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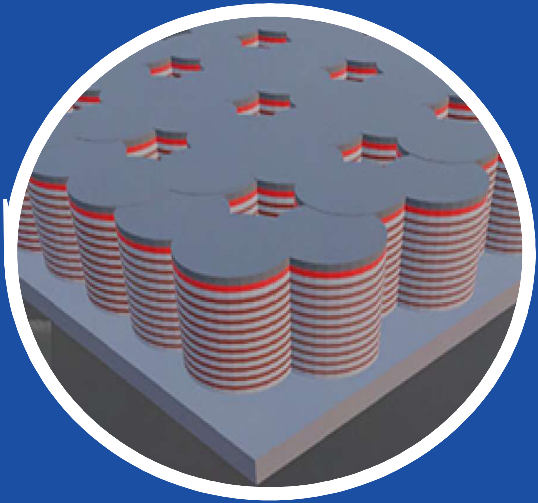
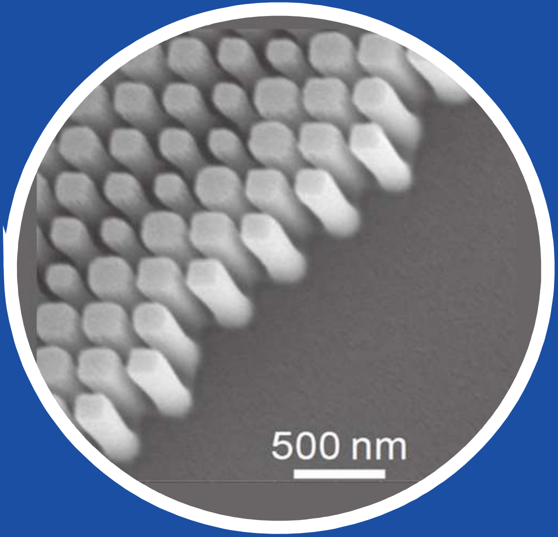
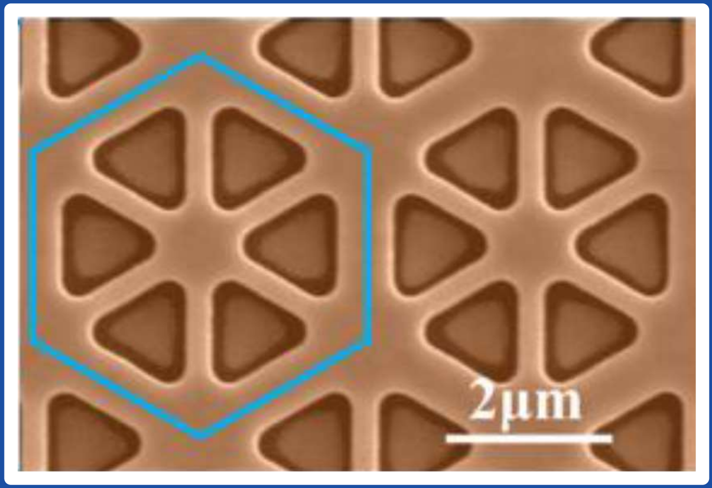


ASRC Nanofabrication Facility Research Showcase Day

October 17, 2024





NANOFABRICATION FACILITY
ADVANCED SCIENCE RESEARCH CENTER

ASRC Nanofabrication Facility Research Showcase Day

A Day of Connection, Collaboration and Celebration

October 17, 2024

City University of New York
Advanced Science Research Center
85 Saint Nicholas Terrace
New York, NY 10031

Email: nanofab@gc.cuny.edu
Website: https://asrc.gc.cuny.edu/facilities/nanofabrication/

Table of Contents

Acknowledgements for the cover images [with abstract page]**:**

Upper Left – Kevin Gu, Astrabeam LLC [p. 38]
Upper Right – Rishabh Kaurav, Vinod Menon, et al, CUNY [p. 27]
Lower Left – Yuan Xu, Jaihao Wu, Nanfang Yu, et al, Columbia Univ. [p. 32]
Lower Right – Sriram Guddala, Alexander Khanikaev, Andrea Alu, CUNY [p. 18]

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Madeline Boreman

Shawn Kilpatrick

Samantha Roberts

Without the dedicated hard work of these colleagues, this event would not have been possible. Thank you.

Morning Program

8:30 AM - 9:00 AM	**Registration and Coffee**
9:00 AM - 9:20 AM	**Opening Remarks**
9:00 AM	**Rein Ulijn** - *Director of Nanoscience, ASRC*
9:10 AM	**Samantha Roberts** - *Nanofabrication Facility Director, ASRC* "Vision of the ASRC Nanofab"
9:20 AM - 10:35 AM	**Session 1: Vision and Mission of the ASRC Nanofab Facility** Session Chair: Samantha Roberts, ASRC
9:20 AM	**Vinod Menon** - *Professor of Physics, City College of New York* "ASRC Nanofab 2008 BC (before construction) to Today - From Blueprint to Polaritonics"
9:45 AM	**Michael Skvarla** - *User Program Manager, CNF, Cornell University* "Evolution of the Cornell NanoScale Facility - Community and Continuity"
10:10 AM	**Ioannis (John) Kymissis** - *Professor Electrical Eng, Columbia University* "MicroLEDs for Display and Non-Display Applications"
10:35 AM - 10:50 AM	**Break**
10:50 AM - 11:35 AM	**Panel: Pathways to Industry** Session Chair: Tavis Ezell
	James Scholtz - *Founder and CEO of Vyir Tech*
	Jacob Trevino - *CIO of Chemeleon*
	Ioannis (John) Kymissis - *Professor, Columbia University*
	Aykut Aksit - *Founder and CEO of Haystack Medical*
11:45 AM - 12:35 PM	**Session 2: Metasurfaces and Fabrication** Session Chair: Salam Elhalabi, ASRC
11:45 AM	**Svetlana Kiriushechkina** - *Research Specialist, Lurie Nanofabrication Facility, University of Michigan* "Nanofabrication of Topological Metasurfaces"
12:10 PM	**Viktoriia Rutckaia** - *Photonics Core Facility Director, ASRC* "Precision Nanofabrication for Photonic Innovation: From Resonators to Metasurfaces and BIC"
12:35 PM - 12:45 PM	**Sponsor Remarks**

Afternoon Program

12:45 PM - 2:00 PM	**Lunch, Dessert and Coffee**
2:00 PM - 3:15 PM	**Session 3: Multidisciplinary Research** Session Chair: Emma Anquillare, ASRC
2:00 PM	**Haogang Cai** - *Assistant Professor, NYU Grossman School of Medicine* "High-resolution Nanofabrication of Bio-chips and Metasurfaces"
2:25 PM	**Daniella Hammer** - *Ph.D Student, Columbia University (PI: Jeffrey Kysar)* "Design and Fabrication of Hollow Microneedles for the Murine Inner Ear"
2:40 PM	**Yuan Xu** - *Ph.D Student, Columbia University (PI: Nanfang Yu)* "High-Precision Holographic Metasurfaces for Large-Scale Single-Atom Optical Tweezer Arrays"
2:55 PM	**Anton Kyrylenko** - *Ph.D Student, CUNY ASRC (PI: Matthew Sfeir)* "Light-Harvesting Semiconductor Metasurfaces for the Enhancement of Photocatalytic Activity"
3:15 PM - 3:30 PM	**Break**
3:30 PM - 4:30 PM	**Session 4: Electronics and Optics** Session Chair: Shawn Kilpatrick
3:30 PM	**Savannah Eisner** - *Assistant Professor, Columbia University* "Robust Ultra-Wide-Bandgap Microelectronics for New Frontiers in Harsh Environments"
3:55 PM	**Maryam Barzegar** - *Postdoctoral Fellow, NYU (PI: Javad Shabani)* "Advanced Nanofabrication Techniques for Realizing Quantum Computing Devices"
4:10 PM	**Lin Jing** - *Postdoctoral Fellow, CUNY ASRC, (PI: Andrea Alu)* "Spin-momentum Locked Thermal Metasurfaces"
4:30 PM	**Closing Remarks**
4:45 PM	**Poster Walkthrough, Cocktails, and Networking Social**
6:15 PM	**Award Ceremony**
6:45 PM	**End of Day**

Invited Speakers and Panelists

Aykut Aksit

Aykut Aksit is the founder of Haystack Medical, a startup focused on developing cutting edge technologies for treating hearing loss and balance disorders. During his PhD at Columbia University, he designed specialized microscale needles for inner ear drug delivery, pioneering a novel approach in the field. The company has secured substantial non-dilutive funding from the NIDCD and holds 20+ patents in microscale medical devices. Aykut is committed to solving significant health challenges by creating practical solutions that bridge engineering and medicine.

Haogang Cai

Haogang Cai is an assistant professor in the Tech4Health Institute and Department of Radiology, at New York University Grossman School of Medicine. He received his Ph.D. degree from the Department of Mechanical Engineering at Columbia University in 2016. From 2016 to 2020, he had postdoctoral training in Biological Sciences at Columbia, and at the Center for Nanoscale Materials at Argonne National Laboratory. His research interests include biomedical and nanoengineering, optical metasurfaces and metamaterials, cell mechanobiology and immunology.

Savannah Eisner

Savannah Eisner is an Assistant Professor in the Department of Electrical Engineering at Columbia University. She received the Ph.D. and M.S. degrees in electrical engineering from Stanford University in 2020 and 2023, respectively, and the B.S. degree from Villanova University in 2017. Her dissertation research focused on the use of uncooled GaN transistors for extreme environment space exploration applications. Her research interests include the design of (ultra)wide-bandgap micro/nanoelectronic sensors and systems for harsh environment applications. Dr. Eisner was a National Science Foundation (NSF) Graduate Research Fellow and a Future Technical Leaders Fellow of the NSF engineering research center for power optimization and electro-thermal systems. She is the recipient of an IEEE Aerospace Best Paper Award.

Svetlana Kiriushechkina

Svetlana Kiriushechkina is Semiconductor Research Specialist at Lurie Nanofabrication Facility (LNF) at University of Michigan, Ann Arbor. She received BSc in physics at the Moscow State University in 2016 and PhD in electrical engineering at the City College of New York CUNY in 2023. In 2018, she joined Prof. Alexander Khanikaev's research group at the CCNY as a PhD candidate and continued to work there as a postdoctoral fellow until 2024. Her research projects focused on metamaterials, topological photonics and polaritonics. She is a co-author of over 15 papers in peer-reviewed journals, including Science, Nature Nanotechnology, Advance Materials. In her current role at LNF funded by the Silicon Crossroads Microelectronics Commons Svetlana specializes in supporting advanced nanofabrication needs for both industry and academic users, and in accelerating research and development projects in semiconductor-related fields.

John Kymissis

Ioannis (John) Kymissis is the Kenneth Brayer Professor of Electrical Engineering at Columbia University and Vice Dean for Infrastructure and Innovation of the Fu Foundation School of Engineering. He graduated with his SB, M.Eng., and Ph.D. degrees from MIT. His M.Eng. thesis was performed as a co-op at the IBM T.J. Watson Research Lab on organic thin-film transistors, and his Ph.D. was obtained in the Microsystems Technology Lab at MIT, working on field-emission displays. After graduation, he spent three years as a postdoc in MIT's Laboratory for Organic Optics and Electronics, working on a variety of organic electronic devices, and also as a senior engineer for QD Vision (later acquired by Samsung Electronics). He joined the faculty at Columbia University in electrical engineering as an assistant professor in 2006, and served as chair of the department from 2000-2024. He is a fellow of the IEEE, Optica, and the Society for Information Display (SID), and is currently the president of SID.

Vinod Menon

Vinod Menon is a Professor of Physics at the City College of New York and doctoral faculty at the Graduate Center of the City University of New York (CUNY). He is a fellow of the Optical Society of America (now Optica), The American Physical Society (APS) and an IEEE Distinguished Lecturer in Photonics (2018-2020). Prior to joining CUNY in 2004, he was at Princeton University (2001-2004) where he was the Lucent Bell Labs Post-Doctoral Fellow in Photonics. He received his MSc in Physics from the University of Hyderabad, India in 1995 and his Ph.D. in Physics from the University of Massachusetts in 2001. Details about his research interests and his group can be found at: https://lanmp.org/ .

Viktoriia Rutckaia

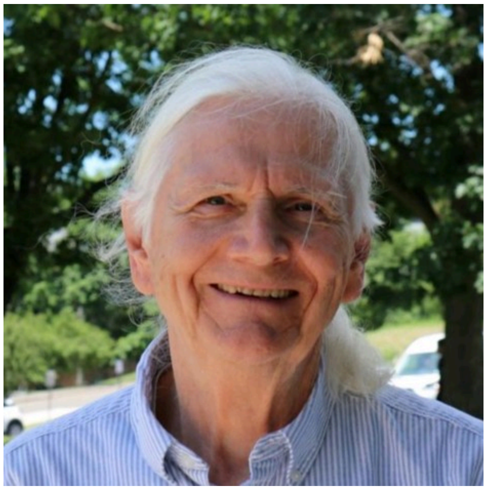
Viktoriia Rutckaia joined the ASRC as the Director of the Photonics Core Facility in April 2023. Her research is rooted in the study of light-matter interactions within dielectric and plasmonic structures, silicon photonics, and active emitting materials. She brings a wide range of skills, including numerical modeling, nanofabrication, and optical characterization of nanodevices, which significantly bolster the research conducted at ASRC.

Prior to this, Rutckaia held a Marie Sklodowska-Curie Individual Global Fellowship at ASRC, working with Prof. Andrea Alu, and at Martin-Luther University of Halle-Wittenberg, under the mentorship of Prof. Joerg Schilling. In 2018, she earned her Dr. rer. nat. degree in Physics from Martin-Luther University of Halle-Wittenberg, Germany. Earlier in her academic journey, she completed her Master's and Bachelor's degrees at Alferov University in 2012 and Peter the Great St. Petersburg Polytechnic University in 2010, respectively.

James Scholtz

James Scholtz is the founder and CEO of Vyir (pronounced Vie-er). He is a physicist and laser and optical engineer with over 20 years of experience designing and building complex optical systems and sensors. He combined his passion for science, innovation, and entrepreneurship with his grit and resourcefulness to develop Vyir's Optical Infrared Camera and its proprietary Nano EnCoater Technology. He is an alumnus of Stony Brook University and The City College of New York, and presently an Activate Fellow.

Michael Skvarla



Michael Skvarla is a User Program Manager at the Cornell NanoScale Science and Technology Facility, responsible for the technical and administrative coordination of the CNF research program, involving several hundred active research projects and their associated personnel. Additional duties include outreach and workforce development.

He received the Bachelor of Science in Physics from Wilkes University in Wilkes-Barre, Pennsylvania, and the Master of Science in Physics from Rensselaer Polytechnic Institute in Troy, New York. After working with the Cornell Physics Department, he joined the CNF in 1982 and has investigated all aspects of micro- and nano-fabrication technologies. He has been a part of the technical evolution of the CNF and currently works to introduce a varied population of researchers to the techniques of micro- and nano-fabrication.

Jacob Trevino

Jacob Trevino, Ph.D. is the Chief Innovation Officer at Chemeleon, a Brooklyn, NY-based start-up company developing next-generation point-of-care diagnostics for the medical community. Dr. Trevino is also an Adjunct Associate Professor at Columbia University in the Department of Electrical Engineering and founder and president of Nanotech NYC. Dr. Trevino has a BS in Physics and BA in Mathematics from Susquehanna University, an MS in Electrical Engineering from Case Western Reserve University and a PhD in Materials Science & Engineering from Boston University. Over the years he has held the position of Nanofabrication Facility Director at the CUNY Advanced Science Research Center, New York University, and the University of Pennsylvania. He has also held senior micro-electro-mechanical systems engineering roles at Analog Devices and Integrated Sensing Systems, Inc.

Abstract Index

** Highlighted Abstracts have been selected for talks **

Physics

Optics and Photonics

Biological Applications

Electronics and Materials

Quantifying Spin Orbit Torques in Transition Metal Multilayer Nanostructures

Ahmet Koral Aykin and Andrew D. Kent

Center for Quantum Phenomena, Department of Physics, New York University, New York, New York 10003, United States

Spin orbit torque (SOT), exerted by the spin current and originating from spin-orbit coupling effects, is of great importance towards efficient manipulation of magnetization for spintronic devices. There have been numerous reports on that the main mechanism which gives rise to SOT is either the spin Hall effect in the non-magnetic layer or interfacial spin-orbit coupling developing at non-magnetic/ferromagnetic interface [1]. A variety of materials have been demonstrated to have high spin orbit coupling, which includes but not limited to Pt, W, and Ta. SOT enables efficient switching of magnetic moments with a reduced power consumption and faster operational speeds as well as simple device structures compared to its alternatives. The key advantages of SOT include its scalability for miniaturized devices, compatibility with existing semiconductor technology, and potential for integration into advanced unconventional computing architectures like neuromorphic computing.

Quantifying the efficiency of SOT and distinguishing between different types of torques are at the center of this rapidly developing field of current-induced magnetization dynamics. Various electrical and optical techniques have been used for that purpose such as Spin Torque Ferromagnetic Resonance (ST-FMR) [2]. ST-FMR is a phenomenon which exploits the interaction between spin polarized current driven at a fixed RF frequency and the magnetization. It is an elegant electrical technique for quantifying both in-plane and out-of-plane torques exerted on the magnetic moments of the ferromagnetic layer.

In ST-FMR, it is important for the ferromagnetic layer to have large magnetoresistance and low coercive fields. For that purpose, we fabricated a micro wire with a 30 µm width and consisting of a film stack [Ta(1.5)/Pt(4)/Co(1)/Ta(2)/MgO(2)] (all numbers are dimensions in nm). The micro wires and electrical contact pads are patterned using aligned electron beam lithography (EBL) with a beam current of 50 nA and sputter deposited at an Ar pressure of 3 mTorr onto 7x7 mm^2 Si chips. The samples are rotated at a rate of 20 rpm to achieve a uniform surface in a ultra-high vacuum (UHV) sputter system with a base pressure around 10^{-8} Torr. The current is spin polarized in 4 nm thick Pt layer as a result of spin Hall effect, which in turn injected to the ferromagnetic layer of 1 nm Co. We study SOT by electrical and optical means and quantify the different types of current-induced torques, revealing the interplay between those torques and anisotropy.

1. Yun, S., Park, ES., Lee, KJ. *et al.* Accurate analysis of harmonic Hall voltage measurement for spin–orbit torques. *NPG Asia Mater* **9**, e449 (2017). https://doi.org/10.1038/am.2017.200

2. Brataas, A., Kent, A. & Ohno, H. Current-induced torques in magnetic materials. *Nature Mater* **11**, 372–381 (2012). https://doi.org/10.1038/nmat3311

Advanced Nanofabrication Techniques for Realizing Quantum Computing Devices

Maryam Barzegar, Lukas Baker, Melissa Mikalsen, Javad Shabani*[1]

Center for Quantum Information Physics (CQIP), New York University, New York

Abstract

Superconductive devices are among the most reliable engineered devices for quantum computing. Our research focuses on developing quantum devices utilizing high-end nanofabrication processes requiring complex, multilayer lithography with precise overlay alignment. Specifically, we focus on the fabrication and optimization of gate-tunable Transmon (Gatemon) qubits[2]. These qubits consist of two key components, namely a capacitor and a single superconductor/semiconductor Josephson junction, which is fabricated onto an epitaxially grown Al/InAs heterostructure. The two components are placed in parallel, creating a resonant circuit with a characteristic frequency
related to the respective charging and Josephson energies, which be given as $f_Q = \sqrt{8E_CE_J}$. The top gate tunes the Josephson energy with a range of ~2-4 GHz. The fabrication process for these devices involves three steps using electron-beam lithography, all of which were carried out at the CUNY ASRC Nanofabrication Facility. The microwave circuit containing the qubit capacitors, as well as the readout resonators were fabricated first. Then, the Josephson junction was formed by etching a 30 nm wide gap into the superconducting layer (Fig. 1a). A dielectric layer was subsequently deposited via atomic layer deposition (ALD). In the final step, the gates were patterned using lithography method and deposited via sputtering.

Likewise, we perform quantum simulation using thin film aluminum Josephson junction arrays, to simulate disorder where "artificial atoms" are emulated by fabricated superconducting islands, and the coupling between artificial atoms is simulated by Josephson junctions. Coupling between islands can be mediated by gate tunable superconductor-semiconductor based junctions[3]. The fabrication of the Array of Josephson Junctions with aluminum leads coupled via an aluminum oxide tunnel barrier begins with electron-beam lithography to define the bottom lead. Aluminum is then sputtered onto the patterned area, and the excess is lifted off. Exposure of the first aluminum layer to the atmosphere creates an aluminum oxide barrier. A subsequent lithography and sputtering step form the top electrode of the Josephson junction (Fig. 1b).

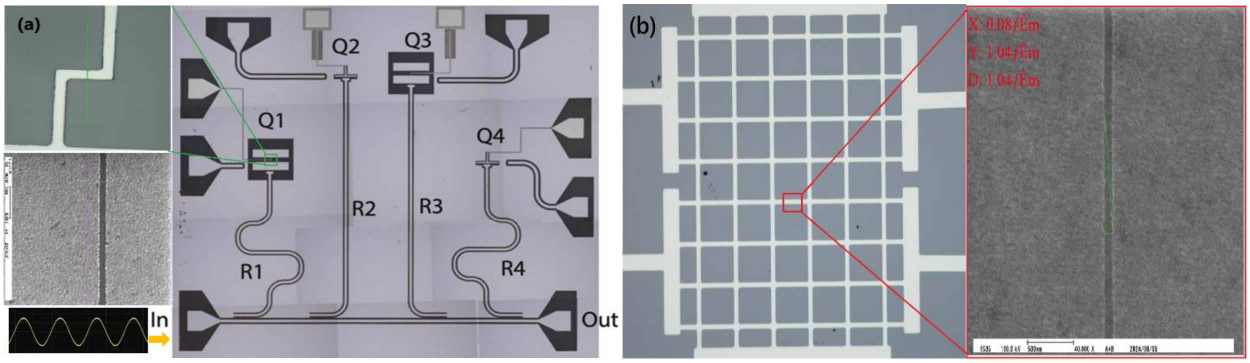


Figure 1. (a) Gatemon qubits with Josephson junction gap. (b) The Josephson junction array

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[1] *js10080@nyu.edu

[2] Phys. Rev. Research 6, 023094

[3] arXiv:2409.09835

A Brief Introduction to Topological Quantum Computation

Matthew Wilson[1,2], Ting He[1], Bo Gao[1]

[1]Department of Physics and Astronomy, Hunter College, The City University of New York

[2]Macaulay Honors College, The City University of New York

It is believed that topological quantum computing technology – quantum computing with anyons, is developed to be naturally protected from decoherence so that no active quantum error correction is needed. Although it is gaining momentum to build scalable and fault-tolerant quantum computer in the near future, it is crucial to solve the open problems in the field. We introduce the key properties that define anyons and how they enable protected encoding and processing of quantum information. We outline the general steps of topological quantum computation and review the recent progress in condensed matter systems where anyons can emerge, along with the challenges these systems face.

Quantum Materials Photonics for Quantum Information Science Applications

Sriram Guddala[1,2], Alexander B. Khanikaev[1,2,3,*], Andrea Alù[1,2]

[1]Physics Program, Graduate Center of the City University of New York, New York, NY 10016, USA.
[2]Photonics Initiative, Advanced Science Research Center, City University of New York, New York City, NY, 10031, USA.
[3]CREOL, The College of Optics and Photonics, University of Central Florida, Orlando, Florida 32816, USA

Quantum materials with atomic layer thickness exhibit quantized electronic energy levels and offer unique optical and electronic properties that are absent in their bulk counterparts[1]. On the other hand, judicially engineered photonic nanostructures, known as metamaterials, display unusual optical properties not found in naturally occurring materials, and enable confinement and routing of light for integrated information processing applications. The prime focus of our research aimed at unifying these two fascinating platforms and explore light-matter interaction in 2D quantum materials integrated with photonic nanostructures for optical routing, information processing, optoelectronics, sensing and envisioned quantum revolution.

We will present novel quantum materials photonic systems that have been explored in this motive. Especially, the novel hybrid states of polaritons – half-light and half-matter quasi particles, with valley encoded information that can be controlled on-chip along unprecedented pathways without being scattered by the defects in the medium. We will demonstrate two intriguing polaritonic phases: topological phonon-polaritons and topological exciton polaritons that would allow on-chip optical control on thermal energy engineering and information processing[2,3].

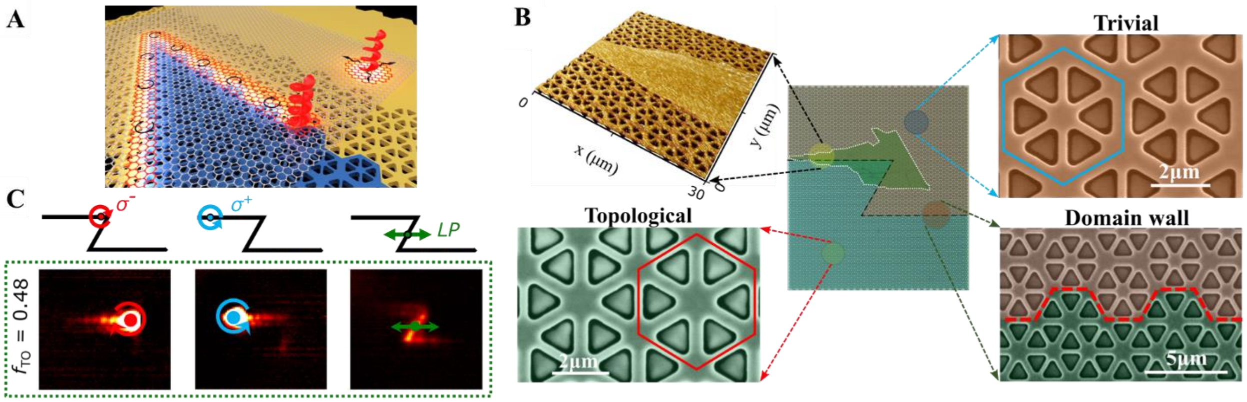


Figure: Topological phonon-polaritons. A) schematic representing funneling of lattice vibrations (phonons) in unidirectional paths with helical polarization. B) hexagonal boron-nitride (hBN) thin film integrated silicon topological photonic metasurface with trivial and topological domains and thin hBN on top of their interface region. C) Experimentally measured unidirectionally propagating topological phonon-polaritons under circular and linear polarization excitations.

1. Basov, D. N., R. D. Averitt, and D. Hsieh. "Towards properties on demand in quantum materials." *Nature materials* 16, no. 11: 1077-1088 (2017).
2. Guddala, S., et al. "Topological phonon-polariton funneling in midinfrared metasurfaces." *Science* 374.6564: 225-227 (2021).
3. Li, Mengyao, et al. "Experimental observation of topological Z2 exciton-polaritons in transition metal dichalcogenide monolayers." *Nature communications* 12.1: 4425 (2021).

Development of an Optical Infrared Camera using Nano-EnCoater Technology

James Scholtz, Abigail Berkowitz, Brandon Nunez, Joseph Demarest

Vyir Tech; New York, New York

Vyir is developing an optical infrared camera that is lower cost with better image quality and can be used in numerous applications including defense, security, methane gas detection, automotive safety, and to enable autonomy.

Technology Vision: A typical infrared camera uses pixels fabricated from semiconductor materials that are electrically read out. These are expensive and low-resolution, preventing their adoption for promising applications. Vyir's optical infrared camera uses pixels fabricated from its nano EnCoater technology that transduce the information from an infrared image into visible laser light and then uses a standard cell phone complementary metal-oxide semiconductor camera for optical readout. This approach enables a 10X reduction in price, reducing hardware size, weight, and power and enhancing pixels by 15X to provide better image quality.

Potential for Impact: Infrared cameras are versatile tools that enable the world to literally be seen in a different light. They enhance our awareness and lead to increased safety, resulting in reduced loss of life and property damage. What you don't see may harm you. Threats on a battlefield can be identified by soldiers with infrared cameras, dangerous gas leaks in the petrochemical industry can be located from a safe distance and automobiles can see at night, through rain, and gain awareness of potential obstacles. Vyir's vision is to make this technology universal.

Biometric Imaging of Ultra-Uniform Substrates Using Raman Spectroscopy

Isabella Viera, Hao Wang

Tech4Health, Radiology, NYU Langone, Long Island City NY, USA

Raman spectroscopy has become an increasingly prevalent analytical technique in chemical detection, yet is incredibly sensitive to substrate form and properties. While current literature focuses on how metallic nanostructures, such as spheres and columns, aid in overcoming the technique's sensitivities, we seek to discuss how varying film thicknesses can achieve a similar effect. We've reported the Raman shifts and signal intensities of micro-engineered nanostructures, with each substrate varying in gold deposition thickness (10nm, 50nm, 200nm respectively). The samples contain an area of polystyrene beads (1 µm) coated with trifluoromethyl benzoic acid. Fingerprint impressions were made using Crystal Violet and Rhodamine B lightly stamped directly onto areas with and without the polystyrene beads. We measured the Raman shift and signal intensities at characteristic peaks in order to both confirm the presence/absence of the dye and to quantify signal strength. Substrates with a larger Au depositional layer reported greater Raman signal intensities, while the 10µm layer displayed the weakest signals, likely due to disruption during the fingerprinting process. Moreover, we measured substrate stability and uniformity using SEM and AFM imaging. Substrates that displayed greater levels of surface uniformity correlated with those displaying greater signal strength. Through this model we aim to optimize the parameters, such as substrate thickness and fingerprinting procedure, which aid in the enhanced detection of desired chemical molecules. In doing so, achieving the optimal conditions that allow for robust and effective Raman imaging.

a)

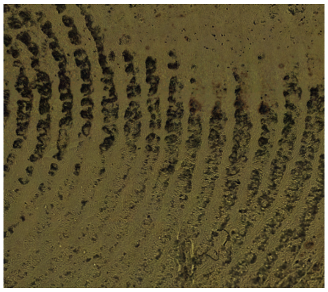


Figure 1: a) Image of fingerprint impression left using crystal violet on 50nm Au.

References:

[1] Liu, X.; Wang, J.; Wang, J.; Tang, L.; Ying, Y. Flexible and Transparent Surface-Enhanced Raman Scattering (SERS)-Active Metafilm for Visualizing Trace Molecules via Raman Spectral Mapping. *Anal. Chem.* **2016**, *88* (12), 6166– 6173, DOI: 10.1021/acs.analchem.6b00858

Strong Coupling in 2D Perovskites

Serena Zachariah

Department of Physics, City College of New York, City University of New York, NY 10031

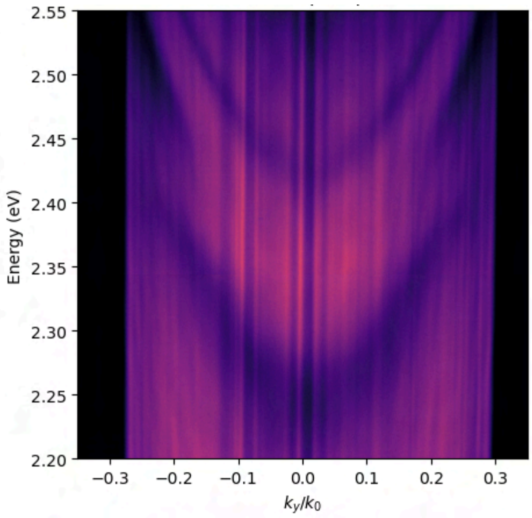
Hybrid organic-inorganic perovskites have attracted significant attention due to their unique optical properties, such as high photoluminescence quantum yields, tunable bandgaps, and excitonic resonances at room temperature. By combining these materials with precisely engineered nanostructures, we create can cavities that support the formation of exciton-polaritons, a clear indicator of strong coupling. This work presents the design, fabrication, and characterization of perovskite-based optical cavities demonstrating strong light-matter interactions.

The planar cavities were fabricated by spinning the perovskite solution on a Distributed Bragg Reflector(DBR), deposited on a glass substrate. The 2D perovskite used here is butylammonium lead iodide (BAPI, n=1). It was spun onto a bottom DBR with a center wavelength around 580 nm.

The thickness of the perovskite layer was changed by changing the concentration of the perovskite solution and/or the spin speed during spin coating. A layer of PMMA was also spun on top of the perovskite to act as a spacer to tune the cavity wavelength. Atomic Force Microscopy(AFM) was used to determine the thickness of the perovskite and PMMA layers.

The top mirror to complete the cavity was made by depositing a semi-transparent layer of silver(~40 nm) on top using Electron beam Evaporation. Plasma Enhanced Chemical Vapor Deposition(PECVD) was also used to make a transferable top DBR to make a higher Q cavity.

Optical characterization of the fabricated cavities using photoluminescence and reflectivity measurements revealed clear Rabi splitting in a cavity with a 40 nm layer of perovskite and a 180 nm layer of PMMA as a spacer.



Keywords: Strong coupling, perovskites, AFM, electron beam evaporation, PECVD, exciton-polaritons, nanofabrication, quantum photonics

Development of a Robust, Adiabatic Mode-(De-)Multiplexer for 10 Modes

Hans G. J. Blomenkamp, Oliver L. Wang, Michal Lipson (Columbia University)

Abstract:

With the ever-growing demand for high-speed telecommunication and inter-computer connections, efficient, low-loss, and energy-saving technologies must be developed.[1] In this project, a 10-mode (de-)multiplexer (DEMUX) is designed by using linear tapered access waveguides to excite the higher-order modes in a bus waveguide with high coupling efficiency.[2]

It is shown that in simulations the coupling efficiency is < -1dB, while in the experiments a constant coupling efficiency is achieved over a wavelength bandwidth of up to 200 nm. In addition, in a fabricated complete mode (de-)multiplexer, the crosstalk is < -15dB. By combining the mode (de-)multiplexing approach with wavelength multiplexing, the number of independent channels can be further increased and high data transmission rates can be achieved.[3]

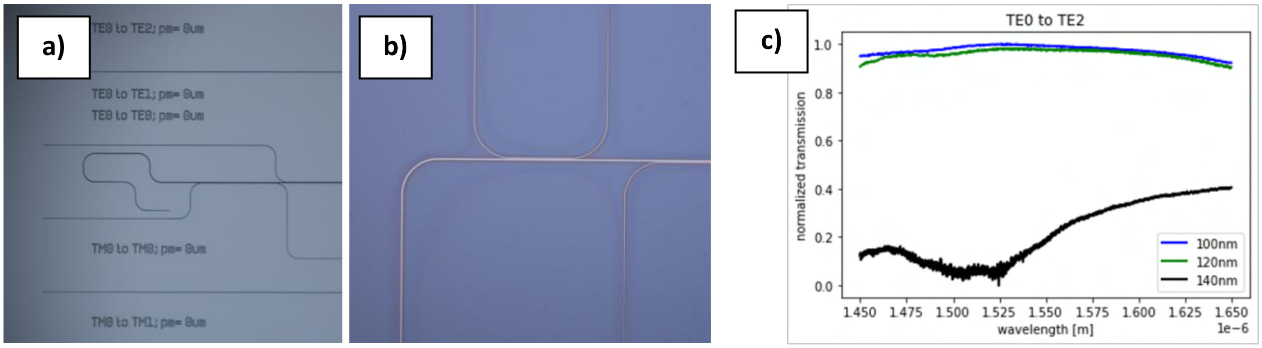


Fig.1: a) shows an optical microscope image of the fabricated adiabatic DEMUX, while b) shows an image of the coupling section. c) shows the normalized transmission of exciting the second higher-order TE mode in the bus waveguide, with the fundamental TE mode in the access waveguide.

References:

[1]: https://www.ncta.com/whats-new/behind-the-numbers-growth-in-the-internet-of-things, Access: 09/03/2024

[2]: NV Vitanov and BM Garraway. “Landau-Zener model: Effects of finite coupling duration”. In: Physical Review A 53.6 (1996), p. 4288. doi: 10.1103/PhysRevA.53.4288.

[3]: Anthony Rizzo et al. “Massively scalable Kerr comb-driven silicon photonic link”. In: Nature Photonics 17.9 (2023), pp. 781–790. doi: 10.1038/s41566-023-01244-7.

About Hans G. J. Blomenkamp

Hans G. J. Blomenkamp (hb2694@columbia.edu) is a 3rd-year Ph.D.-student at the lab of Prof. Dr. Michal Lipson (ml3745@columbia.edu), at Columbia University. Hans studied Nanotechnology with focus on Semiconductor-Technology at the Technische Universität Bergakademie Freiberg, Germany, as a Diplom student (B.S. + M.S.), and worked amongst others, at the University of Tokyo, Japan, and at Nokia of America as a Photonic Test Intern.

Nonlocal metasurface for manipulating light in the Long Wave Infrared

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Metasurface flat optics is paving the way to enhanced and novel functionality while using less material and volume compared to the conventional bulky, expansive, and heavy optics. In the most general case, a metasurface is diffractive and nonlocal (i.e. spatially dispersive), meaning that it can manipulate the spatial, polarization and spectral degrees of freedom of optical wavefronts. In this sense, perturbative nonlocal diffractive metasurfaces sustaining a quasi-bound state in the continuum (q-BIC) are emerging as a leading technology for realizing compact tailored optical devices. Within this context, we realize a wavelength- and handedness-selective nonlocal metasurface that enables imaging in the long-wave infrared (LWIR, 8-14μm). Our metasurface is constituted by a nanopatterned 1.4 um film of Ge on a substrate of ZnSe. The encoded geometric phase profile ensures narrow band focusing only at 10.3 um, corresponding to the peak resonance of the q-BIC of a square lattice, and only for right circularly polarized (RCP) light. The device has been fabricated via electron beam evaporation and electron beam lithography and characterized using Fourier-transform infrared (FTIR) spectroscopy and a custom-built transmission mode microscope based on a mid-infrared quantum cascade laser and a thermal camera.

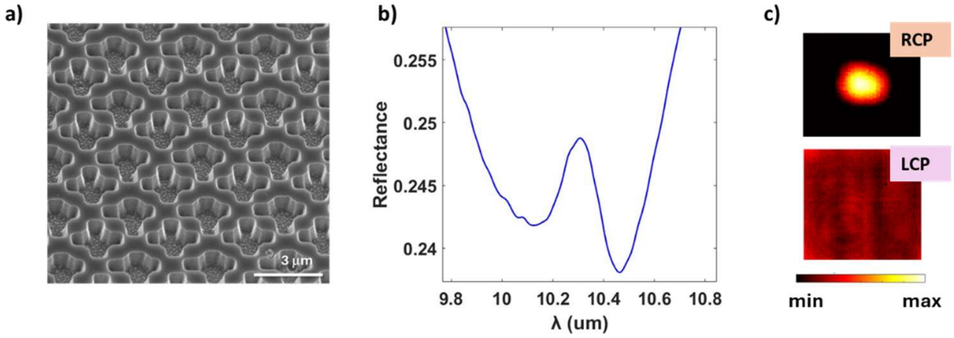

Figure 1. LWIR Metalens characterization. a) SEM image of a portion of the fabricated metasurface. b) FTIR reflection spectrum showing the spectral response of the metalens under unpolarized incident light. The Fano type resonance corresponds to the q-BIC of a 2D square lattice. c) Measured focusing response at the peak of the resonant mode (λ ~10.3 um), for right (top) and left (bottom) circularly polarized input.

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Fabrication and Characterization of Monolayered Transition-Metal Dichalcogenides

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To make devices for quantum networking one must use materials of the highest quality. A quantum transducer, a device that is designed to convert the radio-frequency signal from quantum computers into an optical signal, can be built using a two-dimensional semiconductor material. Such materials are transition metal dichalcogenides (TMDs). In this research, we use the exfoliation method to produce thin layers of WS_2 and $MoSe_2$. It is known from the literature that for TMDs only monolayers (several atoms thick) manifest a strong photoluminescence (PL) emission at room temperature. So, PL at room temperature indicates a monolayer thickness for TMDs. Most of the flakes turned out to be thicker than a monolayer and did not yield any PL signal, except one flake of WS_2. It showed strong PL emission with two peaks around 710 nm and 820 nm. We also studied the PL intensity dependence, showing that the two peaks quench at different rates. The future electrical characterization of the flakes requires nanofabrication of metal contacts. The contacts were made using Electron-Beam Lithography followed by metal deposition and lift-off procedure.

Photoluminescence and Electroluminescence Studies of Transition Metal Dichalcogenide Structures

Maya Alexandra Goldgisser and German Kolmakov

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Atomically thin transition metal dichalcogenide (TMD) layers and heterostructures demonstrated a potential for applications in two-dimensional transistors, sensors, and electroluminescent devices due to strong interaction with light, sizable bandgap, and controlled light-valley interaction [1,2]. In the present work we aim to study photo- and electroluminescence of TMD mono- and multi-layers and their heterogeneous structures. Specifically, we are using molybdenum diselenide ($MoSe_2$) and tungsten disulfide (WS_2) layers exfoliated from bulk crystals. To perform the photoluminescence (PL) and electroluminescence (EL) measurements, the TMD flakes layers were transposed on silicon chips with the procedure similar to that of the method given in Ref. [3]. After spincoating the chip using polymethyl methacrylate, the electric contacts for the EL measurements are written on the chip with the 50 kV-Electron beam lithography (EBL) system and the aluminum/gold contacts are formed with the AJA Orion 8E evaporator system. Following exfoliation, this process is conducted in the clean room of the ASRC Nanofabrication Facility. Exfoliation, PL and EL measurements are done in Grosso's lab and the Photonics laboratory facility of the ASRC Phonics Initiative. Fig.1 shows the $MoSe_2$ flake on the silicon chip (a) and the contacts written on a chip to apply voltage to that flake (b). The authors are grateful to Profs. G. Grosso, V. Dorogan, A. Thielens and V. Rutckaia and Dr. J. Woods for extensive discussions and help with conducting the experiments. This work is supported in part by the Army Research Office, award # W911NF-23-1-0210.

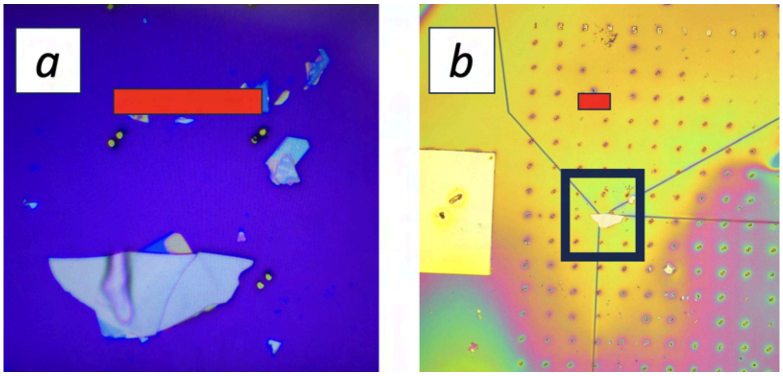

Fig. 1. A micro-photograph of a $MoSe_2$ flake on a silicon chip (a) after the exfoliation and (b) after the contacts are written with the EBL system. The length of the red bar on the pictures is 70 micrometers. A black square in (b) shows the area with the flake in fig. (a).

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Spin-momentum Locked Thermal Metasurfaces

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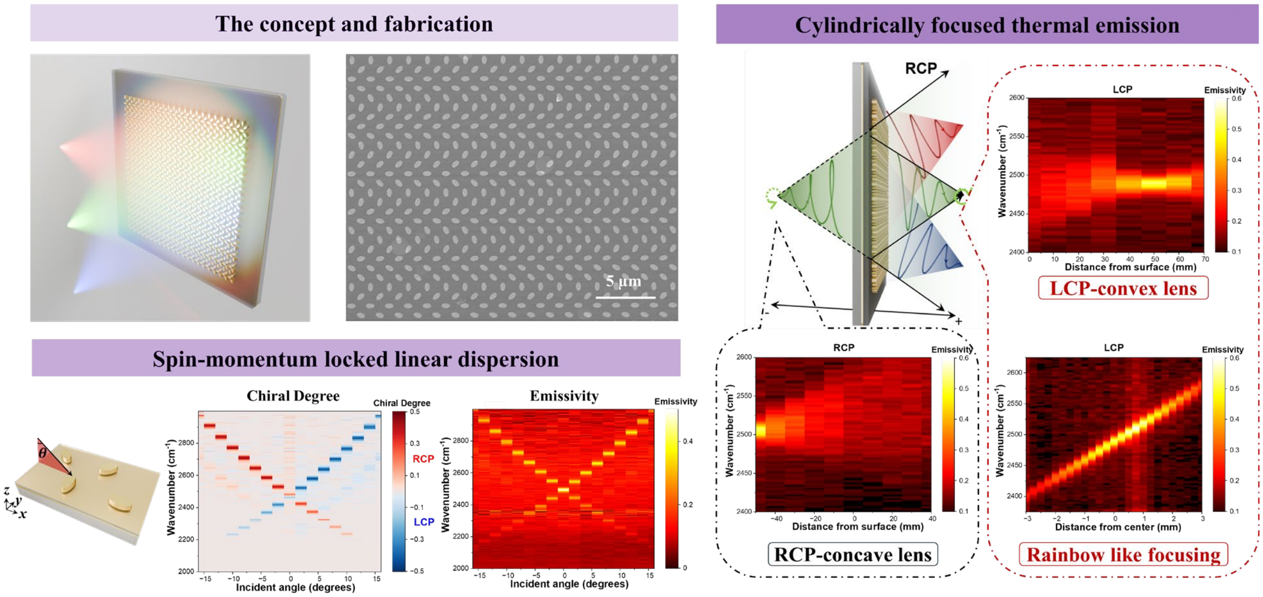
Thermal emission from hot bodies is the most ubiquitous form of light source, yet the properties are inherently hard to engineer because of their incoherent nature. Recent advances in thermal emission engineering have enabled spatially and temporally coherent thermal emissions with defined polarizations by judiciously patterning the surface of thin film materials. However, the wavefront engineering of thermal emission remains largely unexplored. Here, we experimentally demonstrated a single-layer metasurface with high temporal and spatial coherence and spin-momentum locked wavefront control enabled by local engineering. The quasi-bound states in the continuum enable temporal coherence, and spatial coherence is supported by the dispersion of photonic modes. For wavefront engineering, we showcased a spin-momentum locked lens, and the two chiral polarizations function as concave and convex lens, respectively, where the non-local resonances are maintained even with completely aperiodic patterns. The demonstrated platform advances the wavefront control of thermal emission.



We fabricate our metasurfaces using standard lithography and metal lift-off processes. First, a 100 nm layer of Au, with a 10 nm Cr adhesion layer, is deposited onto a quartz substrate via e-beam evaporation. This is followed by the deposition of a silicon dioxide layer (1860 nm) using plasma-enhanced chemical vapor deposition (PECVD). The substrate is then coated with PMMA resist, and the metasurface pattern is defined using e-beam lithography (Elionix 50 keV). To mitigate charging issues during lithography, an anti-charging layer (DisChem DisCharge H2O) is spun onto the PMMA. After lithography, the DisCharge is removed by rinsing with DI water, and the resist is developed using MIBK. Finally, Cr (5 nm) and Au (50 nm) are deposited via e-beam evaporation to form the metasurface layer. The process concludes with Remover PG immersion.

Acknowledgement: ASRC Nanofabrication Facility and all staff members!

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Advanced Nanofabrication for Room-Temperature Polariton Condensate Lattices and Energy Transfer

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This study investigates exciton polariton systems, focusing on nanofabrication techniques for advanced polariton lattice design and energy transfer in organic molecules. We first ex-amine a host-guest system with Rhodamine 3B (R3B) and Nile Blue (NB) dyes embedded in small-molecule ionic isolation lattices (SMILES) [1]. This configuration enhances photoluminescence (PL) while mitigating aggregation-induced quenching, demonstrating superior energy transfer from R3B (donor) to NB (acceptor) compared to conventional mixtures. We assess the impact of the donor's condensate phase[2]] on energy transfer through steady-state, time-resolved, and momentum-resolved spectroscopy, elucidating the roles of molecular coherence and the host matrix.

Additinally, we develop polariton condensate lattices using a top-down approach via Focused Ion Beam (FIB) etching, overcoming limitations of previous bottom-up techniques that con-strained refractive index contrast and lattice geometry. By directly writing high-contrast lattices in a planar microcavity with the SMILES dye system[3], we achieve precise control over periodic, quasi-periodic, and disordered structures, along with defect site introduction. Momentum-resolved spectroscopy reveals the band structure and emergence of polariton condensation. Our research combines enhanced energy transfer in SMILES with FIB-based fabrication methods, advancing the field of exciton polariton studies and facilitating novel device development.

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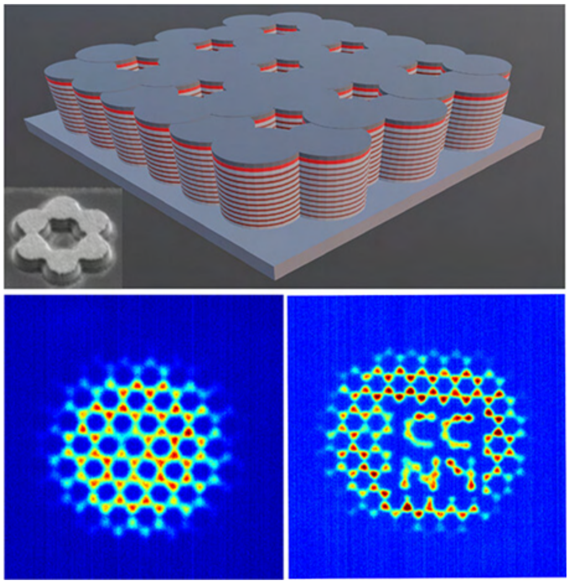

Figure 1. Schematic for patterned honeycomb organic exciton-polariton lattice (top). Room temperature polariton condensate lattice (bottom).

Light-Harvesting Semiconductor Metasurfaces for the Enhancement of Photocatalytic Activity

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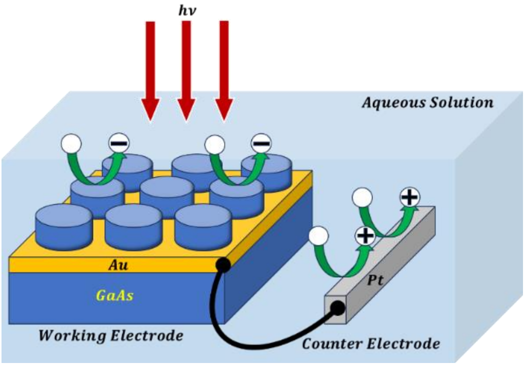
Abstract

A fundamental challenge in the field of heterogeneous photocatalysis is the design and optimization of visible and NIR absorbing semiconductors to maximize the light harvesting efficiency. We posit that a key limitation at longer optical wavelengths results from a mismatch of the characteristic length scales for charge transport, as determined by the depletion width, and absorption length. To address this issue, we present a general framework for tailoring light absorption in nanopatterned arrays of conventional semiconductors. This approach maximizes the generation of carriers in the depletion region and overcomes limitations imposed by relatively poor material quality and weak absorption by nanoscale materials in the visible and NIR spectral region. Key to our design is the optimization of magnetic dipolar Mie resonances with near-unity absorption that preferentially generate charge carriers near the liquid-solid interface, enabling short transport distances and high conversion efficiencies. We demonstrate this approach using moderately doped (~ 10^{18} cm^{-3}) Gallium Arsenide (GaAs) thin films that are patterned to create plasmonic/dielectric hybrid metasurface of 2-D periodically surfaces of nanostructured resonators. We discuss the modeling, simulation and fabrication process for the metasurfaces of ~200 nm height, and the analysis of the resonant mode on the incident photon-to-current efficiency in a photoelectrochemical cell. Our optical measurements on the GaAs metasurface showed a strong absorption resonance near ~ 700 nm. The incident photon-to-current conversion is 22× higher in the GaAs metasurfaces for resonant excitation as compared to flat-film GaAs, which is strong evidence that these metasurfaces maximize the charge carrier generation near the solid-liquid interface. Furthermore, we extend this approach to thin films of amorphous silicon (a-Si) as well as crystalline silicon (c-Si) wafers, to produce metasurfaces with strong absorption resonance at ~600 nm. These structures facilitate the carrier generation on non-epitaxial heterostructures and the use of high-sensitivity ultrafast spectroscopy methods. Transient optical measurements are used to understand the effect of the Mie resonance on charge carrier generation and collection.



Parametric All-Optical Modulation on Chip

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Abstract: We demonstrate parametric all-optical modulation in a periodically-poled lithium niobate microring resonator on chip. It employs quantum Zeno blockade between two distinct waves, a signal and a pump, through their sum-frequency generation at a large per-photon efficiency of 8.2 MHz. With pump pulses at 6 mW peak power, 85.7% modulation extinction is observed, achieving an efficiency improvement of over 30 times compared to previous implementations. These results, together with inherent advantages in photonic integrated circuits, open the door to scalable technology for all-optical and quantum information pro

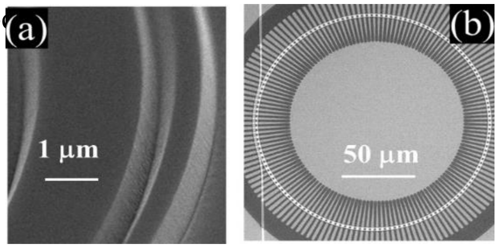

Fig 1: (a) and (b) are the images of the etched pulley coupler before poling process and the periodic poled lithium niobate microring after removing the poling electrodes, respectively.

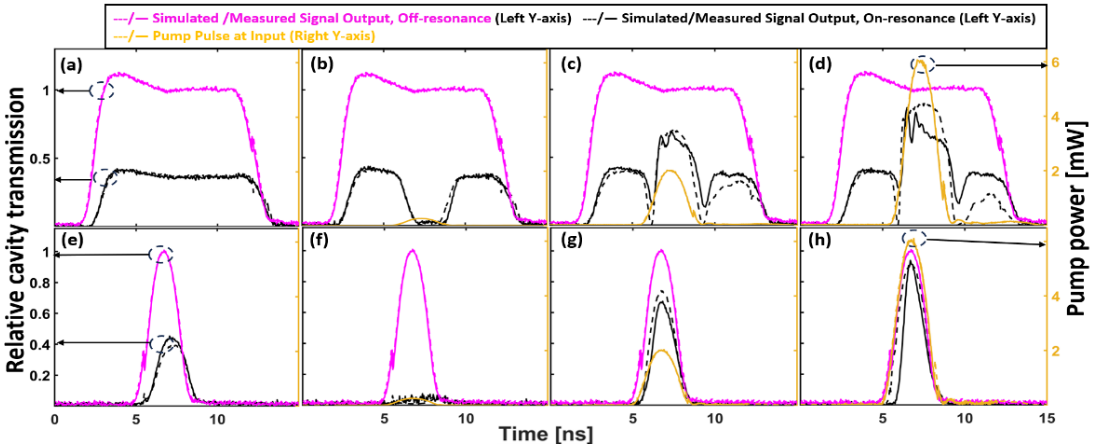

Fig 2: Measured and simulated cavity transmission under various power settings. The top panels plot the results for the case of quasi-CW signal and pulsed pump, with the signal transmission under different conditions: (a) without pump, (b) pump peak power at 0.25 mW, (c) pump peak power at 2 mW, and (d) pump peak power at 6 mW. The bottom panels plot the signal transmission in the case of pulsed signal and pulsed pump, where, similar to the top panels, (e) is the result without pump, and (f), (g), (h) are with pump peak power at 0.25 mW, 2 mW, and 6 mW, respectively. In all figures, the solid curves represent the experimental results. The dashed curves are the simulation results. The pink curves are the signal relative transmission under off-resonance. The black curves are the signal relative transmission on resonance with different pump peak powers. The orange curves give the pump pulse profiles at the input.

Li, Z., Chen, J., Ma, Z., Tang, C., Sua, Y.M. and Huang, Y.P., 2024. Parametric all-optical modulation on a chip. *Physical Review Applied*, *21*(6), p.064049.

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Considerations for Enhanced Photochemical Charge Transfer Using Polaritons

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(Dated: September 13, 2024)

Embedding excitonic materials in an optical cavity can lead to the formation of exciton-polaritons, a phenomenon known as strong coupling. This phenomenon can enhance and control various pho-tochemical processes, facilitating advancements in fields such as additive manufacturing, artificial photosynthesis, optoelectronics, and quantum information processing. However, a key challenge is the ”dark-state problem,” where photoexcitation populates dark states (DSs) rather than exciting the lower polariton (LP). We address this by developing an angle-resolved spectroscopic method to selectively excite polaritons while avoiding DSs under phase-matching conditions. We then explore different cavity designs to enhance charge transfer (CT) processes in donor-acceptor systems using these polaritons under phase-matching conditions. Metal cavities, fabricated using electron-beam evaporation, can support surface plasmon polaritons (SPPs) and waveguide modes. SPPs generally have very short lifetimes, making them challenging to detect. Waveguide modes, while detectable, also have short lifetimes compared to CT processes, relaxing before CT occurs. In contrast, Bloch surface waves in distributed Bragg reflectors (DBRs), made by plasma-enhanced chemical vapor de-position with alternating silicon nitride and silicon dioxide layers, offer longer lifetimes and steeper dispersion. This allows for the selective excitation of polaritons far from the DSs and provides sufficient time for photochemical CT before relaxation to the ground state (GS).

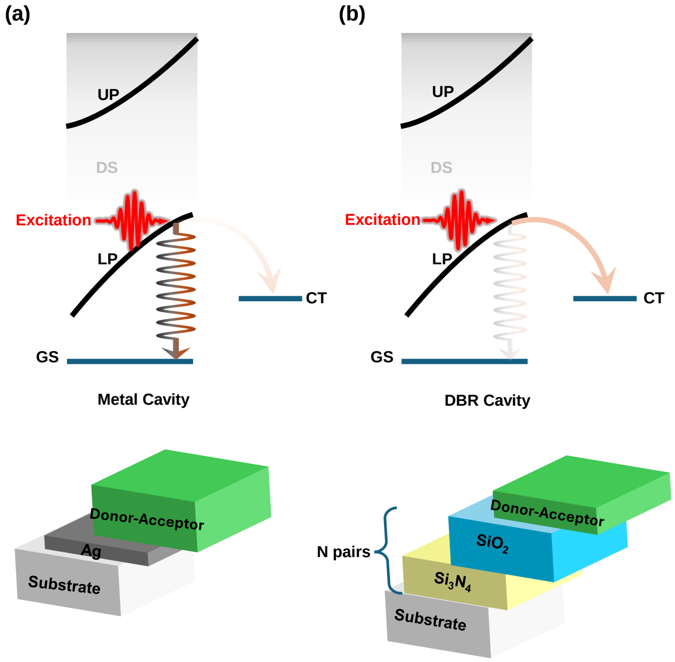

FIG. 1. Selective excitation of lower polaritons in (a) metal and (b) DBR cavities, where relaxation to the ground state (GS) and transition to the charge transfer (CT) state compete with each other, with darker arrows indicating higher population transfer.

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Monolithic 2D MEMS-based Multilayer Laue Lens (MLL) Optics for High-resolution Hard X-ray Nanofocusing

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Abstract: In this work, we report on our recent progress in developing 2D MEMS-based multilayer Laue lens (MLL) nanofocusing optics for high-resolution hard X-ray microscopy. Among various X-ray focusing optics, MLLs show great potential for achieving high efficiency in the hard X-ray regime. Since MLLs are one-dimensional focusing elements, in order to achieve point focusing, two MLLs must be orthogonally aligned with one another. This involves eight independent motions with nanoscale resolutions. Moreover, when nm-scale spatial resolution imaging is considered, the stability of the MLLs and their alignment also needs to be maintained throughout the experiments. Those requirements pose significant technical challenges for a microscopy system itself and require an extremely complex and stable instrument. Recently, we developed monolithic 2D MEMS-based MLL nanofocusing optics. The new optics utilized a microfabricated silicon template to accommodate two linear MLL optics in a pre-aligned configuration. The angular misalignment between the two lenses was controlled within tens of millidegrees, and the lateral position error was on the micrometer scale. Using the developed 2D MLLs, we have demonstrated an astigmatism-free point focus of approximately 14 nm by 13 nm in horizontal and vertical directions, respectively, at 13.6 keV photon energy [1,2]. The success of 2D MLL optics with an approaching 10 nm resolution is a significant step forward for the development of high-resolution hard X-ray microscopy and applications of MLL optics in the hard X-ray community.

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Fabrication and Experimental Demonstration of High-Precision Holographic Metasurfaces for Large-Scale Single-Atom Optical Tweezer Arrays

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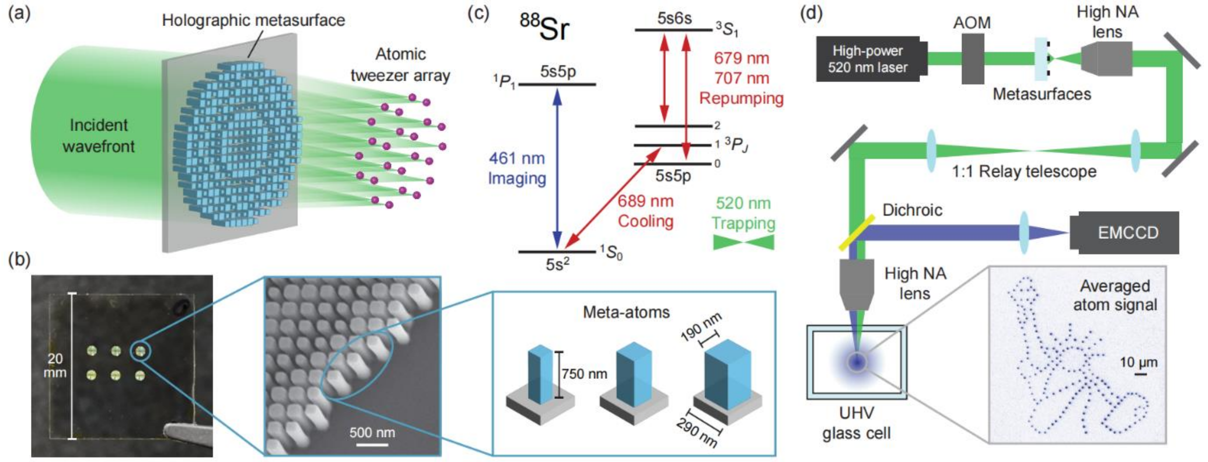

Optical tweezer arrays have emerged as a highly competitive platform for quantum computation, quantum simulation, and quantum metrology, enabling unprecedented levels of control over single atoms and molecules. However, the generation of optical tweezer arrays relies on delicate optical devices, such as acousto-optic deflectors or liquid crystal spatial light modulators, which come with intrinsic limitations on the array geometry and size. Here we realize optical tweezer arrays via holographic metasurfaces and demonstrate single-atom trapping of ultracold strontium atoms. We realize two-dimensional arrays with more than 250 optical tweezers in arbitrary array geometries, trap spacings on the micrometer-scale, and single-atom detection fidelities >99.8%. We show that metasurface arrays have a high degree of uniformity in optical intensity, trap frequency, and positional accuracy, which we characterize using the trapped atoms as sensitive probes. Thanks to their sub-wavelength pixel size, holographic metasurfaces can generate larger, more densely-packed tweezer arrays compared to existing devices, offering the prospect to realize tweezer arrays with >100,000 sites.

To fabricate the transmitting holographic metasurface for visible light at 520 nm, we employ a novel material platform, silicon-rich silicon nitride (SNR), with a CMOS compatible workflow. We use plasma-enhanced chemical vapor deposition (PECVD) to deposit a 750nm thick SRN layer on a fused silica substrate. By adjusting the ratio of precursor gases (SiH_4, N_2, and NH_3), we achieve a high refractive index of 2.3 for the SRN, while maintaining negligible absorption. This ensures the metasurface has a high-diffraction efficiency of 60% and a power handling intensity larger than 25 W/mm^2.

This work demonstrates that metasurface-generated atomic arrays open the door towards robust, field-deployable and highly integrated quantum devices based on large, single-atom arrays for atomic clocks, quantum computing, and quantum optics experiments.

Automatization of the Setup to Perform Optical Characterization of Nanostructures

Ayisha Yankey, *High School for Math Science & Engineering, CCNY*

Supervisor: Viktoriia Rutckaia, *Advanced Science Research Center, CUNY*

Metasurfaces, nanostructures have rapidly evolved to become a transformative technology in both optics and material science. Emerging from the field of metamaterials—artificially structured materials with unnatural properties—metasurfaces are thin, two-dimensional layers engineered to control electromagnetic waves with unprecedented precision. With the progression of research, metasurfaces have extreme potential to further surpass conventional technology paradigms, providing efficient, miniaturized solutions with advanced functionality.

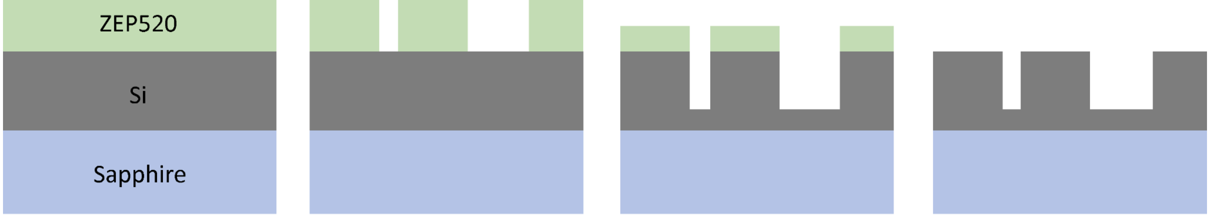

Figure 1. Typical fabrication steps of a metasurface.

Metasurfaces are fabricated using advanced nanofabrication techniques, such as electron beam lithography (EBL) and reactive ion etching (RIE), which allow for the precise patterning of sub-wavelength structures on a material's surface. Once fabricated, optical characterization is crucial to assess their performance. Spectroscopy is used to measure parameters like transmission, reflection. Such characterization ensures that metasurfaces meet design specifications and function effectively in their intended applications.

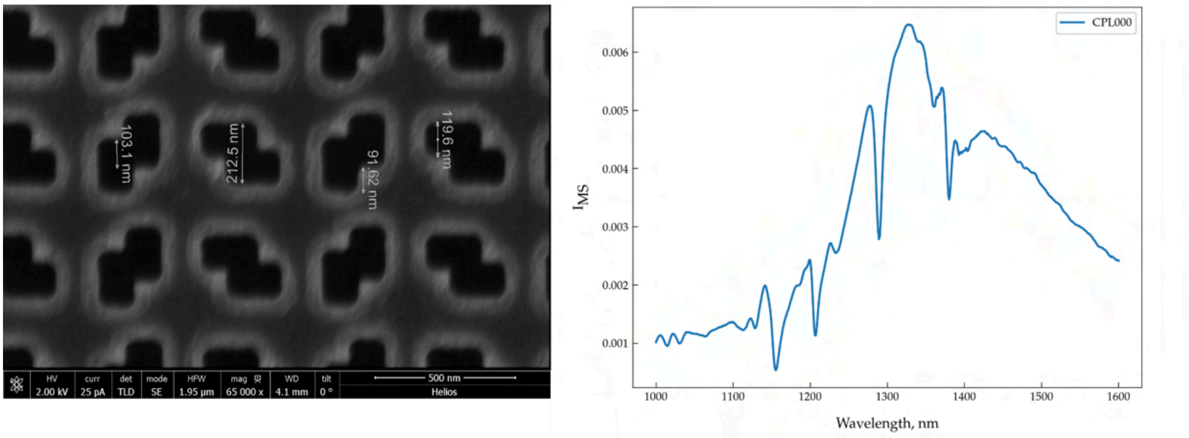

Figure 2. Fabricated metasurface, measured transmission spectra.

This study presents an automated system for efficient characterization and analysis of metasurfaces, a critical advancement in optical and material sciences. Traditional manual methods for metasurface analysis are labor-intensive, time-consuming, and prone to human error, limiting the ability to acquire large, accurate datasets. Our approach integrates a laser-based optical setup with an automated rotational stage and spectrometer, facilitating rapid and precise data collection. Automation not only streamlines the metasurface analysis process but also enhances data reliability, supporting further advancements in the development of metasurfaces, particularly in biosensor applications. Our findings demonstrate the transformative potential of automation in scientific research, offering a pathway toward more efficient and scalable material analysis.

Ultra-Sharp Microneedles: Advancing Inner Ear Drug Delivery with Microengineering

Aykut Aksit, PhD, *Co-founder and CEO, Haystack Medical*

Inner ear disorders affecting hearing and balance present significant clinical challenges due to the intricate anatomy and inaccessibility of the cochlea. Current drug delivery methods are invasive and imprecise. They either lead to complications or remain ineffective. Haystack Medical introduces a groundbreaking microengineering solution: ultra-sharp microneedles designed for safe, direct, and minimally invasive delivery of therapeutics to the inner ear.

Developed through extensive research at Columbia University and CUNY ASRC over a decade, our microneedles are fabricated using two-photon lithography via the Nanoscribe system to achieve nanoscale sharpness and precision, intricately designed to navigate the complex ear anatomy. This fabrication process can be combined with templated electrodeposition to create metallic microneedles [1]. The ultra-sharp tips gently displace the connective fibers of the round window membrane (RWM), minimizing tissue disruption and enabling direct cochlear access.

Our preclinical studies, encompassing over 400 experiments and human cadaveric tests, demonstrate the safety and efficacy of the microneedles for both drug delivery and diagnostic fluid sampling [2,3]. The needles facilitate precise dosing without adverse anatomical or functional consequences, with perforations healing spontaneously within 48 hours.

Collaborations with ENT specialists at Columbia-NewYork-Presbyterian Hospital have been instrumental in refining the device for the clinic. Integrating our microneedles with existing endoscopic systems and developing specialized delivery mechanisms tailored to middle ear anatomy represent significant strides toward practical implementation.

This microneedle technology holds promise for enabling novel therapeutics that were previously untenable due to delivery constraints. By providing a reliable and safe method for inner ear access, we are revolutionizing the management of hearing loss and balance disorders.

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For further information, please visit https://haystackmedical.com.

Design and Fabrication of Hollow Microneedles for the Murine Inner Ear

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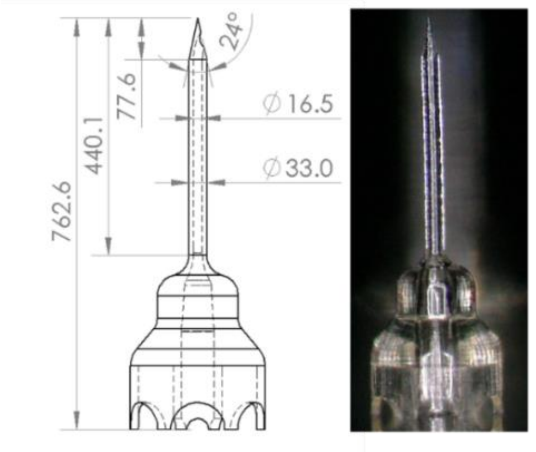
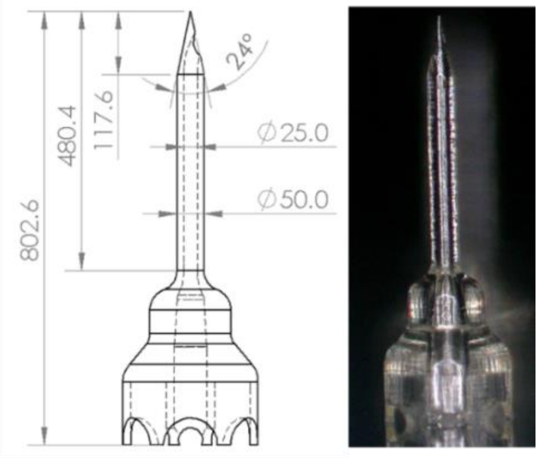
Disorders of the inner ear constitute some of the most prevalent sensory disorders in humans, with hearing loss alone estimated to affect greater than one fifth of the global population [1]. As audiovestibular treatments evolve, delivering and diagnosing inner ear diseases will require novel, minimally invasive surgical tools. In recent years, our lab has developed and studied microneedles of various geometries and materials for perforating, injecting, and aspirating fluid via the round window membrane (RWM), the only non-osseus portal to the cochlea accessible within the middle ear space [2,3]. The primary aim of this work is to adapt the single-lumen microneedle design currently used in the guinea pig for the mouse, an animal model with widespread translational relevance in therapeutic research due to its well-studied genome. Microneedles were fabricated using 2-photon polymerization lithography (2PP), a nano- and microfabrication tool that has become increasingly popular due to its ability to produce high resolution, complex structure geometries not feasible with traditional methods such as etching. In response to observed differences in murine cochlear anatomy, we demonstrate the design and fabrication of two different polymeric, hollow microneedle designs with diameters of 33 µm and 50 µm and lengths over 400 µm using a modified post-printing development procedure. Furthermore, we report preliminary experimental results indicating the ability to perforate the mouse RWM using ex vivo force measurements obtained with a custom-built microindentation instrument and confocal microscopy.





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Synthetic Carbohydrate Receptor Microarrays Bind Monosaccharides with Micromolar Avidities Through Multivalent and Cooperative Binding

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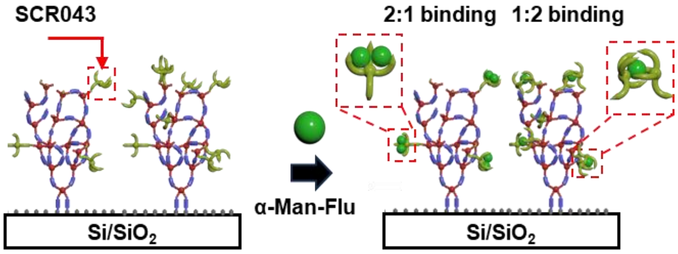
This study focuses on the development and optimization of **SCR043**-functionalized polymer brush microarrays using grafted-to grafted-from radical photopolymerization (GTGFRP) for selective binding of mannosides. **SCR043**, derived from **SCR019**, contains a terminal pentene substituent allowing covalent incorporation into massively multiplexed polymer brush arrays during GTGFRP. Hypersurface photolithography (HP) was employed to create microarrays where brush height and density can be controlled independently. Polymer brush patterns were characterized via optical microscopy, profilometry, X-ray photoelectron spectroscopy, Raman microscopy and time-of-flight secondary ion mass spectrometry. The binding capacity of the microarrays was assessed using fluorescein-labeled α-mannoside (**α-Man-FL**) and α-galactoside (**α-Gal-FL**). The study demonstrated that **SCR043**-functionalized brushes can distinguish between mannosides and galactosides, with stronger binding observed for mannosides. The effects of polymer brush height, **SCR043** density, and [glycan] on binding affinity (K_d) were systematically analyzed, revealing that optimal conditions yielded a detection limit of 10^{-5} M for **α-Man-FL**. Cooperativity in binding was also explored, with Hill coefficients (H_c) ranging up to 12.4, indicating complex multivalent interactions. The findings illustrate the potential of **SCR043**-functionalized microarrays for sensitive glycan detection and discrimination in biological applications.



Development of an Inductively Coupled Plasma (ICP) Etch Recipe for Maximum Selectivity and Maximum Etch Rate of SiC

Philip Czudak[1,2], Emma Anquillare[2] and Samantha Roberts[2]

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Silicon carbide (SiC) is a critical material for advanced semiconductor applications due to its wide bandgap, high thermal conductivity, and robust mechanical properties [1]. However, the strong Si-C bonds present significant challenges during etching, requiring the development of optimized etch processes. This study presents an optimized etch recipe for SiC wafers masked with Nickel (Ni), using an Inductively Coupled Plasma (ICP) etcher. The research systematically investigated the effects of various etching parameters, including argon flow rate, CF4:H ratio, chamber pressure, forward power, and ICP power, to maximize etch rate and selectivity. The experimental protocol involved fabricating SiC samples on 4-inch, 4-H SiC wafers, which were cleaned with a 3:1 sulfuric acid to hydrogen peroxide solution, followed by a moisture bake and spin-coating with AZ-5214E photoresist. Patterning was achieved using image reversal lithography, and a 100 nm Ni mask was deposited through electron-beam evaporation. The samples were diced into uniform chips and etched individually in an ICP-Cl system, followed by Ni mask removal with Nickel Etchant TFB. Profilometer measurements were taken at critical process stages to evaluate etch rates and selectivity.

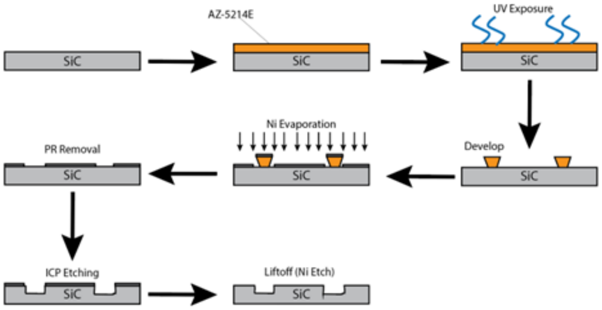

Figure1: The main fabrication steps.

The optimal conditions identified were a CF4:H ratio of 20% (36sccm: 9sccm), Ar gas percentage of 10% (5sccm), chamber pressure of 11mTorr, forward power of 100W, and ICP power of 1300W. This recipe achieved an etch rate of $115.432\frac{nm}{min}$ and a selectivity of 16.117.

The systematic variation of parameters led to clear target values that would ensure high selectivity and etch rates, demonstrating the effectiveness of the developed recipe. The optimized process facilitates the fabrication of complex SiC structures with high precision, which is essential for applications in harsh environments and high-power electronics. Future work will focus on refining the parameter space to further enhance etching performance and adapt the recipe for other plasma chemistries and mask materials.

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Wafer-scale Millimeter-wave Metasurface Antenna Fabrication for CubeSat-based Remote Sensing

Kevin X. Gu, *Astrabeam LLC*

Abstract – Astrabeam recently completed a NASA SBIR Phase I technical feasibility study of developing millimeter-wave metasurface (MTS) holographic antennas to support NASA remote sensing science missions on CubeSat platforms beyond Ka-band. The proposed MTS antenna utilizes a novel dielectric substrate material that is electrically extremely low-loss, thermally high-conductive, mechanically robust, and supports fabrication of micron-scale fine metal features. Astrabeam's Phase I results have successfully demonstrated the design concept and fabrication feasibility of implementing such compact-size, deployable, low-profile, lightweight, and high-performance MTS antennas. This poster presentation summarizes a step-by-step lithography fabrication process of implementing the MTS holographic antenna features. The fabrication experiments were performed at CUNY ASRC Nanofabrication Facility and Cornell NanoScale Facility.

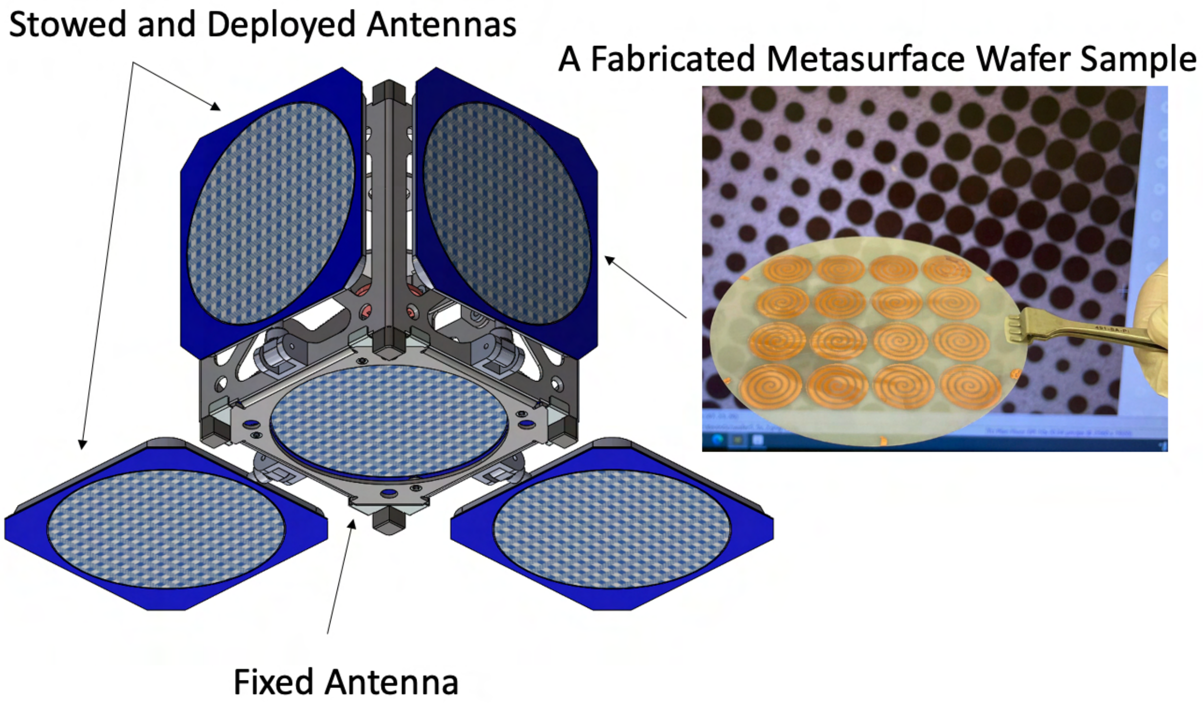

Figure 1. CubeSat-based antenna concept and a fabricated metasurface wafer sample.

Engineering an optically tunable fluid: colloidal metamaterial based on Janus particles

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Metamaterials made of alternating layers of metals and dielectrics, known as hyperbolic metamaterials, have been shown to enhance emissions, which is of interest in biomedical imaging and detection. However, so far, they have only been fabricated on flat surfaces. Creating a dispersible metamaterial based on Janus particles would create the opportunity to use such materials in biological systems.

In this research, we have investigated a colloidal metamaterial that contains spherical silica particles ranging from 0.5–4 μm in diameter with metamaterial caps consisting of multiple layers of alumina, germanium, and silver. We will report on similarities and differences of optical properties in the colloidal metamaterial system in comparison to same metamaterial on a flat surface.

Reduced-scale T-gate Fabrication for High-Temperature GaN HEMTs via Metal Liftoff

Ethan Liu, Savannah Eisner

Abstract:

Gallium Nitride-based High Electron Mobility Transistors (HEMTs) have been extensively investigated for high-temperature applications due to their robust thermal stability and superior material properties [1]. Studies have revealed that device geometry could significantly impact the device's performance at elevated temperatures. Notably, the reduced gate length of the device is found to be less affected by high temperatures, as carriers traveling at saturation velocity exhibit a weaker temperature dependence [2]. Additionally, circular-shaped device designs have been shown to experience lower gate leakage compared to traditional linear device designs under intense thermal stress. This can be attributed to the enclosed format, which minimizes trap generation induced by overlapping mesa sidewall defects, thereby mitigating the leakage currents at high-temperature conditions [3,4]. Beyond the pivotal device's DC electrical characteristics, the Radio Frequency measurement is equally crucial for assessing the device's performance at high temperatures. The implementation of the ground-signal-ground (GSG) test structure and T-shaped gate fabrication is instrumental in ensuring signal integrity and enhancing device performance. The GSG structure can effectively minimize the parasitic effect and ensure signal integrity, while T-shaped gates address noise figure issues and maintain high operating frequencies.

This work aims to fabricate the Depletion-mode Indium-Aluminum-Nitride (InAlN)/Gallium Nitride (GaN) HEMTs, incorporating both T-gated and GSG designs. The Elionix Electron Beam Lithography System (ELS) plays a crucial role in shrinking gate length and constructing circular T-gate. First, 12 nm of atomic layer deposition (ALD) Aluminum Oxide was deposited on a lattice-matched InAlN/AlN/GaN-on-Si wafer, followed by 65nm of plasma-enhanced chemical vapor deposition (PECVD) Silicon Nitride (SiN). The Elionix was then utilized to create a 100 nm wide trench as the bottom gate of the T-gate, followed by sulfur hexafluoride (SF_6) and buffered oxide etchant (BOE) etching process. A second exposure with a broader pattern was applied again by the Elionix ELS. Nickle and Gold (Ni/Au) were then evaporated and lifted off to form the gate structure.

The current challenges involve electron beam lithography exposure, developing the electron beam resist, and executing the metal liftoff process for specialized patterns, which feature long, narrow gate paths connected to large square bond pads. Furthermore, the assessment of the exposed resist using Atomic Force Microscope (AFM) and stylus profilers has been hindered by artifacts resulting from the geometry and size of the measurement tips.

Future work involves improving exposure with Beamer program enhancement and utilizing high-aspect ratio AFM tips for measurement. Moreover, the cross-sectional SEM assessment will be applied to verify the pattern both before and after the metal liftoff process.

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