TEAM 21

EyeDea Labs

Real-Time and Non-Invasive Monitoring of IOP in Glaucoma Patients

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EYE PHYSICIANS & SURGEONS OF ARIZONA

Clinical Need

Glaucoma

- Affects nearly **3 million people** in the United States
- Leading cause of blindness

Cause: Imbalance of aqueous humor drainage
Result: Elevated intraocular pressure (IOP) damages the optic nerve;

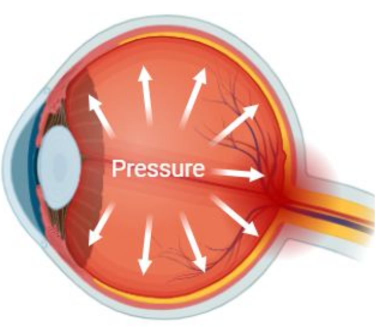


Fig.1. Elevated IOP

Current IOP monitoring devices are invasive and allow only infrequent monitoring.

No Nocturnal Non-Invasive IOP Monitoring Devices.

Mission Statement

EyeD.E.A Labs is dedicated to developing a **less-invasive**, **more frequent, nocturnal IOP monitoring system** for examining glaucoma progression and improving patient outcomes.

User Needs

User	Needs
Physicians	- More frequent IOP readings - Improved Patient Compliance
Patients	Comfortable, non-contact IOP monitoring method
Caregivers	- Reduced financial burden - Flexible care schedule

Target Specifications

Specification	Metrics	Ideal Value
Battery Life	Battery life (hrs)	18 hours
Transducer Frequency	Operational freq	2-20 MHz
Deformation Force	Corneal Deformation	0.06-0.08 N
Gel Impedance	Acoustic impedance	1.0-1.2 MRayl
Data Storage	Storage capacity	5000 readings
Time required	Test interval	5 seconds
Measurement Range	Range of IOP	5-50 mmHg
Corneal Temperature	Damage temperature	<312-332+ K

[3]

Dominant Concept

Wearable Interface

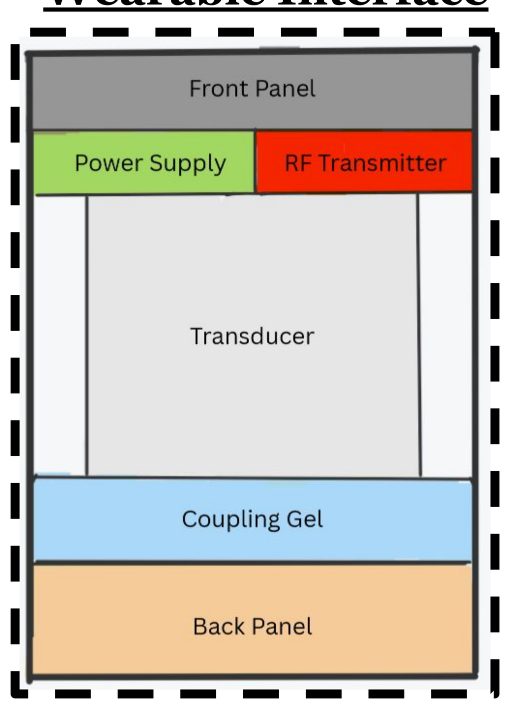
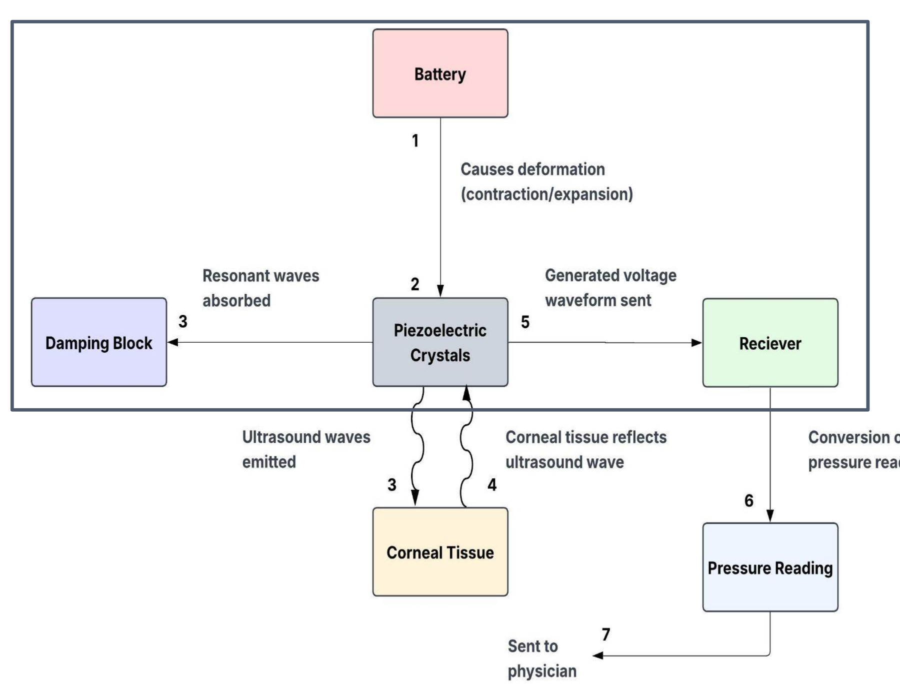


Fig.2. Assembly of transducer array for producing and receiving ultrasound waves

Product Architecture



House Of Quality

Fig.3. Schematic of ultrasound transmission and receiving mechanism by piezoelectric crystals. [2]

Technical Models

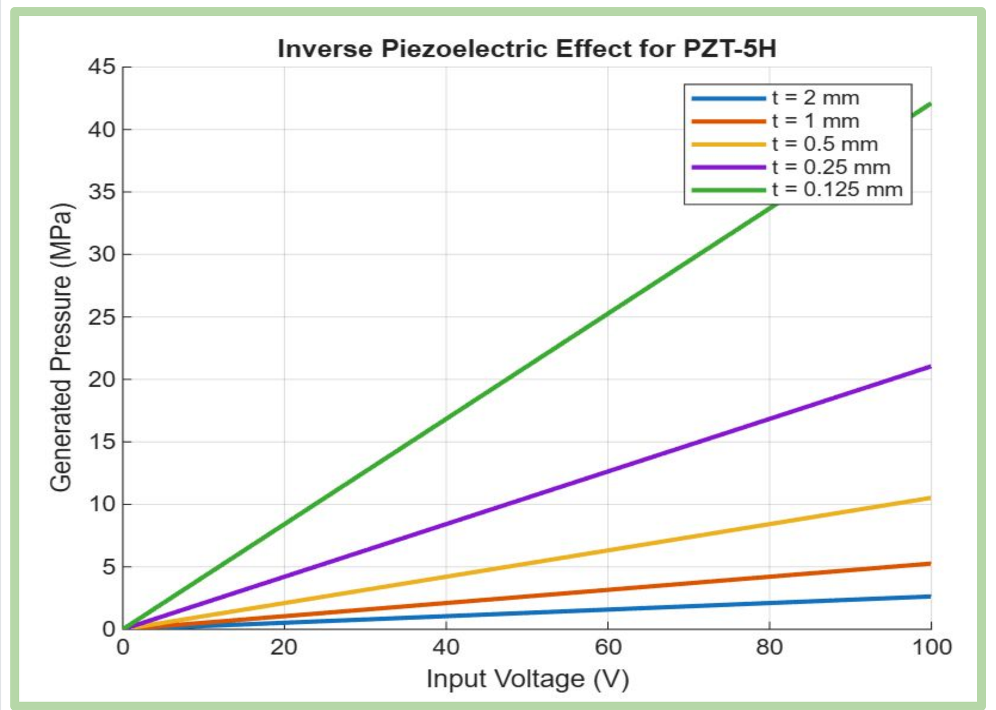


Fig 4. Relationship between input voltage and associated generated pressure.

$$V = P * g * t$$

V = Voltage Applied on PZT (V)
P = Pressure generated on PZT (N/m²)
g = Piezoelectric Constant
t = thickness of PZT crystal (m)

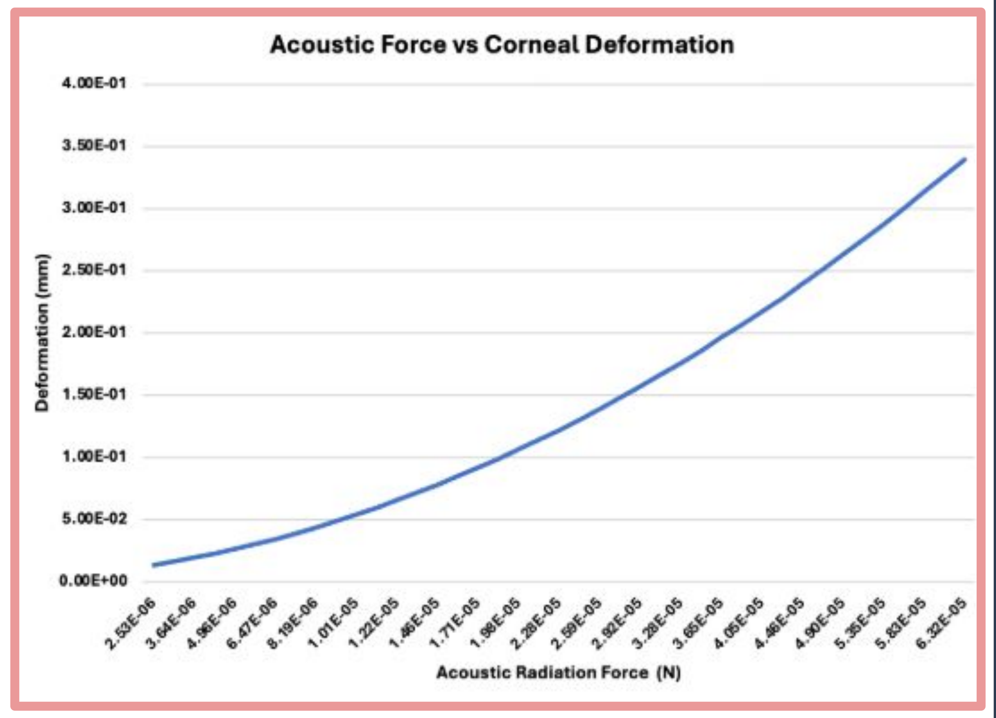


Fig 5. Deformation of the central cornea (mm) in response to an acoustic force wave.

$$F = \frac{2\alpha I}{c}$$

F = Force per unit volume (N)
α = Ultrasound Attenuation (dB/mmHz)
I = Intensity of Ultrasound wave (W/m²)
c_l = Longitudinal wave velocity (m/s)

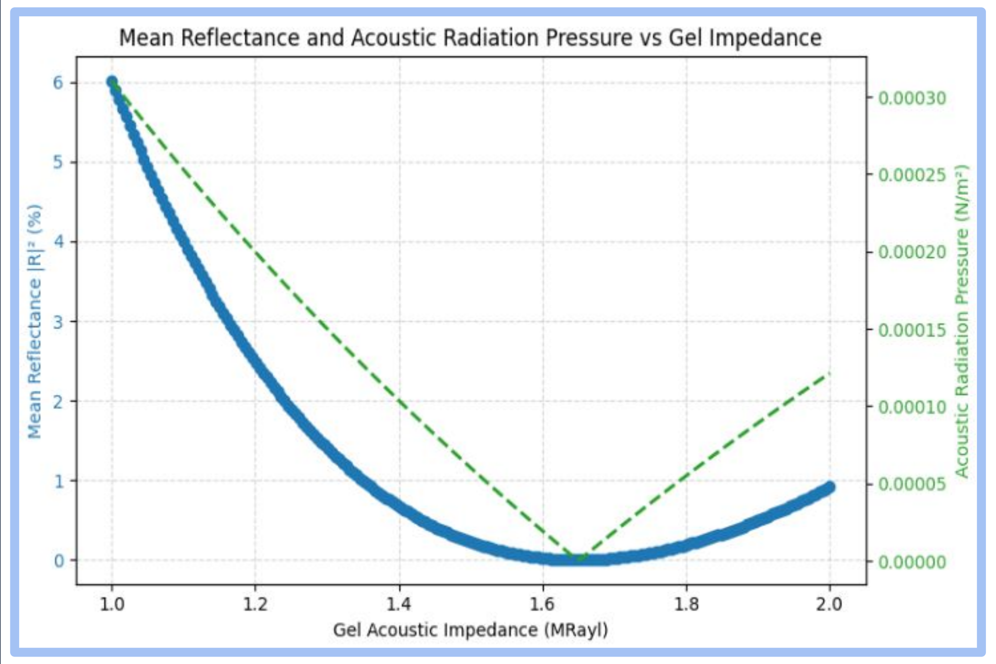


Fig 6. Mean reflectance and acoustic radiation pressure against varying gel impedances.

$$P_{radiation} = \frac{2.I(0)}{c(cornea)} |R_{gel/cornea}(f)|$$

$P_{radiation}$ = Acoustic Radiation Pressure (N/m²)
I(0) = Intensity of Ultrasound Wave (W/m²)
$R_{gel/cornea}$ = Reflectance at the gel/cornea interface (%)
c_{cornea} = Speed of sound in cornea (m/s)

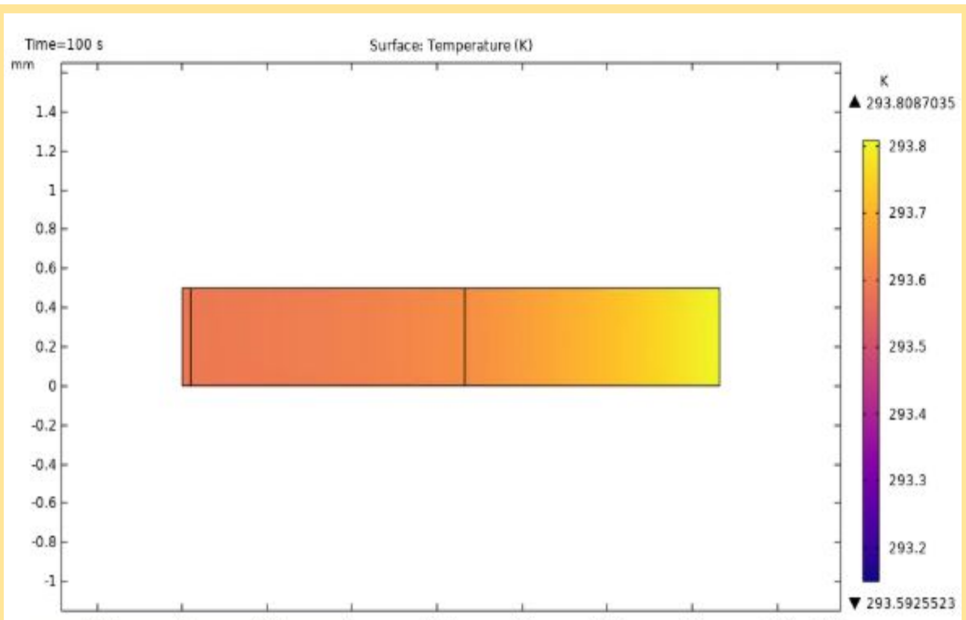


Fig 7. Two dimensional representation of tissue and device layers colored by temperature induced by ultrasound after 100 seconds of delivery.

$$p \cdot c_p \cdot \frac{dT}{dt} = k \cdot \frac{d^2T}{dx^2} \qquad \frac{q}{A} = -k\frac{dT}{dx}$$

p = Density of material (kg/m²)
c_p = Heat capacity (J /kg*K)
T = Temperature (K)
t = Time (seconds)
q = Heat (W/m²)
k = Thermal conductivity (W/m*K)
A = Surface area interface (m²)

Design for Manufacturing

Materials	Cost
Lithium Polymer Rechargeable Battery	$5.95 (per unit)
Cotton Fabric (lining)	$2.99 (per yd)
Polyester Elastic	$0.85 (per ft)
Ultrasound Transducer	$5.77 (per unit)
Bluetooth RF Module	$3.51 (per unit)
PDMS Gel	$0.07 (per g)
Total	$19.14
Manufacturing Cost	$57.42
Selling Price	$172.26

Design Status and Future Work

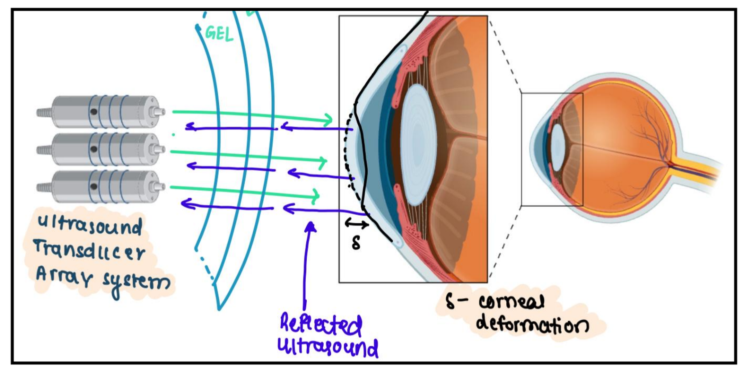


Fig.8. Transducer ultrasound system interacting with the eye to produce IOP measurements

Project Timeline

Current Design Status

1. Designing proof of concept experiments for validating optimal transducer frequency.
2. Correlating acoustic radiation force measurements with intraocular pressure fluctuations.

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