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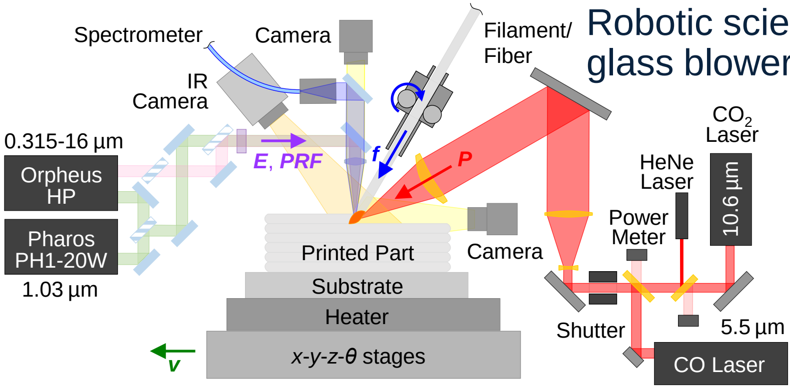
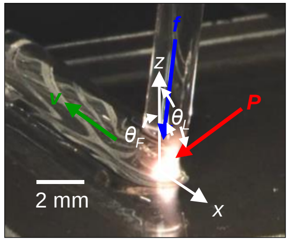
Digital Glass Forming

N Khadka, N Azad, N Nawal, R Landers, E Kinzel



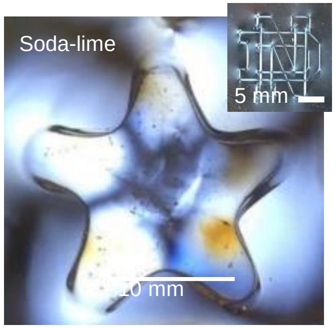
Robotic scientific glass blower

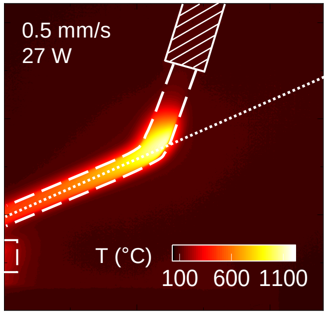


- 250 W CO_2 laser, 20 W USP laser
- 4-axis Aerotech ANT platform
  - 350 mm/s, 75 nm rep., 160×160×150 mm^3
  - Substrate heating up to 550°C
  - In-situ diagnostics
- Quartz, soda-lime, borosilicate glasses or alumina filaments Ø0.125-2 mm

Research

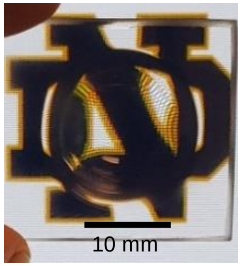
- Improving deposition rates (goal 20+ mm^3/s)
  - Configuration and volumetric absorption in glass
- Improving feedback control
  - Thermal and force sensing
- Creating junctions (capillary tubes and opt. fiber)
- Engineering stress field in glass
- Integrating subtractive/index modification with ultrafast laser
- Modeling process to predict morphology and track deflection

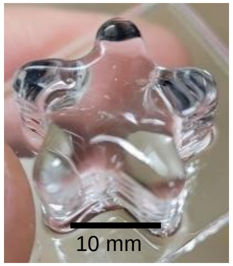


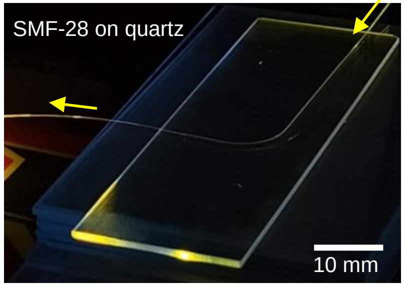


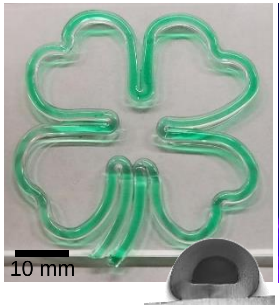
Accomplishments/Milestones

- High transparency solid glass articles with smooth surfaces
- Freestanding structures
- Printed capillary tubing
- Printed photonics



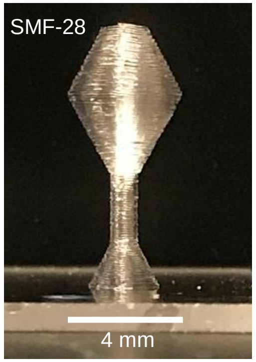


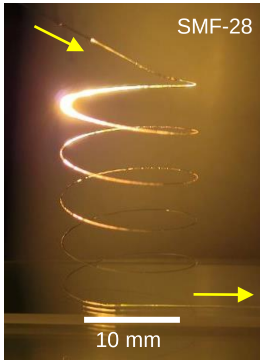


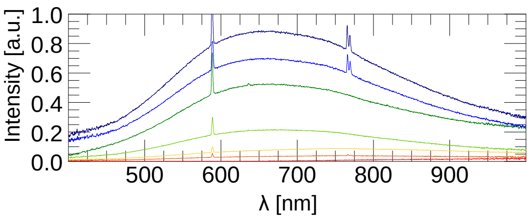


Applications

- Microfluidics
- Printed photonics
- Printed optics
- Light weight, low CTE structures
- Glass-to-metal hermetic seals
- Integrated devices
  - Bourdon tubes
  - Active photonics
- Stress engineered optics







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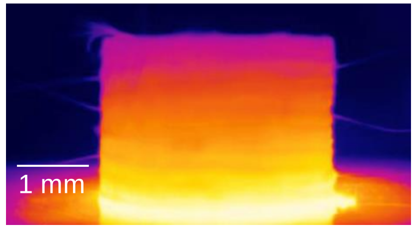
High-Temperature Embedded OFDR

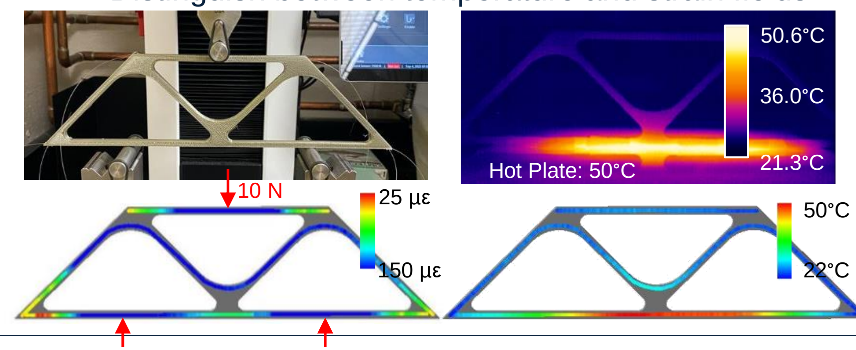
Brian Hlifka, Tengfei Luo, Edward Kinzel



- Distributed fiber testing relates changes in the frequency domain scatter profile to strain and temperature shifts
- Continuous monitoring along standard fiber
- Optical distributed sensor interrogator (ODiSi 6100)
- Fusion splicer, OSA, YSL-5 supercontinuum light source

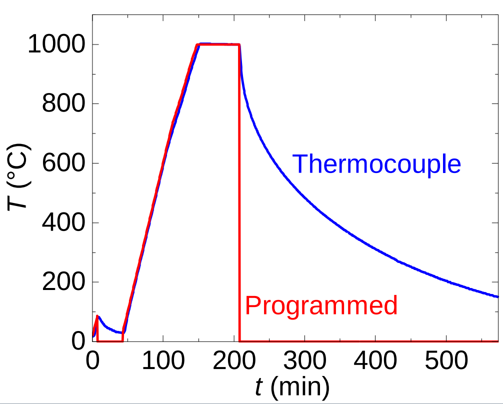
Research

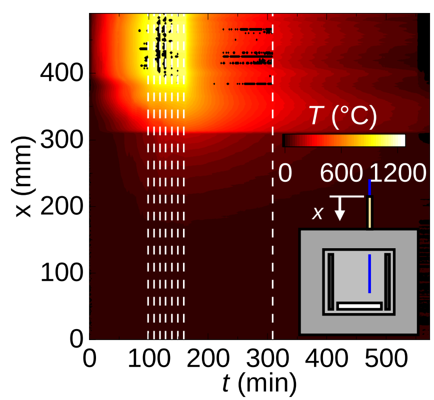
- Persistent <1100°C measurements by continuously monitoring relative frequency shifts
  - Improving fiber performance with laser processing
- Embedding techniques for C/C and other CMCs
- Solving for unknown heat load by projecting temperature response into known vector space
  - Distinguish between temperature and strain fields



Accomplishments/Milestones

- Generating fiber sensors using custom keys
- Measurement up to 1000°C using SMF-28
- Embedded fiber in C/C green bodies and FFF prints
- Initial superposition based thermal load extraction





Applications

- Smart CMCs using structural health monitoring particularly at high temperatures
- In-process monitoring during fabrication for C/C production as well as additive manufacturing
- Expanding fiber based sensing beyond local strain/temperature

Advanced Laser Powder-Bed Fusion

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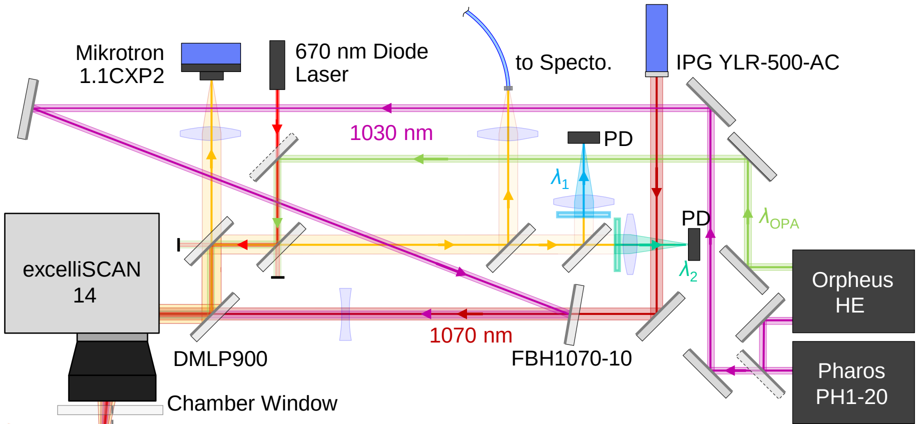
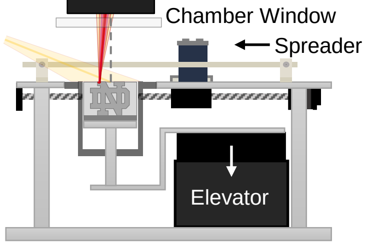
J Krantz, G Reyes, E Kinzel, R Landers





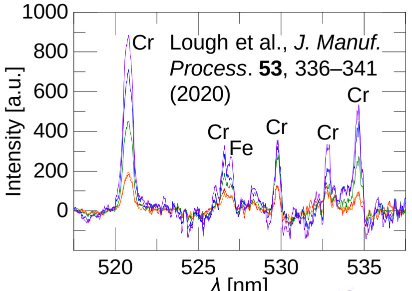
- Open platform
- 500 W Fiber Laser and 20 W USP laser
- ScanLabs excelliSCAN 14
- Ø50 mm×50 mm build volume
- Pressure from 0.001 to 10 atm

Research

- Hybrid additive/subtractive manufacturing
  - USP laser ablation
- Laser Induced Breakdown Spectroscopy
- In-situ residual stress characterization
  - Laser Speckle Photometery to resolve sub-diffraction movement
- Automated in-situ feature extraction
- Integrated machine learning

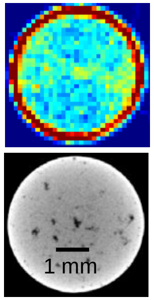
Accomplishments/Milestones

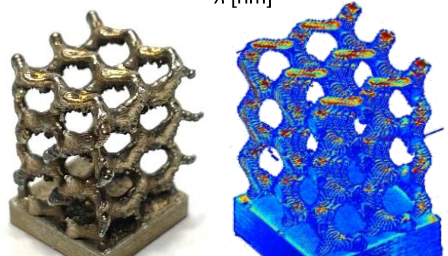
- Correlating in-situ SWIR imaging with ex-situ pro. measurements
  - Feature extraction
- Modal analysis based meas. of recoil forces
- Optical Emission Spectroscopy



Lough et al., *J. Manuf. Process.* **53**, 336–341 (2020)

West et al. *Manuf. Letters.* **13** (2017)

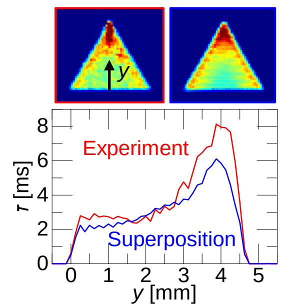


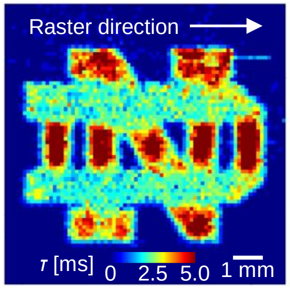


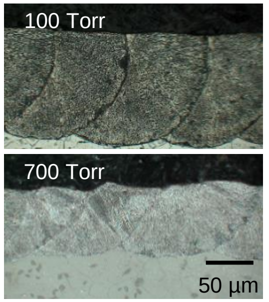
Lough et al., *J. Mater. Proc. Tech.* **302** (2022)

Applications

- Validation of parts while building and application of ML to predict part performance
- Excising damage in-situ and sub resolution patterning (e.g. high aspect ratio holes)
- Understanding pressure and atmosphere effects on melt pool morphology
- Monitoring stoichiometry changes in-situ







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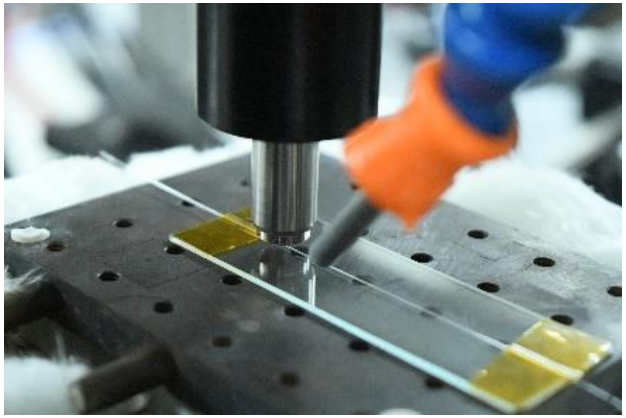
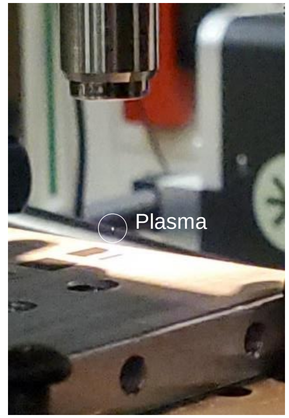
Ultrashort Pulsed Laser Processing

N Khadka, B Sánta, E Kinzel, M Rosenberger, A Hoffman

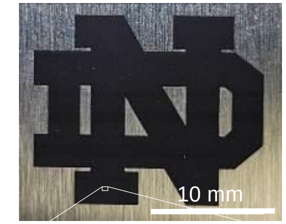


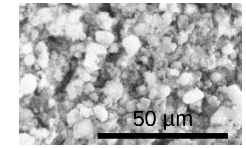


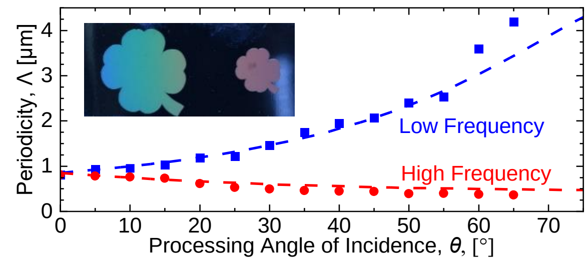
- USP laser 20 W Pharos PH-1 (230 fs pulses)
- Orpheus OPA (λ=315 nm–16 µm)
- 4-axis Aerotech ANT platform
  - 350 mm/s, 75 nm rep., 160×160×150 mm^3

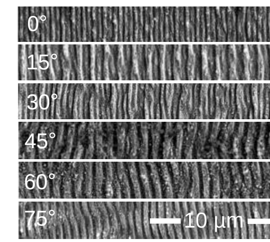
Research

- BRDF/BRTF and spectrally resolved meas. using OPA
- EM modeling of non-periodic structures
- Understanding AOI and polarization processing effects
- Laser/material interaction fundamentals



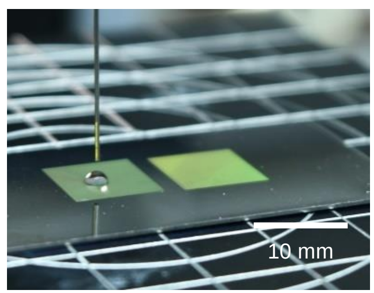


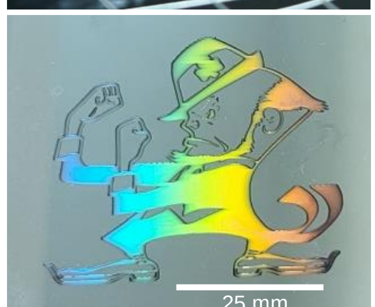




Accomplishments/Milestones

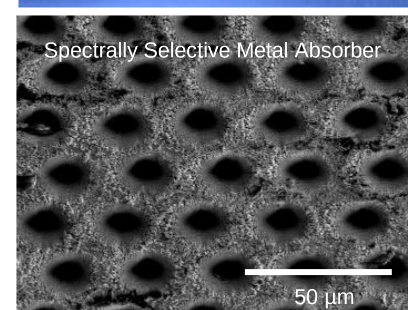
- Controlled hydrophobicity
- Laser Induced Periodic Surface Structuring
- Structural color
- Multiscale hierarchical texturing
- Broadband black surfaces
- Antireflection surfaces
- Processing fiber





Applications

- Solar thermal absorbers
- Photovoltaics
- IR optics
- Microfluidics
- Optical fiber functionalization
- Laser shock peening



Thermoelectric Coupled Nanoantennas

G Bernstein, E Kinzel, A Orlov, W Porod, G Szakmany

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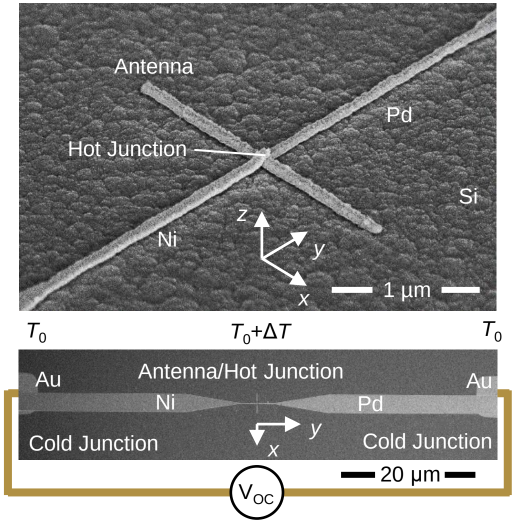
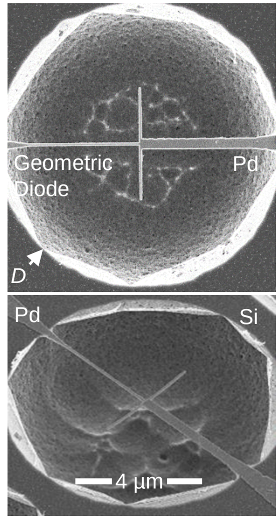
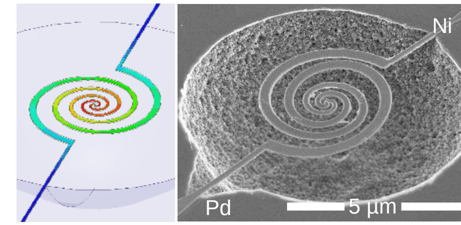


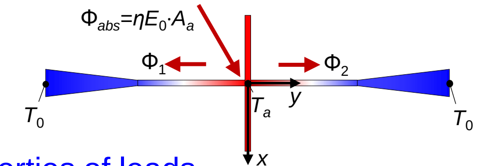


- IR radiation absorbed by antenna, heats junction, induces open circuit voltage
- Maximum aperture area/thermal mass ratio

Research

- Improving sensitivity
  - Alloys and semiconductors
  - Cavity diameter/form
- Vacuum packaging
- Machine learning based synthesis
  - Imaging, spectral, and angular resolution
- Radiation hardness





Thermo-electrical properties of leads

$$D^* = \frac{1}{16}\sqrt{\frac{\pi}{k_b T_D}}\,\eta\,\frac{\Delta S\sqrt{\bar{\sigma}}}{\bar{k}}\,\frac{D_a^{3/2}}{\sqrt{A_c}}$$

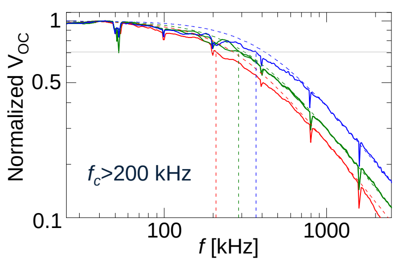
Cavity diameter

Cross-sectional area of leads

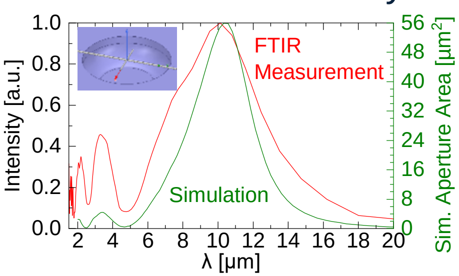
EM efficiency

Accomplishments/Milestones

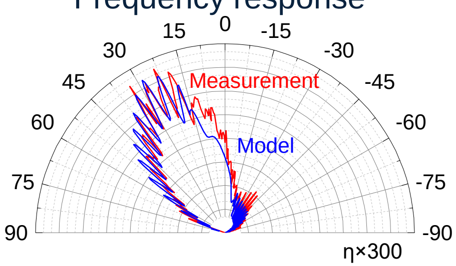
- Extremely fast due to minimal thermal mass
- Polarization selectivity
- Spectral selectivity
- Angle-of-incidence selectivity
- Coherence selectivity



Frequency response



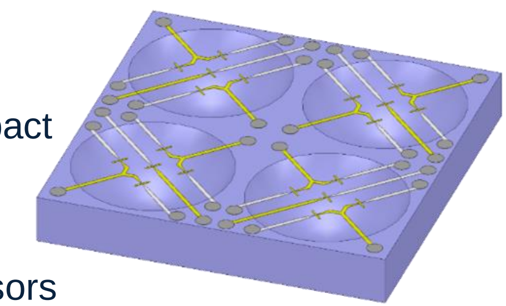
Measured spectral response

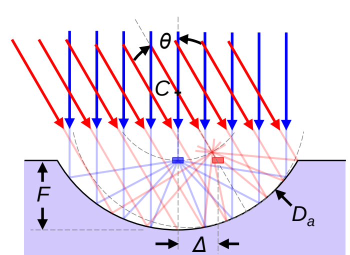


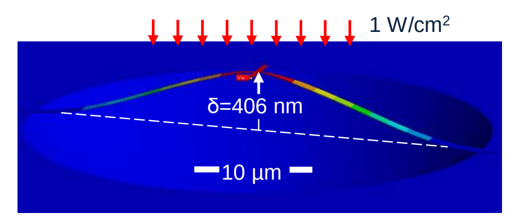
Measured CO_2 laser response

Applications

- Laser detection
- Lens-free imaging
- Ultra lightweight/compact spectroscopy
- High-speed thermal imager
- Shack-Hartmann sensors







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Microsphere Photolithography

Botond Sánta, Erick Gómez Pérez , Edward Kinzel

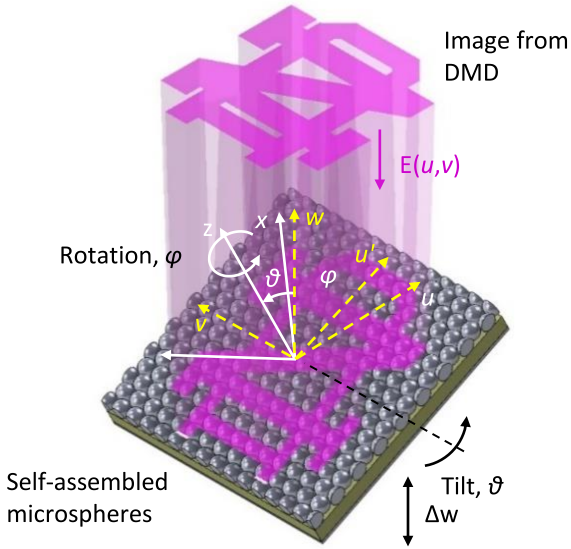
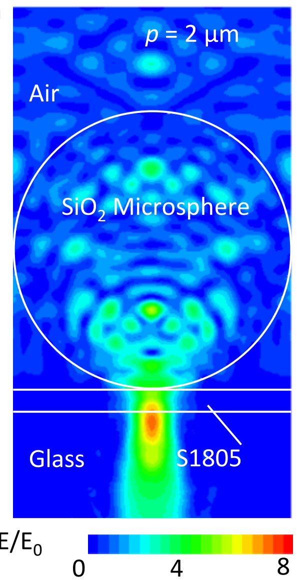


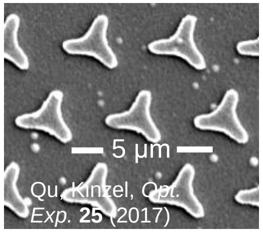
Image from DMD

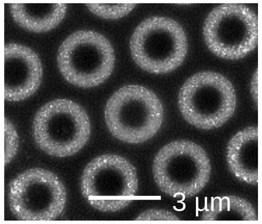


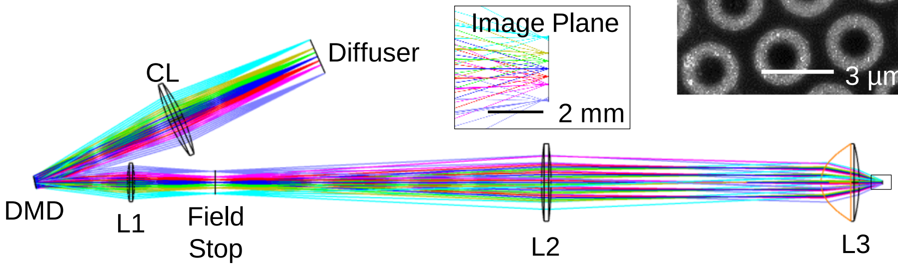
- Microspheres focus light to nanoscale photonic jets
- DMD direct write incl. Fourier optics angular spectrum control

Research

- Fourier based direct write
- Simultaneous control of light field using SLM
- Incorporation of electrodeposition to remove high-vacuum PVD
- Scale-up using roll-to-roll

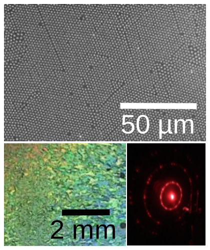


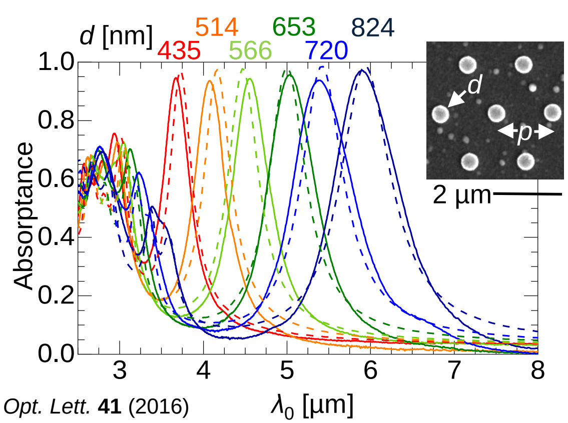




Accomplishments/Milestones

- Functional metasurfaces over conformal surfaces
- Predictive modeling of process
- Reusable mask based microspheres
- Spatial and element hierarchy
- Direct write

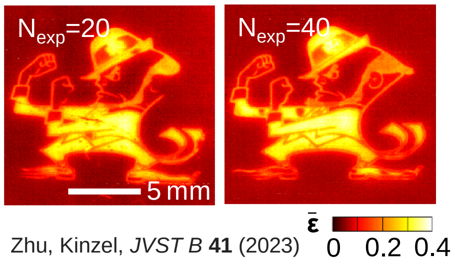




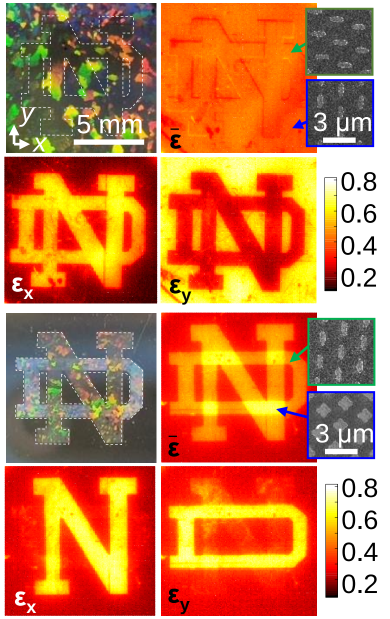
Qu, Kinzel *Opt. Lett.* **41** (2016)

Applications

- Large area metasurfaces
- Frequency filtering over conformal surfaces (e.g. IR wavelengths)
- Functional surface measurements (SERS/SEIRA templates)
- Fiber based sensors



Zhu, Kinzel, *JVST B* **41** (2023)



Zhu, Qu, Kinzel, *Appl. Opt.* 60 (2021)

Metasurface Enabled Microbolometers

E Gómez Pérez, T Liu, M Almasri, D Anderson, E Kinzel

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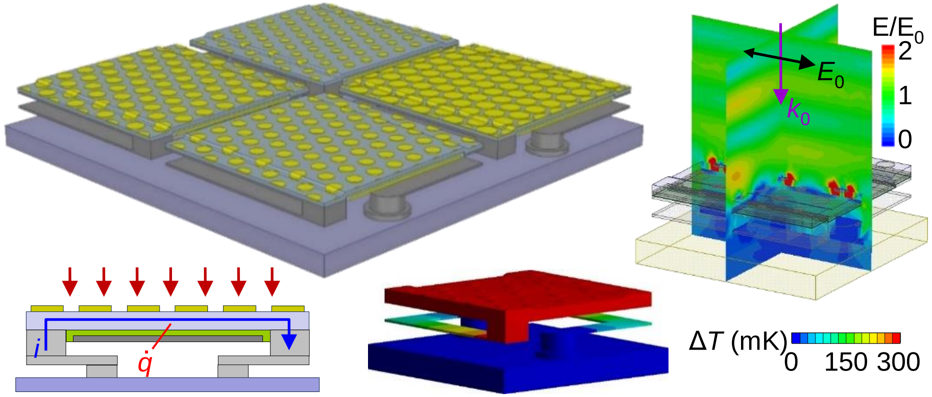
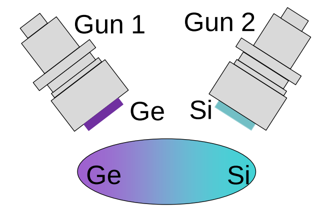
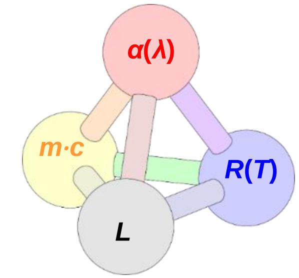


- Metasurface enabled microbolometer architecture
  - Each pixel has an EM absorptance response determined by the metasurface geometry
  - Affects electrical and thermal response
  - Removes Fabry–Pérot cavity and gives greater design freedom

Research

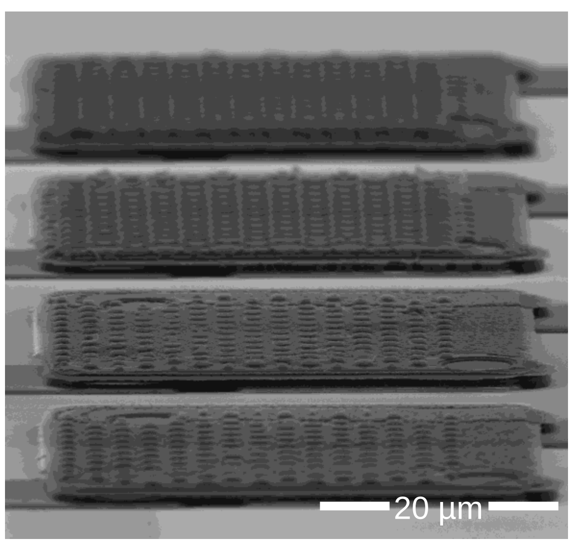
- Understanding material dependence using combinatorial deposition to relate stoichiometry to performance
  - *R*, *TCR*, noise, permittivity trade space
  - Hybridization with phononic modes in dielectric
- Incorporating machine learning for spectral recognition
  - ML driven metasurface design
  - Design of metasurfaces for ML
- Characterization with infrared response using OPA





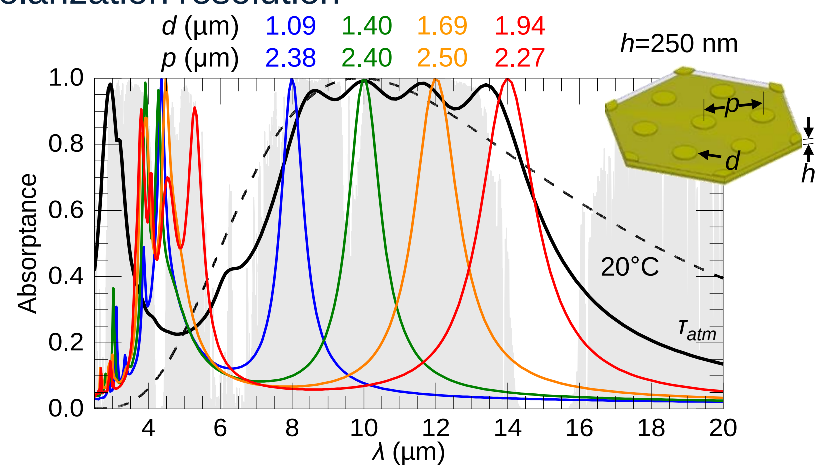
Accomplishments/Milestones

- Design of metasurfaces for spectral and polarization selectivity
- EM and thermal lumped element and full-wave models for microbolometer performance
- Fabrication demonstration



Applications

- Improved thermal imager performance
- Automatic material recognition
- Polarization resolution



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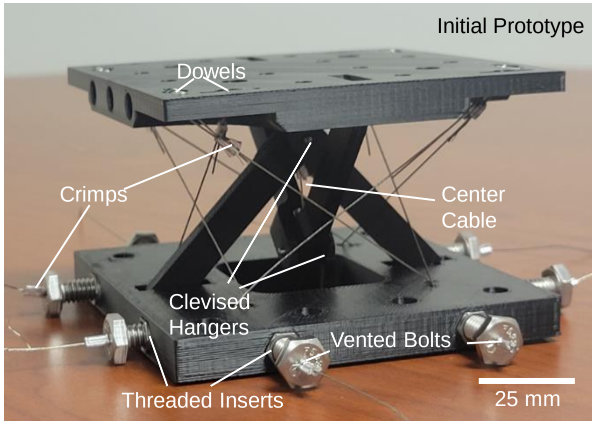
Thermal Tensegrity

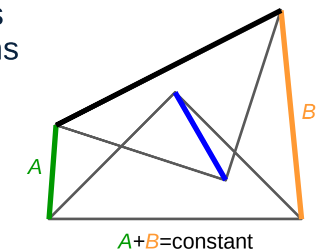
Tom Juliano, Edward Kinzel



- MINIMIZE thermal transport AND mechanical compliance
  - Opposite of typical thermal interface material problem
- Tensegrity (all members connected in tension)
- Thin members have reduced thermal conduction

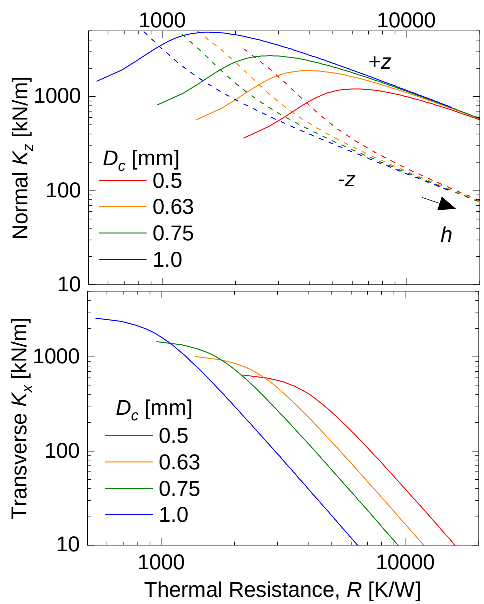
Research

- Practical application to fixturing for Digital Glass Forming
- Design rules for thermal tensegrity
- Manufacturing processes
  - Incorporating high temperature (brittle) materials
- Dynamic effects
- Thermal expansion effects
- Kinematic structures and mechanisms
  - Continuous cables provide links with fixed link sum of link lengths



Accomplishments/Milestones

- Initial prototype
  - Crimped 0.5 mm steel cables
  - Simple tensioning
  - Supports under compression
- Rough modeling of stiffness and thermal transport.



Applications

- Digital glass forming heated beds
- High temperature robot manipulators
- Articulating hypersonic vehicle skins