Using Laser for Mid-Air Haptic Rendering

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Mid-air Tactile Display

Ultrasonic waves

Air jets

UltraHaptics (U of Bristol)

AIREAL (Disney Research)

Laser: Very long travel distance
Key Research Problem

How can we induce natural and safe mechanical sensations using laser?
Mechanical Effects of Laser

- Optical breakdown
- Ablation
- Thermoelastic effect – Non-invasive
- A pulsed laser with a short exposure time (ns) for noninvasive mechanical effects

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Irradiance [W/cm²]

- plasma induced ablation
- photoablation
- photomechanical interactions
- photothermal interactions
- photochemical and photobiostimulative interactions

Exposure time [sec]

- 10⁻¹⁵
- 10⁻¹²
- 10⁻⁹
- 10⁻⁶
- 10⁻³
- 10⁰
- 10³
Direct Laser Radiation on the Skin

• Measurements of mechanical effects on a cadaver skin sample

• Simulation of laser-induced thermoelastic effects in the human skin

• Perceptual and EEG experiments
Direct Laser Radiation – Perceptual Responses

Significant individual differences
Alternative – Indirect Laser Radiation

Q-Switched Pulse Laser 532 nm

Lens

52 cm

Red-coated Tape
White Tape
Thermoelastic Effect – Concept

- Transient elastic waves
- Quasi-steady state
Indirect Laser Radiation - Video
Thermoelastic Effect – Simulation
Measurement Setup

Pressure sensor

Accelerometer
Stimuli – Force Measurements
Stimuli – Acceleration Measurements
Stimuli – Force vs Acceleration

![Graph showing force and acceleration over time](image)

- Force (N):
  - 0.82 N
  - -10.12 N

- Acceleration (G):
  - 207.02 g
  - -89.96 g

Time (ms)

Force (N)

Acceleration (G)
Perception – Stimuli

**Laser**
- Q-switched laser
- Wavelength 532 nm
- Pulse with 7.76 ns
- Radiation energy 27.3 mJ

**Mechanical**
- 300 Hz
- 0.75 g

**Electrical**
- 300 Hz
- 0.50 mA (male)
- 0.35 mA (female)

- M1: 5 ms
- M2: 25 ms
- E1: 50 ms
- E2: 250 ms

All five stimuli had clear feels and similar perceived strengths.
Perception – Perceptual Space (Female)

Laser ≈ M1 (Short mechanical stimulus)
Perception – Perceptual Space (Male)

Dimenson 1

Dimenson 2

Laser ≈ M1 (Short mechanical stimulus)
Perception – Multiple Choice Selection

Laser ≈ M1 (Short mechanical stimulus)
LaserStroke – System

M-Nano

Front

Side

M-Nano

Laser Head

Counterweight

Gimbal

Yaw

Pitch
LaserStroke – Video
LaserStroke Specification

• Temporal resolution
  • Laser shot frequency limited by 30 Hz
  • Tactile sensation only lasts 1.5 ms

• Spatial resolution
  • Motor control resolution: 0.022° (about 0.4 mm at 1 m distance)
Spatial Acuity

• Point Localization Threshold

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Take Home Messages

• Laser haptics can be an alternative to ultrasonic waves for mid-air haptic stimulation.

• Its progress, however, is relatively immature.
References

• Jae-Hoon Jun et al., Laser-induced thermoelastic effects can evoke tactile sensations, *Scientific Reports*, 2015.


Many Thanks to

• The Laser Touch team

• PIONEER Program, NRF of Korea