(Automated Lightweight Portable Analyzer for C-Axes)

ALPACA

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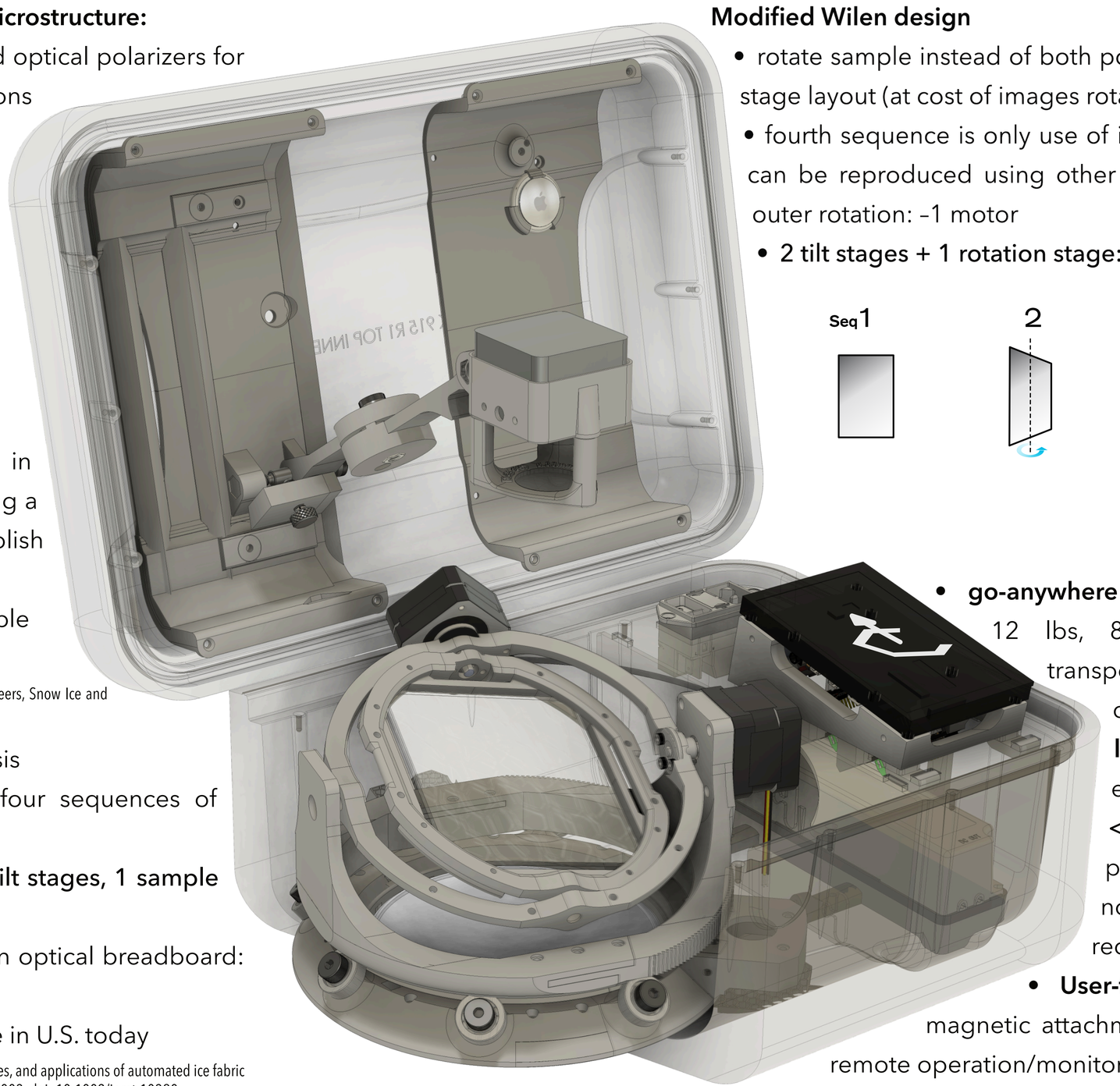
BACKGROUND

Polarimetric analysis of ice fabric and microstructure:

- observe thin sections between crossed optical polarizers for extinction angles, crystal axis orientations
- still-unparalleled crystal-level detail
- detection of continuity disruptions
- ground truth for remote sensing techniques, e.g., polarimetric radar
- powerful constraints for ice flow



PRIOR ART

Rigsby: manual "universal stage"

- for each crystal, rotate thin section in azimuth and three other axes, following a branching algorithm, to establish extinction behaviors and thus c-axis
- repeat process for every crystal in sample
- time-, labor-, and frostbite-intensive

C. C. Langway Jr., "Ice Fabrics and the Universal Stage," Army Corps of Engineers, Snow Ice and Permafrost Research Establishment, Wilmette, Illinois, 62, Aug. 1958.

Wilen: automated instrument and analysis

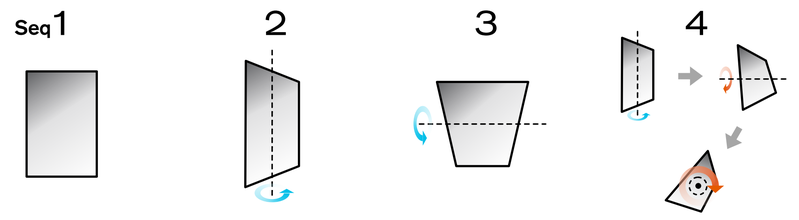
- image all crystals simultaneously in four sequences of predetermined orientations
- **2 polarizer rotation stages, 2 sample tilt stages, 1 sample inner rotation stage**: 5 motors
- commercial motion stages mounted on optical breadboard: high-precision, high-cost, lab-bound
- one device built circa 2000; one device in U.S. today

[1] L. A. Wilen, C. L. Diprinzio, R. B. Alley, and N. Azuma, "Development, principles, and applications of automated ice fabric analyzers," *Microscopy Research and Technique*, vol. 62, no. 1, pp. 2–18, Sep. 2003, doi: 10.1002/jemt.10380.

WORKING PRINCIPLES

Modified Wilen design

- rotate sample instead of both polarizers: –1 motor, simplifies stage layout (at cost of images rotating)
- fourth sequence is only use of inner rotation stage. Position can be reproduced using other sequences' tilt stages and outer rotation: –1 motor
- **2 tilt stages + 1 rotation stage:** 3 motors

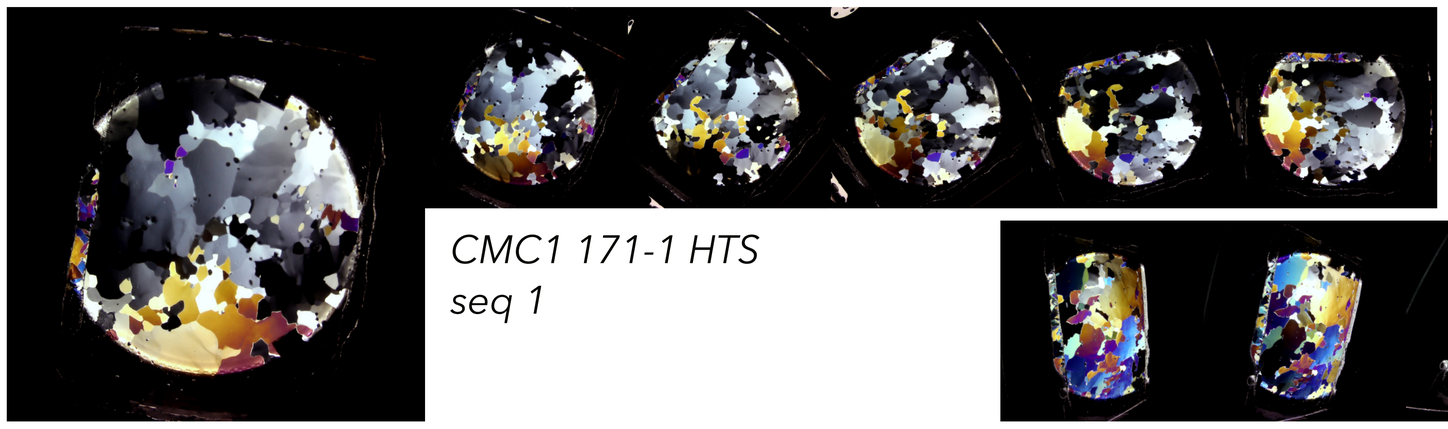


DESIGN GOALS

- **go-anywhere**: low SWaP (15" x 12" x 7", 12 lbs, 80 W), integrated robust transport case, quick and simple deployment and teardown
- **low barrier to entry**: COTS electronics, materials cost <$2,000, all CAD custom parts **3D printed** or laser cut: no machining skills or tooling required to replicate
- **User-friendly**: GUI software, magnetic attachments, single external cable, remote operation/monitoring/data access
- **flexible science**: modular extensible Python codebase

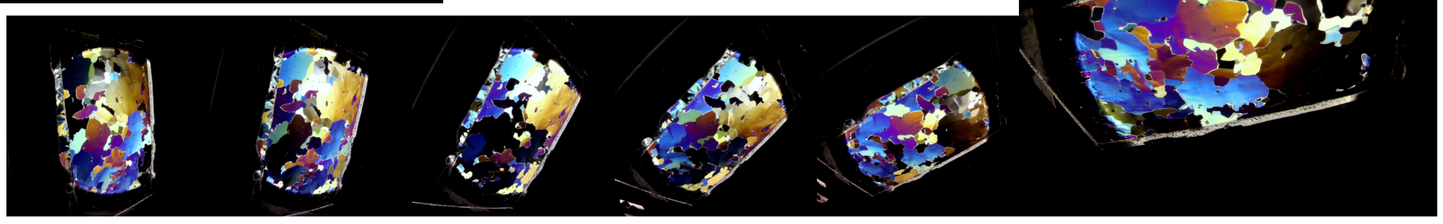
FIRST TESTS & SCIENCE

Deformation history of Allan Hills ice: synthesis of bubble elongation, grain, and c-axes observations



CMC1 171-1 HTS seq 1

CMC1 171-1 HTS seq 3



ROADMAP

Field tests at NSF-ICF took place earlier than originally scheduled, but demonstrated design as operational. Data collection will complete at UMN.

- mechanical design refinements: enlarge illuminated area of thin sections, improve weight balance and stability of tilt stage, adjust magnet strengths
- **graphical user interface** for easier instrument control and operation
- **data processing and analysis software** development
- nice-to-haves: integrated field repair toolkit and spare parts
- **multiple exposure stacking** for high dynamic range data: reduced noise, **increased precision** for extinction angle-fitting/c-axes
- automated optical stage position calibration using sample plate + software
- non-polarimetric multi-angle **imaging of bubbles** and other features

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