Sandia National Laboratories

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Design and evaluation of a monolithic optical element for task-specific compressive classification

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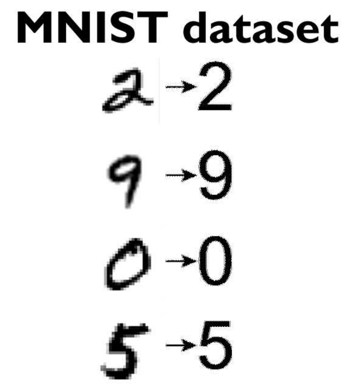
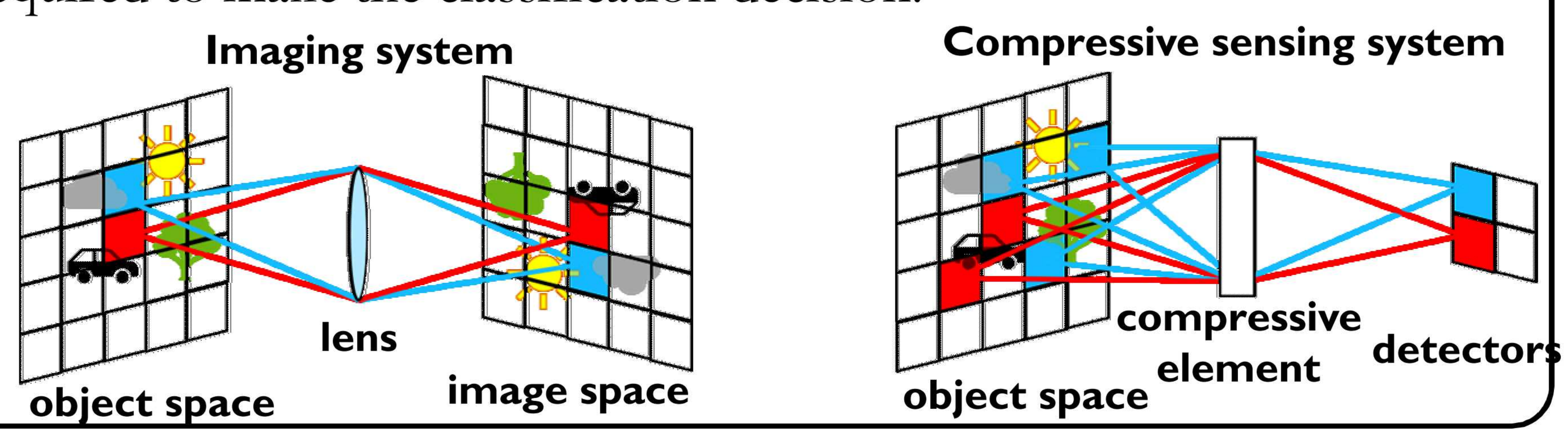
Compressive sensing

Traditional optical systems create human interpretable images that contain more information than is required for many applications such as automated classification. Compressive sensing can reduce size weight and power of the systems by only recording the information required to make the classification decision.

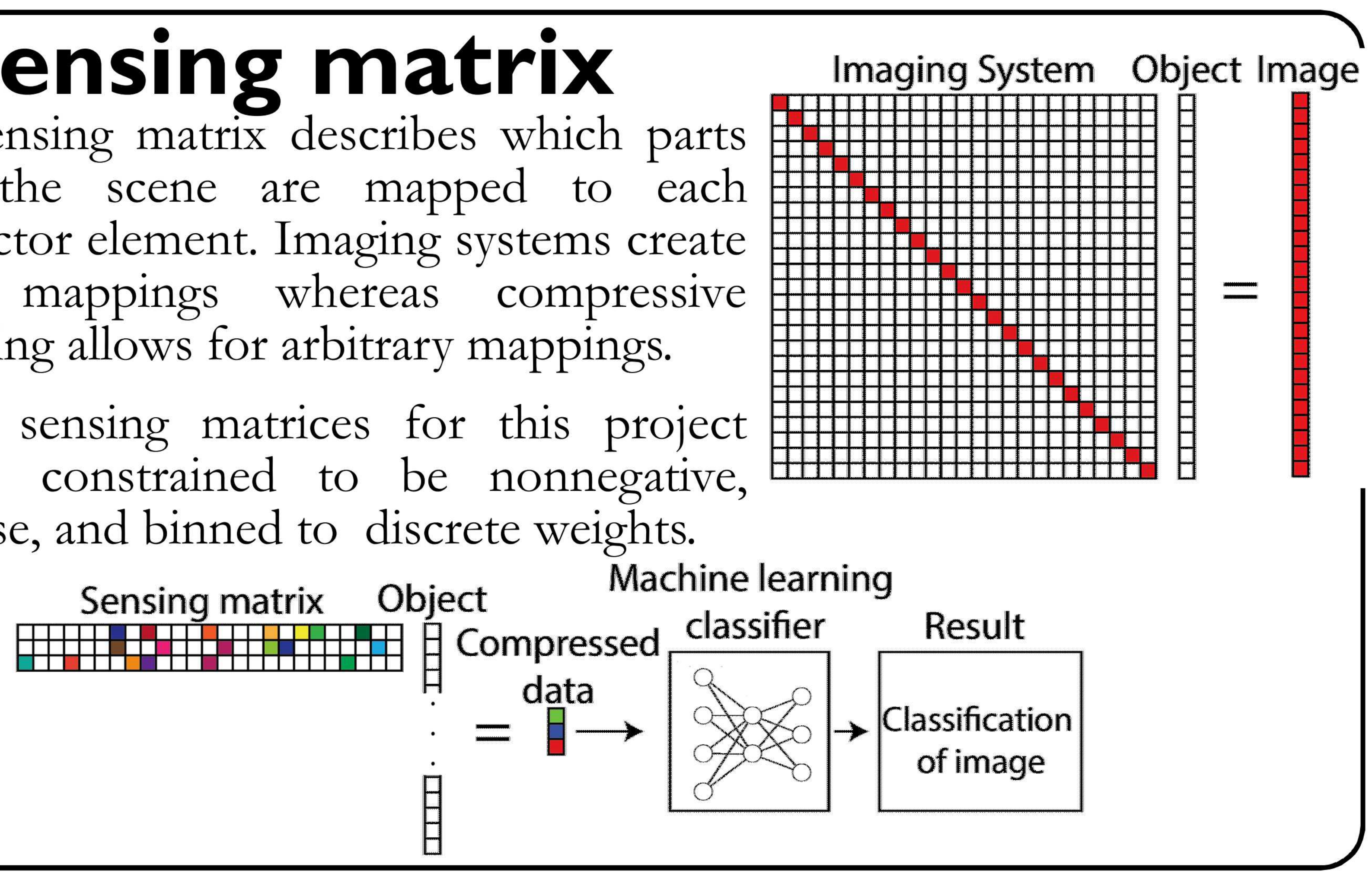




Sensing matrix

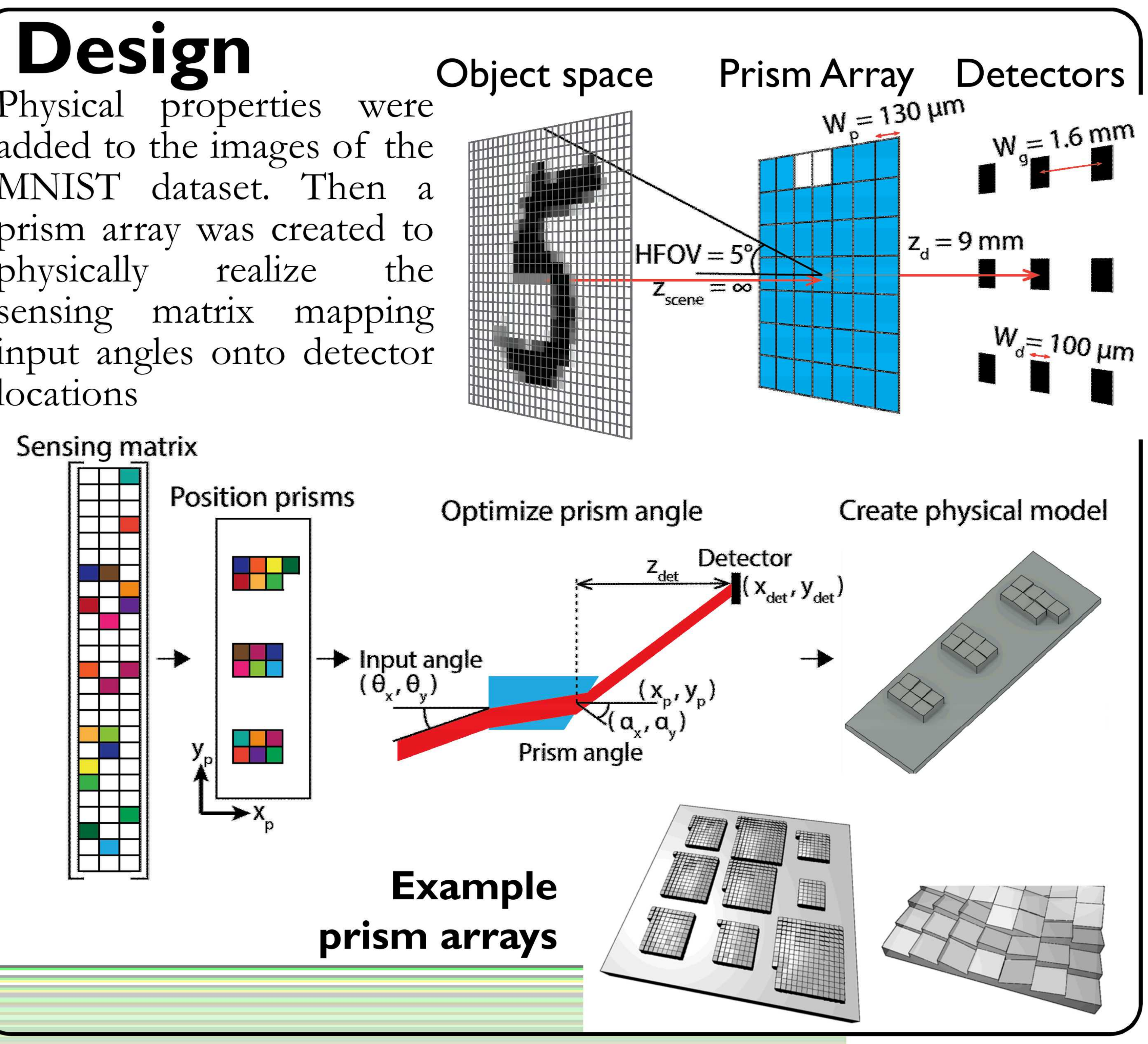
A sensing matrix describes which parts of the scene are mapped to each detector element. Imaging systems create 1:1 mappings whereas compressive sensing allows for arbitrary mappings.

The sensing matrices for this project were constrained to be nonnegative, sparse, and binned to discrete weights.



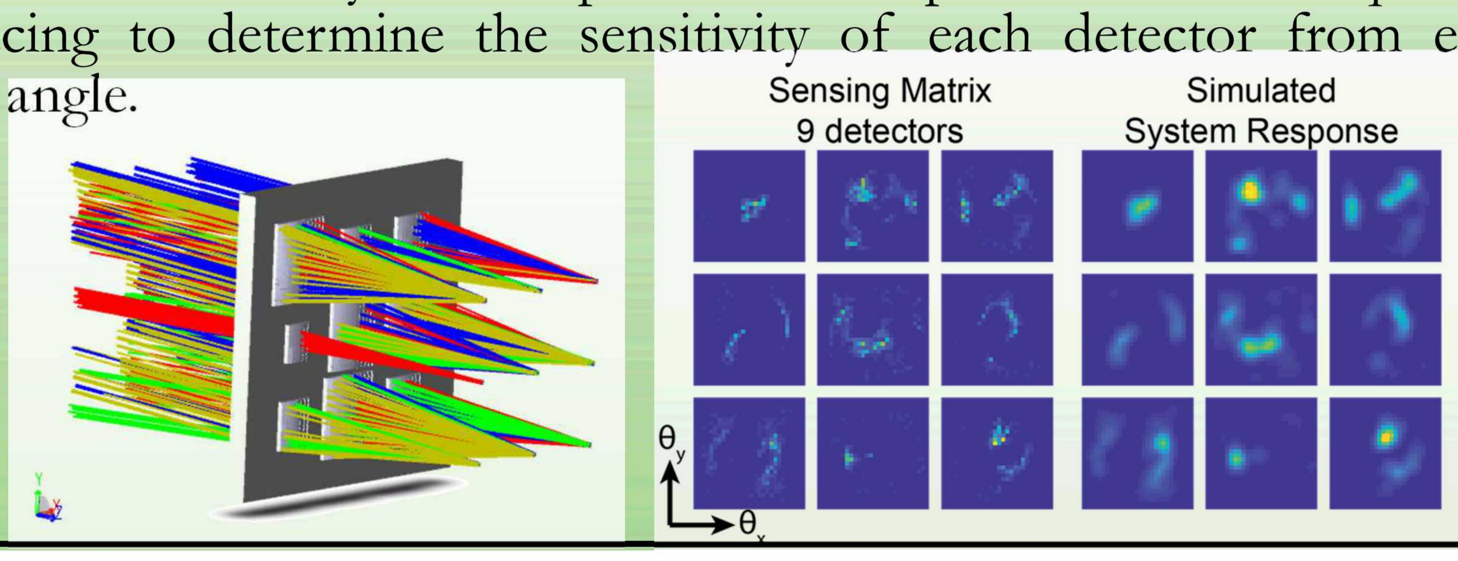
Design

Physical properties were added to the images of the MNIST dataset. Then a prism array was created to physically realize the sensing matrix mapping input angles onto detector locations



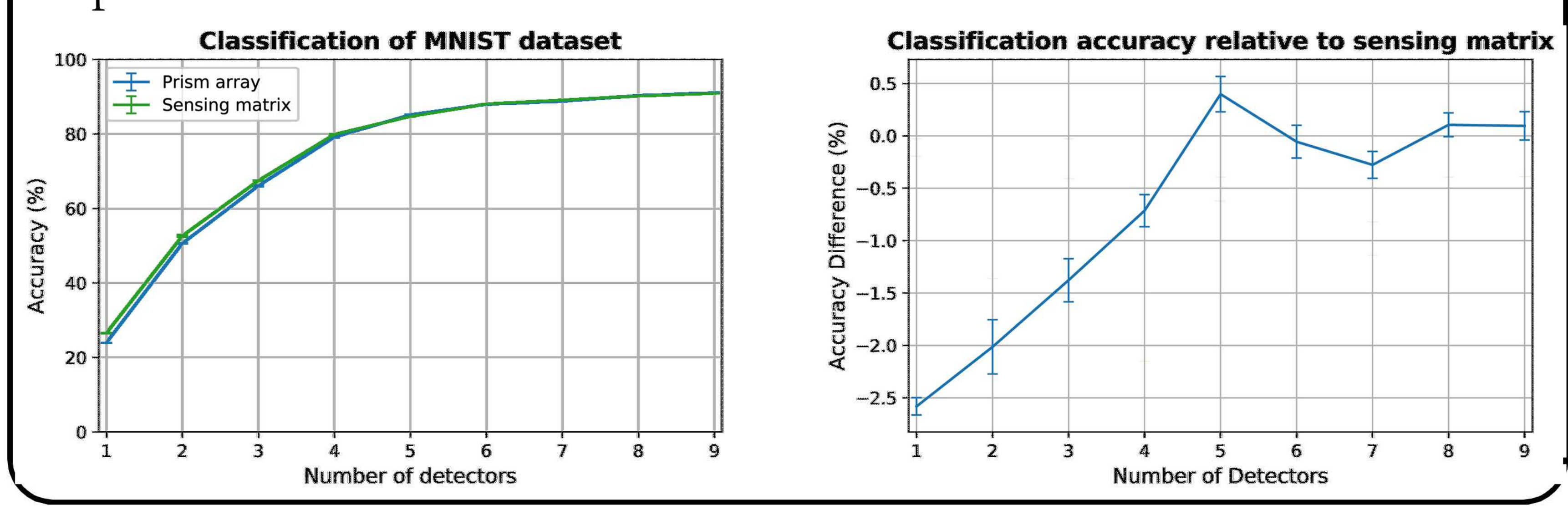
Raytrace simulation

We simulated the system response with OpticStudio non-sequential raytracing to determine the sensitivity of each detector from each input angle.



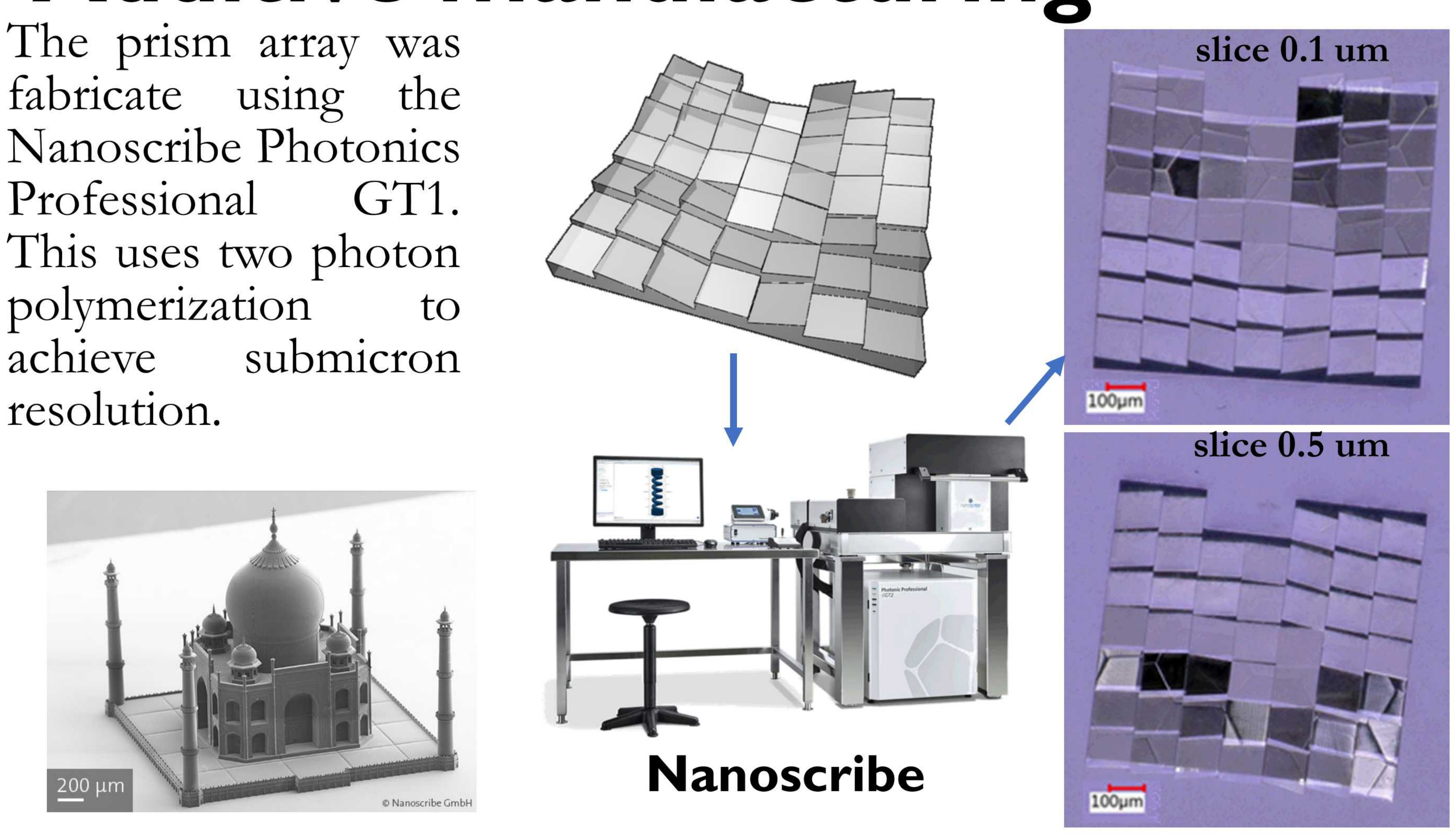
Classification accuracy

Classification accuracy was the ultimate performance metric of the system We classified the MNIST dataset using a random forest classifier. The dataset was compressed using the simulated system response matrices.



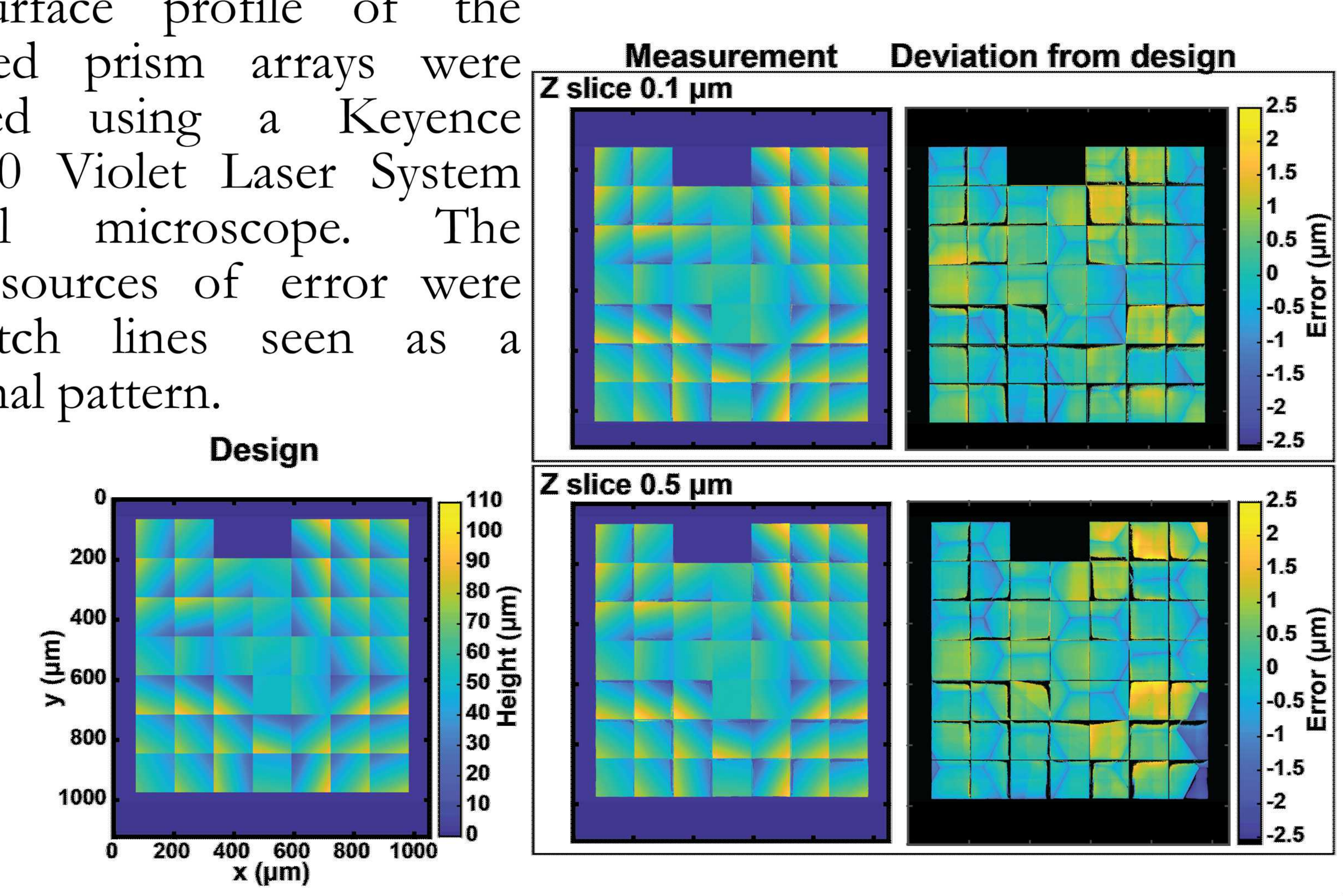
Additive manufacturing

The prism array was fabricate using the Nanoscribe Photonics Professional GT1. This uses two photon polymerization to achieve submicron resolution.



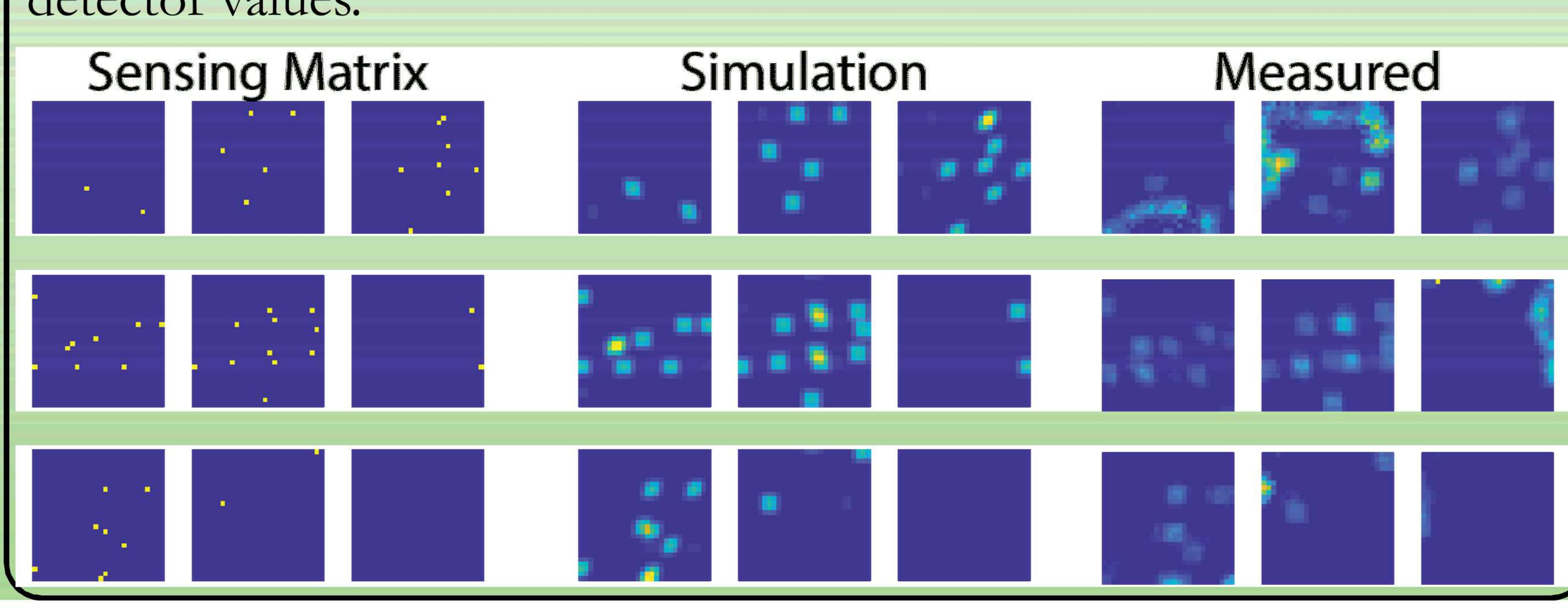
Physical characterization

The surface profile of the fabricated prism arrays were measured using a Keyence VKX250 Violet Laser System confocal microscope. The largest sources of error were the stitch lines seen as a hexagonal pattern.



Hardware response function

The hardware response function is measured by scanning a collimated light through all of the 28 by 28 input angles and recording the detector values.



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