Environmental monitoring using subatomic physics technologies

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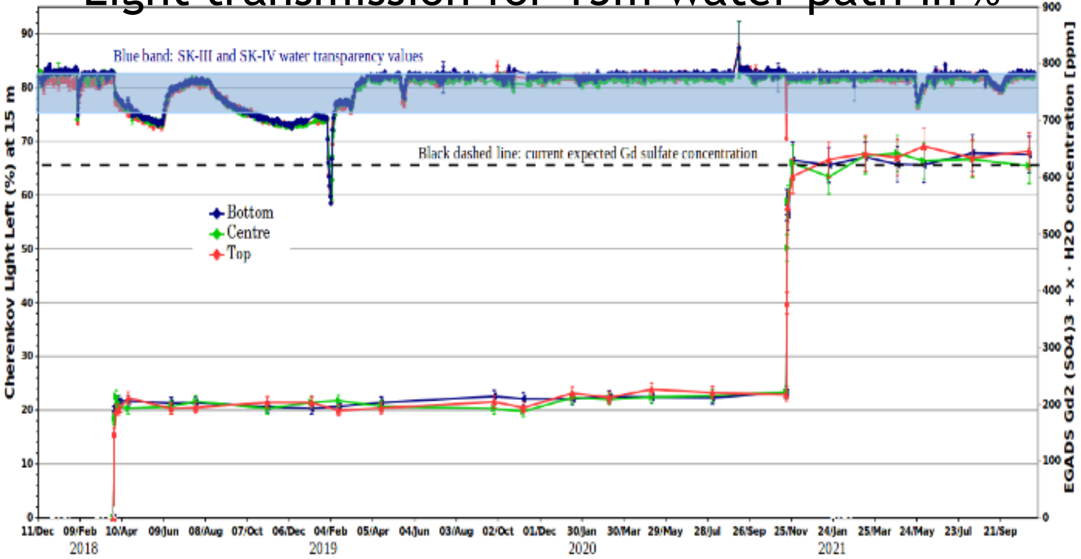
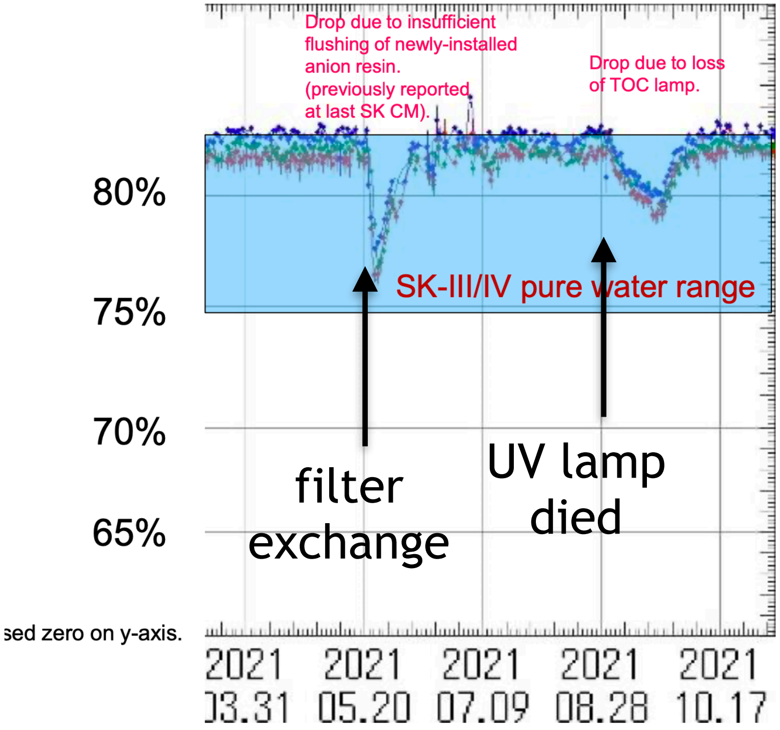
- Environmental challenges in particular due to global warming
  - Clean air
    - air pollution due to forest fire, coal burning, automobile/industrial exhausts, …
  - Clean water
    - water pollution due to algae growth, flooding, pesticides, oil spills, microplastics, …
- Optical monitoring of the environment
  - Advancements in photon counting technologies
    - SiPM, LED/Laser diode, fast electronics
  - Continuous and distributed large data collection
    - revolutionalize the capability of environmental monitoring (with AI)
- Opportunity for TRIUMF to be involved
  - Photon counting expertise and synergies with ongoing projects
    - HyperK, nEXO/ARGO, P-ONE

Water transmission monitoring in Kamioka

- Transmission changes are monitored
  - time correlation is a powerful tool in identifying the source
- Revolutional in water monitoring
  - instead of water sampling and lab. test

Light transmission for 15m water path in %

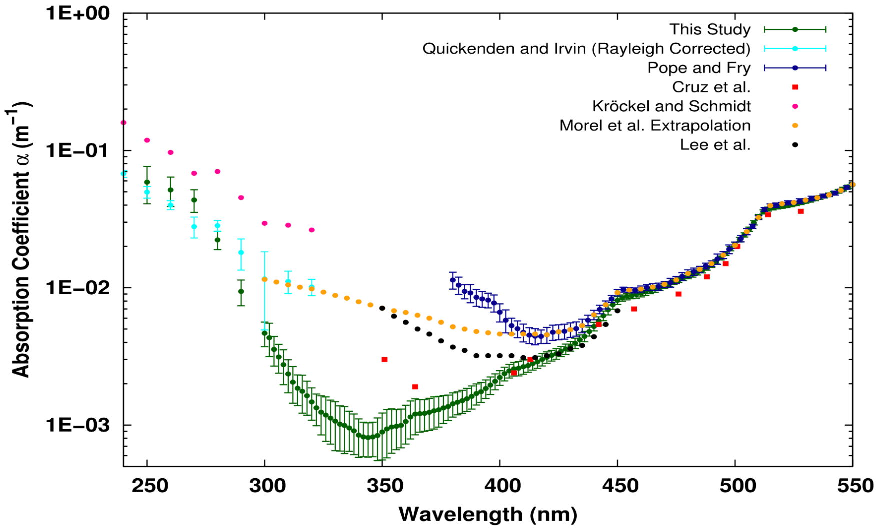


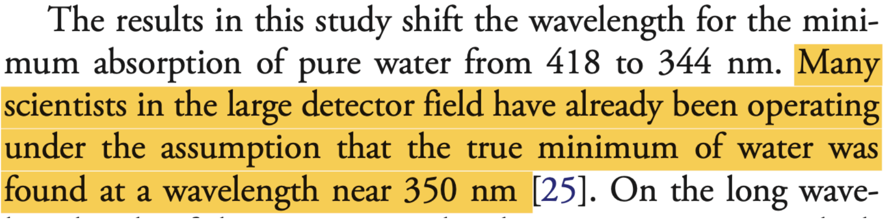


SK calibration: Lidar with 4π detector coverage

- State-of-the-art water measurement by SK
  - confusion of scattering and absorption caused errors on UV light absorption in water:
    - SK knew this already
- Further improved water studies like atmospheric lidar possible
  - sub-nsec timing
  - narrow beam
  - polarization
    - depolarization ratio δ determines angular distribution
- Results can help Oceanography
  - studies for global warming

Applied Optics 25 (2016)7163



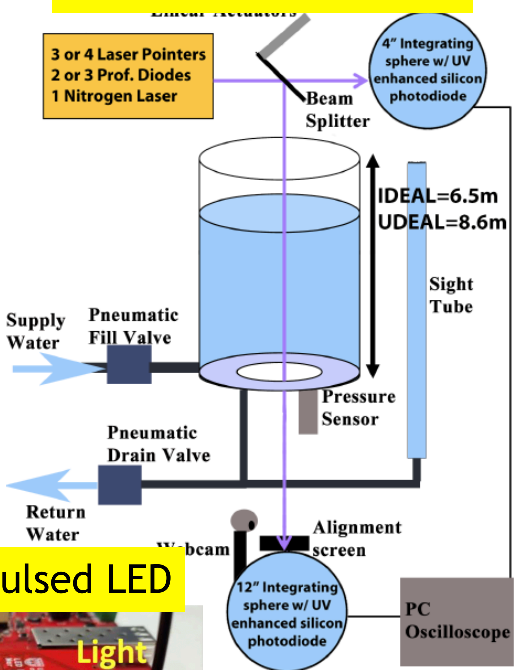

The results in this study shift the wavelength for the minimum absorption of pure water from 418 to 344 nm. Many scientists in the large detector field have already been operating under the assumption that the true minimum of water was found at a wavelength near 350 nm [25]. On the long wave-

Old SK paper is cited

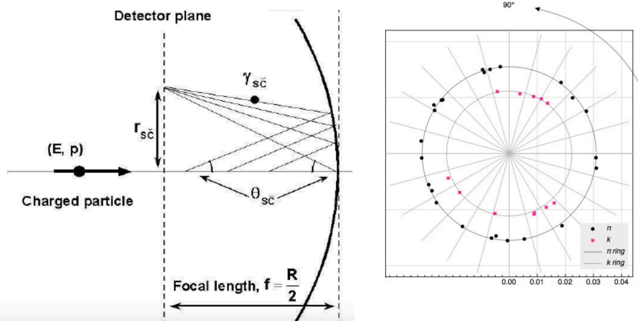
Adopted ideas

Point-to-parallel focus mirror

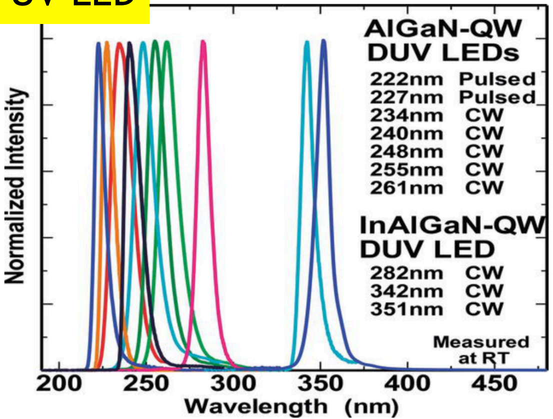
SK UDEAL
8m-tall water monitor



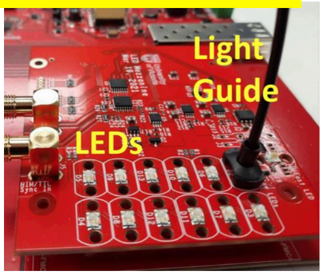
Angle-to-point focus
ring imaging Cherenkov



UV-LED

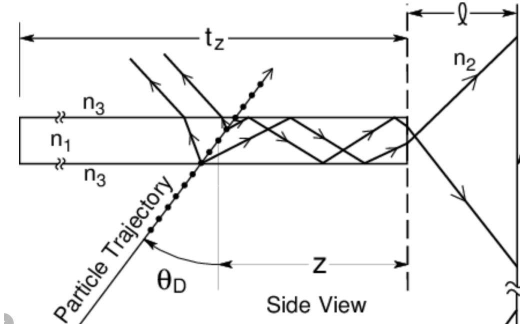


mPMT pulsed LED

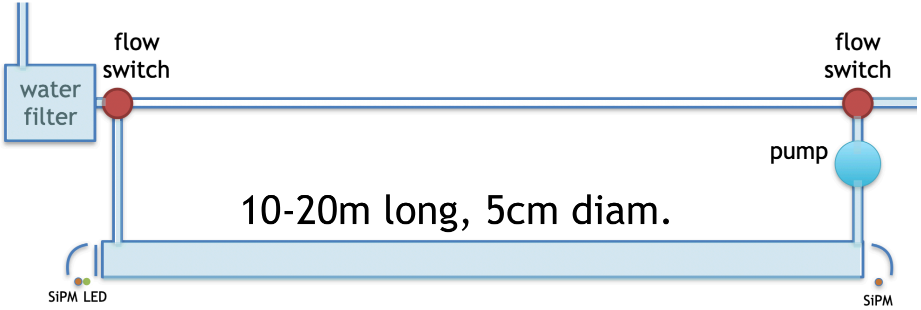


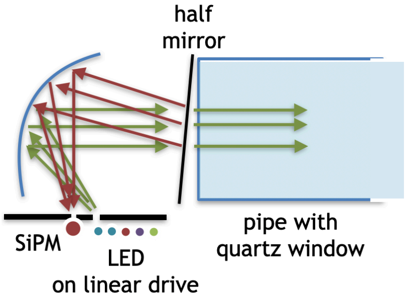
SiPM

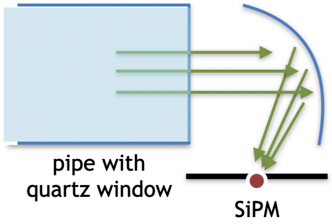
DIRC quartz Cherenkov



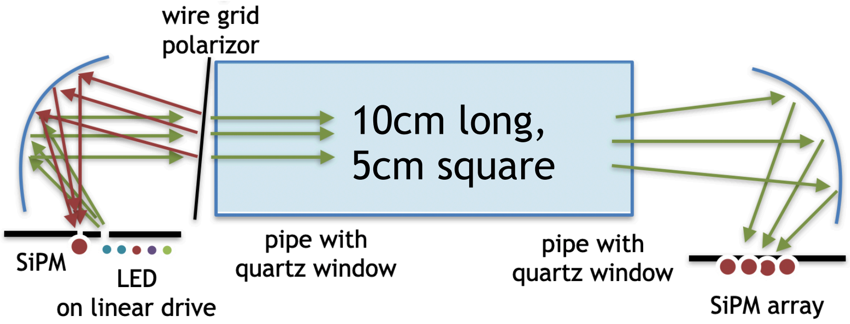
Transmission

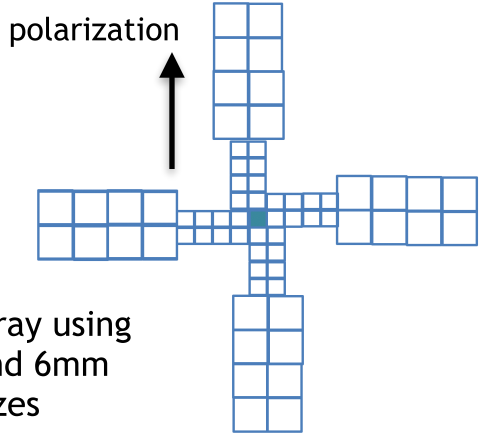






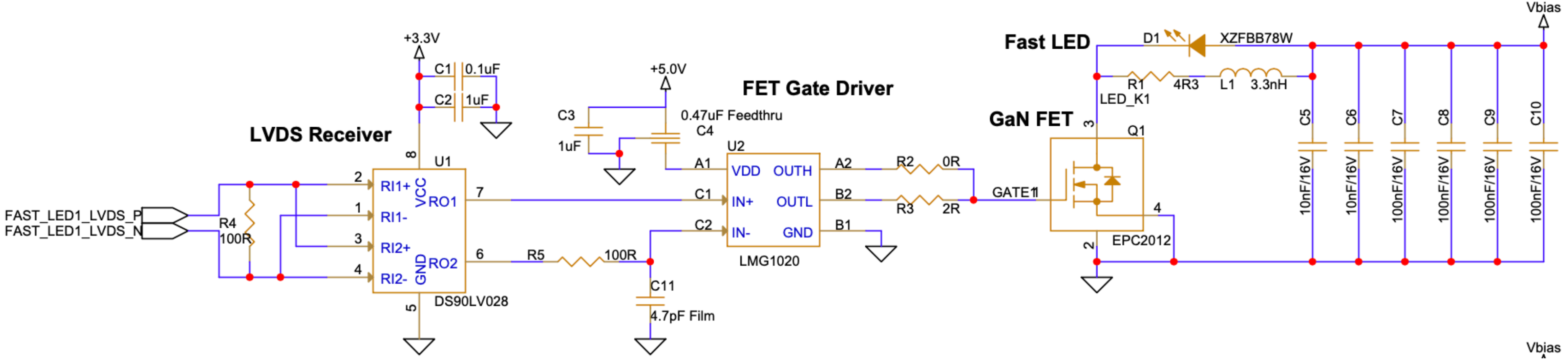
Scattering

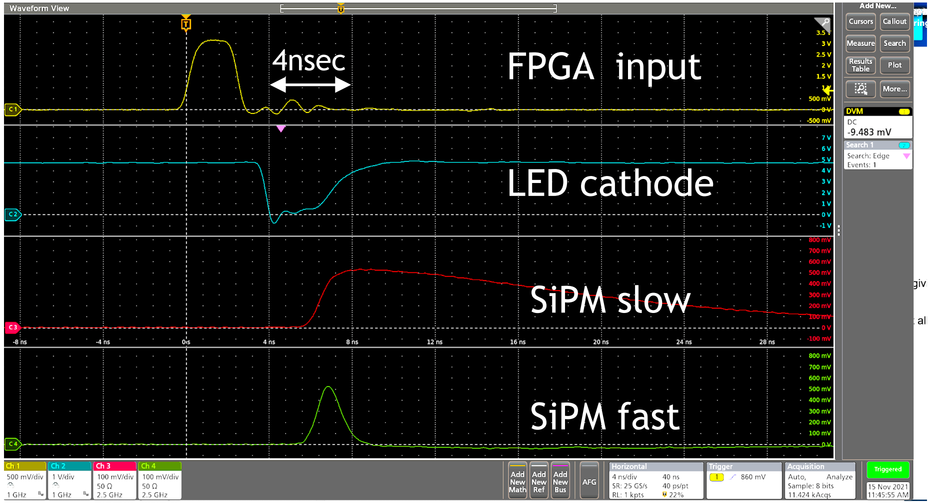




SiPM array using 3mm and 6mm pixel sizes

Sub-nsec pulsed LED: Nick Braam (UVic)





- LED: UV-LED available
  - 278nm, 365nm, 405nm, 475nm
- Driver circuit
  - GaN gate FET (new technology)
  - Capacitor bank to over-drive
- Low cost: $15-25 per channel

Sensitivities of the water monitor system

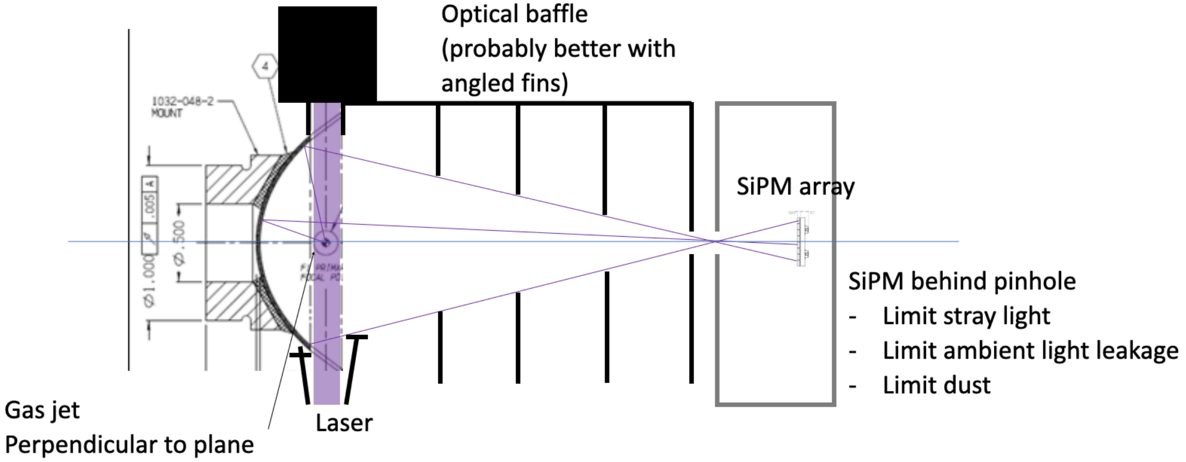
- Limitation of spectrophotometer: typical sample size of ~1cm
  - Concentrating the sample to enhance the sensitivity
  - SuperK (UDEAL) solution: long water pipe passing parallel light through
- Absorption in 10m water gives enough sensitivities for drinking water
  - Benzene: common toxin in oil spills
  - Microcystin: toxin from blue-green Algae in lakes (water source)
  - NDMA: disinfection byproduct after water treatment

	drinking water limit	absorption coeff.	absorption in 10m	absorption in 1cm
Benzene	5 µg/L	240 /mol/cm @254nm	1.47% @254nm	0.00147%@254nm
Microcystin	1.5 µg/L	13,225 mol/cm @254nm	4.5% @254nm	0.0045% @254nm
	1.5 µg/L	40,000 mol/cm @240nm	13.2% @240nm	0.0132%@240nm
NDMA	0.04 µg/L	10,000 /mol/cm @240nm	1.2% @240nm	0.0012%@240nm

Drinking water monitoring project (NSERC Alliance)

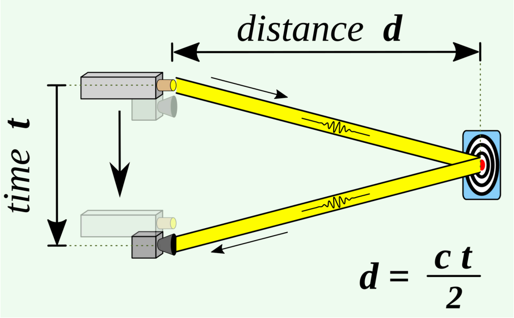
- Detector and software development
  - TRIUMF and HyperK groups at U.Winnipeg, U.Regina
- First Nations communities: deployment, student involvement
  - First Nations University of Canada (FNUniv)
  - Cowessess First Nation, Ahtahkakoop Cree Nation
- Water treatment community: compare with weekly water sampling test
  - Weyburn Water Treatment Facility
  - Water treatment engineering faculty at U.Regina
    - "Paradigm change" in dynamically adjusting the water treatment parameters
- Environmental study community and government engagements
  - Environmental study faculties at U.Regina and U.Winnipeg
    - "Understanding the cause of contamination events"
  - Regional Centre of Expertise (RCE) Saskatchewan (UNESCO organization)

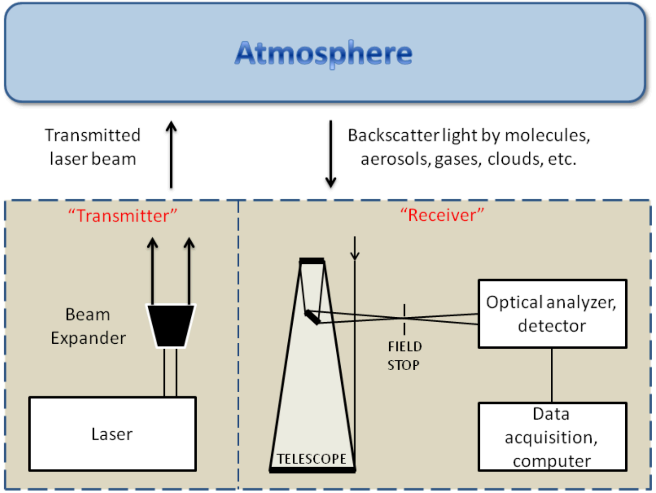
- Laser light (Mie) scattering from particulates in the gas jet
  - Multiple laser photons scattered from each particulate
    - count rate corresponds to particulate density & cross section
  - Scattered lights are focused by eliptic (point-to-point) mirror
- Innovation based on dark matter detector experience
  - Compact system using SiPM array with high counting rate



- We have technologies to address urgent societal challenges:
  - Global warming
    - clean water, clean air
  - Photon counting technologies
    - high sensitivity (and we know how to take advantage of it!)
    - low cost (SiPM, LED/diode laser, fast electronics)
    - continuous/distributed environmental monitoring → data (AI) revolution
- Towards TRIUMF detector development centre:
  - Technology development for subatomic physics
  - Transfer technologies for social benefits
    - environment/sustainability, interdisciplinary, commercialization, connect to the First Nations communities
    - would help justify funding for a new building that comes from the province
    - resonate with young talents

- Lidar
  - time of flight on back scattered light
- Atmospheric Lidar
  - backscattering from aerosols, clouds etc.
  - precise monitoring of the atmosphere
- Lidar for Oceanography
  - Lidar with polarization
    - Phytoplankton (heat budget, carbon fixing)
  - pure water parameter (background) is important
    - we basically do 4π Lidar in SK and HK





REVIEW article

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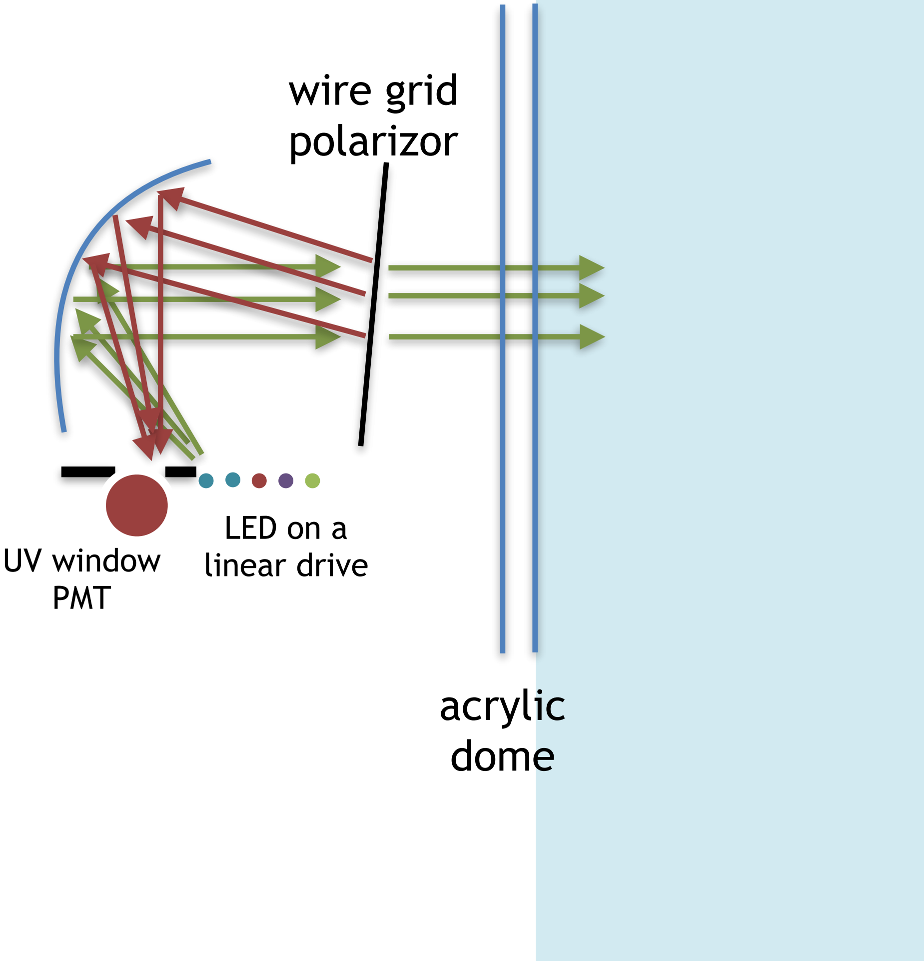
Going Beyond Standard Ocean Color Observations: Lidar and Polarimetry

Polarimetric Lidar in HyperK implemented in mPMT



- mPMT LED system
  - sub-nsec LED for Lidar
  - parallel light with a parabolic mirror
    - point-to-parallel focus
  - polarizer
    - polarimetry (depolarization ratio)
    - half mirror for monitoring)
  - linear drive
    - selection of LED colour
    - changing the direction of the light
  - LED intensity monitored by backscattering
- A similar system could work for Ocean Lidar
  - Deep Ocean Oceanography
    - detect contaminations
    - Phytoplankton: heat budget, Carbon fixing
  - Similar idea in P-ONE?