A co-deployed dust-logging instrument for the IceCube Upgrade and IceCube-Gen2

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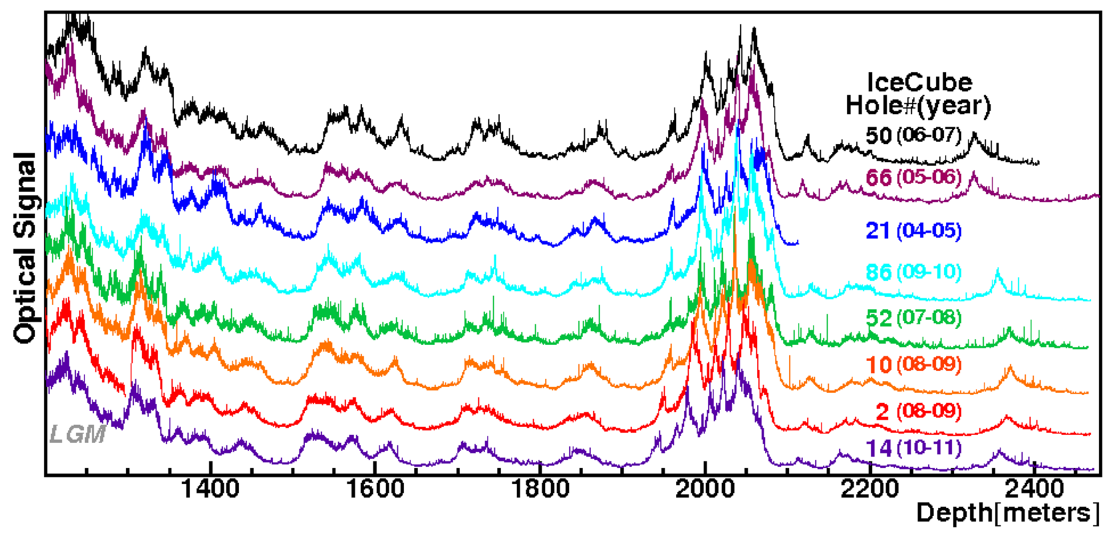
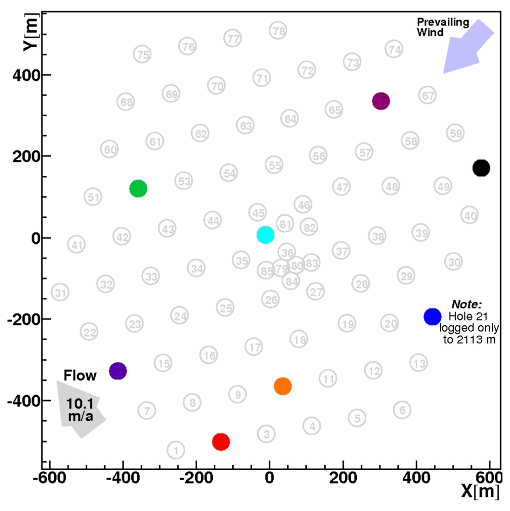
Goal

Knowledge of the ice stratigraphy, that is the depth dependence of the impurity concentration in the ice, is vital to even reconstruction. In IceCube this was originally measured using a laser dust logger[1]. The results for eight holes are shown on the right. Certain features in the stratigraphy change in depth with the lateral location in the detector. These undulations originate from ice layers tracing the shape of the bedrock.
We here present a newly developed instrument, called LOMlogger. It will be deployed in the IceCube Upgrade, exploring 250m of ice below IceCube and act as a proof of principle for ice stratigraphy measurements in IceCube-Gen2.





Working principle

The LOMlogger utilizes the same principle as the original dust logger[1]: light is emitted horizontally into the ice during the descent of the instrument in the bore hole and is scattered in the ice. A small fraction reaches the detector. The result of the measurement is the scattering profile of the ice with respect to the depth.
In this version the light emitter and receiver are separated into two devices. Both are situated on the instrumentation line and measurements are performed during the detector deployment.

LOM[2] as light receiver

IceCube Gen2 prototype photosensor module with 16 PMTs logs the scattered photons. It delivers the stratigraphy as a photon count for each emitted pulse.

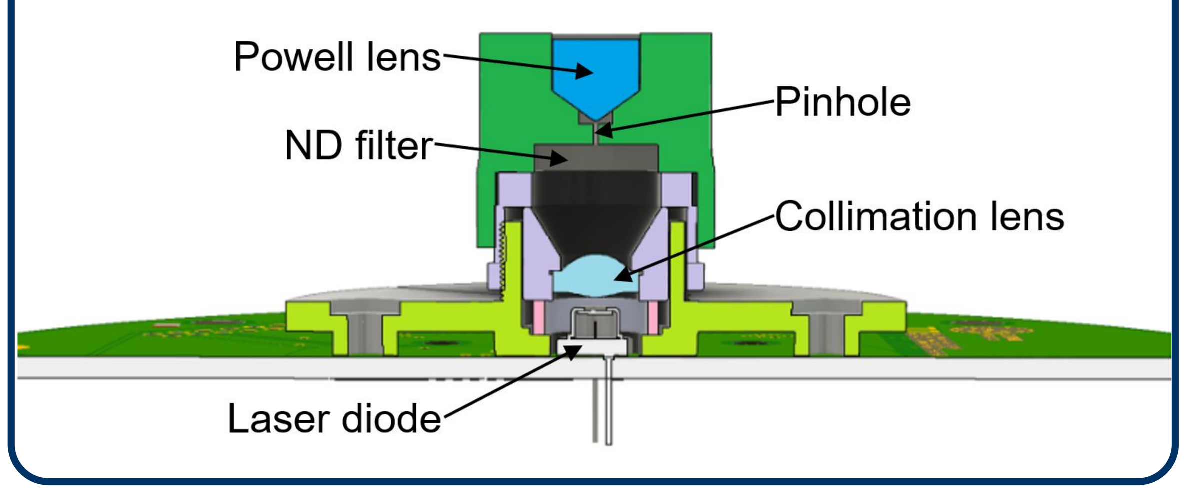
Baffle as background mitigation measure

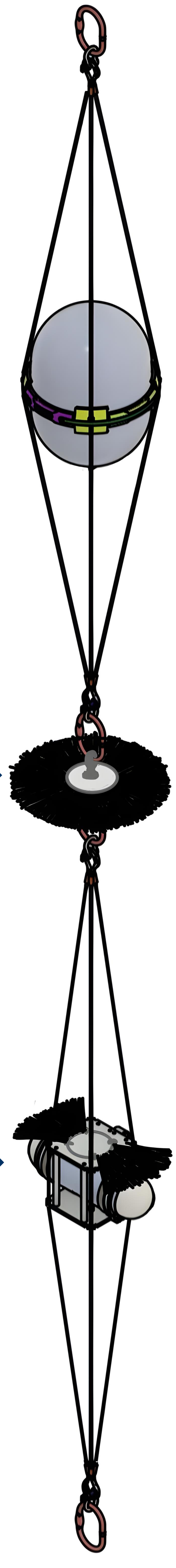
The LOM needs to be shielded against light that scatters through the water column of the borehole. Black nylon brushes (baffles) are designed to absorb the light, but let the water flow through with little resistance.

Modified POCAM[3] as light emitter

Retrofitted isotropic light source with new optics for a low divergence horizontal beam.

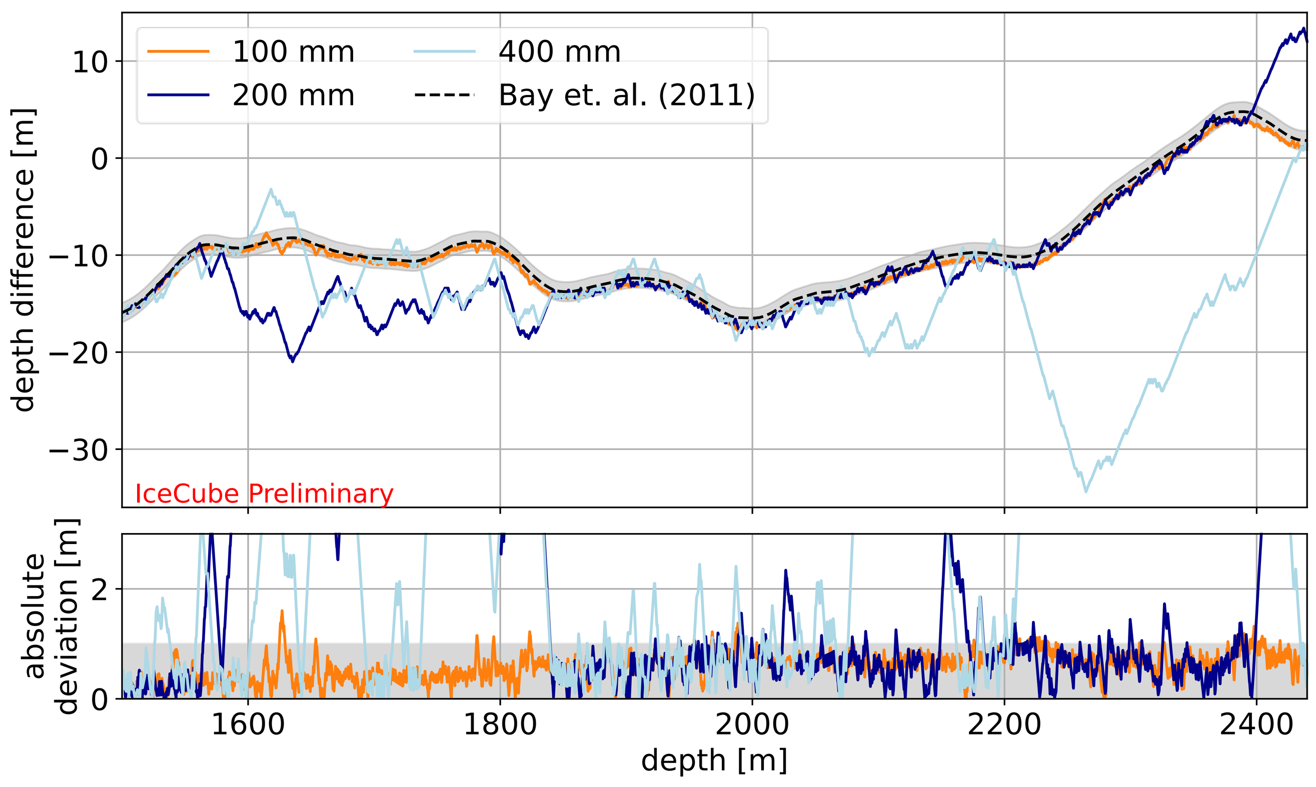
- Laser diode RTL405-600MGE (white component) as pulsed light source to be flashed at ~1kHz
- Focused by Adjustable Laser Diode Collimation Tube LTN330-A (violet, light blue and pink parts)
- Horizontal fanned out beam achieved by a LGL160 Powell lens (dark blue component) with pinhole in front of it to provide the required incoming beam size
- Intensity can be reduced with neutral density filter (gray rectangle)





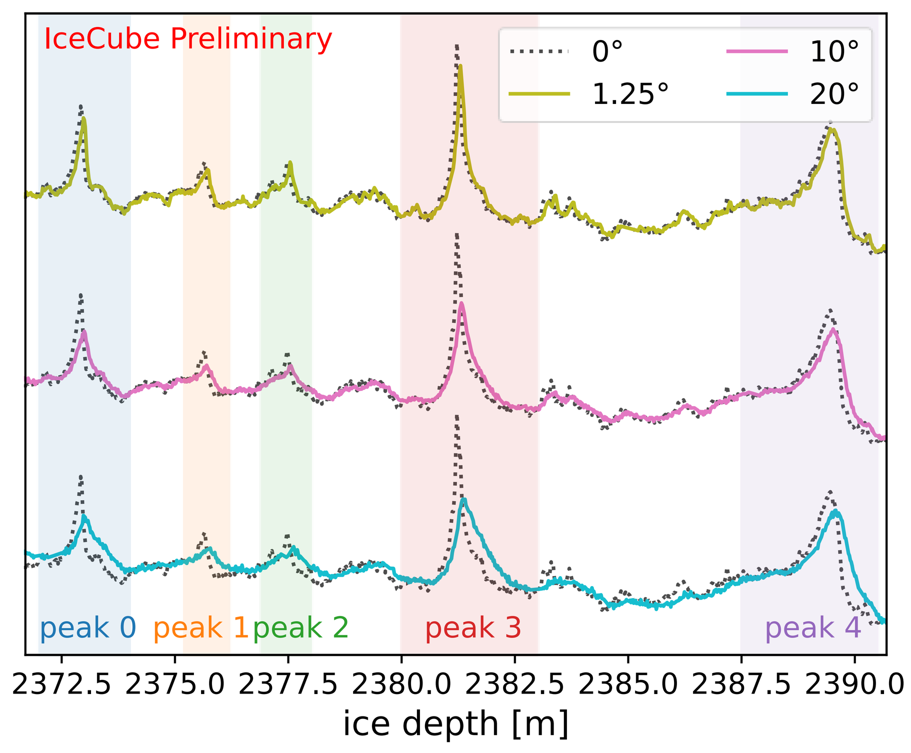
Requirements for the light emitter

Layer undulation analysis entail matching features between different stratigraphies via a dynamic time warp algorithm[4].
The required feature size to be resolved by the instrument to perform stable stratigraphy matching (average deviation <1m) has been deduced to be at 20cm and below.



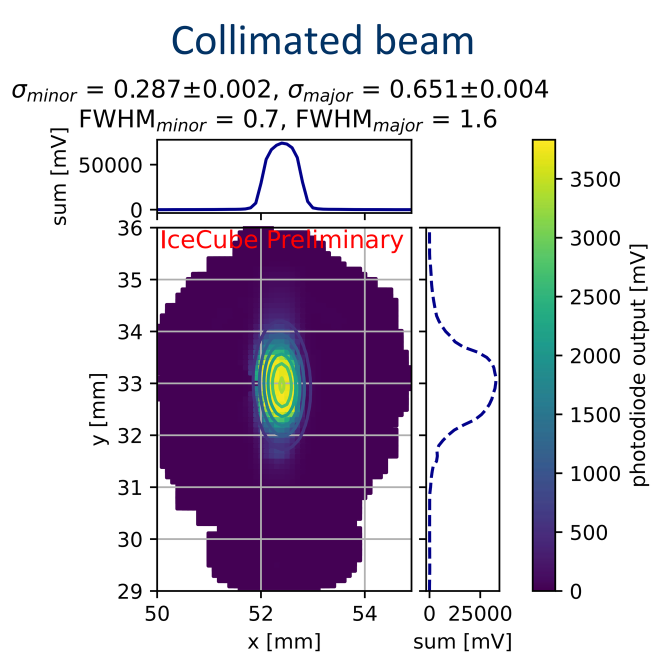
To achieve a <20cm resolution the following requirements for the optical system were derived from Simulation:

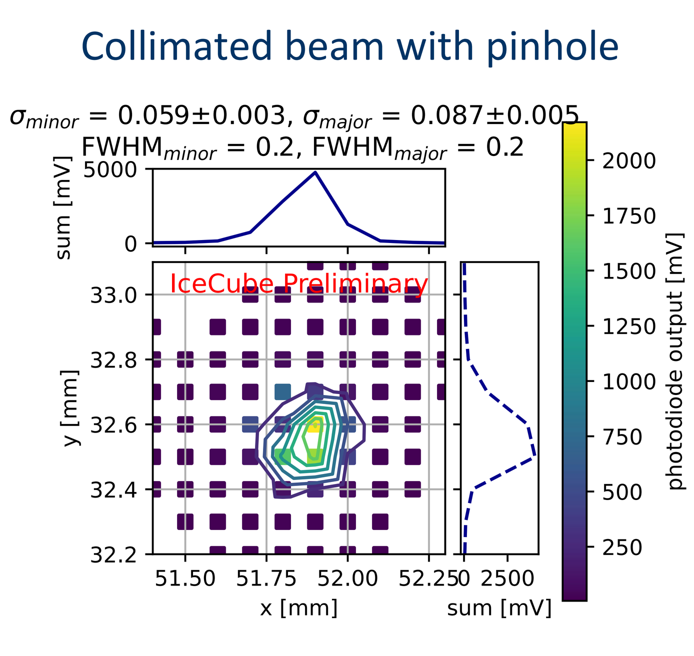
- *Vertical beam divergence:* less than 10° (see plot on the right)
- *Beam inclination:* less than 10°
- *Beam intensity:* $3 \cdot 10^8 - 8 \cdot 10^8 \frac{\gamma}{pulse}$

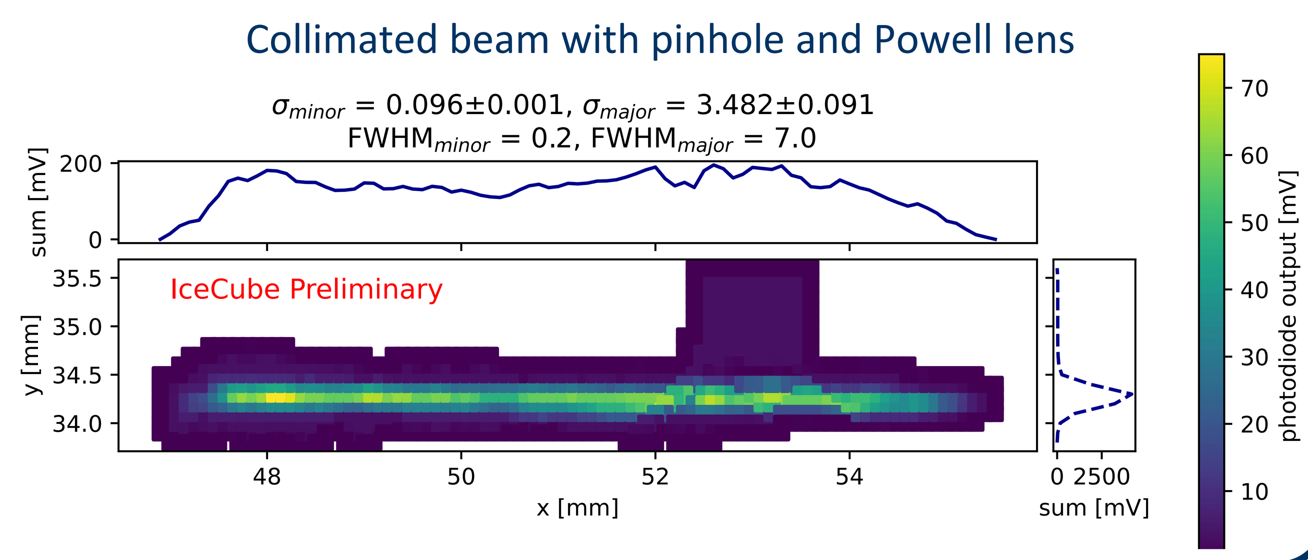


Prototype verification of the light emitter

Beam profile scans after collimation (upper left plot), pinhole (upper right plot) show that the pinhole delivers a Smaller beam size Than needed. The beam profile with the Powell lens (lower plot) shows the desired shape. The vertical beam divergence after the Powell lens is 0.06(1)°, so two orders of magnitude better than the requirement.







[1] R. C. Bay et al. Journal of Geophysical Research: Atmospheres 115 no. D14, (2010).
[2] IceCube Collaboration, A. Kappes et al. PoS ICRC2025 (these proceedings) 1072.
[3] Henningsen et al. Journal of Instrumentation 15 no. 07, (Jul, 2020) P07031.
[4] C. Myers et al. IEEE Trans Acoust 28 no. 6, (1980) 623–635.

Proceeding:

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