Noninvasive Glucose Sensing with Light

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1. Background

► Diabetes is a chronic condition that causes abnormal blood glucose level

► More than 10% of the U.S. population have diabetes

2. Motivation

► Off-the-shelf products are invasive and inconvenient

OneTouch UltraMini   *FreeStyle Libre 2*

3. Rationale

► Glucose is optically active

► The concentration of glucose molecules C is directly proportional to the rotation angle of the polarization direction α

Measured Rotation   Concentration   Optical Path

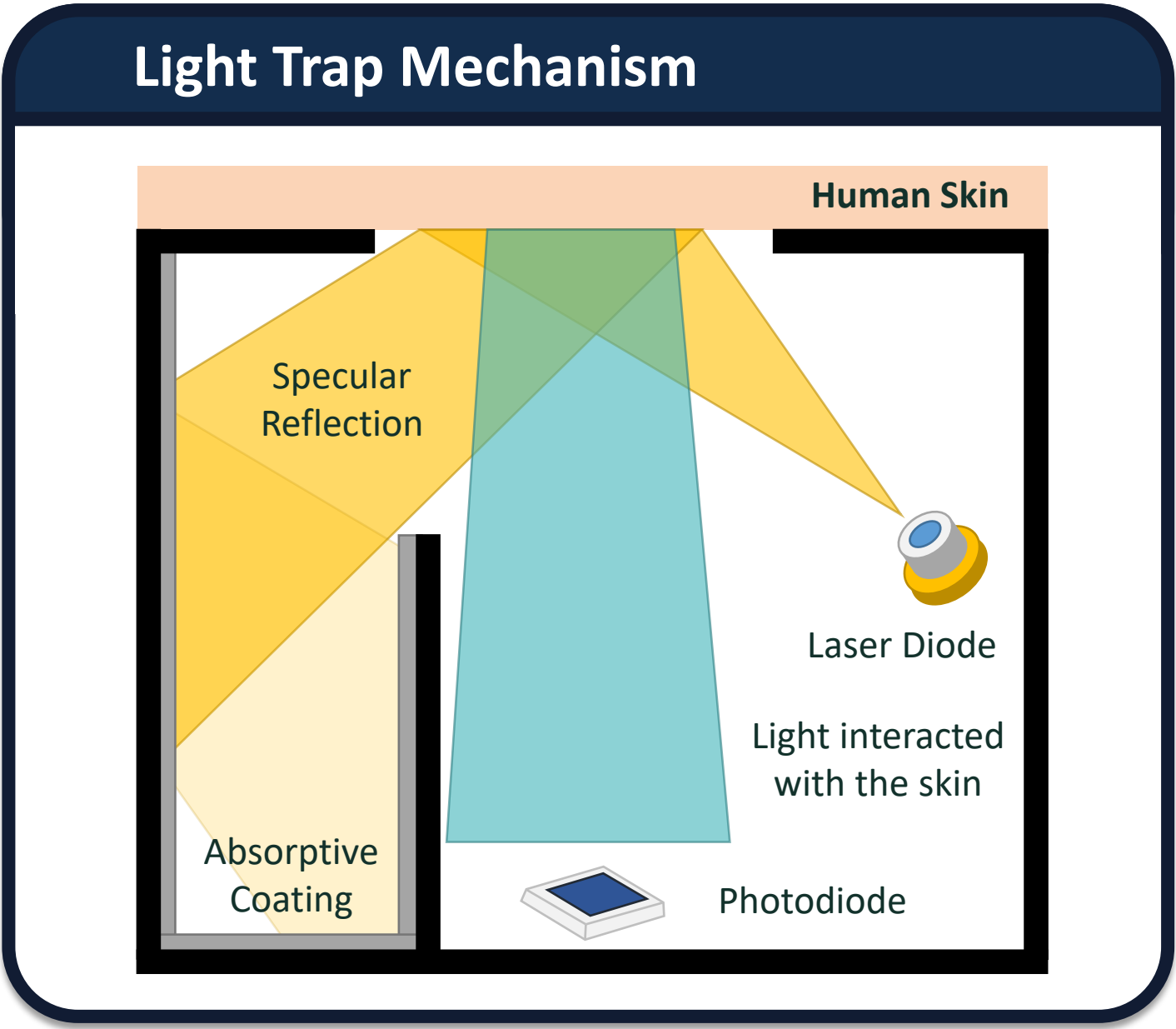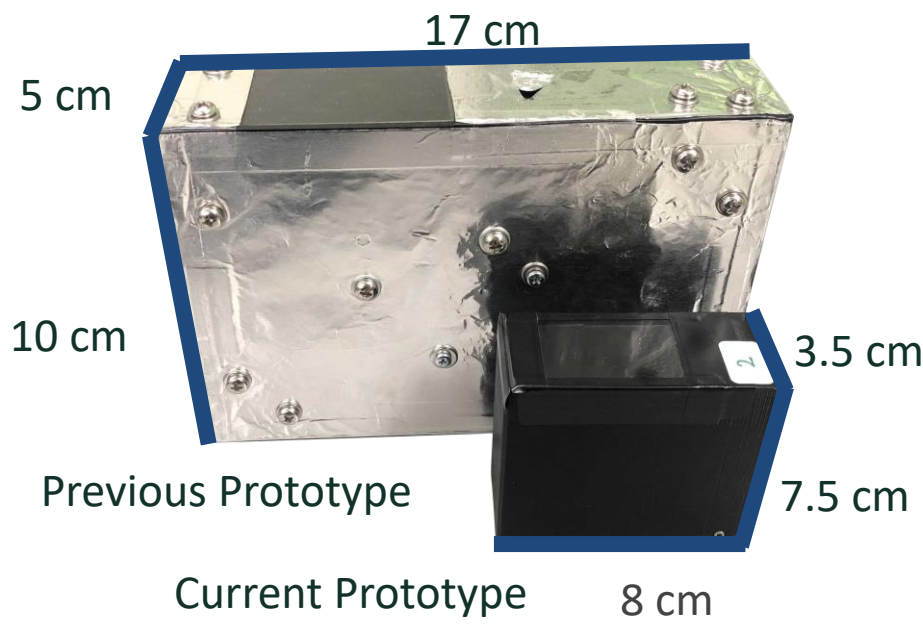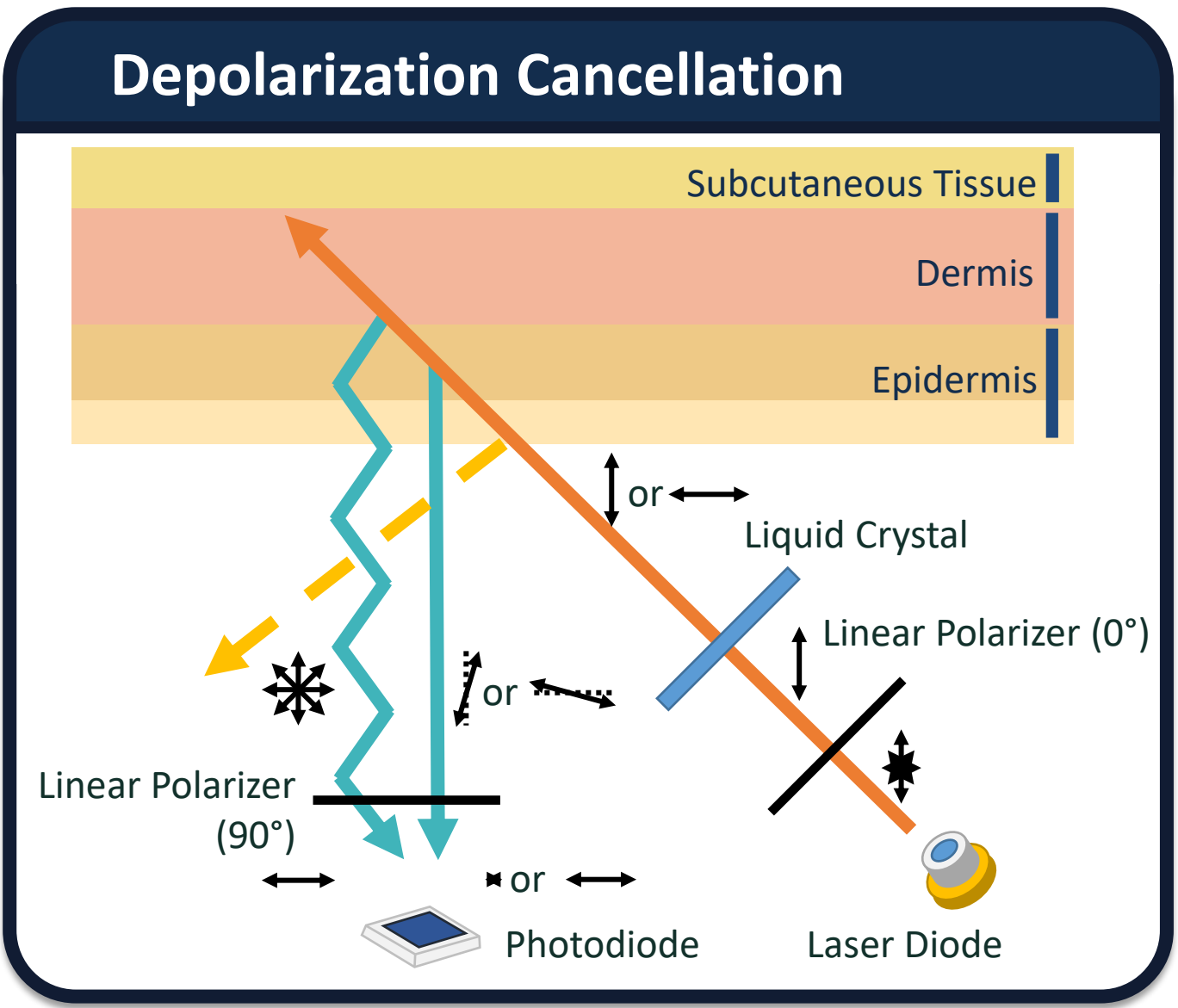$$\alpha = R(\lambda, T) \cdot C \cdot L$$

Rotatory power of glucose at wavelength λ and temperature T

4. Challenges

► Human skin is highly absorbing and scattering

► User diversity

► Confounding molecules

► Specular reflection

Optical Properties of Human Skin

53% Absorbed

Subcutaneous Tissue
Dermis
Epidermis

40% Randomly Polarized Light
2% Polarized Light
5% Specular Reflection Light
Polarized Light

5. Earlier Work [1]

► Extracting weak polarized signal through depolarization cancellation

► Probing the skin using 3 wavelengths and 50 intensities
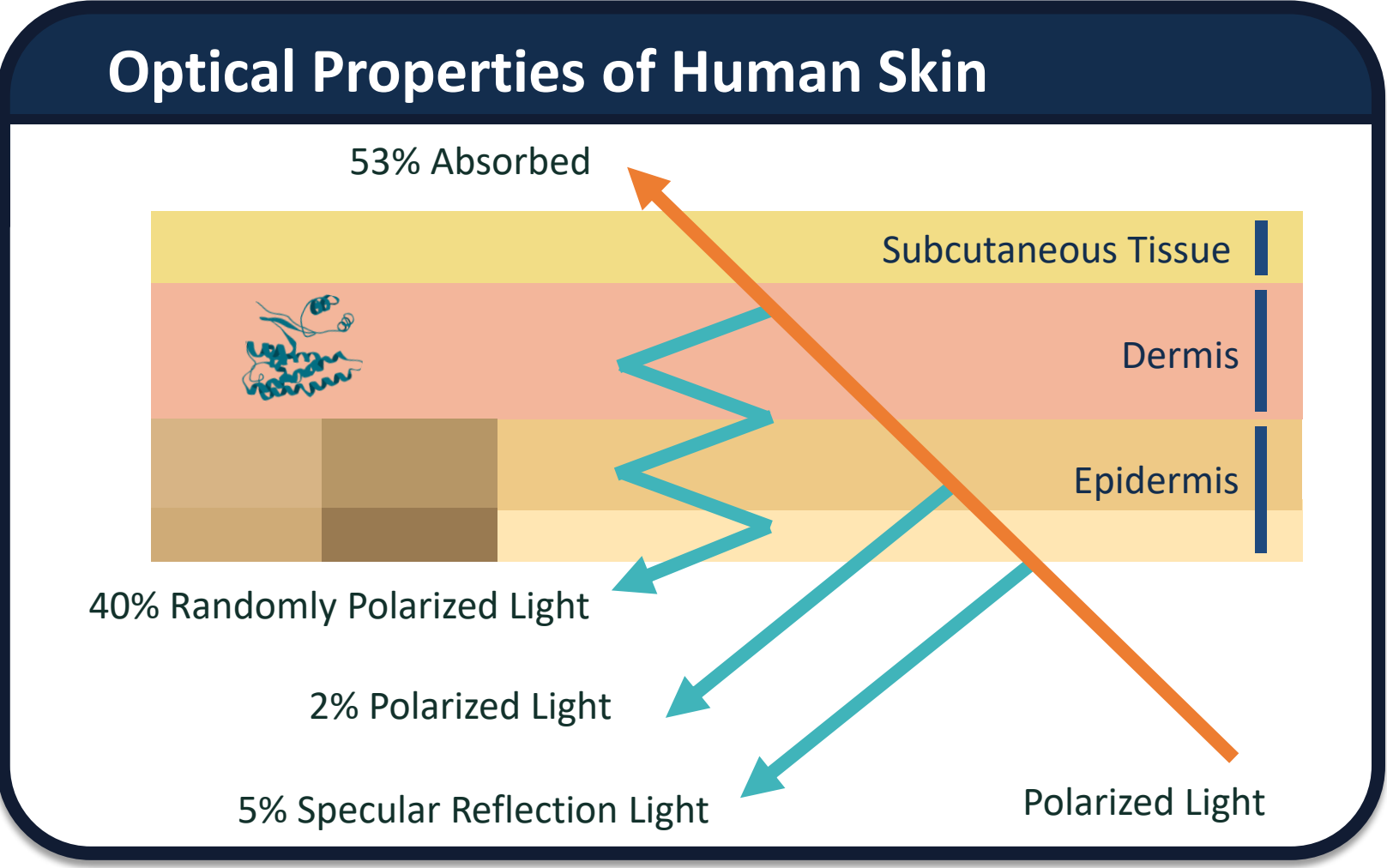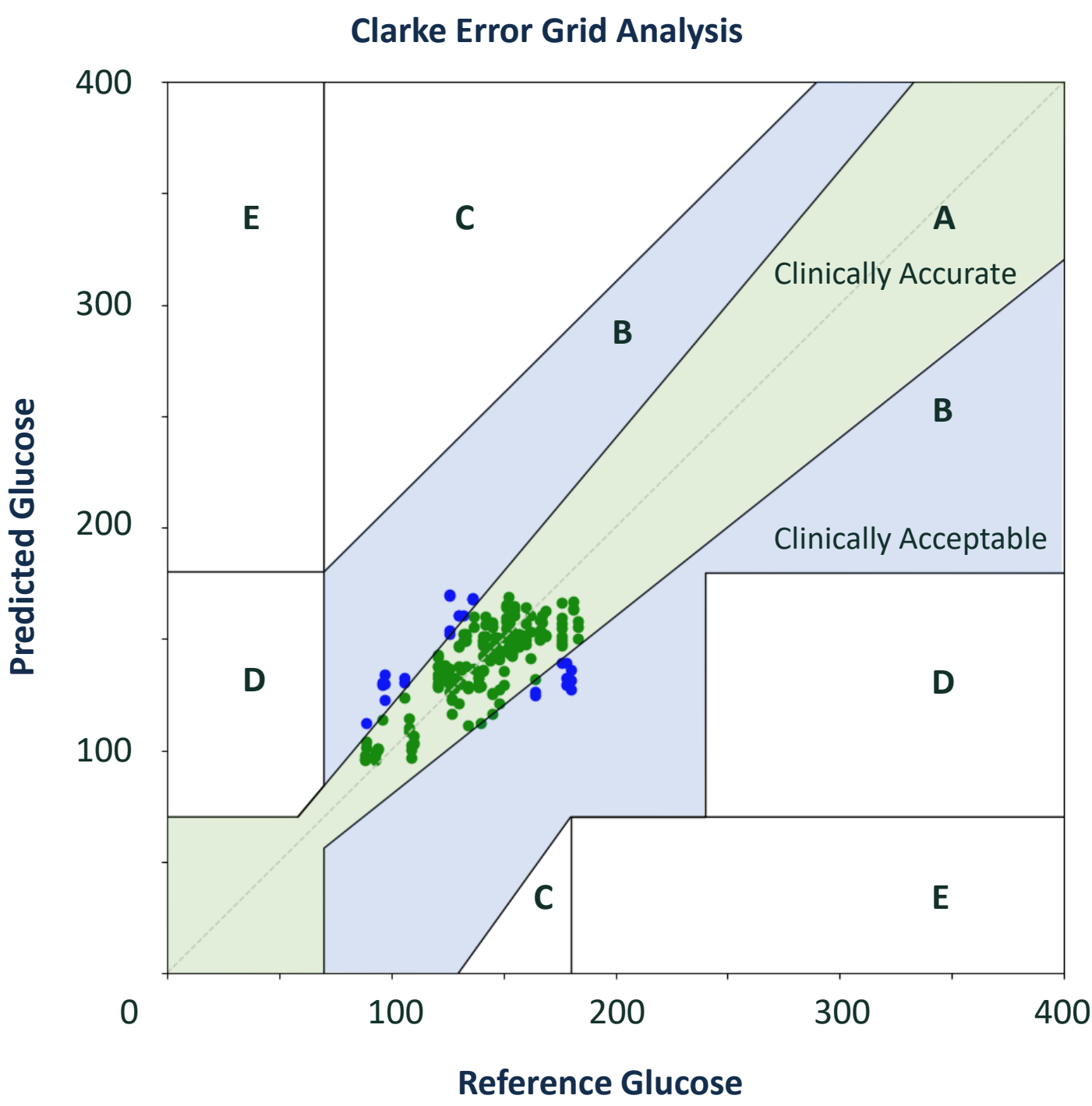
► Predicting BGL using a machine learning model

17 cm
5 cm
10 cm
Previous Prototype
Current Prototype   3.5 cm   7.5 cm   8 cm

Depolarization Cancellation

Subcutaneous Tissue
Dermis
Epidermis
or
Liquid Crystal
Linear Polarizer (0°)
Linear Polarizer (90°)
or
Photodiode   Laser Diode

Light Trap Mechanism

Human Skin
Specular Reflection
Absorptive Coating
Laser Diode
Light interacted with the skin
Photodiode

6. Ongoing Work

► Miniaturizing the prototype

► New structural design that traps specular reflected light in a chamber

► Refining feature extraction and machine learning models

## 7. Preliminary Result

► 1 participant, 216 samples

► 9.5% mean absolute relative difference (MARD)

► Our result is comparable with previous result of 10% MARD with 50 participants and 391 samples

Clarke Error Grid Analysis

E   C   A
Clinically Accurate
B
B
Clinically Acceptable
D   D
C   E

Predicted Glucose
Reference Glucose

8. Future Work

► Clinical pilot study with diabetic patients from diverse background

► Implementing the system into a wearable
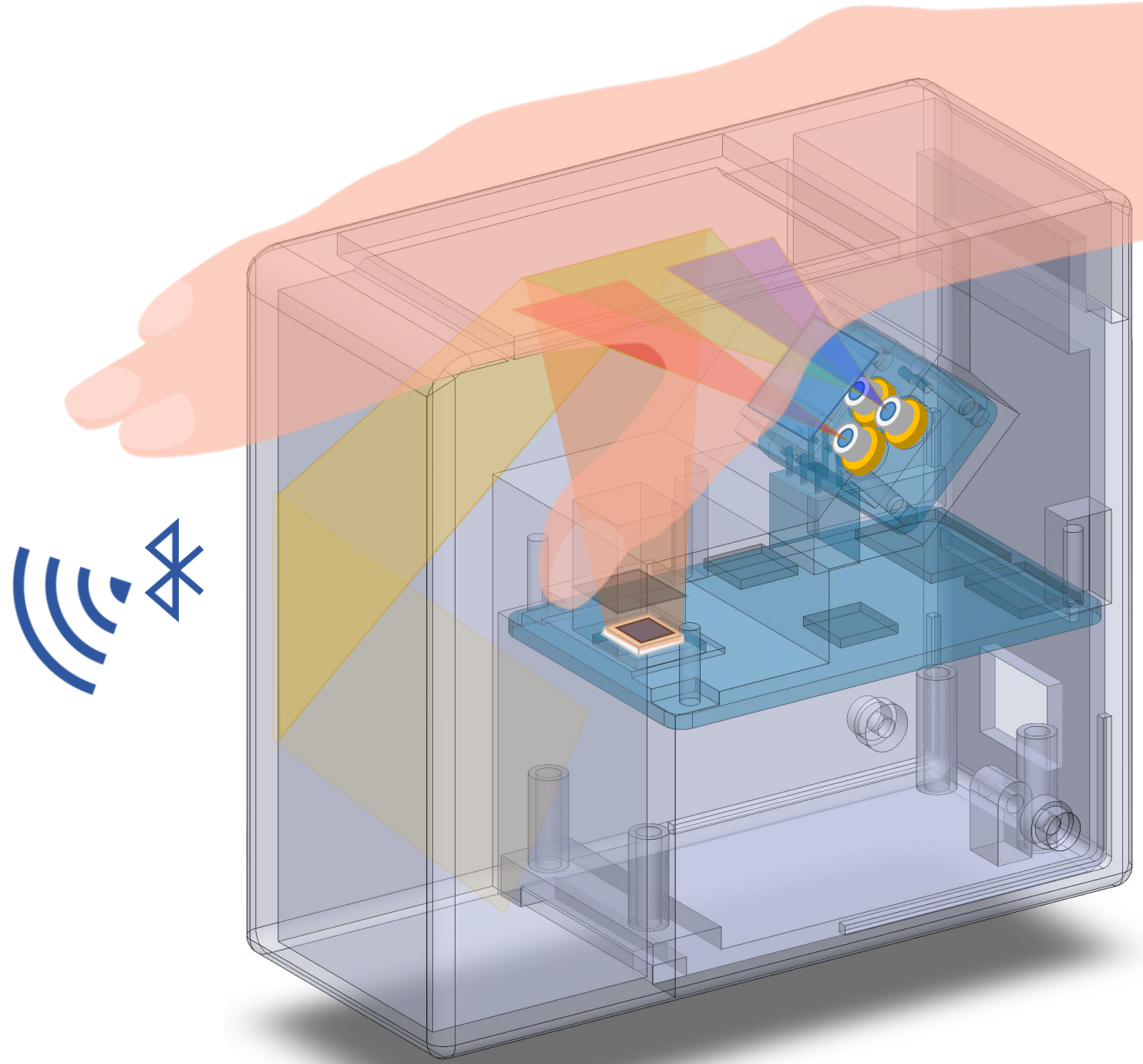
Prediction ◄ Machine Learning ◄

[1] Li, Tianxing, et al. "Noninvasive glucose monitoring using polarized light." *Proceedings of the 18th Conference on Embedded Networked Sensor Systems.* 2020.