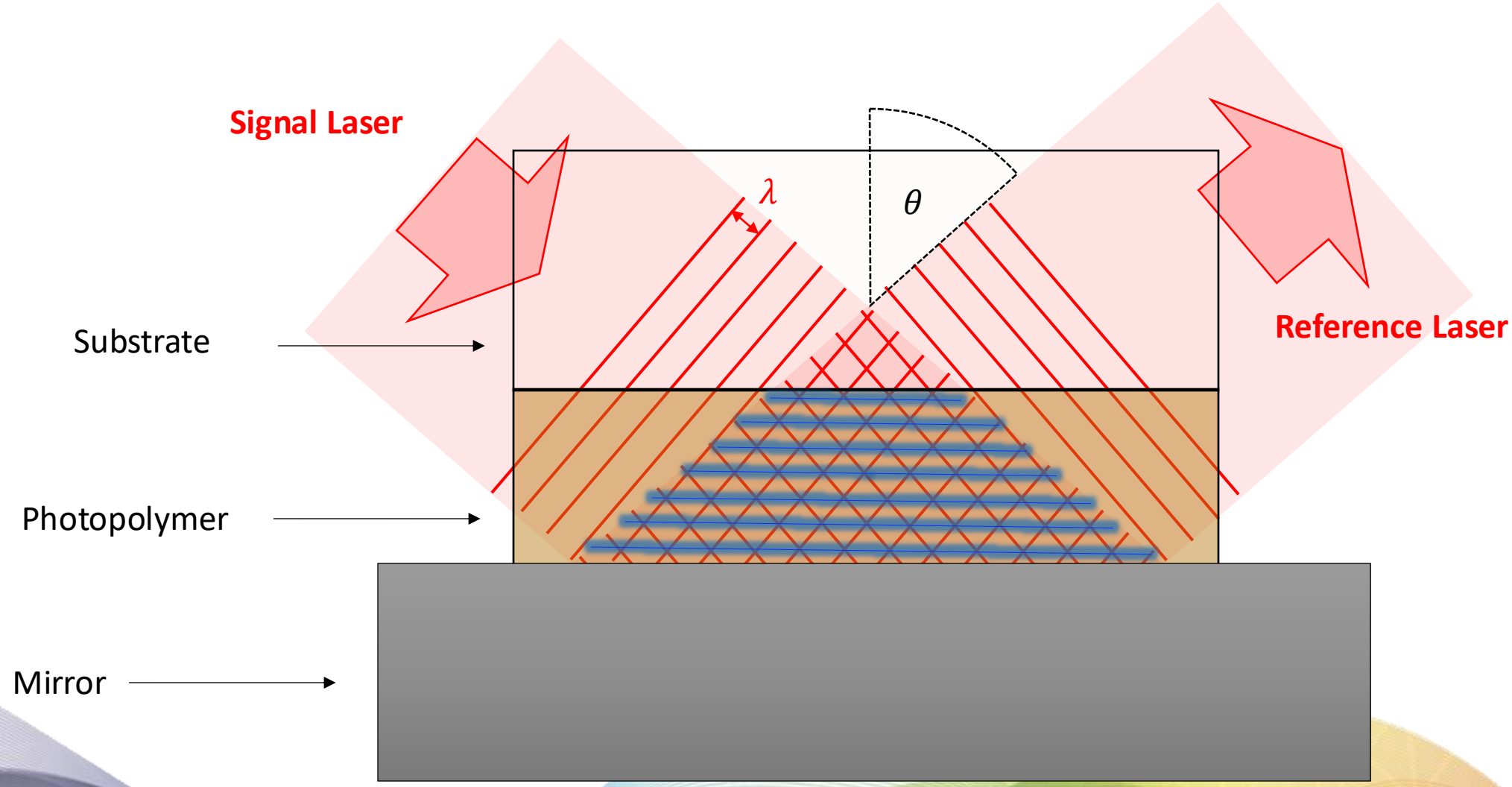
metaAir on 6 windows on Airbus A320 cockpit mock-up



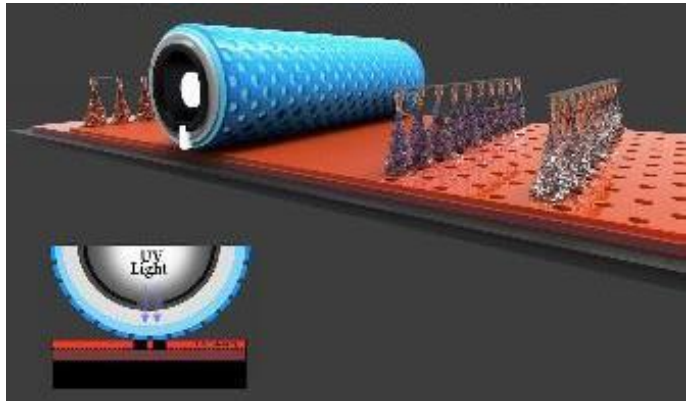
metaAir for A320 sliding window

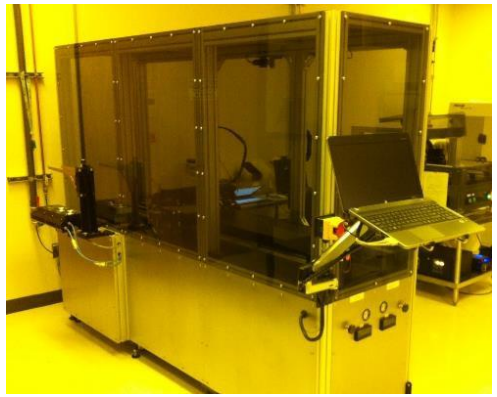


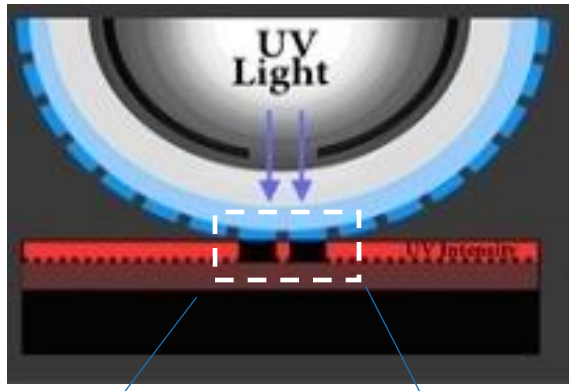
Making a mirror for a laser using a mirror and a laser



Rolling Mask Lithography (RML®)

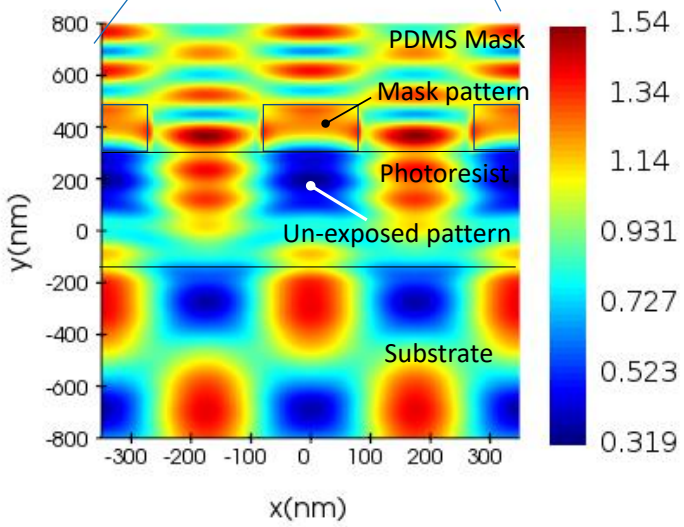






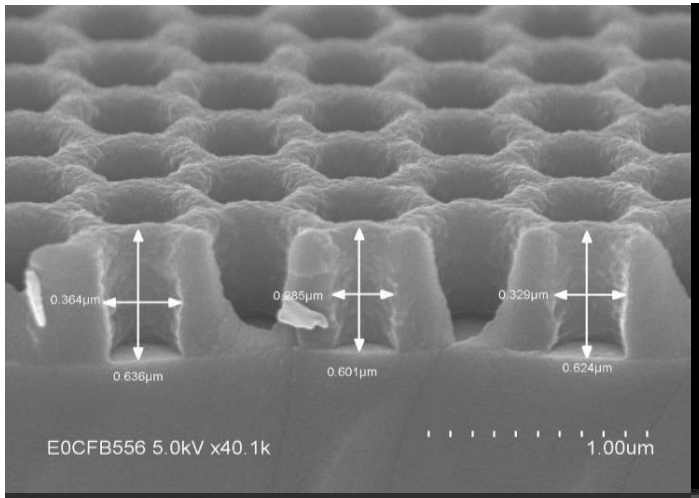
- Continuous and scalable
- Inexpensive
- Ultra-fast fabrication
- Phase lithography

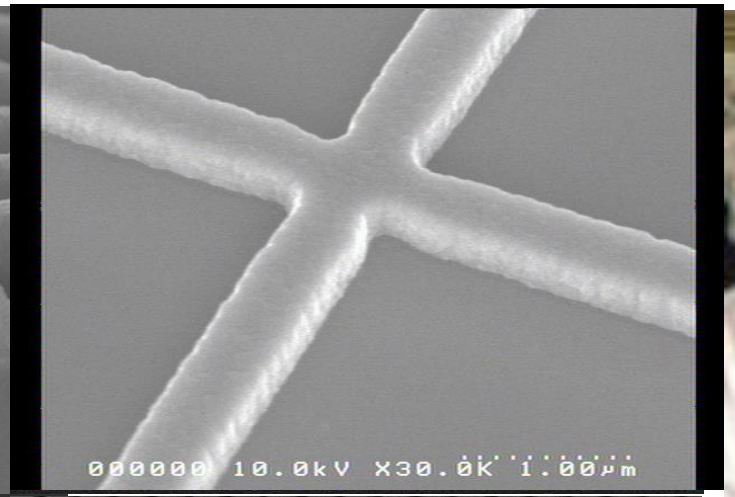
- RML® proprietary tool substrate size: 1m x 0.3m
- Resolution: 150nm
- Capacity: 3m/min

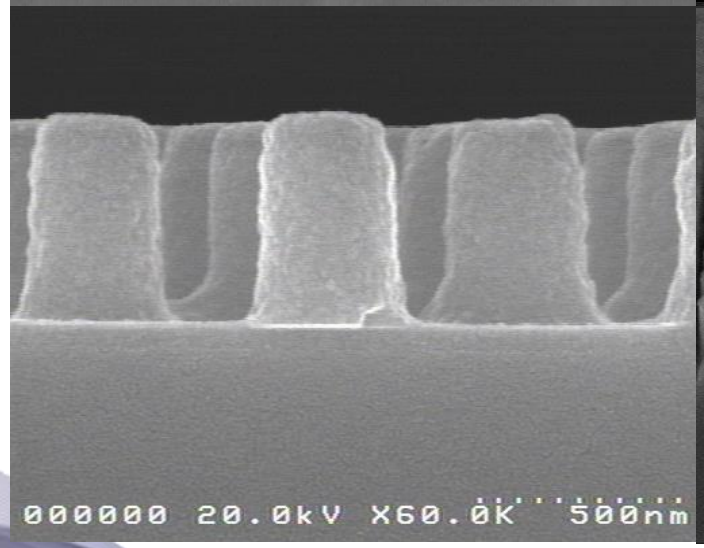


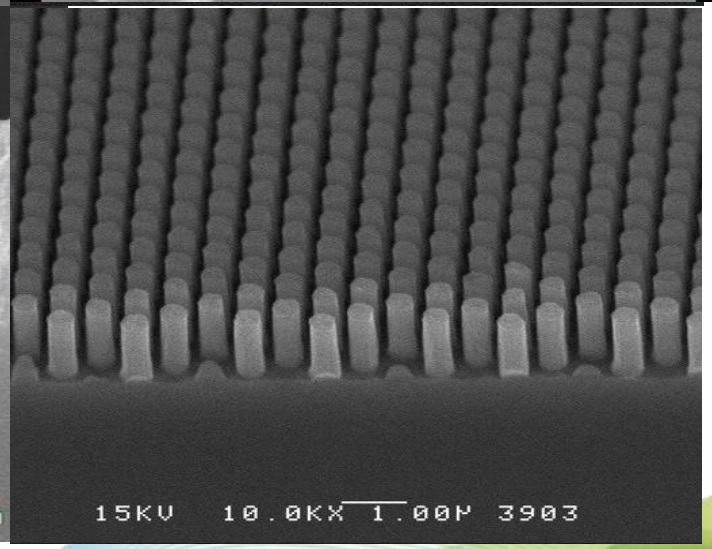
- vs. amplitude lithography: smaller feature sizes
  - Diffraction limited, 5um for far field (at volume)
- vs. NIL: no residuals, enables liftoff/additional layers (at larger feature sizes)

Made with RML®



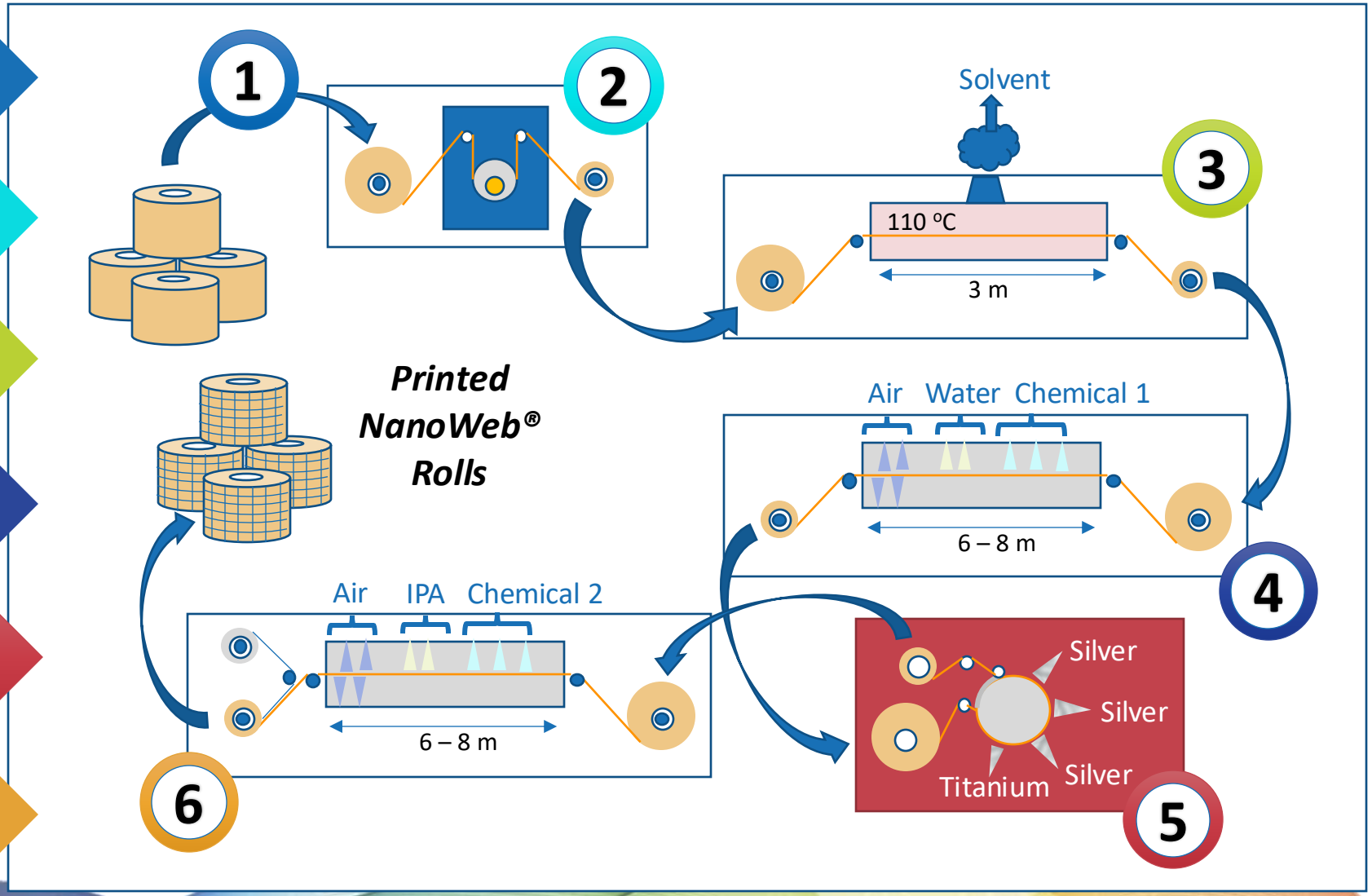






R2R Rolling Mask Lithography

1. **Loading**
   Pre-coated PET film with bi-layer photoresists.
2. **Exposure**
   Printing with RML technology using UV-365nm and proprietary mask
3. **Baking**
   Stabilizing chemistry of printed design in photoresist.
4. **Development**
   Creation of 3D structures in Photoresist.
5. **Metallization**
   Metal in deposition to create continuous metal mesh.
6. **Lift off and Protection**
   Removal of unwanted material and protection of mesh prior to re-winding.



Nanoimprint Lithography Workflow

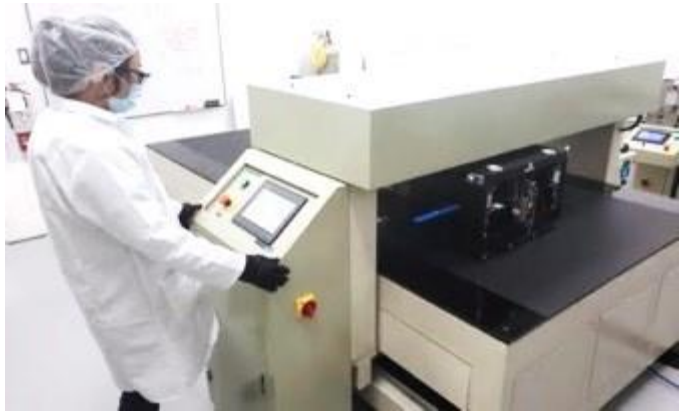
META®

Design & Simulation
- Graphics, Photonics, EBL Optimization

Ni Shim Master
- Etching, replicating, electroforming

UV –NIL Master
- Casting, Electroforming, Metrology

Electron beam lithography



Step-and-repeat Nano-imprint lithography

Recombined Ni Shim

Plasmonic full parallax display foil product

Recombination
- UV Step & Repeat NIL

Ni Master
- Electroforming

R2R Casting
- UV-NIL

R2R Coating
- E-beam deposition

De-Met
- Mask printing
- Water based lift off

Conversion
- Adhesive
- Slitting/ Trimming

R2R UV-NIL Line - Industrial Foil Production Process

- Ultra high-resolution replication: nanometer scale
- Wide Web Embossing: up to 1200mm
- High speed: up to 150 m/min
- Ni Working Shims
- Cold UV Lamps

Thank You

info@metamaterial.com

META®
Go Beyond.