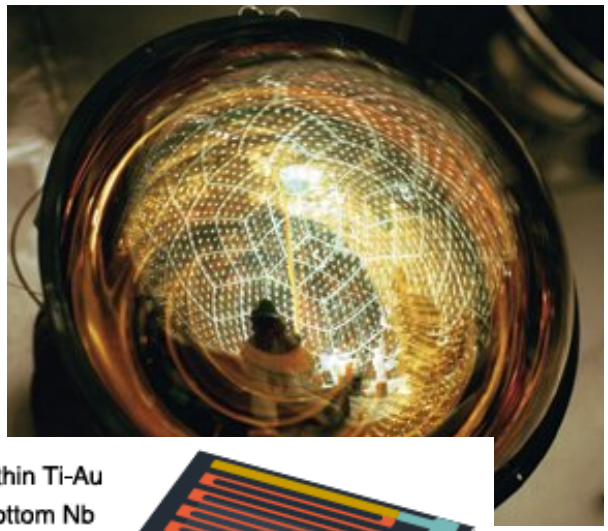
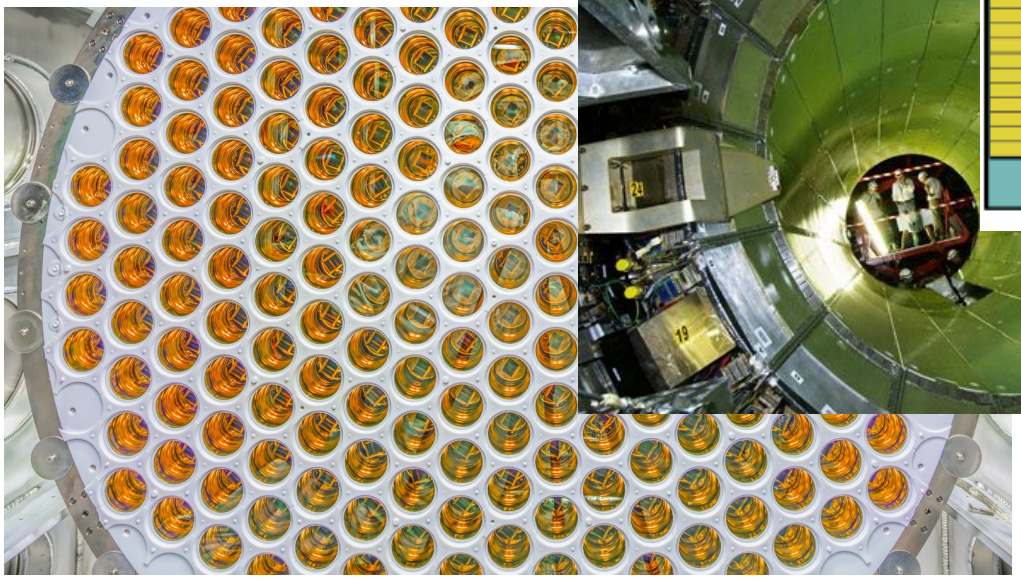
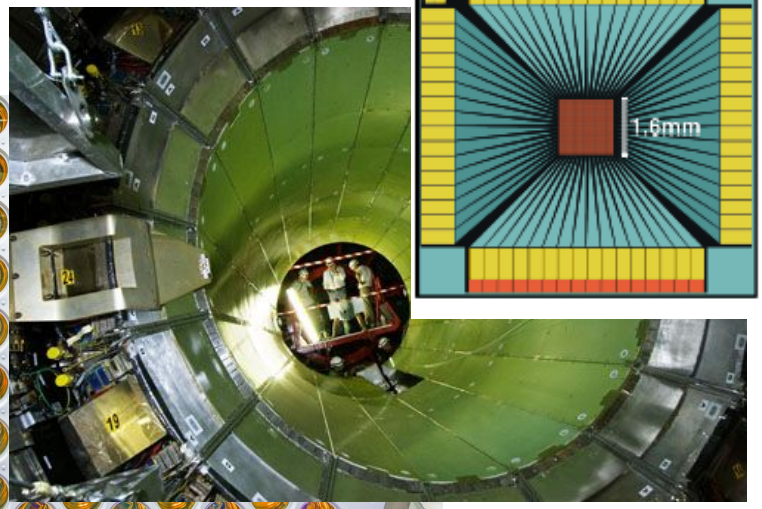
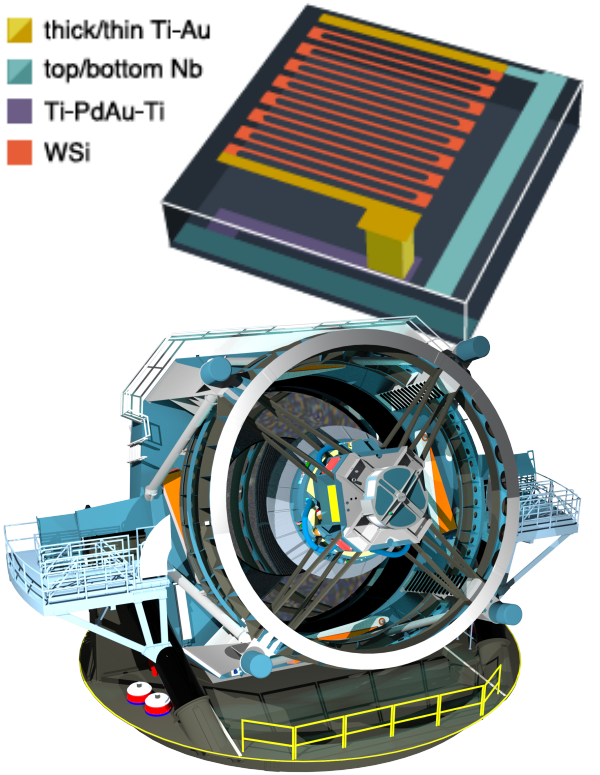
Photodetectors

BRN Group:
Lindley Winslow and Peter Krizan
with Graham Giovanetti, Adriana Lita, Felix Sefkow









There are 5 PRDs:

PRD 1: Extend wavelength range and develop new single photon counters to enhance photodetector sensitivity

PRD 2: Advance high-density spectroscopy and polarimetry to extract all photon properties

PRD 3: Adapt photodetectors for extreme environments

PRD 4: Design new devices and architectures to enable picosecond timing and event separation

PRD 5: Develop new optical coupling paradigms for enhanced or dynamic light collection

PRD 1: Extend wavelength range and develop new single photon counters to enhance photodetector sensitivity

Thrust 1: Increased IR sensitivity

Thrust 2: UV and VUV Scintillation and Cherenkov Photon Detection

Thrust 3: Single Photon Detection (SiPMs, LAPPDs, CCDs, SNSPD…)

Thrust 4: Advanced materials for photodetectors

PRD 2: Advance high-density spectroscopy and polarimetry to extract all photon properties

Thrust 1: Sensor-integrated spectroscopy

Thrust 2: Energy-resolving single-photon detection

PRD 3: Adapt photodetectors for extreme environments

Thrust 1: Cryogenic operation at liquid noble temperatures

Thrust 2: Low-radiological-background sensors and detector packages

Thrust 3: Long-lived and radiation hard sensors

PRD 4: Design new devices and architectures to enable picosecond timing and event separation

Thrust 1: Sensor structure optimization

Thrust 2: Sensor and electronics integration

PRD 5: Develop new optical coupling paradigms for enhanced or dynamic light collection

Thrust 1: Novel light propagation and collection systems

Thrust 2: Dynamic physical reconfiguration of multichannel devices

Thrust 3: Tracking Systems with Optical Readout

What did we see at CPAD 2021?

Photodetectors: SiPMs

A SiPM for the readout of the fast component of barium fluoride - Hitlin
Time resolution and efficiency of SPADs and SiPMs for photons and charged particles - Windischhofer
Nuisance Processes in p-on-n SiPMs - Gallina
Integration of mini TECs on the CMS MTD barrel timing layer 16 ch SiPM array to reduce the DCR after very high irradiation - Hearing

Photodetectors: Systems

Increasing photodetector light collection with metalenses - Stanford
Thickness Uniformity of Amorphous Selenium Films Utilizing the University of California, Santa Cruz Fabrication Facility - Abbaszadeh
Transparent Thermoplastic Acrylic Scintillator - Wang
3D printing of photocurable scintillating and low-background materials - Febbraro
A Novel Scintillator Detector for the Mu2e-II Experiment and a Muon Tomography Search for Hidden Chambers in the Great Pyramid - Dukes
Spectral Photon Sorting with the Dichroicon in Large Neutrino Detectors - Land
Theia Physics Potential - Askins

Photodetectors: Shorter Wavelengths

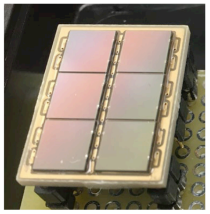
Large Area Picosecond Photo-Detectors (LAPPDs) for ANNIE and Future Neutrino Experiments - Tiras
Recent results from the pixel-based accelerated aging of Large Area Picosecond Photodetectors ($LAPPD^{\mathrm{TM}}$) - Chirayath
MPGD-based detectors of Cherenkov photons in COMPASS and for future applications - Tessarotto
Development of (V)UV-Sensitive GaN Geiger-Mode Photodiodes - Otte
Development Towards a Camera Readout and Barium Tagging Optical TPC,or CRAB-OTPC, for the NEXT Collaboration - Byrnes
Skipper-CCD for quantum microscopy: status and plans - Magnoni
Micro- and Nano- Machined Vacuum Photodetectors - Winn

Photodetectors: Longer Wavelengths

A Cooper pair transistor single photon detector with quantum enhanced sensitivity - Li
Superconducting mm-wave detector development at Argonne National Laboratory - Barry
Cosmology with On-Chip Superconducting Millimeter-Wave Spectrometers - Karkare
Mapping the CMB at High-Frequency with Kinetic Inductance Detectors on the South Pole Telescope - Anderson

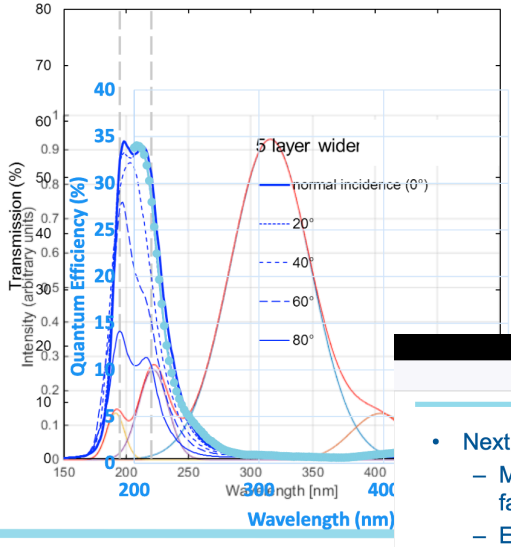
Progress on a photosensor for the readout of the fast scintillation light component of BaF_2

PRD 1: Thrust 3 - Single photon detectors
PRD 5: Thrust 1 - Novel light collection systems

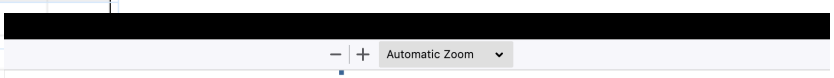


ALD bandpass interference filters

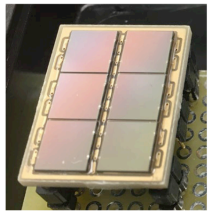
- A five-layer filter encompasses both the 195 nm and 220 nm peaks and provides improved slow component suppression
- Upper side performance has been measured on an APD at zero bias



Measurement is scaled using a model to obtain the QE at nominal gain/bias



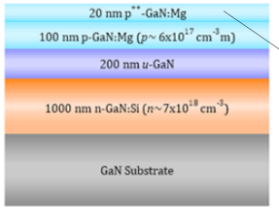
- Next steps in the program
  - Measure spectra with Y-doped BaF_2 crystals to verify the fast/slow scintillation yield
  - Employ 3 x 2 chip array of 6x6mm chips in series/parallel configuration to read out larger crystals – we have samples in hand
  - Measure radiation hardness with γ's and neutrons
  - Burn-in studies for MTF
  - Fab more sophisticated five-layer filters on remaining wafers – this is getting underway as JPL reopens
  - Produce delta-doped superlattice, back-illuminated versions that will have improved QE and timing characteristics

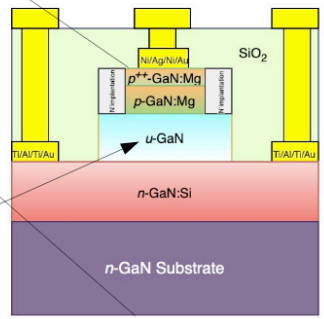


Georgia Tech GaN Structures

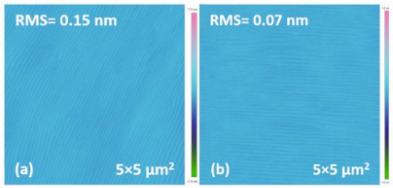
https://doi.org/10.1117/12.2576888

- epitaxial growth





surface roughness:



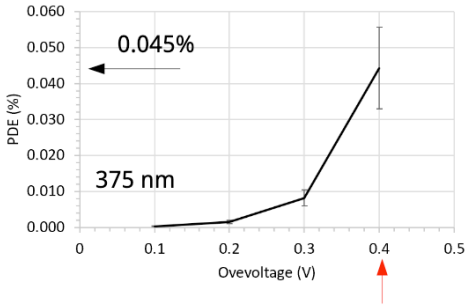
Avalanche region

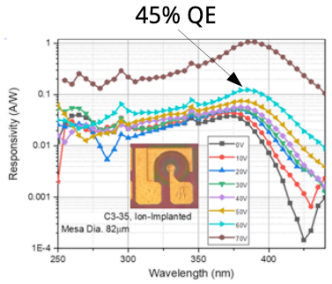
Growth on: u-GaN/sapphire n-GaN bulk substrate

PRD 2: Thrust 2
VUV/UV Sensitive Detectors.
PRD 2: Thrust 4
Novel Materials

GAN SPADs are now showing performance similar to early SiPMs.

Photon Detection Efficiency





~0.1% breakdown probability at 0.4V overvoltage (~0.5% above breakdown voltage)

Operation at higher overvoltages will result in higher breakdown probabilities

EXPERIMENTAL COSMOLOGY AT ARGONNE NATIONAL LABORATORY

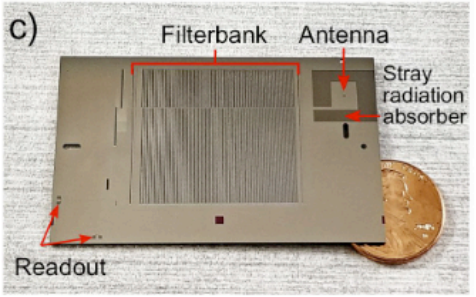
Pete Barry
Amy Bender
Tom Cecil
Clarence Chang
Riccardo Gualtieri
Stephen Kuhlmann
Juliang Li
Marharyta Lisovenko
Val Novosad
Zhaodi Pan
Gensheng Wang
Volodymyr Yefremenko
Jianjie Zhang

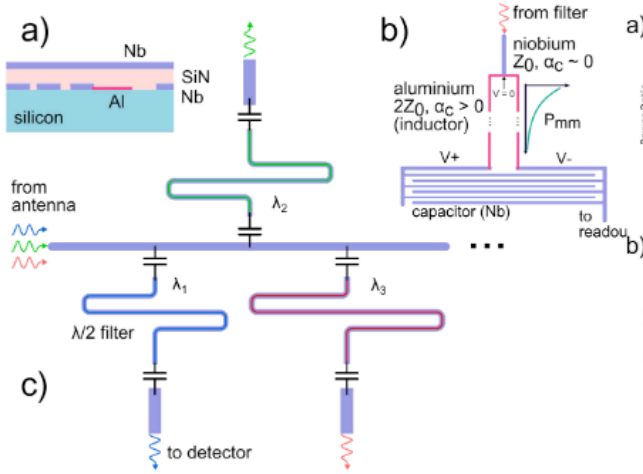
PRD 2: Thrust 1
Sensor Integrated Spectroscopy

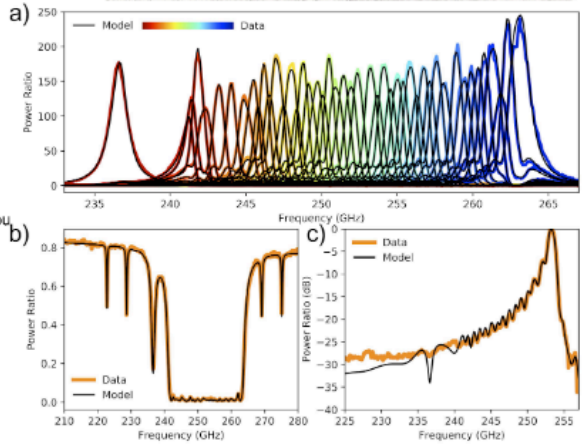
SPT-4 (spectroscopy)

Second generation detector arrays

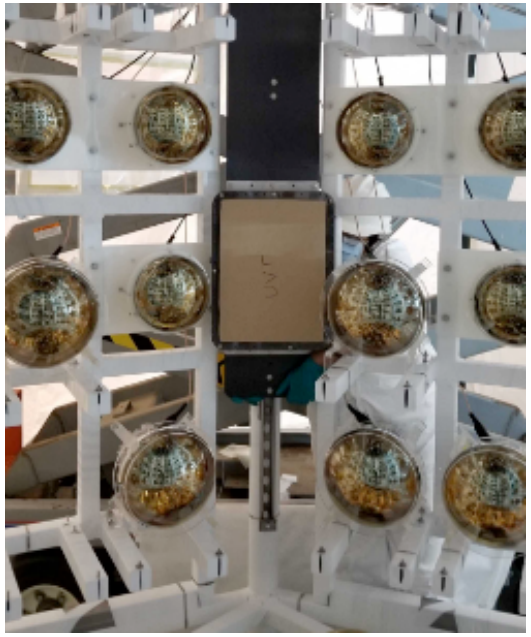
- Extension of on-chip filtering toward superconducting filter-bank circuits
- Each 'pixel' now becomes a medium resolution spectrometer
- Science case: *stay for Kirit's talk!*







Great Progress and Many Interesting Results

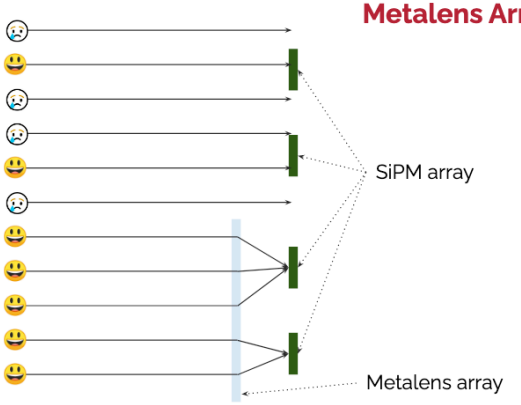


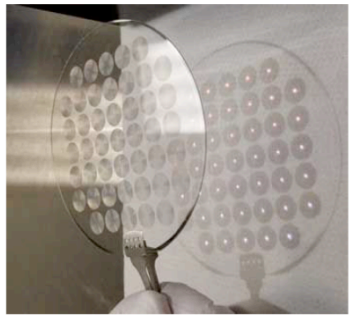
LAPPD Deployed in ANNIE

Metalens for SiPM Array

Importance to instrumentation

Metalens Array





Capasso Group, Harvard University

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Spectral Photon Sorting

The Dichroicon

- Implements spectral photon sorting
  - Winston cone of dichroic filters
  - Long wavelengths diverted to front PMT
  - Short wavelengths pass to rear PMT
- Benchtop model designed and tested
  - Demonstrated C/S separation with dichroicon prototype

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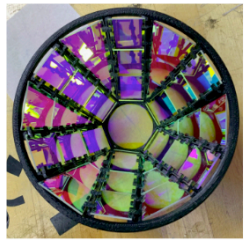
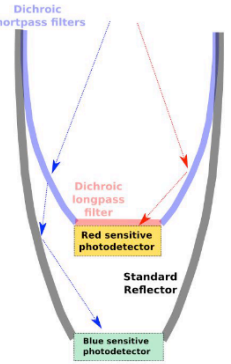
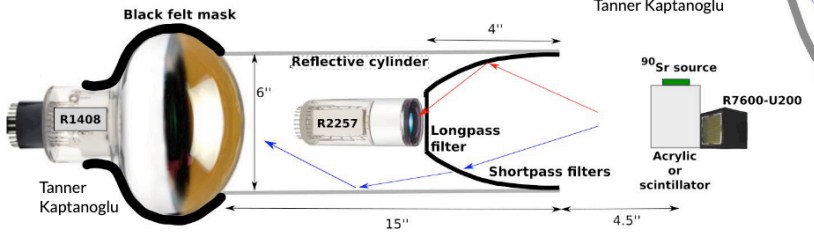


Tanner Kaptanoglu





Parting Notes:

Photodetectors are at the heart of many experiments ranging across wavelengths, temperatures, particle energy and frontiers.

Blue Sky: When should we start thinking about what could be done with these high-performance cryogenic sensors i.e. the Quantum Frontier meets the Intensity and Energy Frontier?

Near Term: Would a BRN style workshop focussed on photodetector technology make sense? Is it a good time to bring together the various physics communities and a variety of experts beyond HEP?