Multi-touch Technology

6.S063 Engineering Interaction Technologies

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how does my phone **recognize touch?**
and why the… do I need to press hard on **airplane screens…**

how would you **build** a multi-touch device?

- which hardware do you use?
- how does it work?

draw some **sketches!**

<2 minute brainstorming>

there are lots of different…

types of touch technology::

resistive
capacitive
camera-based
[…]

before we look at all of these,
let’s zoom out a bit…

before touch…

in which year was the **first touch screen** invented?

<30s brainstorming>

1986: Sensor Frame (McAvinney)

Steve Jobs, 2007:
“And we have invented a new technology called multi-touch, which is phenomenal.
[0:33:33]

but there is **tech close to multi-touch**
that actually was invented even earlier…

1963: Ivan Sutherland's Light Pen (as part of SketchPad)

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we have come a long way since then…

30 years later, multi-touch has reached the consumer market…

and then there’s still stuff
that **hasn’t reached the consumer market yet**

1991: Pierre Wellner, Digital Desk

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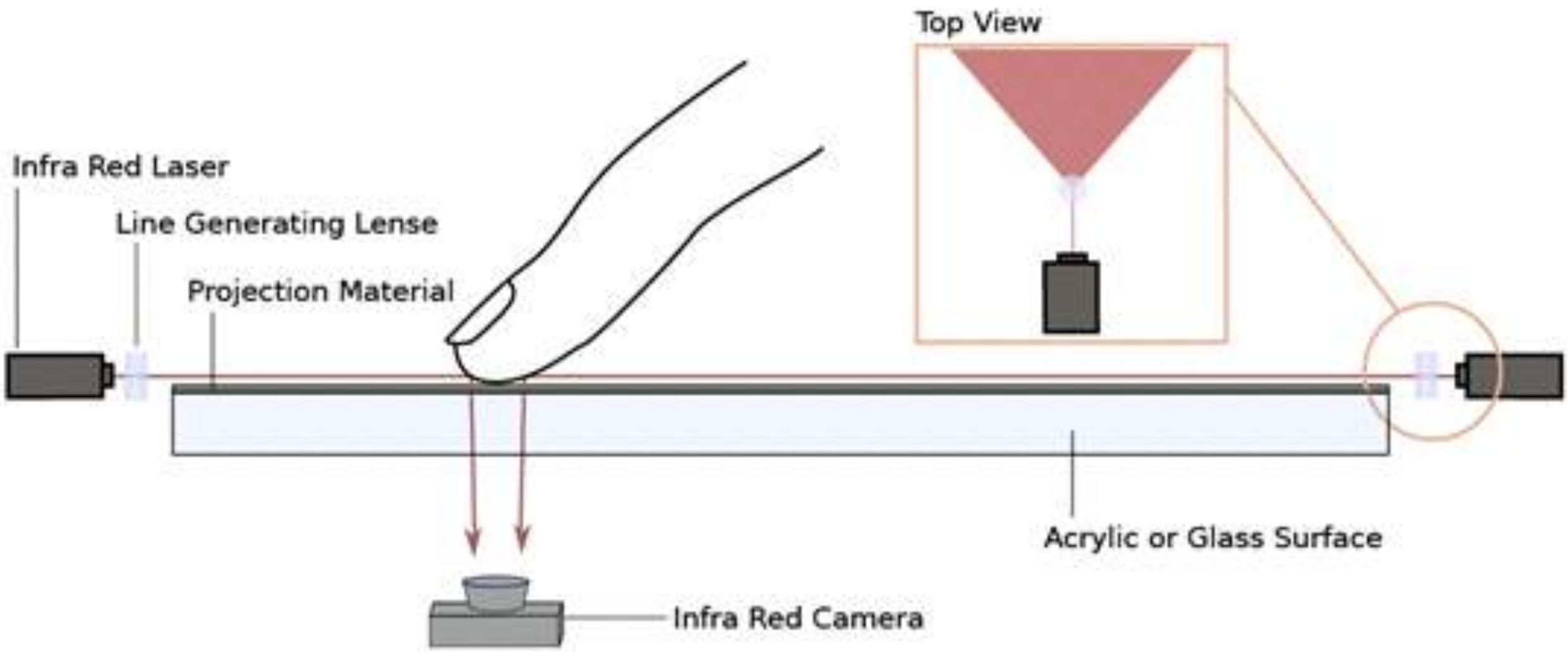
multi-touch:
engineering principles

camera based:

laser light plane (LLP)

LLP - Laser Light Plane

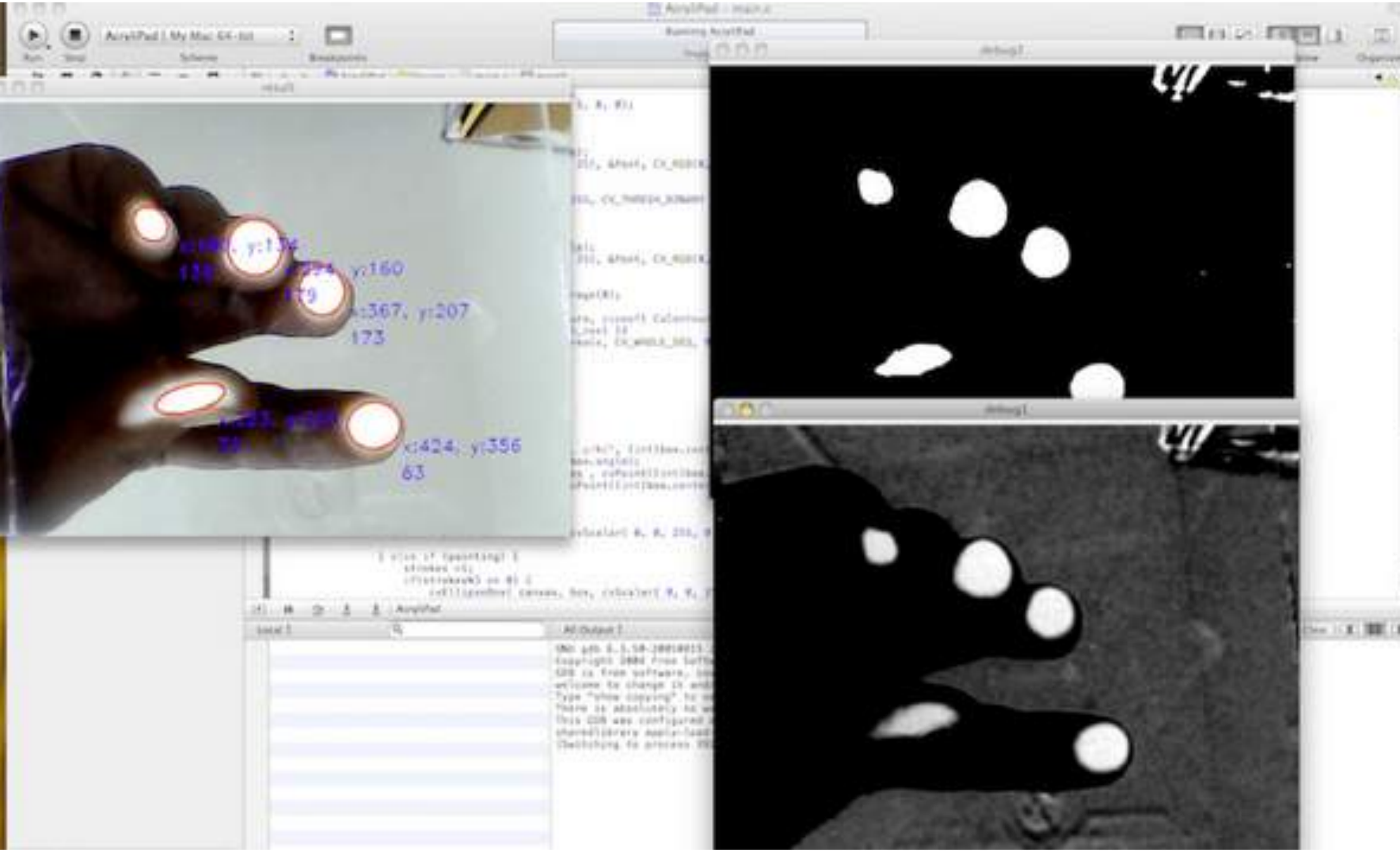


how does this recognize touch?

<30s brainstorming>

laser light plane (LLP)

- **laser light** shines as close as possible above the surface
- when finger hits light plane, **finger lights up**
- you can see this as **bright spots** in the camera image



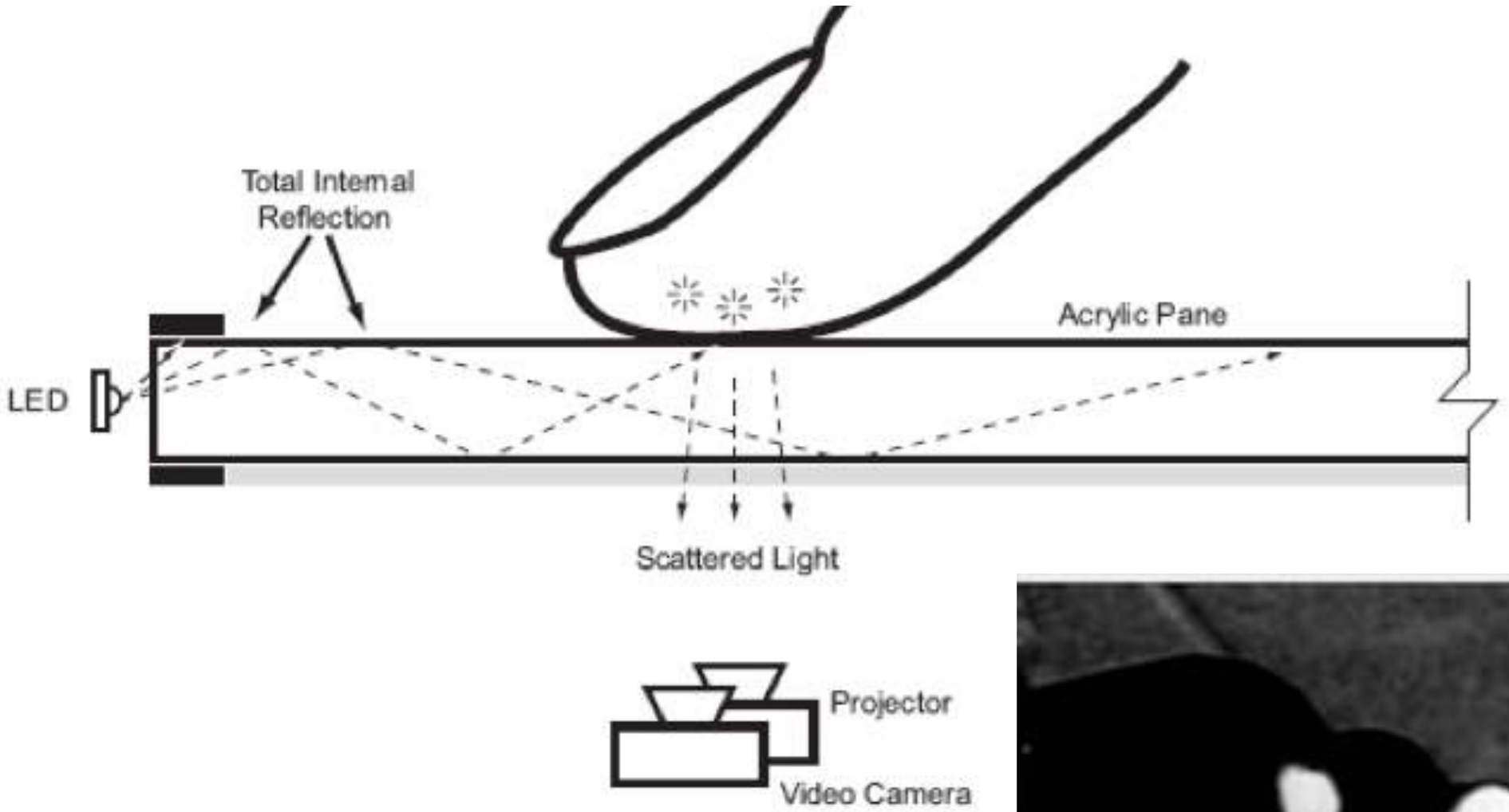
easy to do computer vision **tracking** based on this

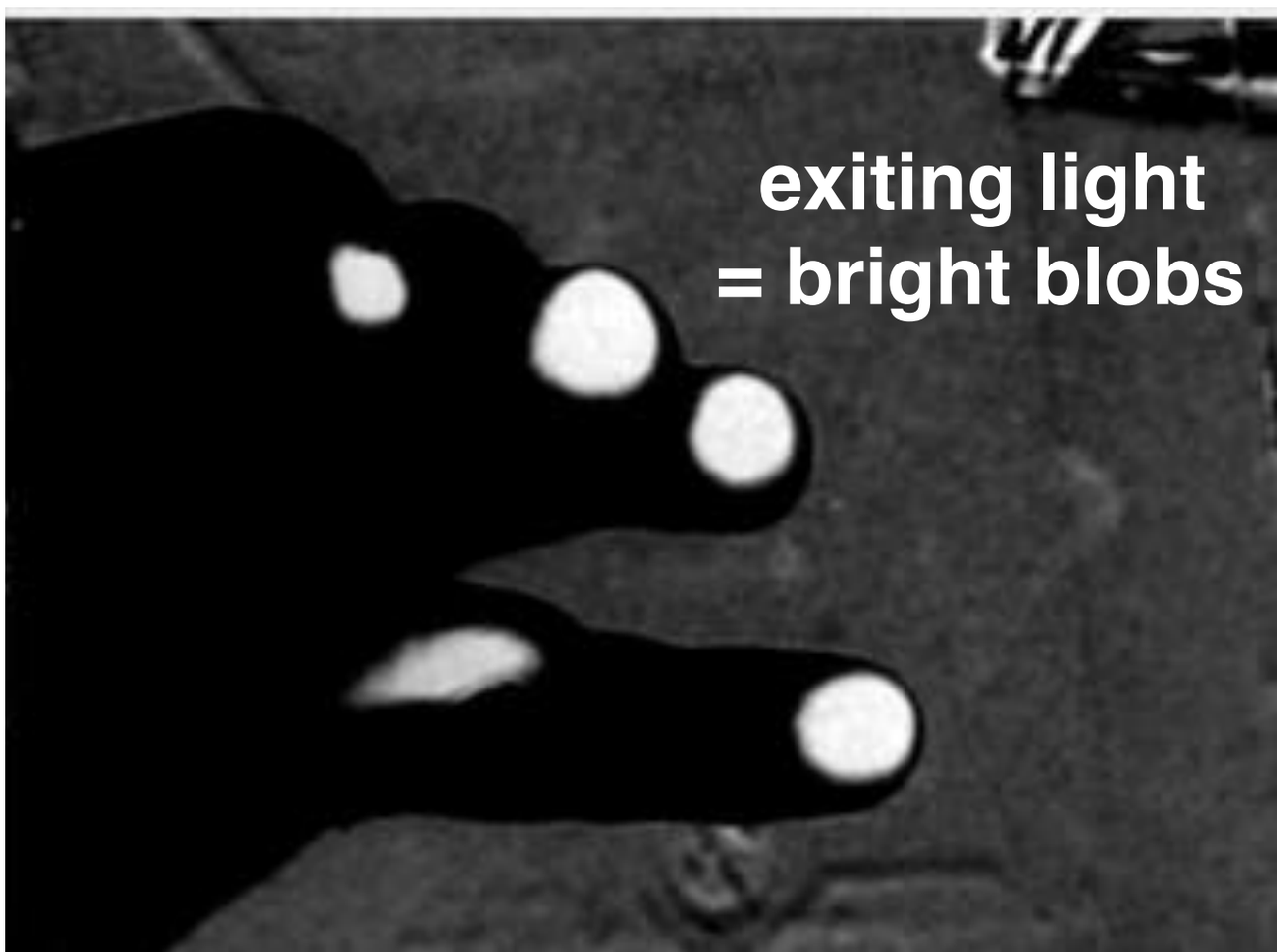
camera based:

frustrated total internal reflection

frustrated total internal reflection (FTIR)

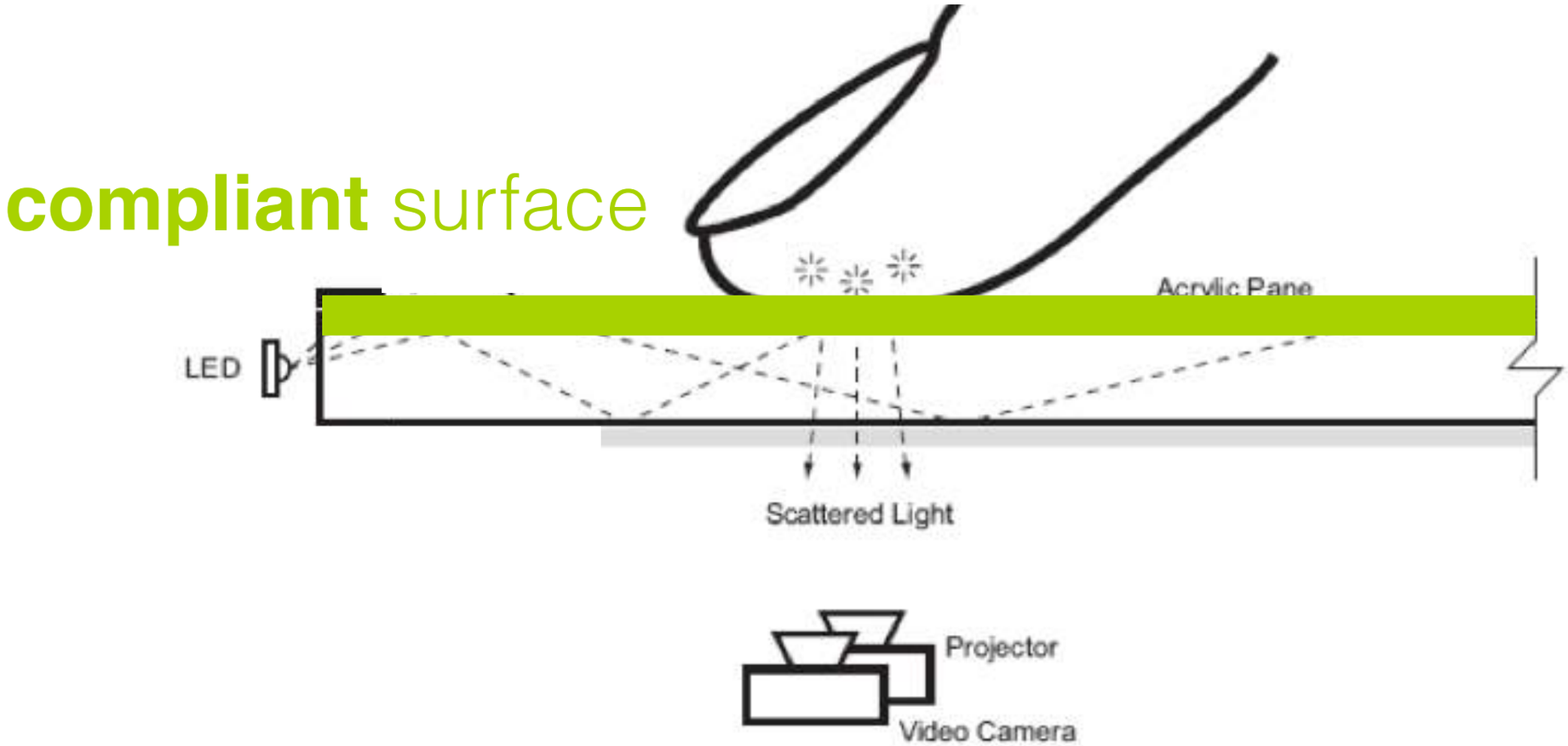
frustrated total internal reflection (FTIR)





frustrated total internal reflection (FTIR)

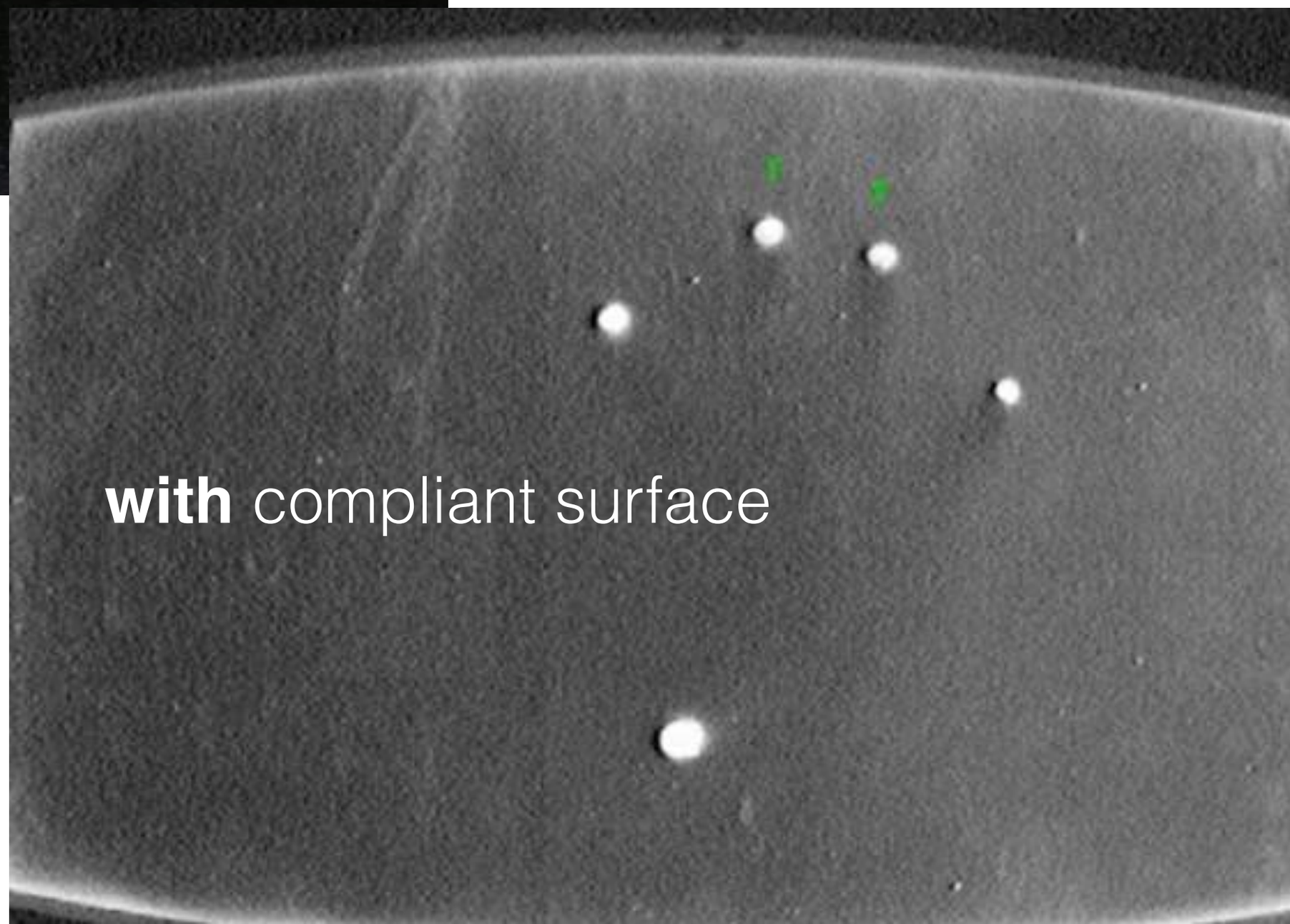
- **light is inserted** into the sides of acrylic panel
- light **internally reflects** because of FTIR phenomena
- when **finger touches** panel, light gets ‘frustrated’
- it escapes internal reflection and **scatters downwards**
- you can see this as **bright spots** in the camera image

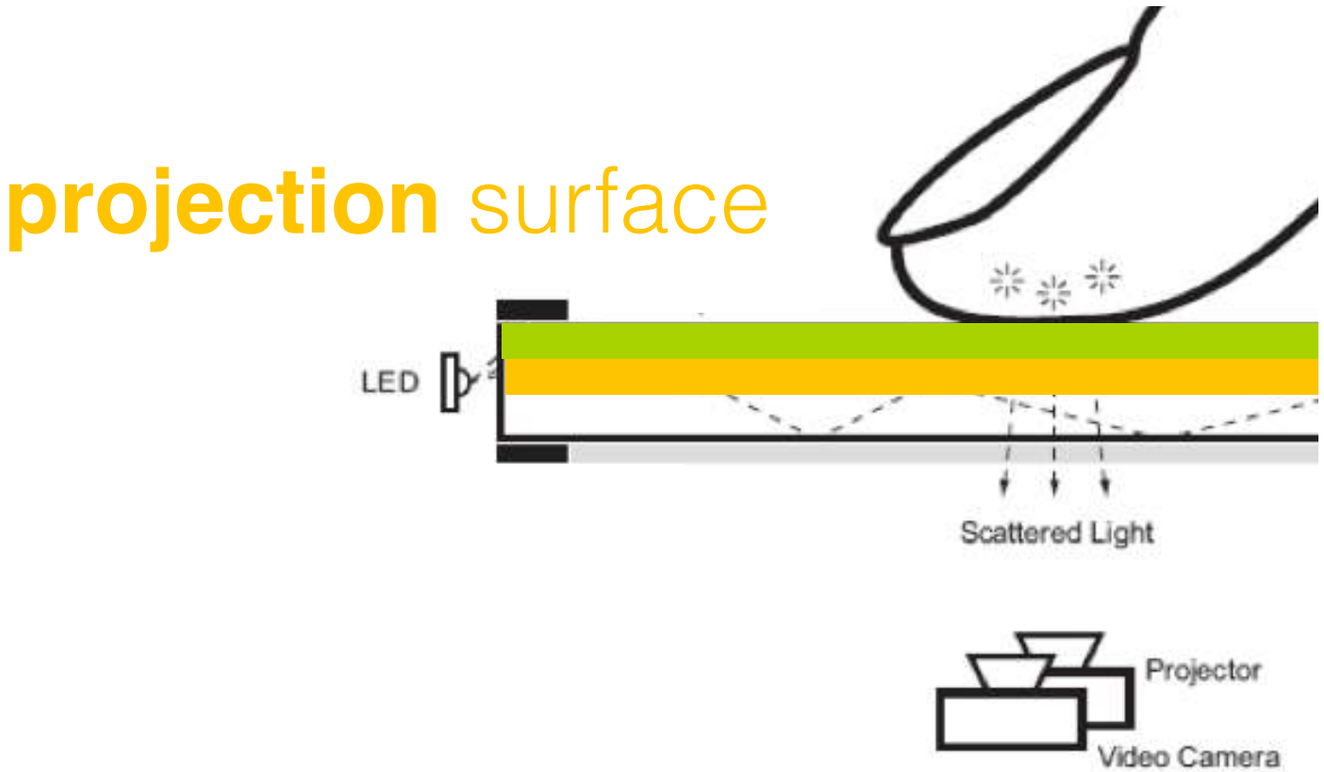


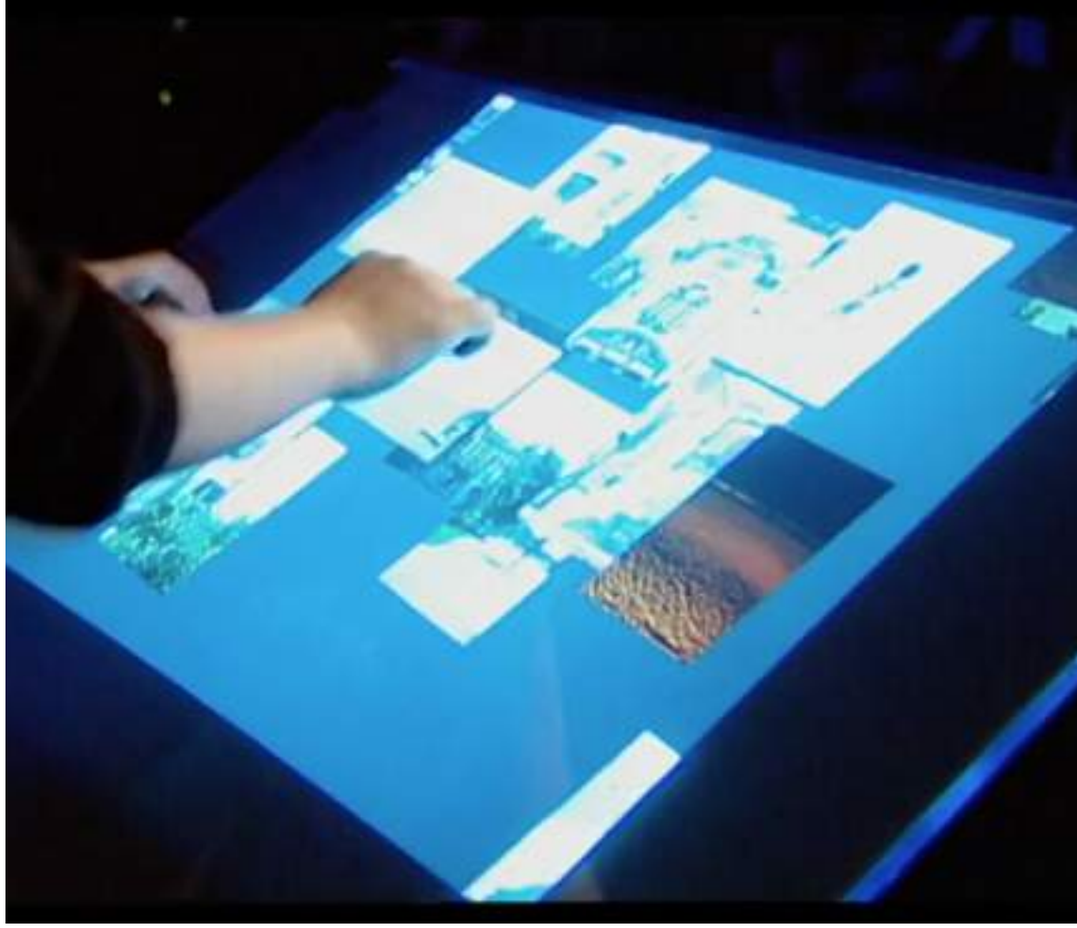
optional: compliant surface

- silicone **rubber layer**
- improves **dragging**
  - acrylic doesn’t allow fingers to slide well, silicone does
- improves sensitivity of the device
  - otherwise you need to press very hard


without
compliant surface

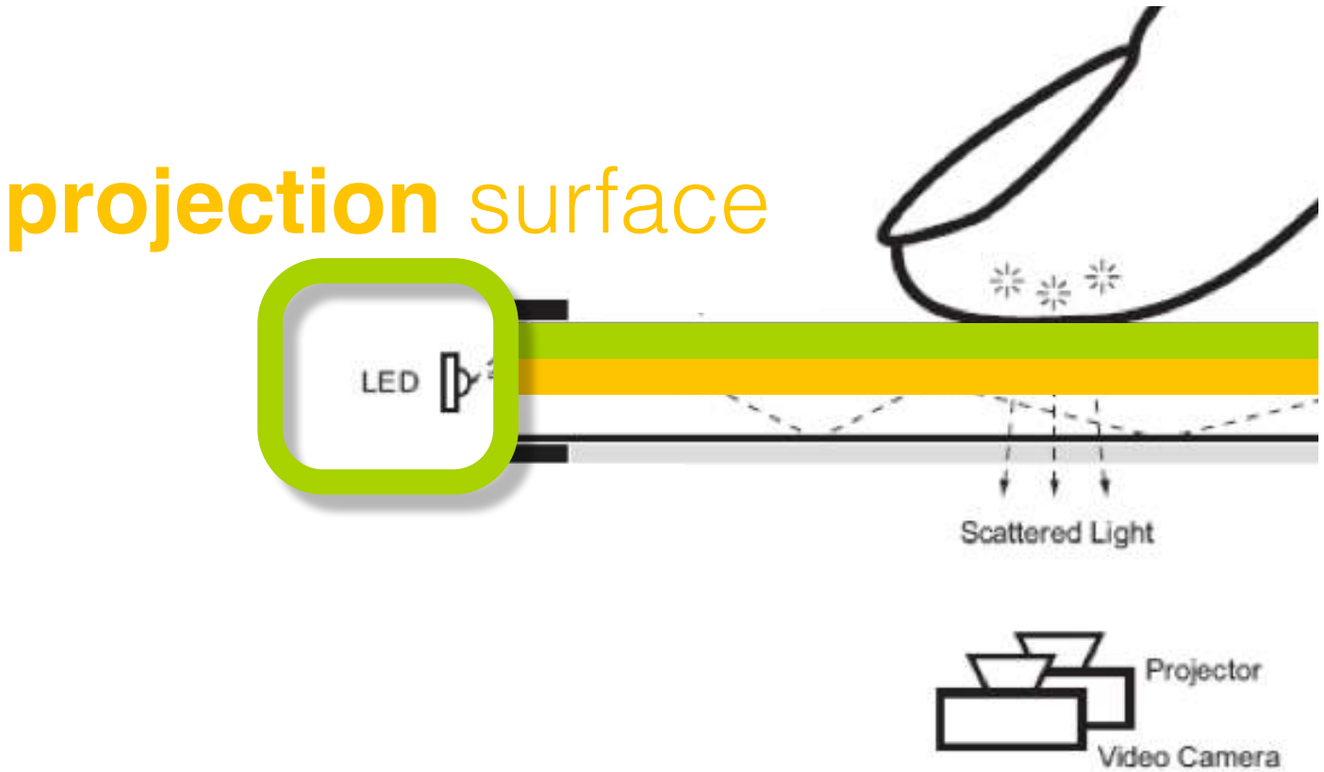

with compliant surface

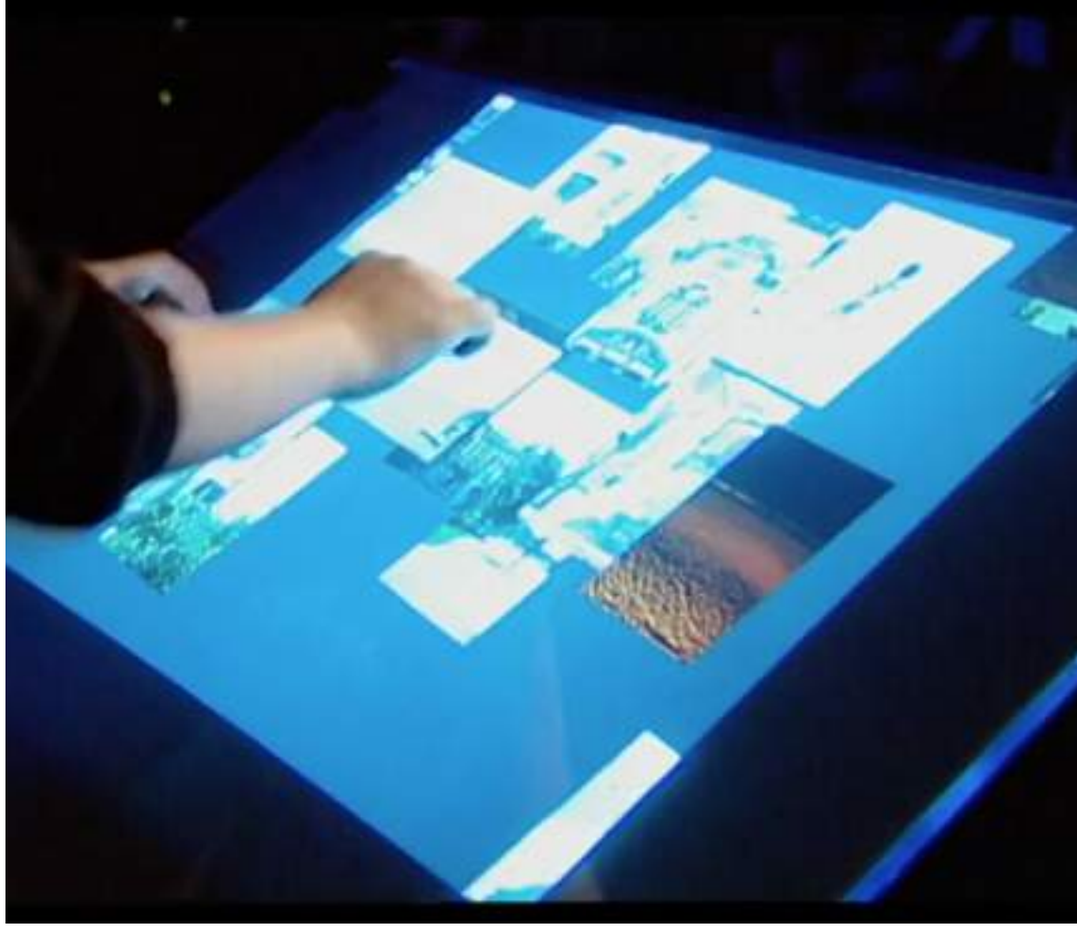




optional: projection surface

- allows to **display an image** on the touch surface
- can be made of e.g.paper, mylar, vellum, rosco grey

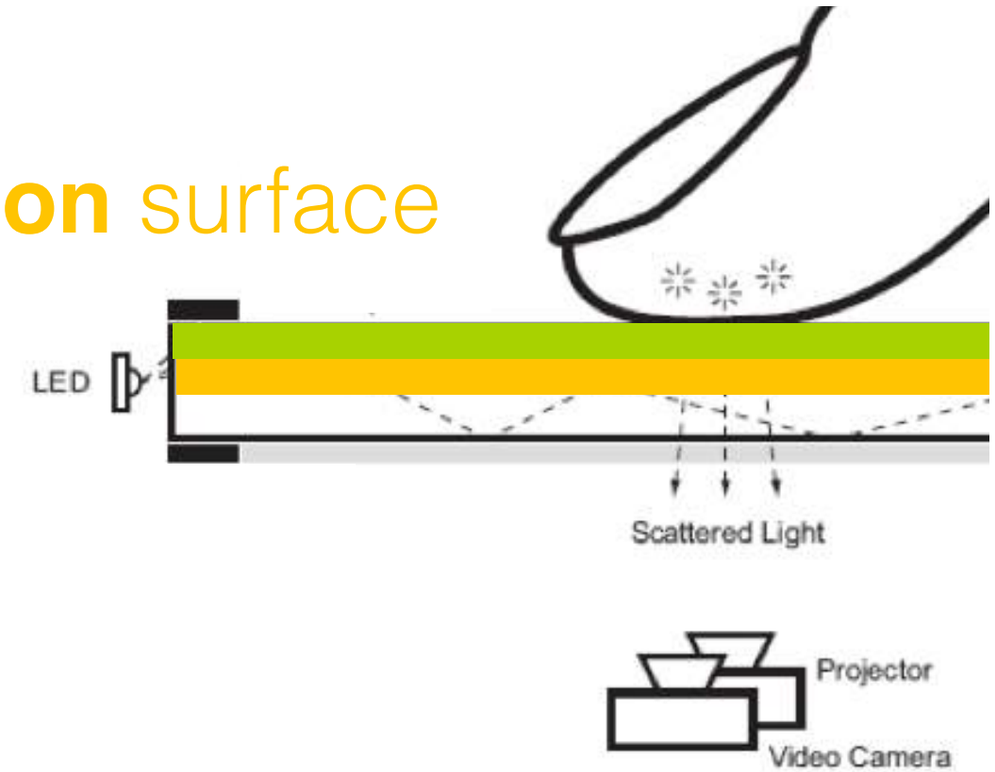


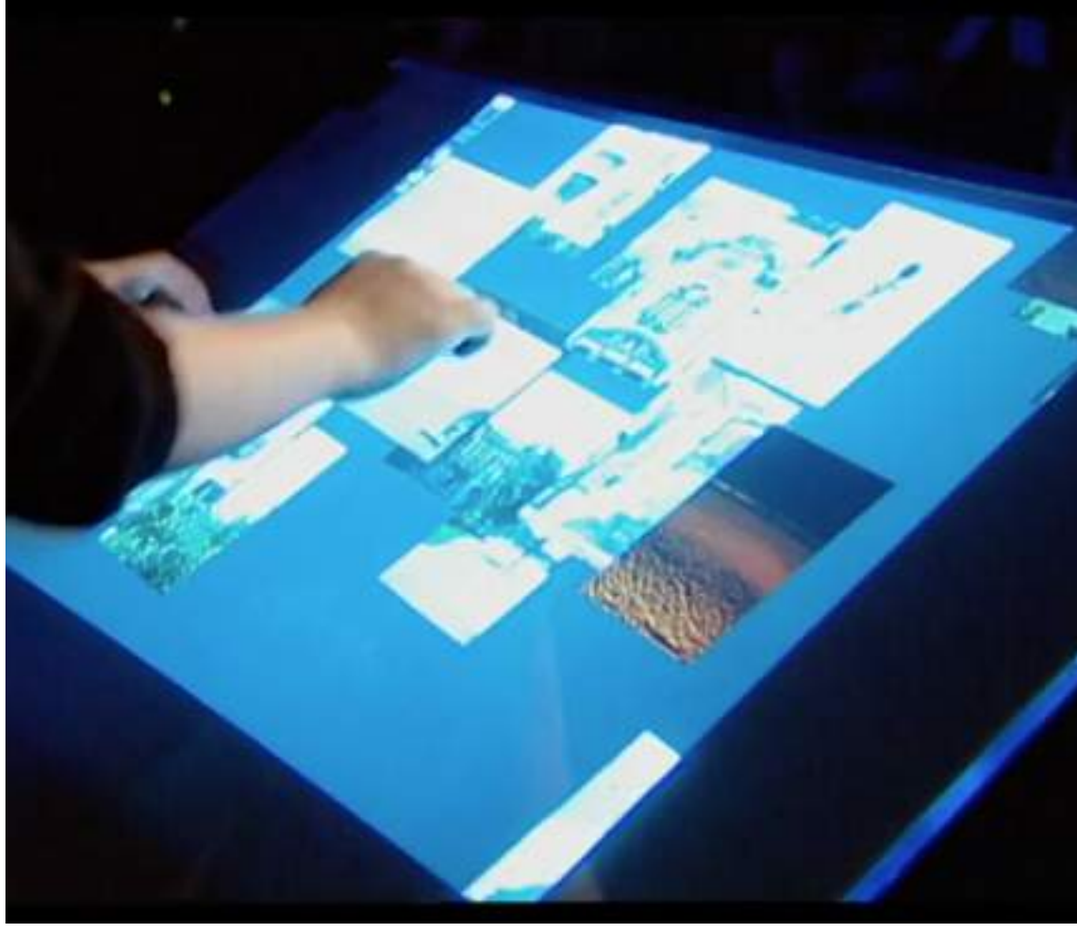


if you want to project images onto your device,
which type of LEDs do you need to use?

<30 second brainstorming>

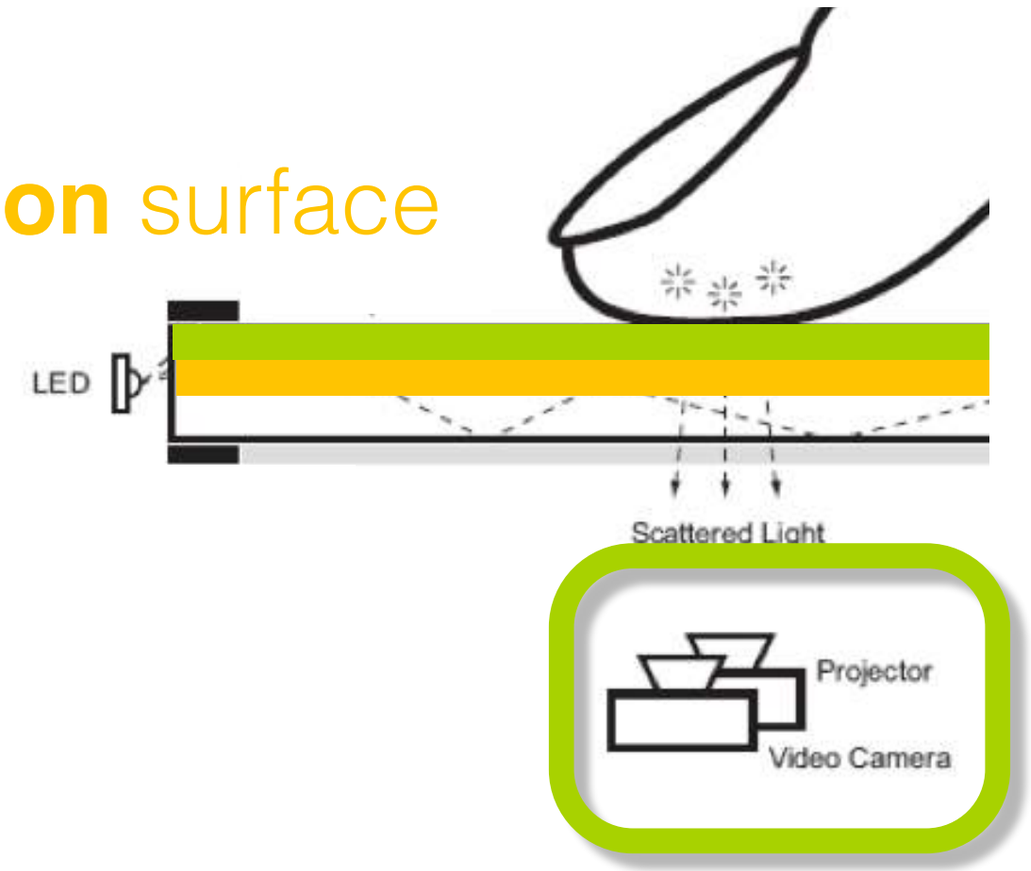
projection surface

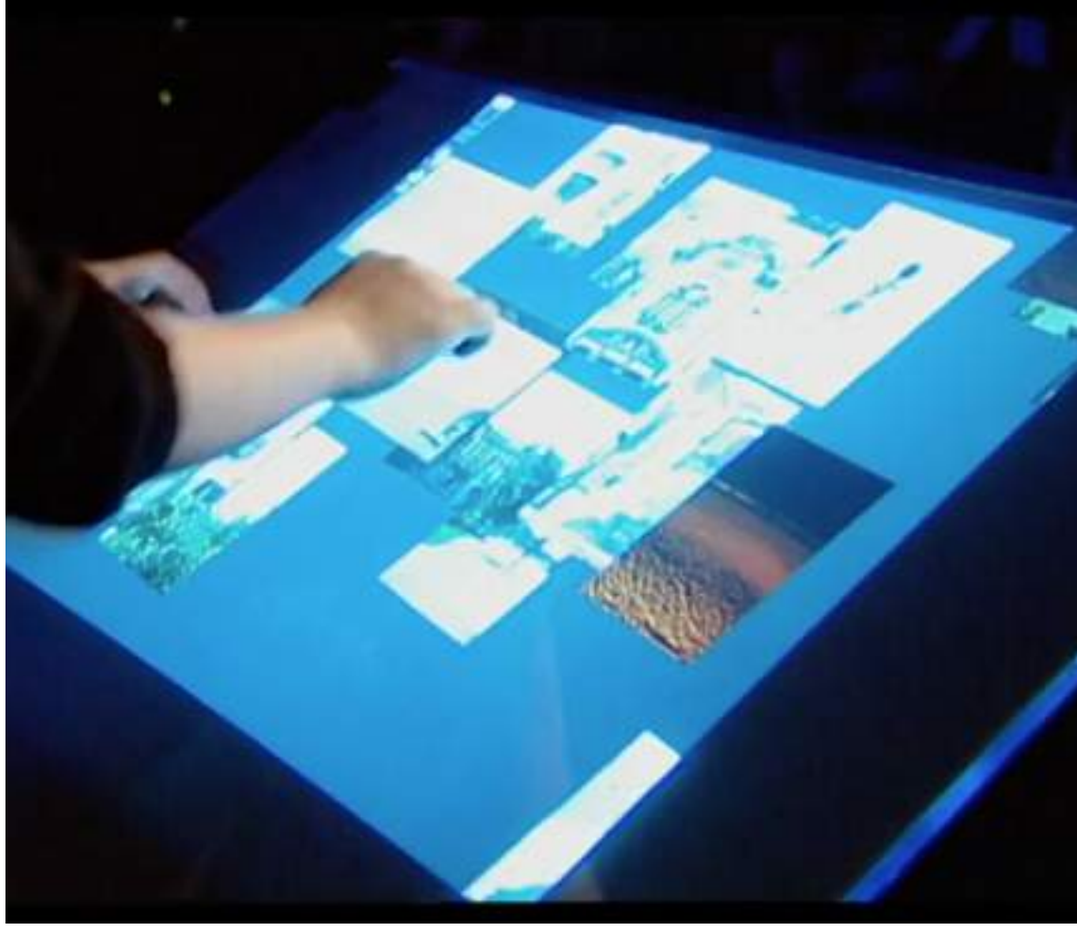




infrared LEDs
because otherwise your injected light for finger tracking overlays with your projected content

projection surface

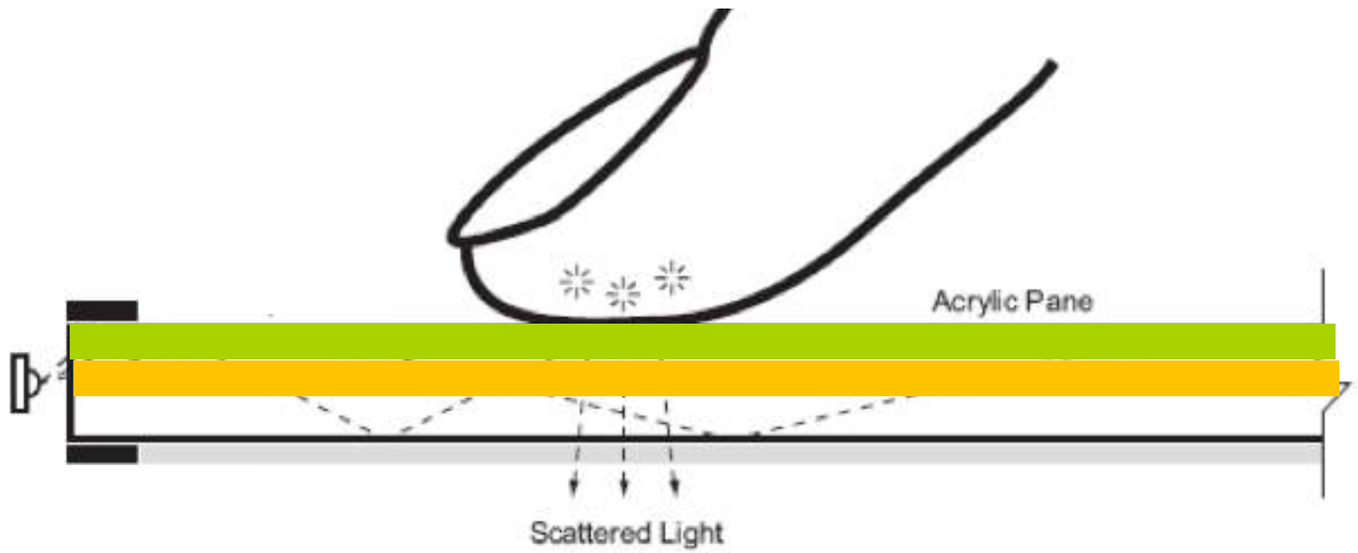




and what does that mean for the **camera?**

<30 second brainstorming>

infrared LEDs



visible light projector

infrared camera

[Jeff Han, 2006]

Low-Cost Multi-Touch Sensing through Frustrated Total Internal Reflection

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Figure 1: Simple examples of multi-touch interaction using our FTIR technique

ABSTRACT
This paper describes a simple, inexpensive, and scalable technique for enabling high-resolution multi-touch sensing on rear-projected interactive surfaces based on *frustrated total internal reflection.* We review previous applications of this phenomenon to sensing, provide implementation details, discuss results from our initial prototype, and outline future directions.

ACM Classification: H.5.2 [**User Interfaces**]: Input Devices and Strategies

General Terms: Human Factors

Keywords: multi-touch, touch, tactile, frustrated total internal reflection

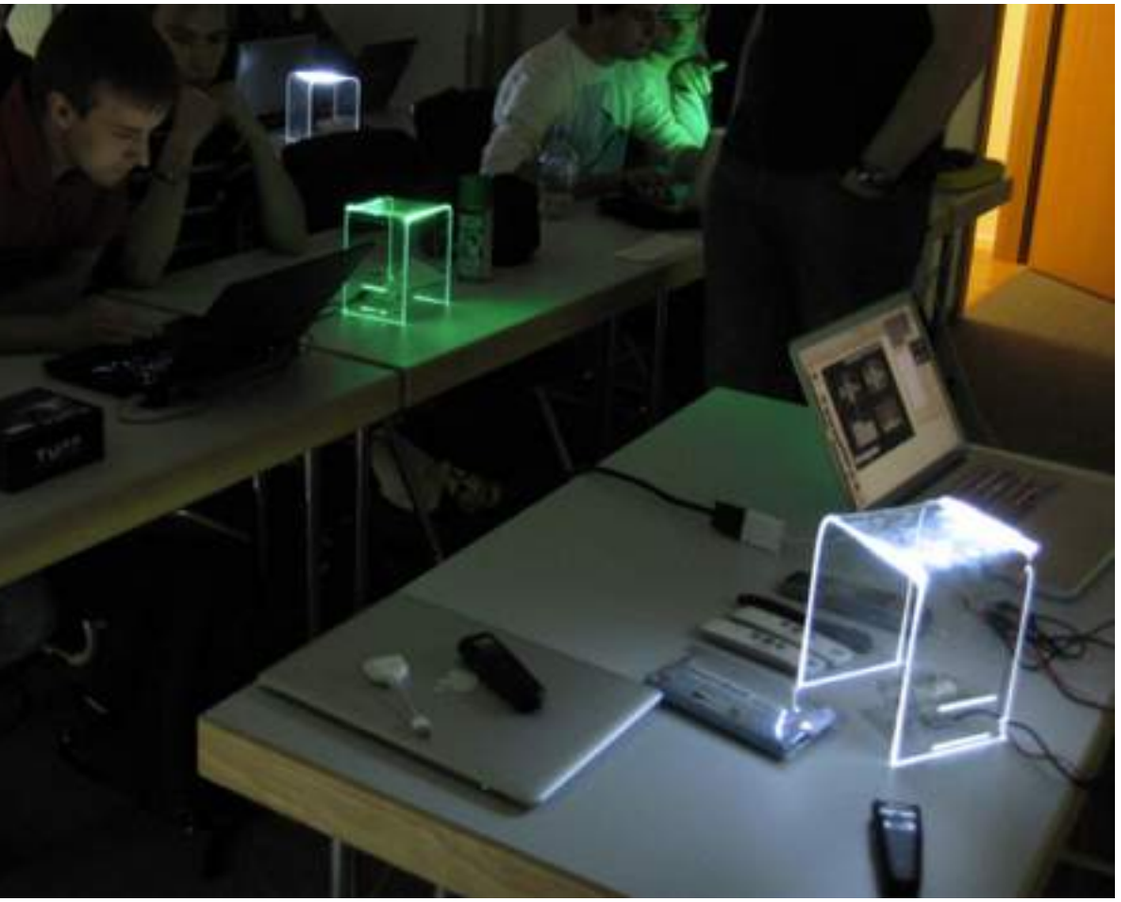
We present a simple technique for robust multi-touch sensing at a minimum of engineering effort and expense. It is based on *frustrated total internal reflection (FTIR)*, a phenomenon familiar to both the biometric and robot sensing communities. It acquires true touch image information at high spatial and temporal resolutions, is scalable to large installations, and is well suited for use with rear-projection. It is not the aim of this paper to explore the multi-touch interaction techniques that this system enables, but rather to make the technology readily available to those who wish to do so.

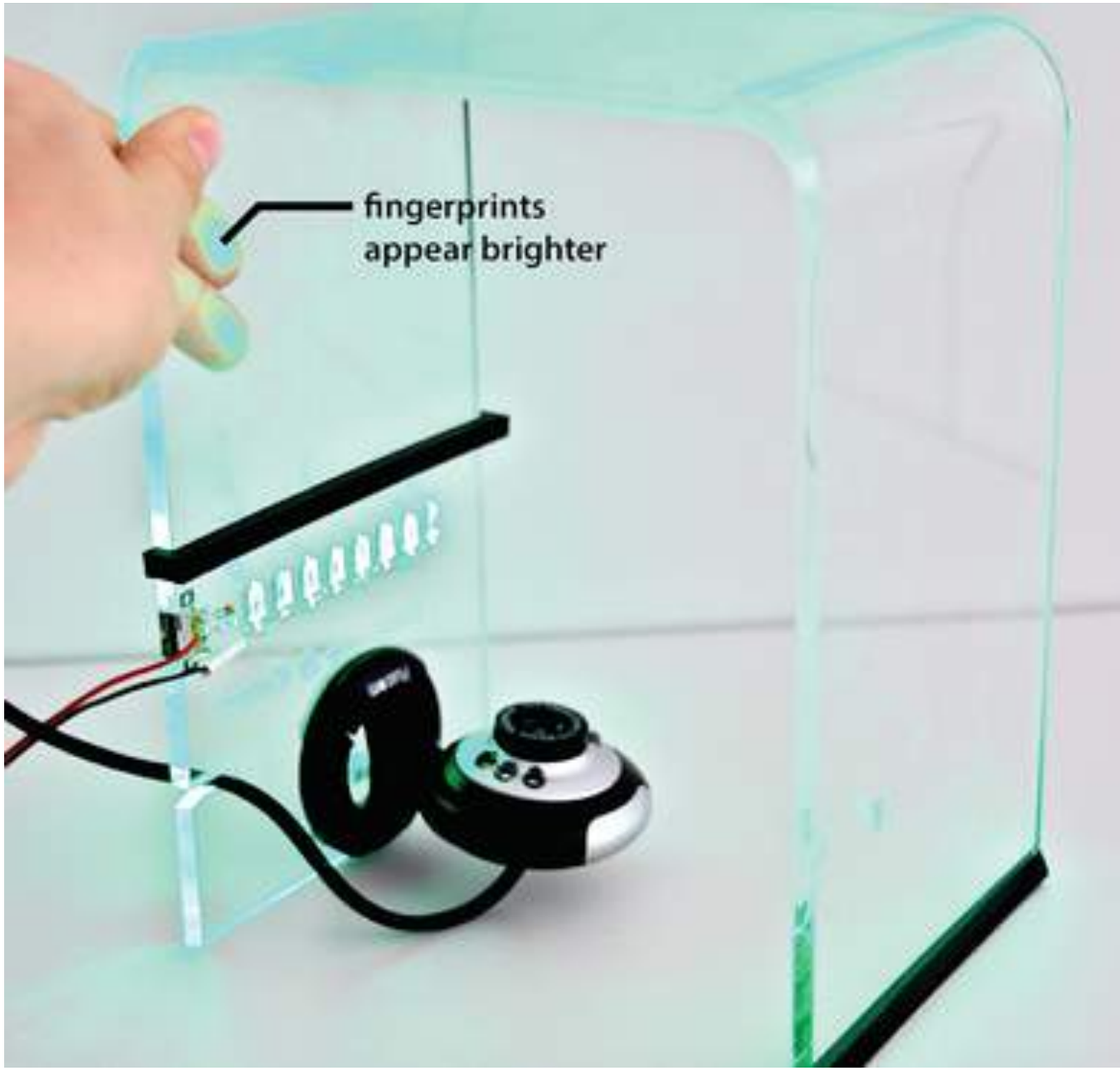
RELATED WORK
A straightforward approach to multi-touch sensing is to simply utilize a plurality of discrete sensors, making an individual connection to each sensor as in the *Tactex MTC Express* [20]. They can also be arranged in a matrix configuration with some active element (e.g. diode, transistor) at each node

UIST 2005 paper (just got lasting impact award)

Steve Jobs, 2007:
“And we have invented a new technology called multi-touch, which is phenomenal.
[0:33:33]

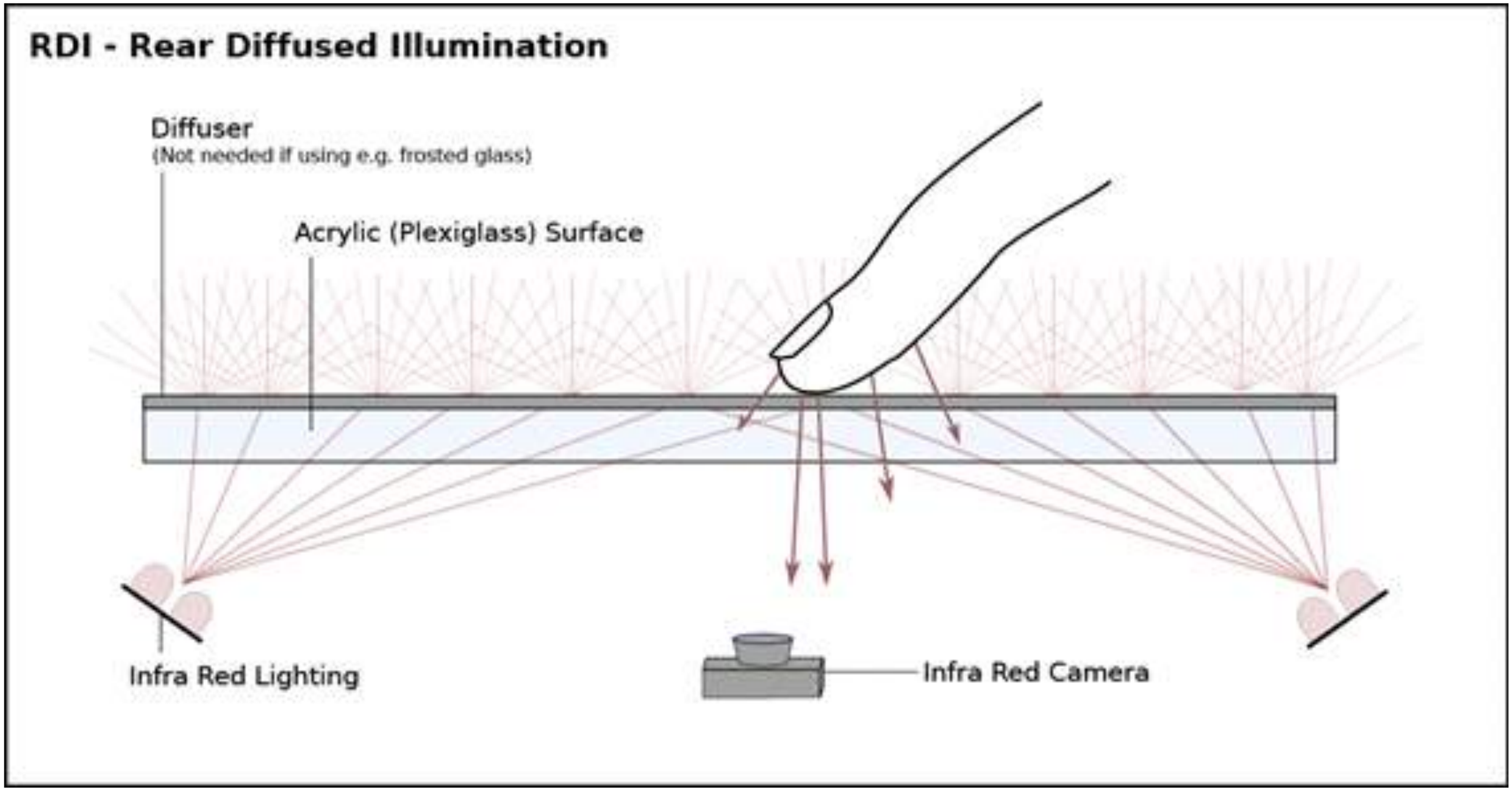
this is pset1!





camera based:

rear diffused illumination (rear DI)



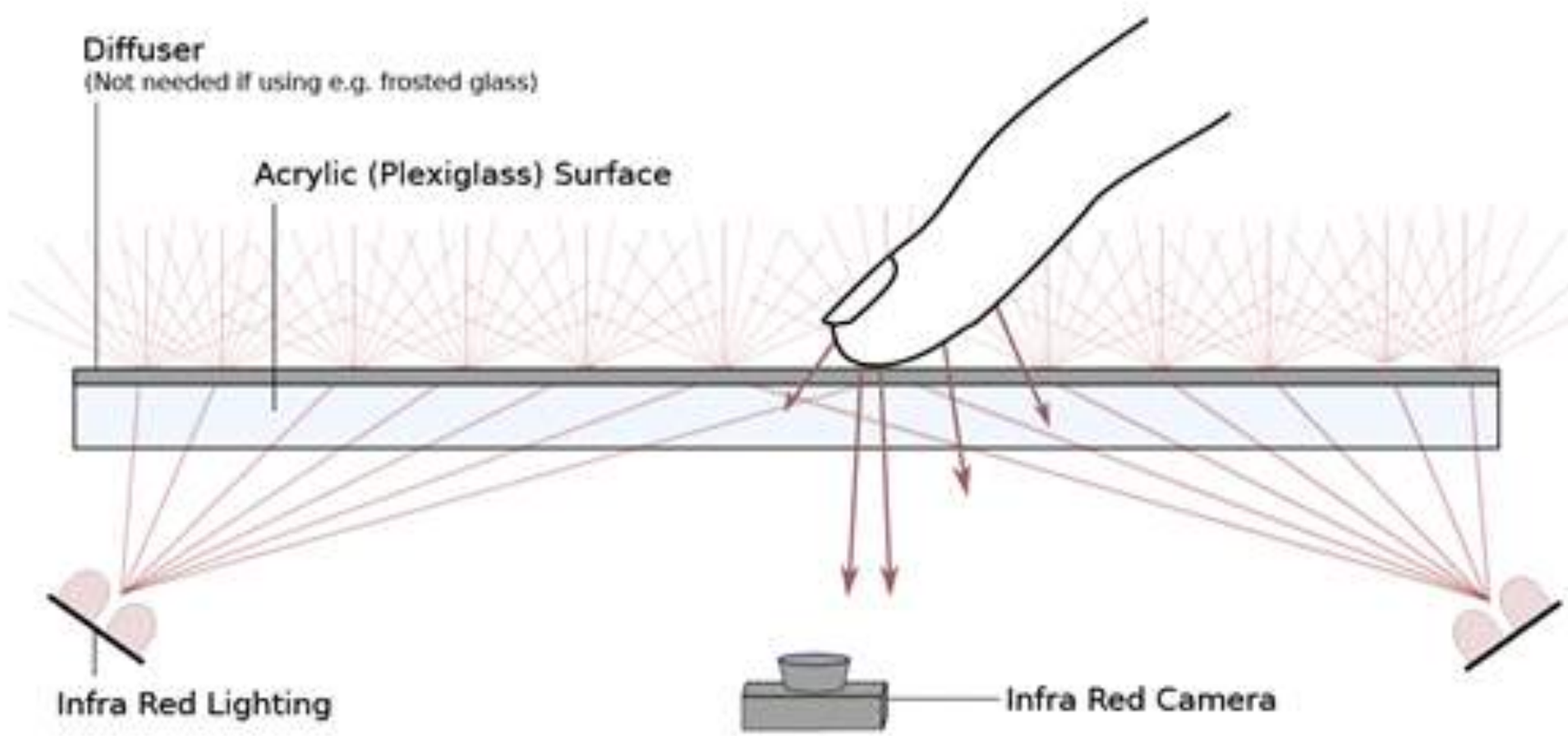
how does it work?
how does the camera image look like? white or black spots?

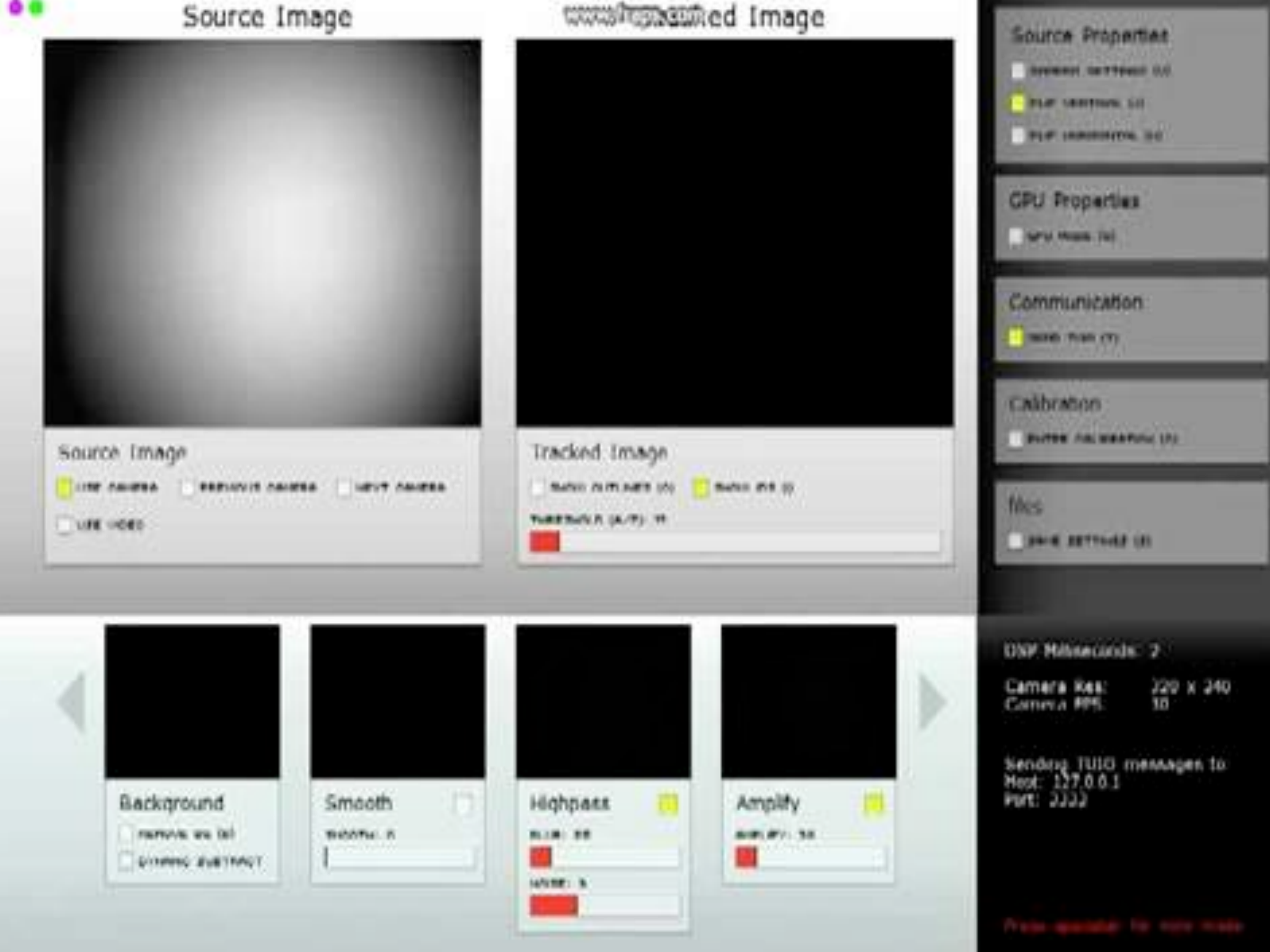
<30 second brainstorming>

rear diffused illumination (rear DI)::

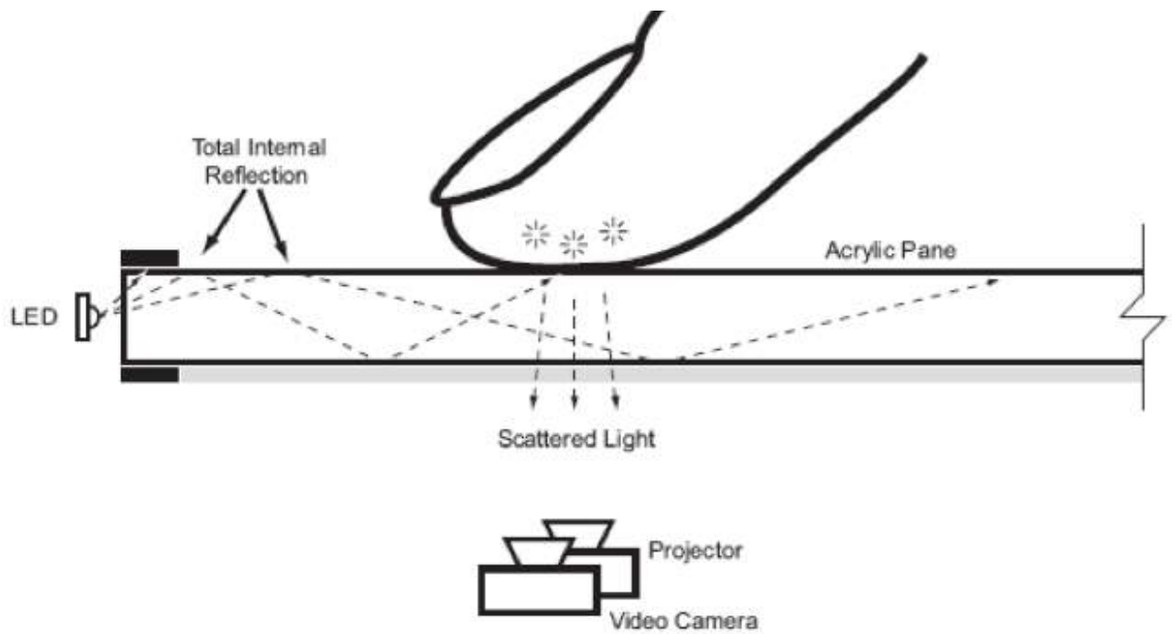
- same as FTIR, just light comes from below

- **light shined from below** the touch surface
- a **diffuser** is placed on top of the touch surface
- when the light hits a finger, light is **reflected downwards**
- appears as **bright blob** in the camera image

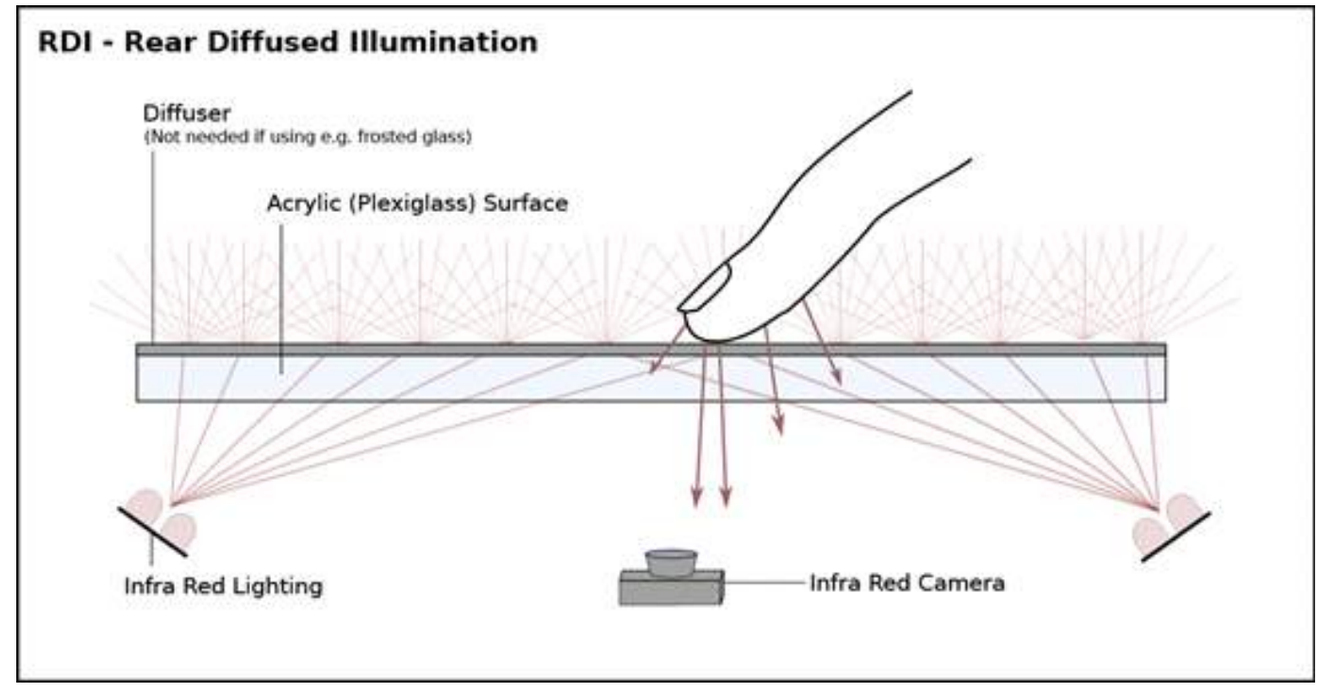



Source Image
Tracked Image
Source Image
Tracked Image
Source Properties
GPU Properties
Communication
Calibration
files
Background
Smooth
Highpass
Amplify
Camera Res: 320 x 240
Camera FPS: 10
Sending TUIO messages to
Host: 127.0.0.1
Port: 3333

FTIR



rear-DI

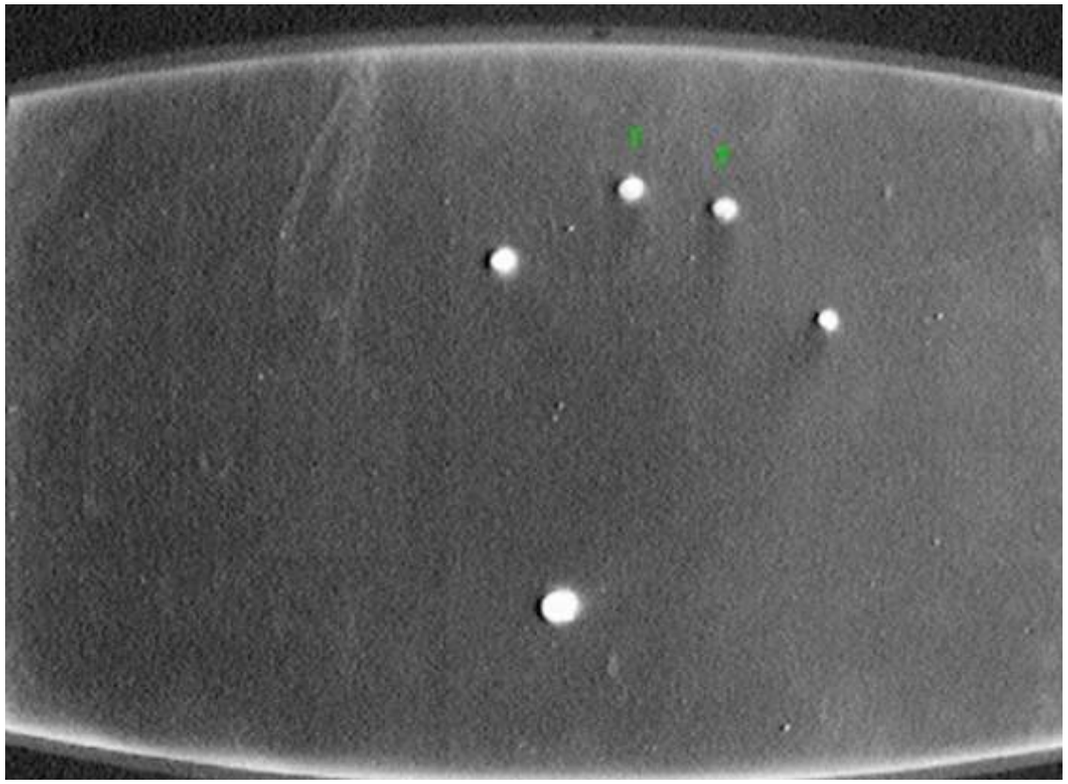


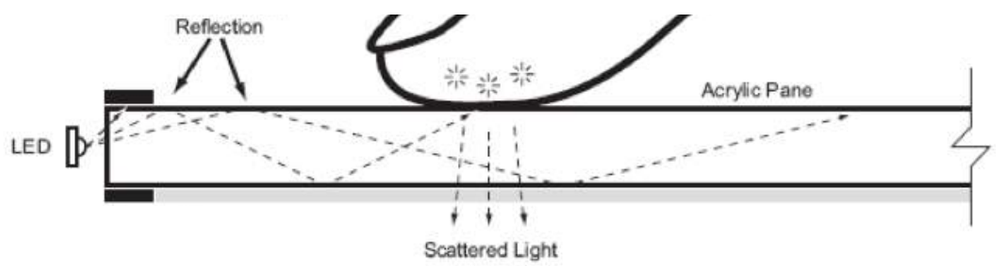
mh, so the result the same then?

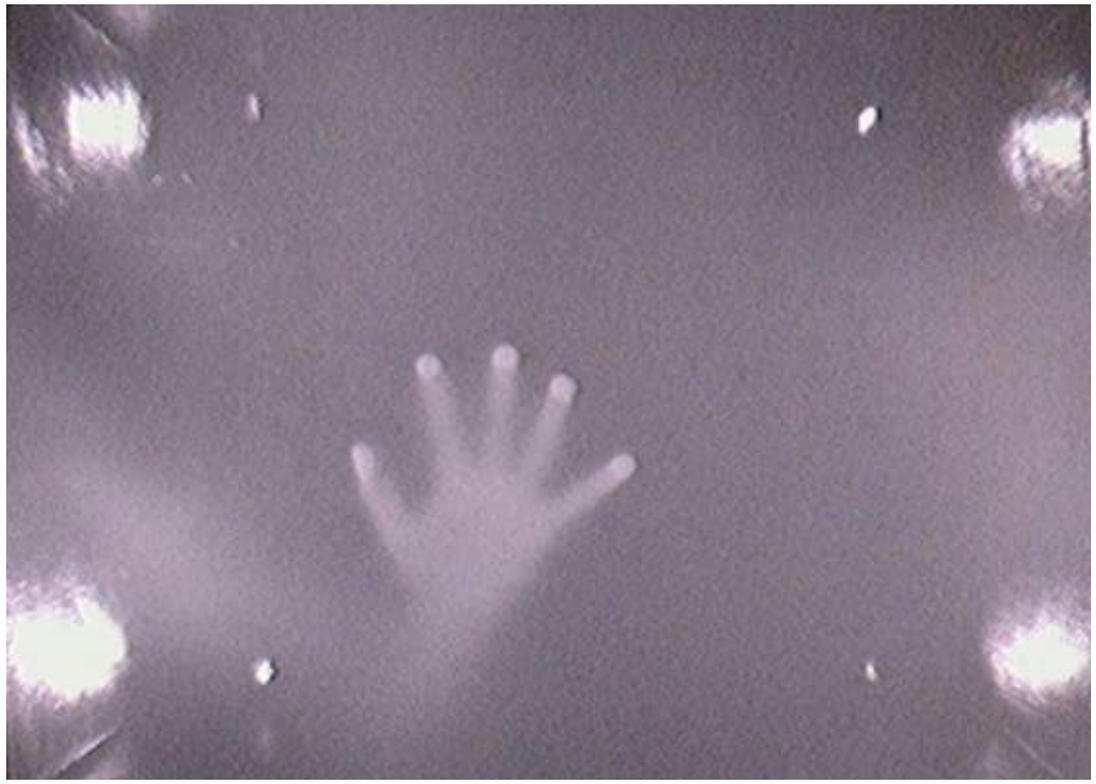
what can **rear diffuse illumination detect** that FTIR cannot?

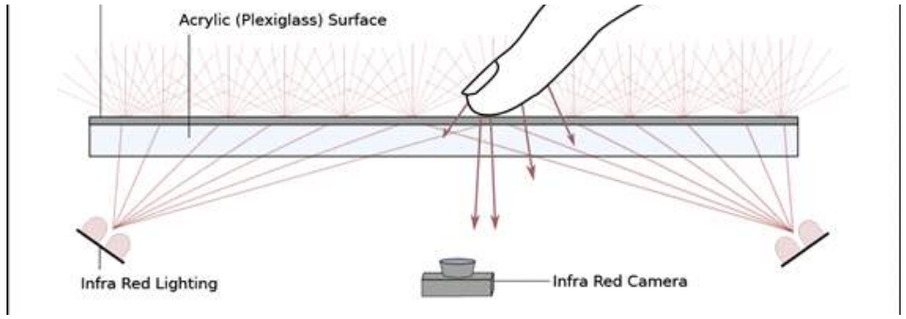
<30 second brainstorming>

FTIR vs. rear-DI









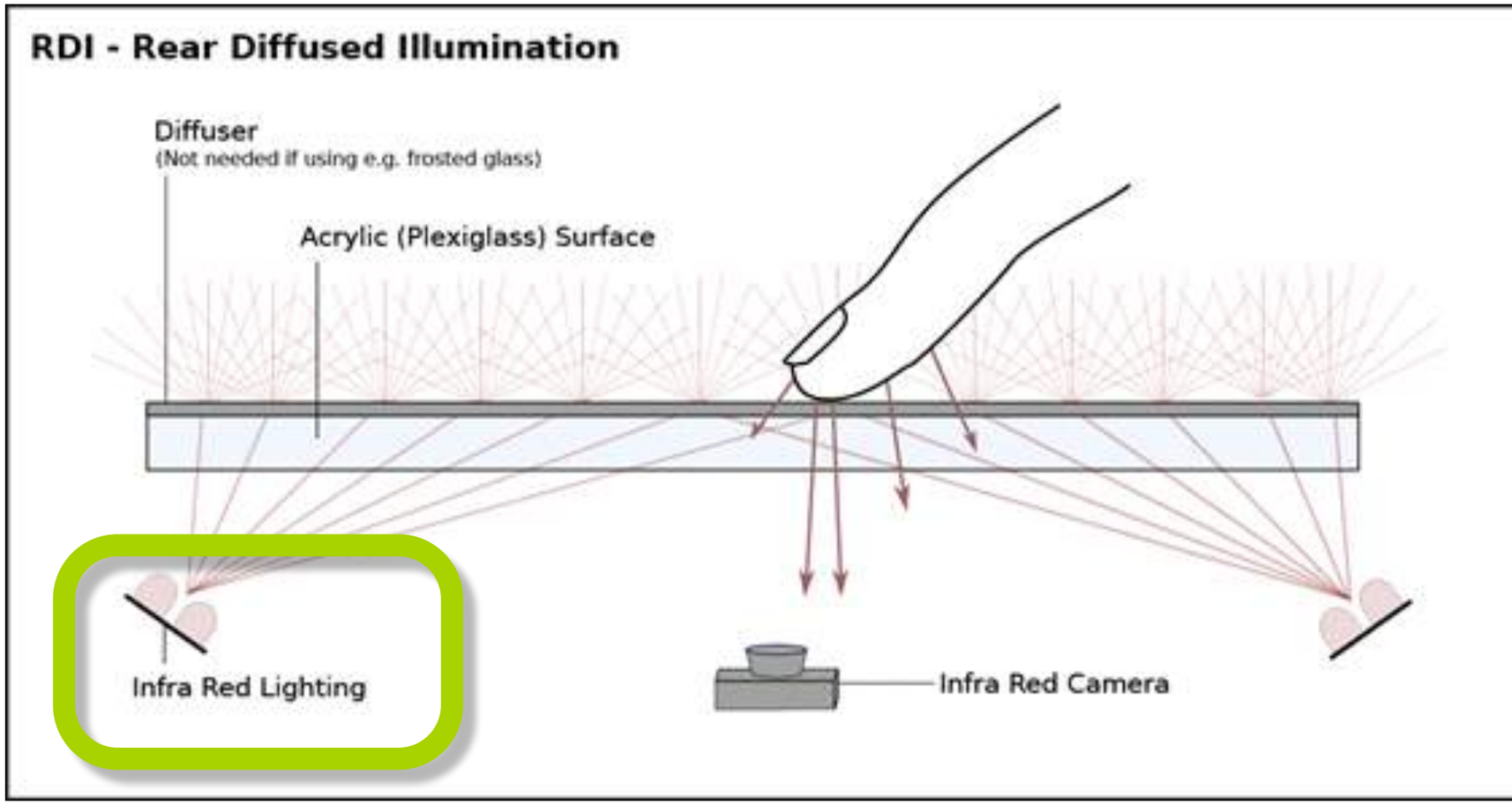
only detects objects
in **direct contact** with surface
(light bounces inside sheet)

can detect objects
hovering over the surface
(light reaches above sheet)

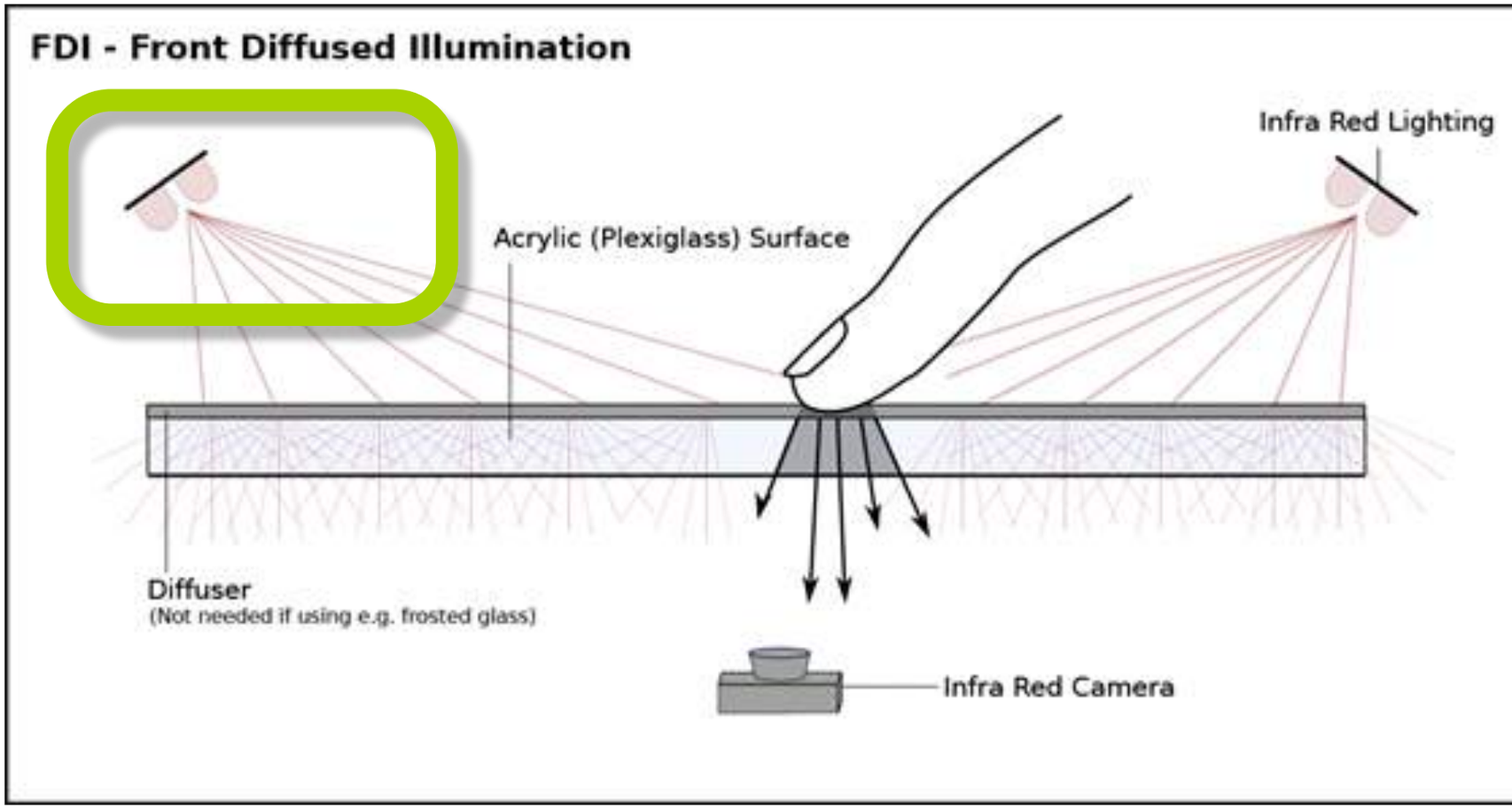
camera based:

front diffused illumination (front DI)

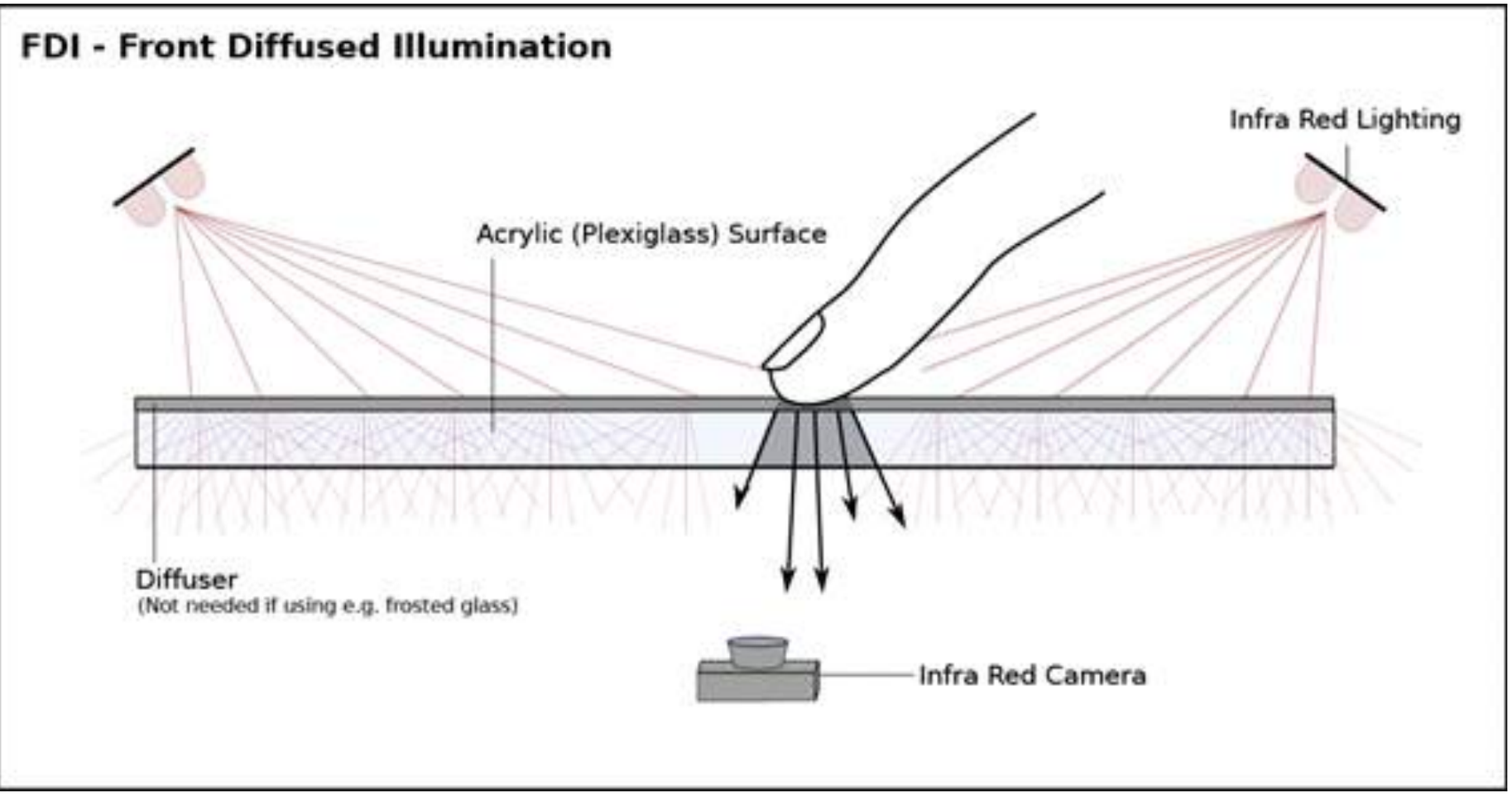
rear DI
light from below



front DI
light from above



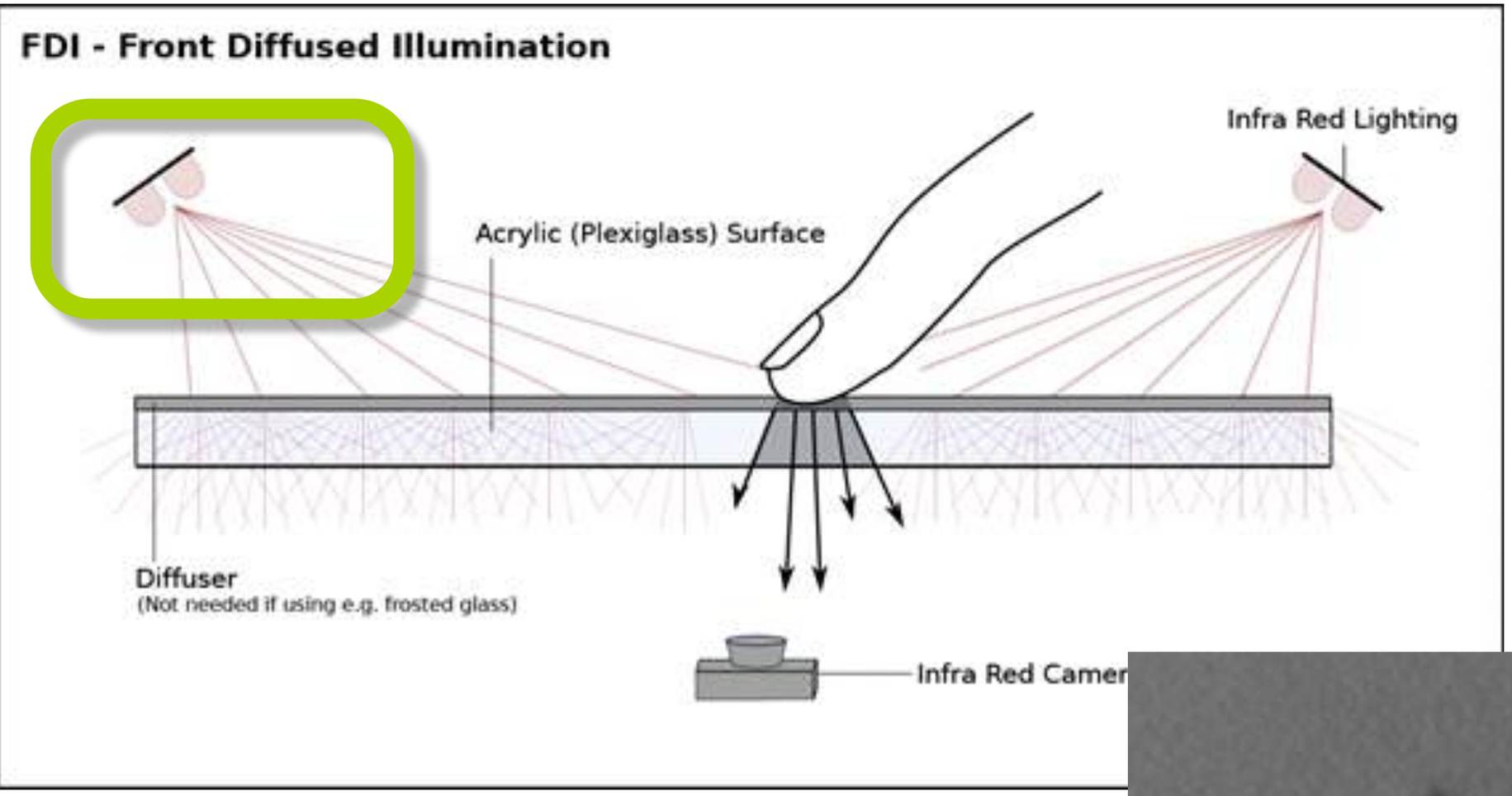
front DI



how do we expect the camera image to look like?

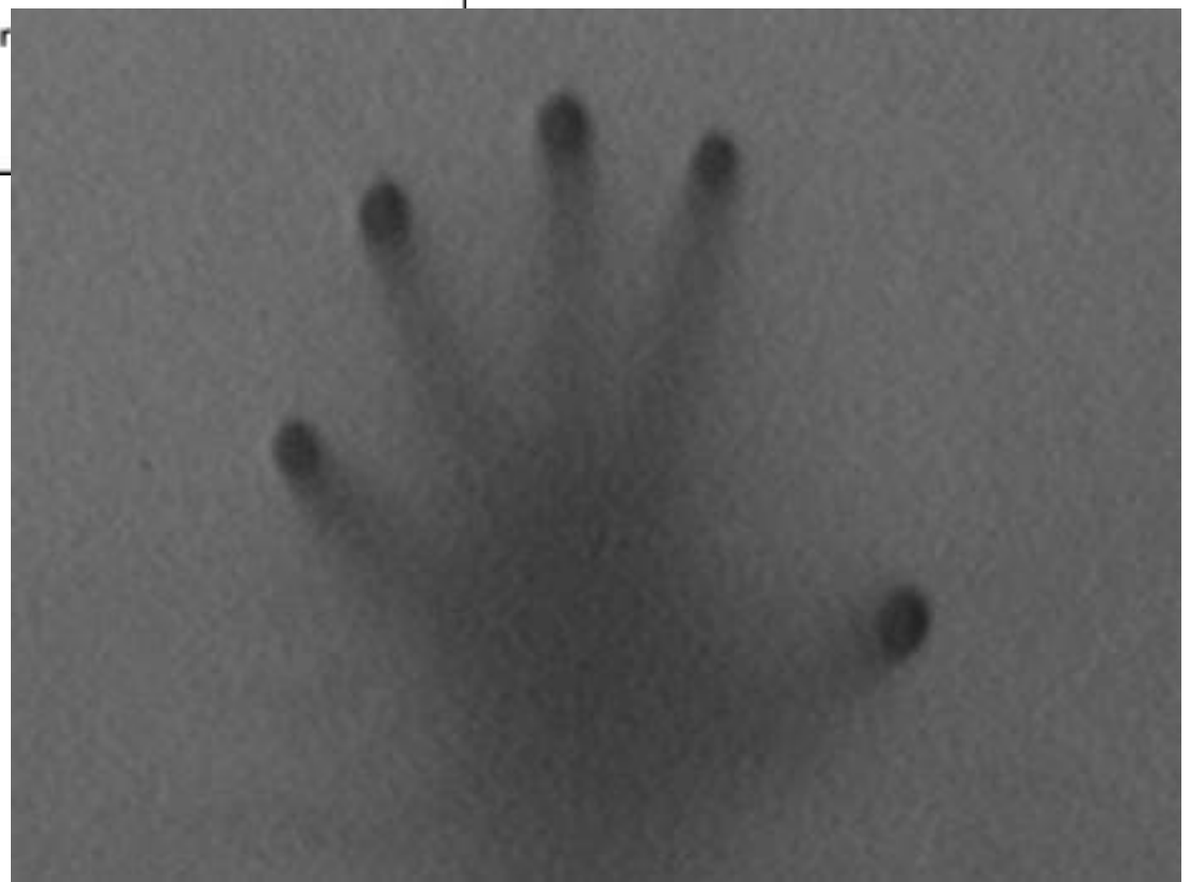
<30 second brainstorming>

front DI



finger **blocks** the light
from the camera

= fingers are black



front diffused illumination (front DI)::

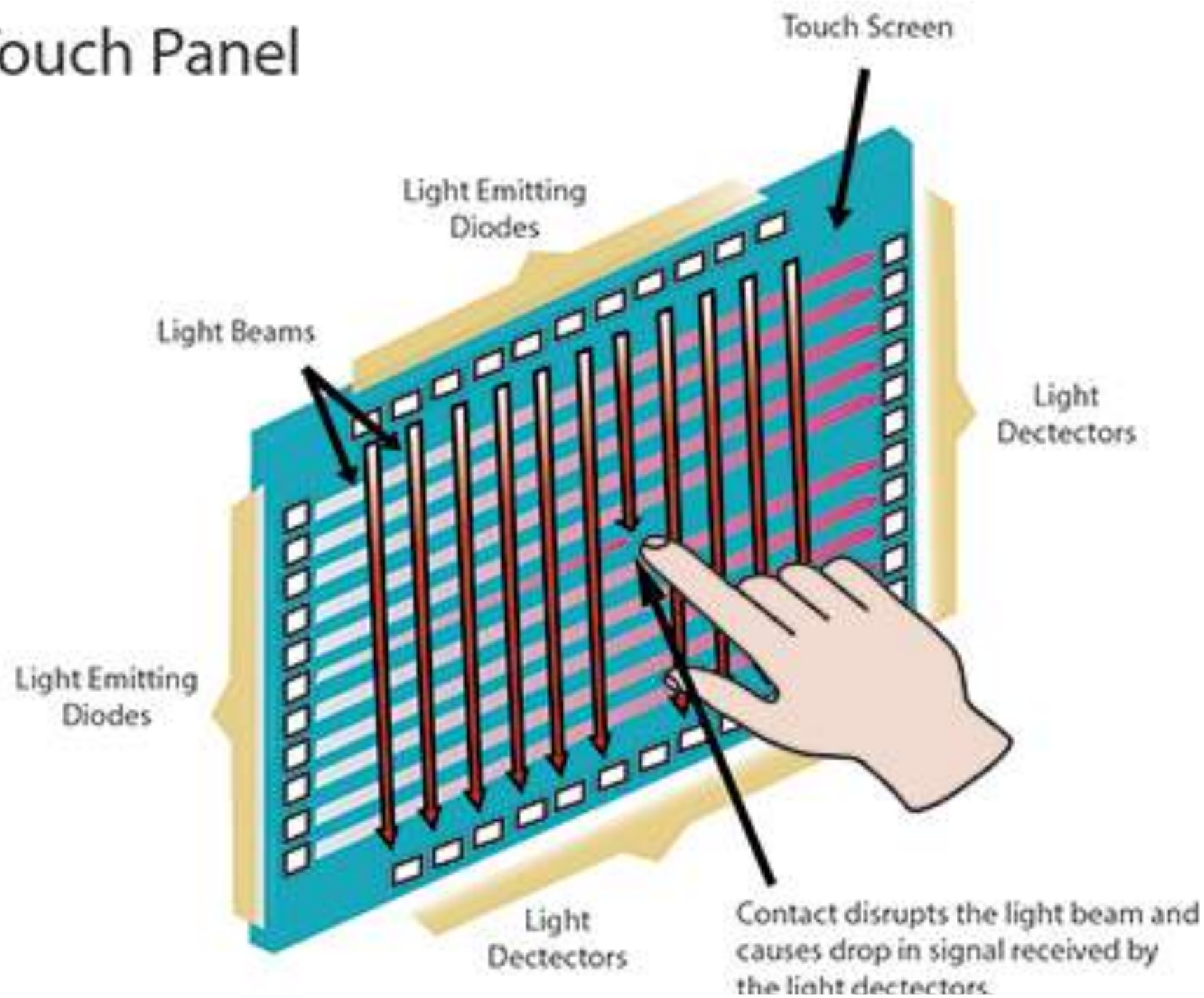
- light shined from **above** the touch surface
- a **diffuser** is placed on top of the touch surface
- when a finger touches, a **shadow** is created underneath
- appears as **black blob** in the camera image

[MTBiggie]

optical (sensor based):

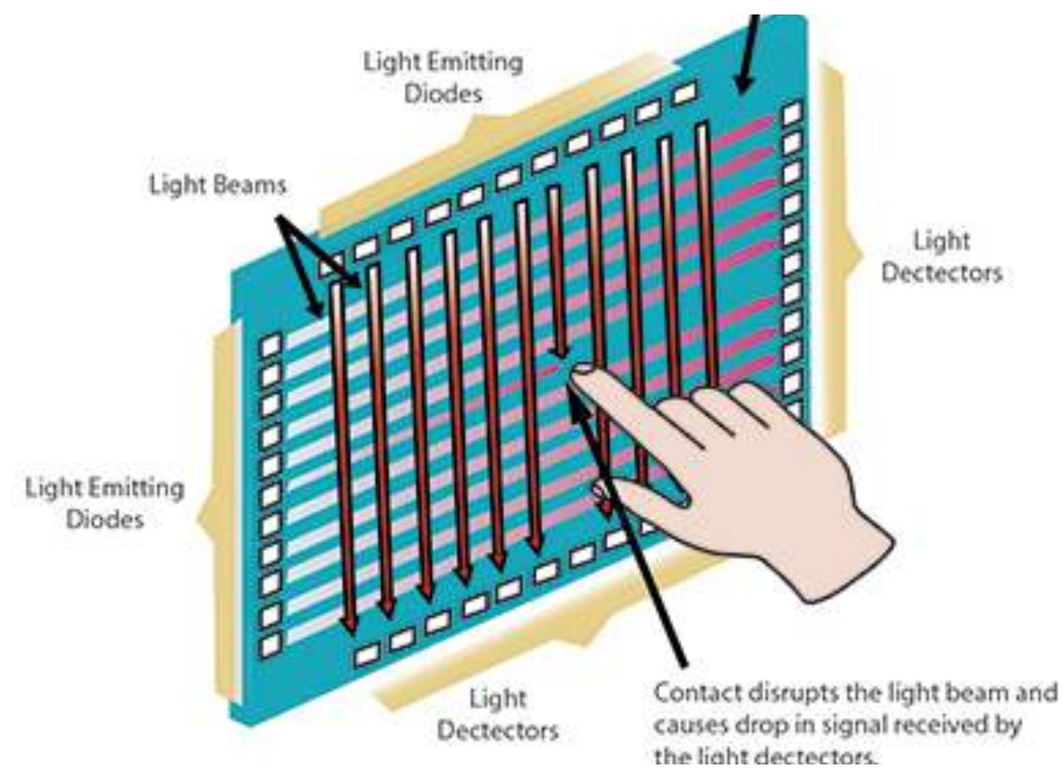
infrared touch panels (ITP)

Infrared Touch Panel

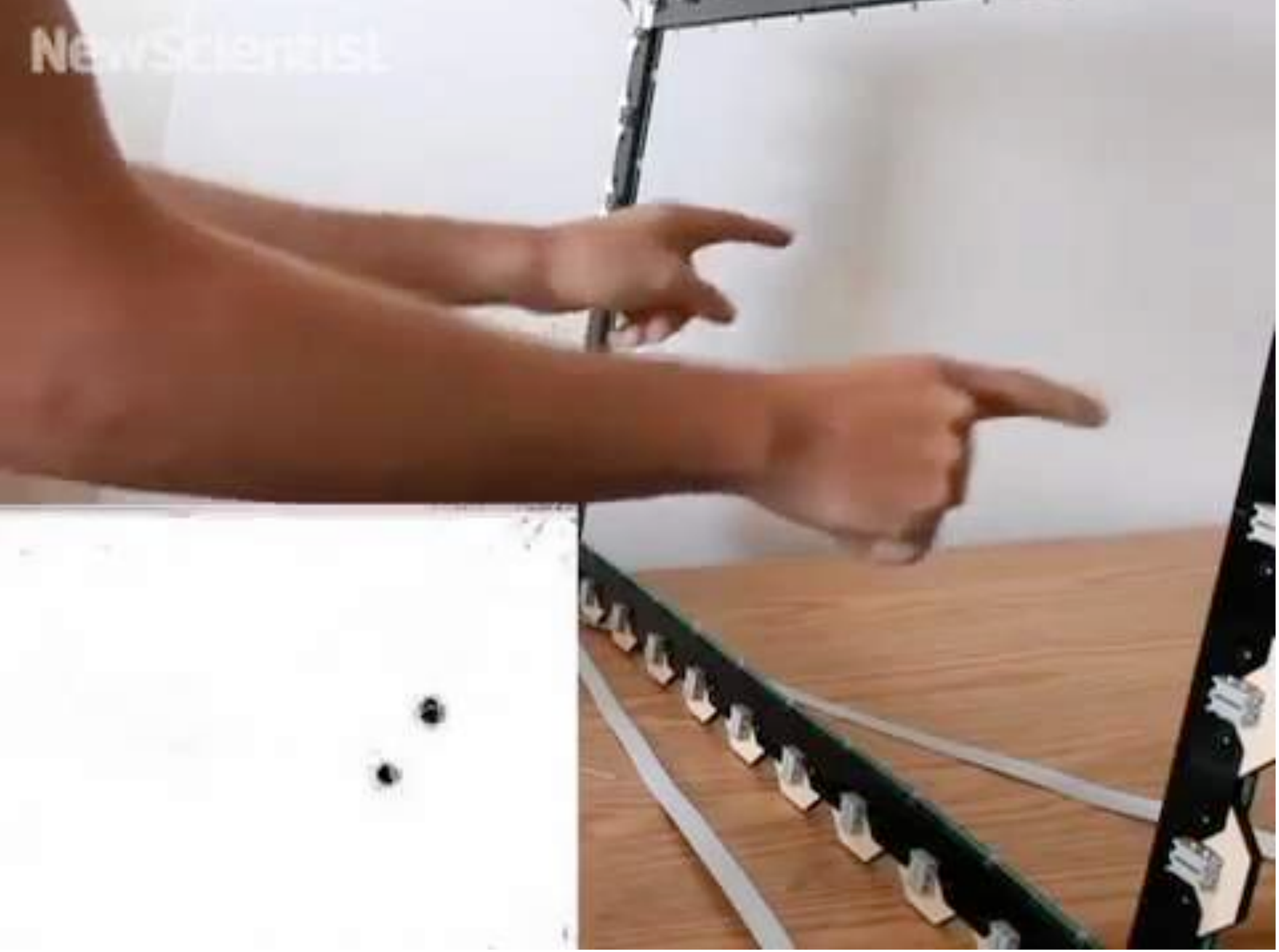


infrared touch panels (ITP)

- **infrared LEDs** and **light sensors**
- placed in a grid on bezel
- LEDs transmit light to light sensors on the other side
- anything that disrupts light, will register as touch



1986: Sensor Frame (McAvinney)

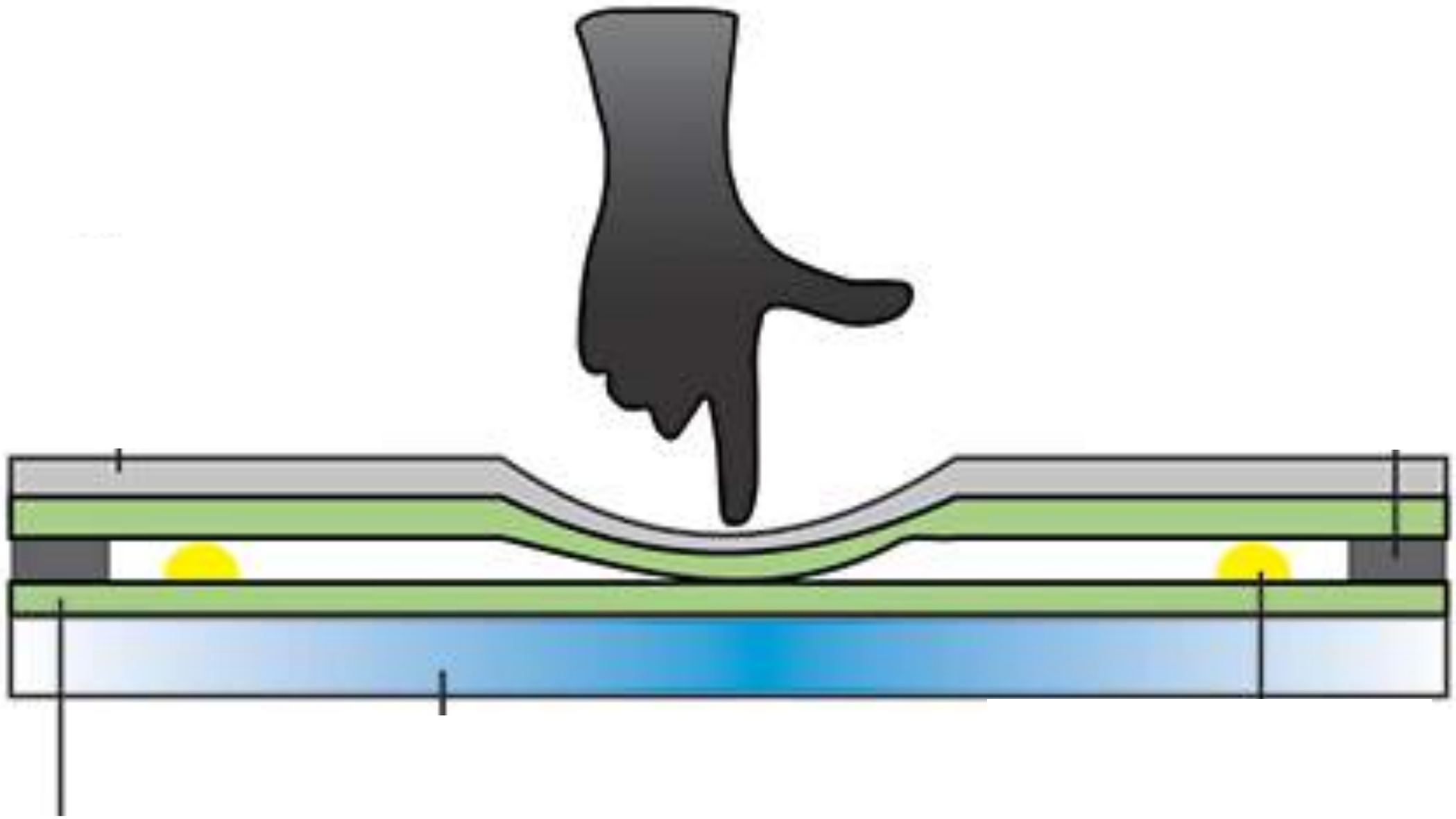


2011: ZeroTouch

electric:

resistive touch panels (RTP)

Resistive Touch Panel

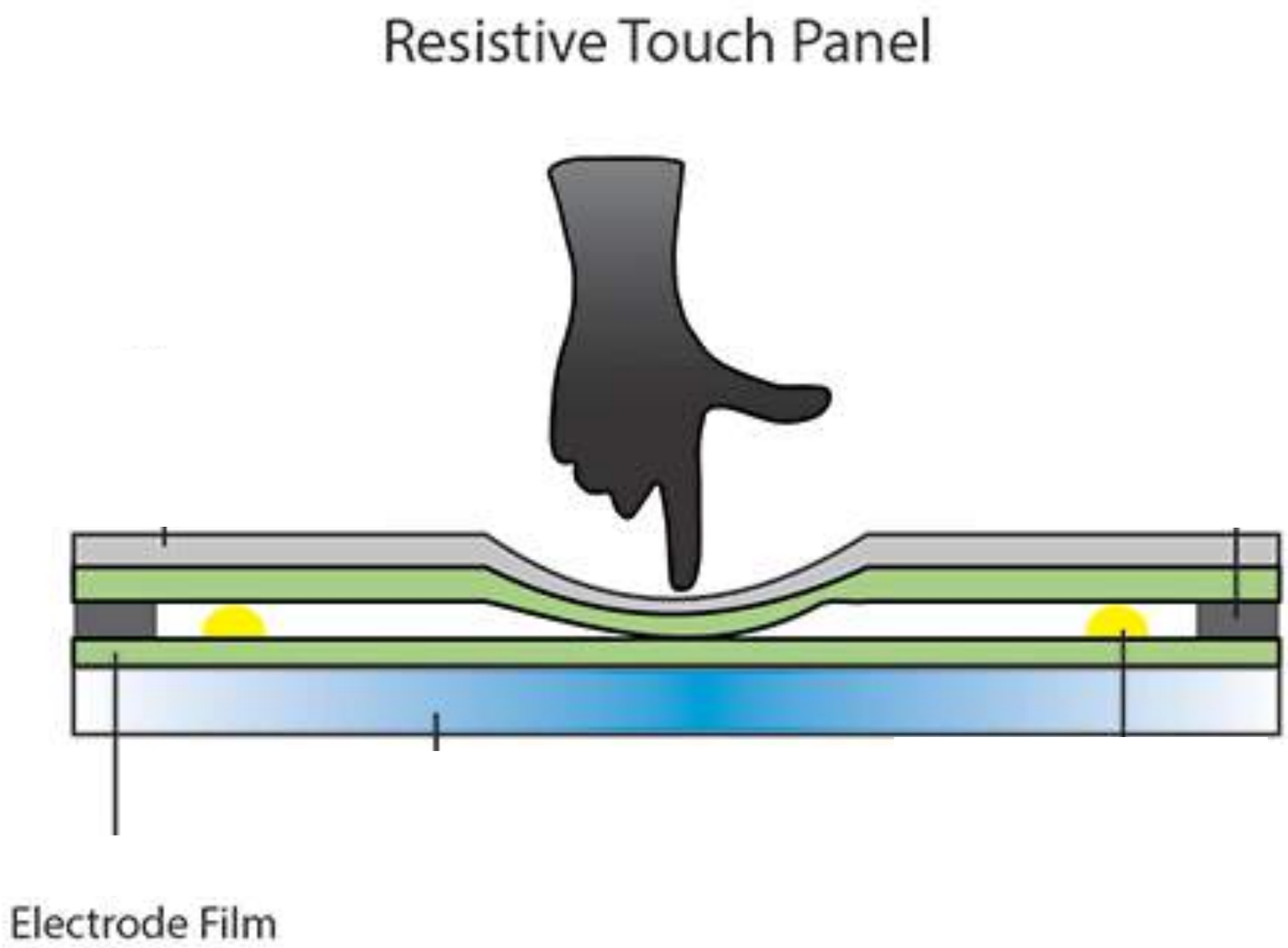


Electrode Film

resistive touch panels (RTP)

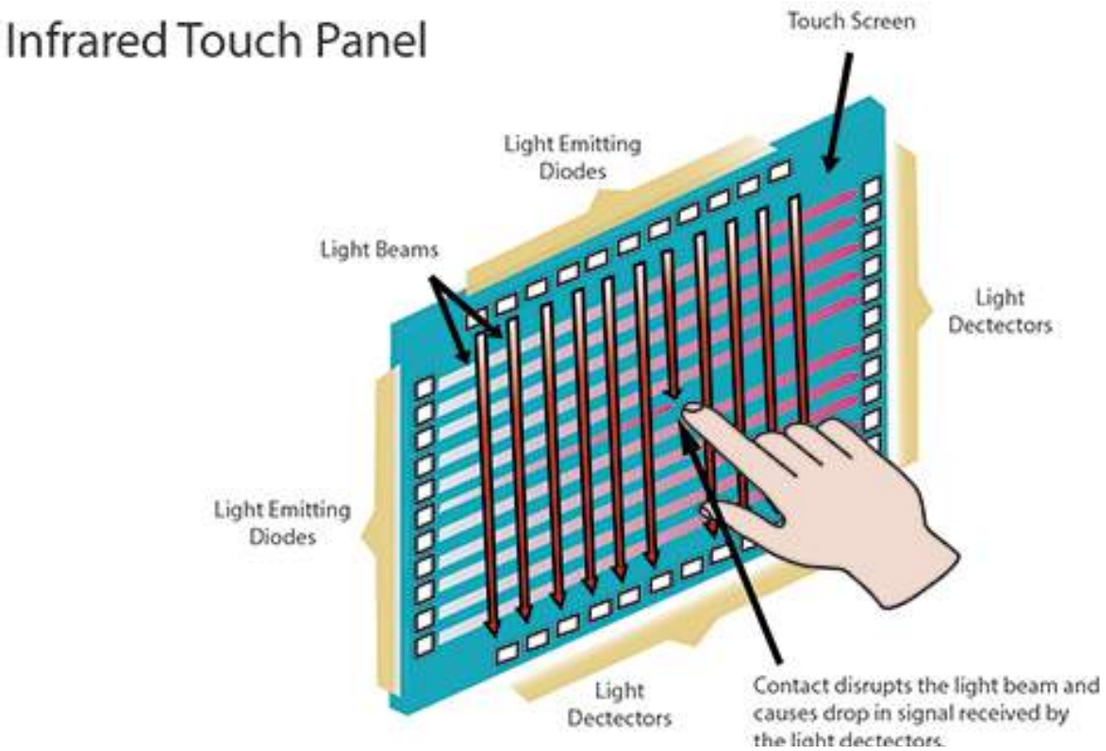
- the **top and bottom** sheet are **conductive**
- they have a **gap in-between,** no electricity flowing
- when the top sheet gets pressed by a finger, the pressed point **makes contact** with the bottom sheet
- **electricity now get conducted** at the contact point

- this is why in airplanes you have to push so hard…



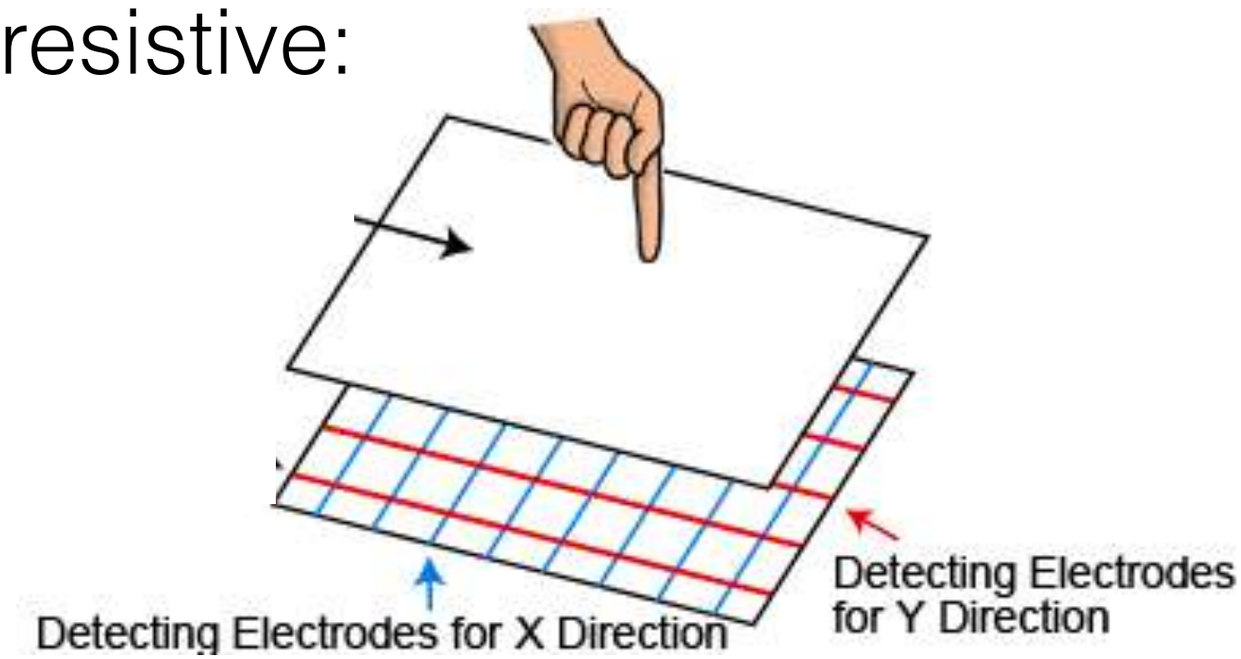
how do we know **where** the user touches the screen?

<30 second brainstorming>



same principles
as for the infrared touch panel

resistive:



x-y grid
top layer: all horizontal lines
bottom layer: all vertical lines

when contact is made
only these two line
conducts electricity

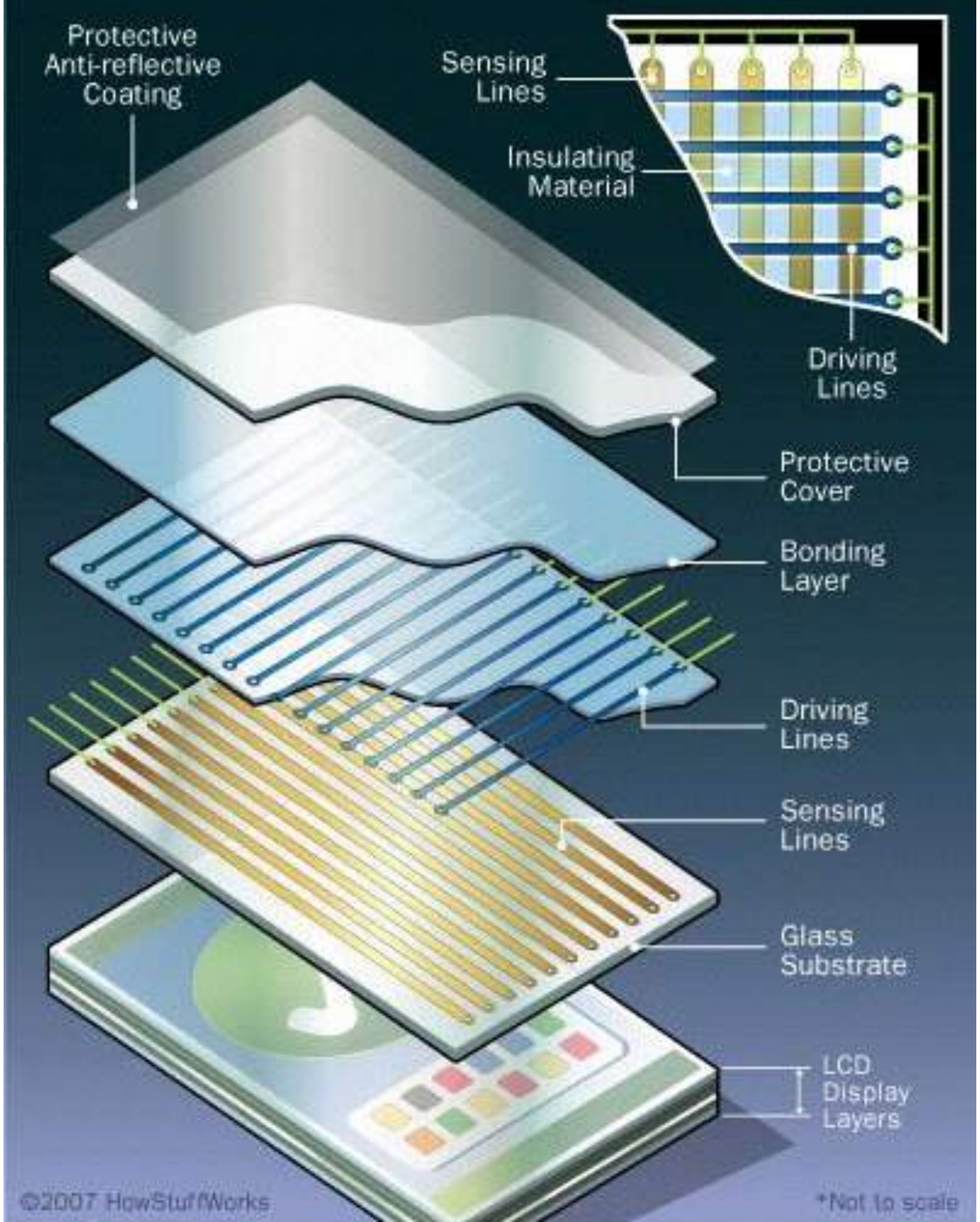
benefits::

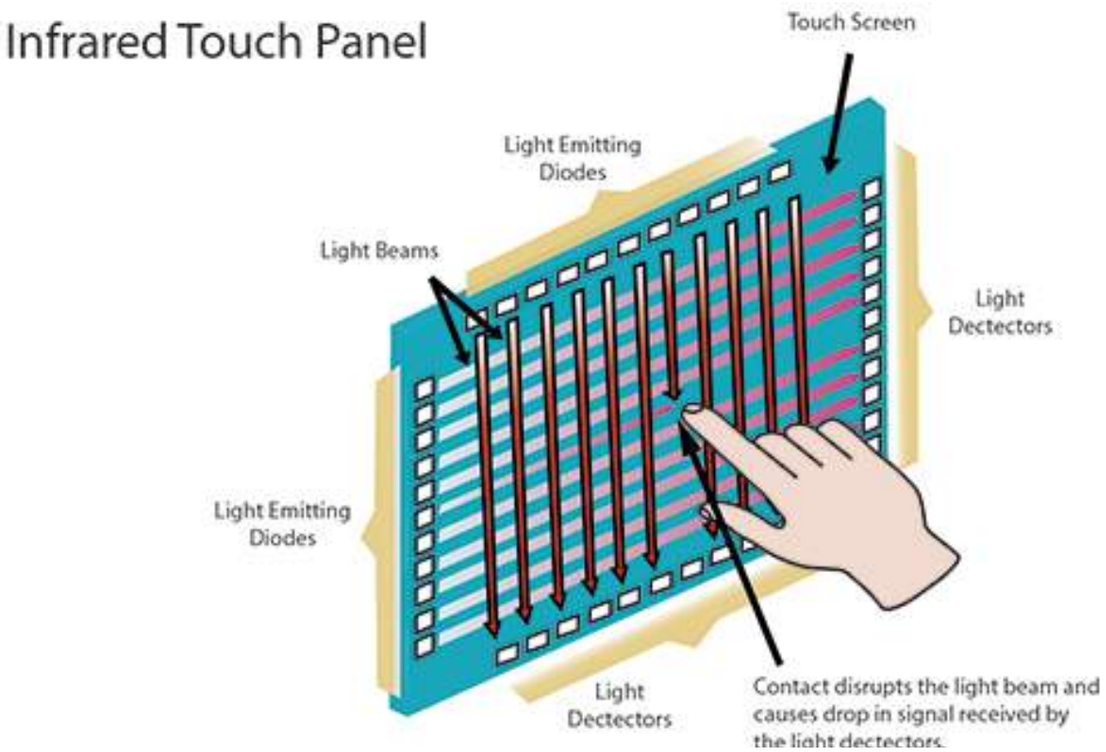
- lowest cost
- low power consumption
- work with finger, stylus, glove

- poor response to light touch…
- dragging…

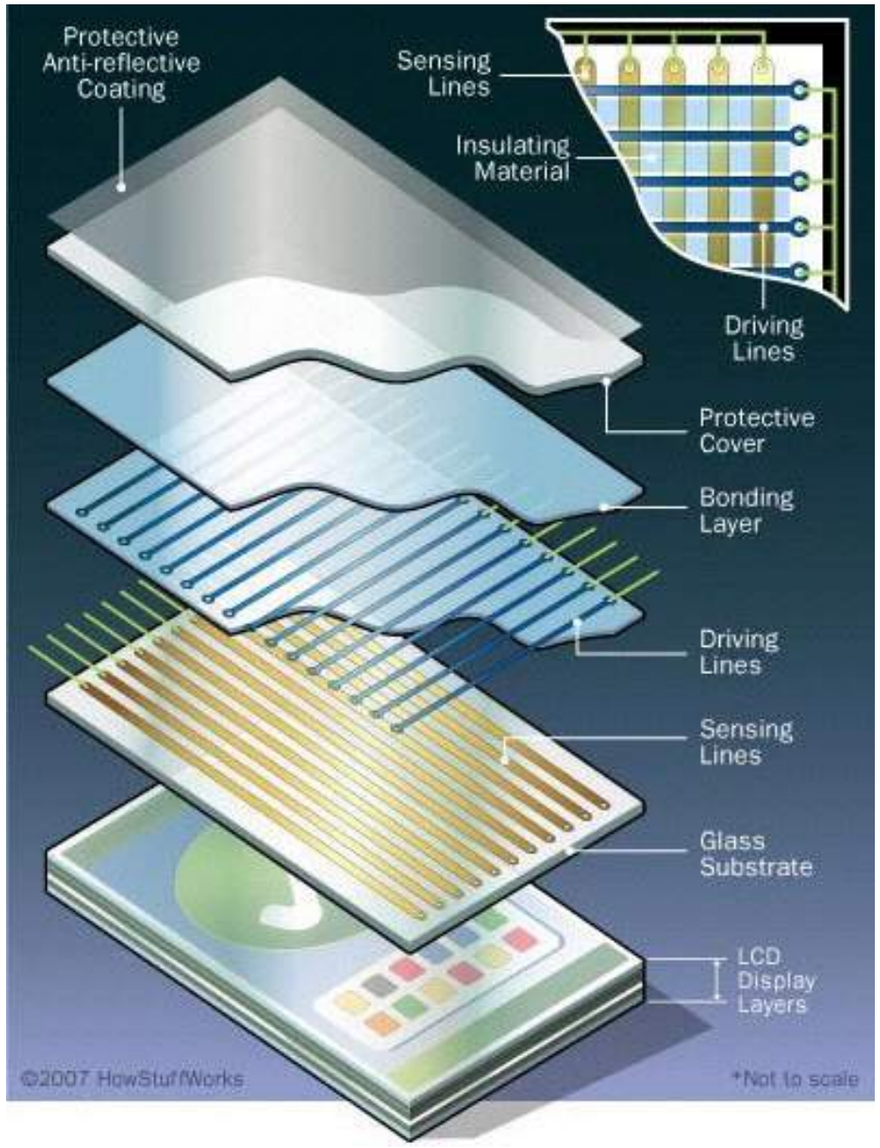
- 26% of the market

projected capacitance (PCAP)

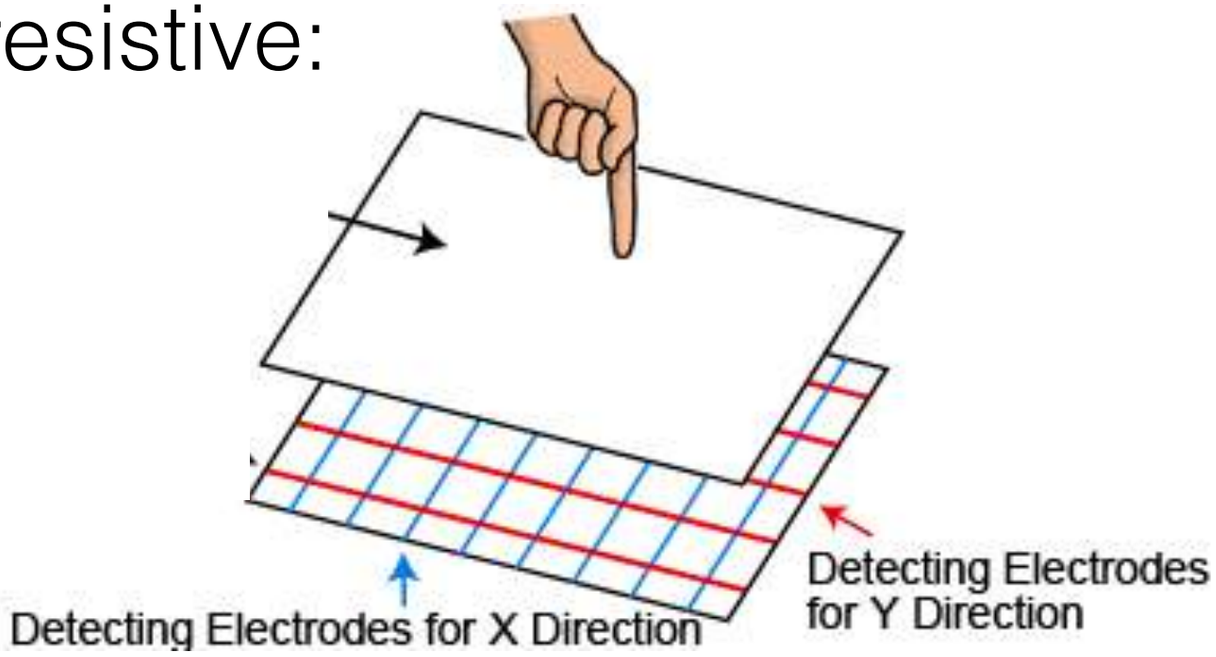

Protective Anti-reflective Coating
Sensing Lines
Insulating Material
Driving Lines
Protective Cover
Bonding Layer
Driving Lines
Sensing Lines
Glass Substrate
LCD Display Layers
©2007 HowStuffWorks
*Not to scale



capacitive:



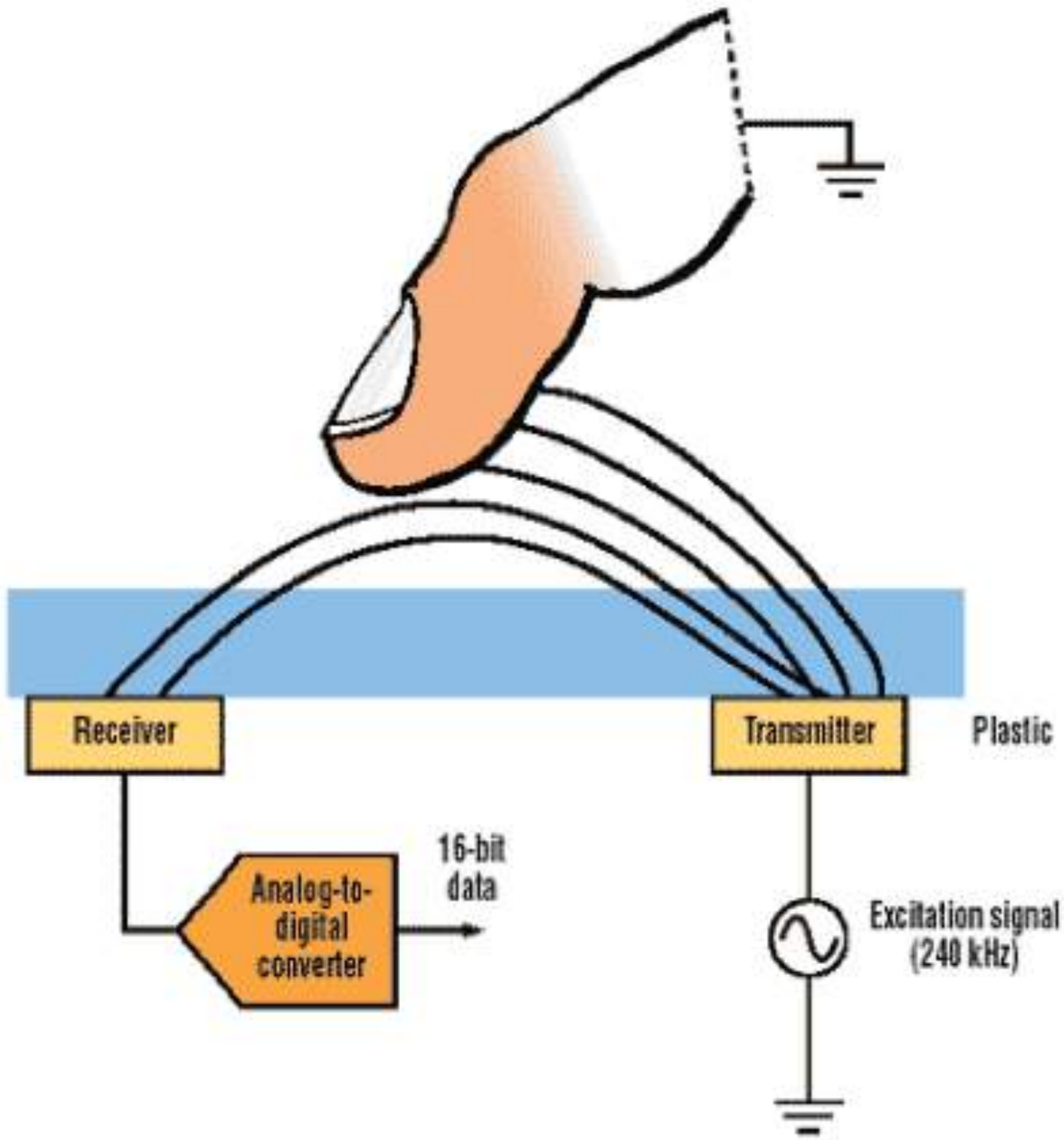
resistive:



again
same principle

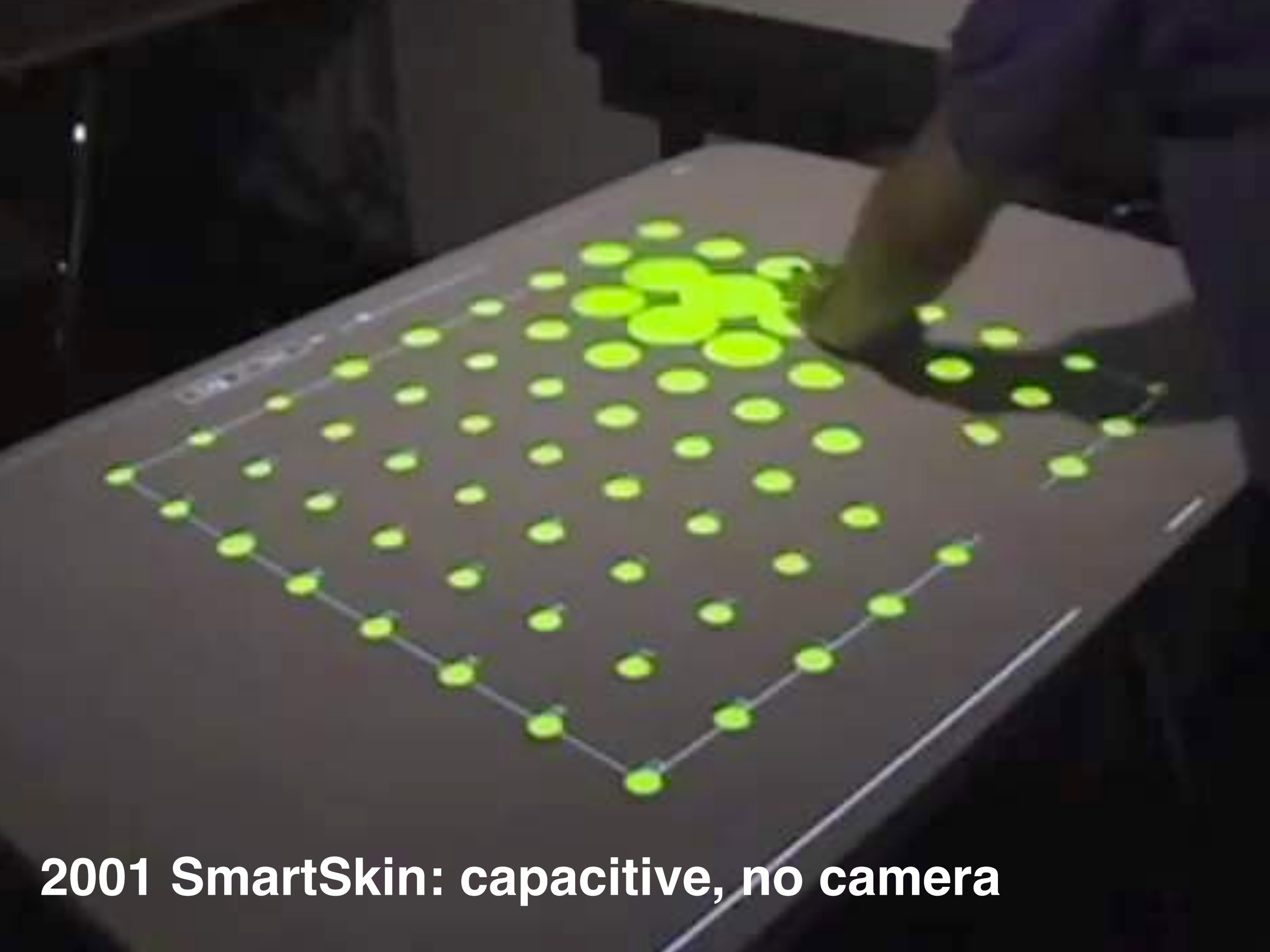
projected capacitance (PCAP)

- 2 parallel conductive layers with grid lines
- **continues scanning** of x/y grid lines **('always on')**
- grid lines create **electro static field**
- when finger touches, the **change in the electrodes** can be detected


Receiver
Transmitter
Plastic
16-bit
data
Analog-to-
digital
converter
Excitation signal
(240 kHz)

this is what your iphone uses…

2007: ‘we invented a new technology’



2001 SmartSkin: capacitive, no camera

SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces

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http://www.csl.sony.co.jp/person/rekimoto.html

ABSTRACT

This paper introduces a new sensor architecture for making interactive surfaces that are sensitive to human hand and finger gestures. This sensor recognizes multiple hand positions and shapes and calculates the distance between the hand and the surface by using capacitive sensing and a mesh-shaped antenna. In contrast to camera-based gesture recognition systems, all sensing elements can be integrated within the surface, and this method does not suffer from lighting and occlusion problems. This paper describes the sensor architecture, as well as two working prototype systems: a table-size system and a tablet-size system. It also describes several interaction techniques that would be difficult to perform without using this architecture.

Figure 1: An interactive surface system based on the

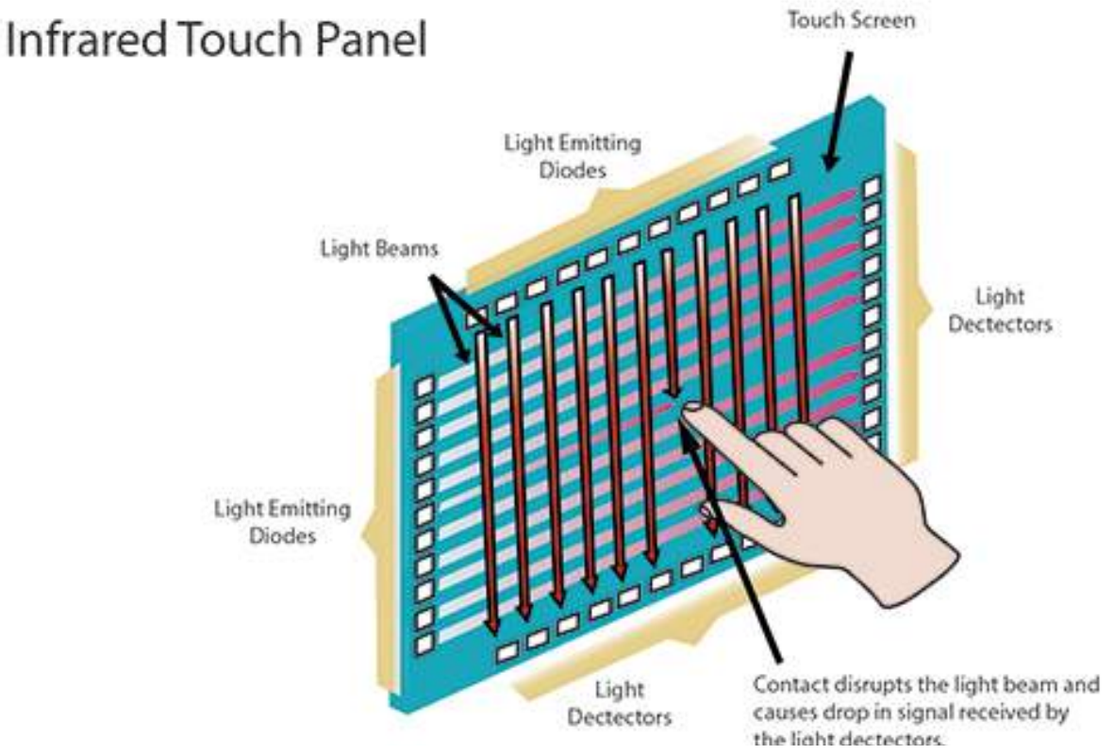
CHI 2002

projected capacitance (PCAP)

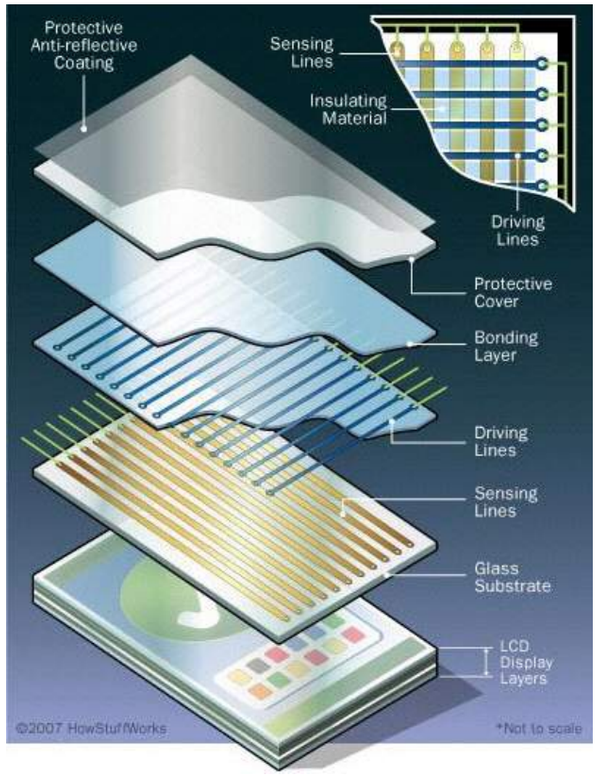
- no pressure force needed for detection
- susceptible to electrical noise
- more expensive than resistive

- smart phones, tablets etc.
- 64% of the market

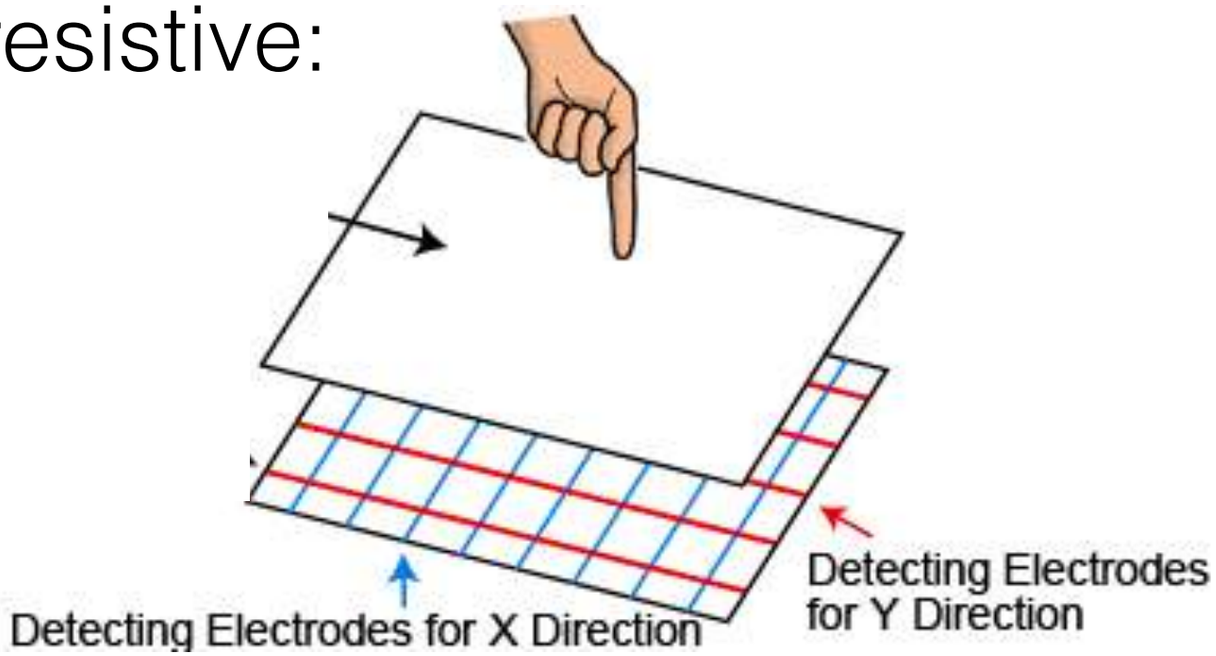
surface acoustic waves (SAW)



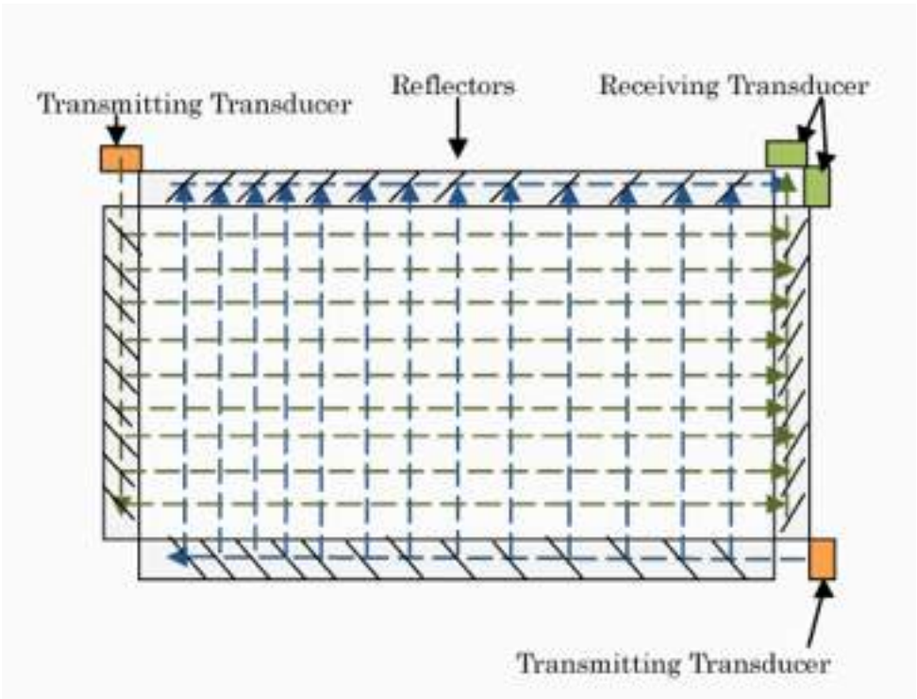
capacitive:



resistive:

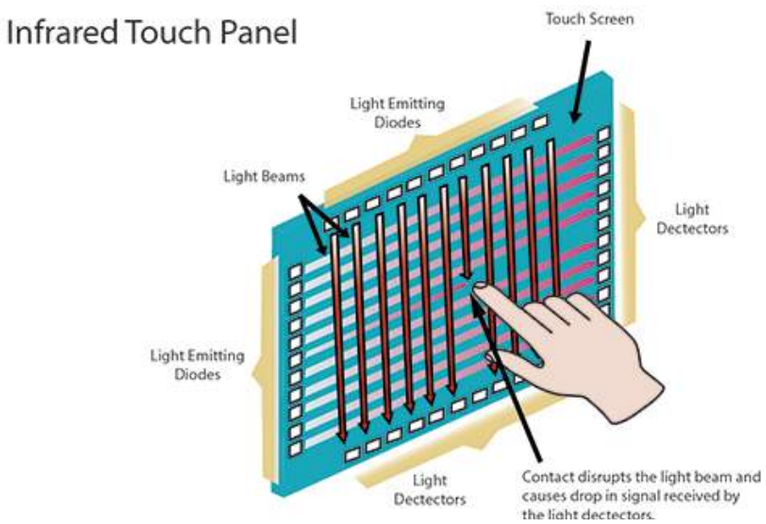


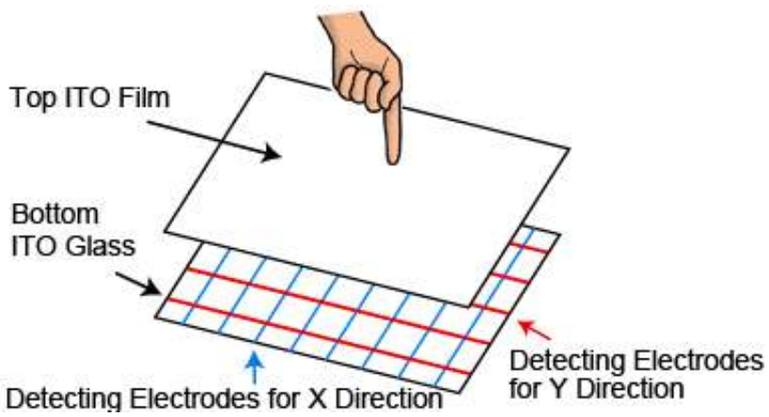
surface acoustic:

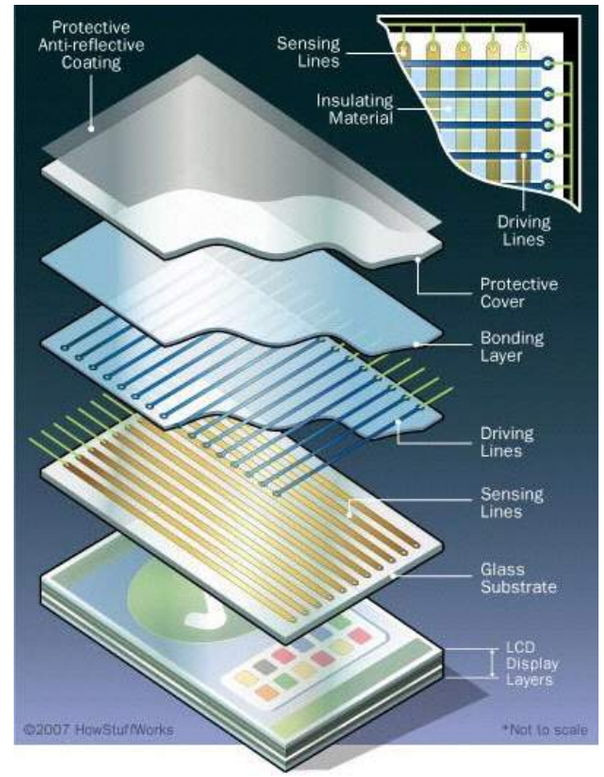


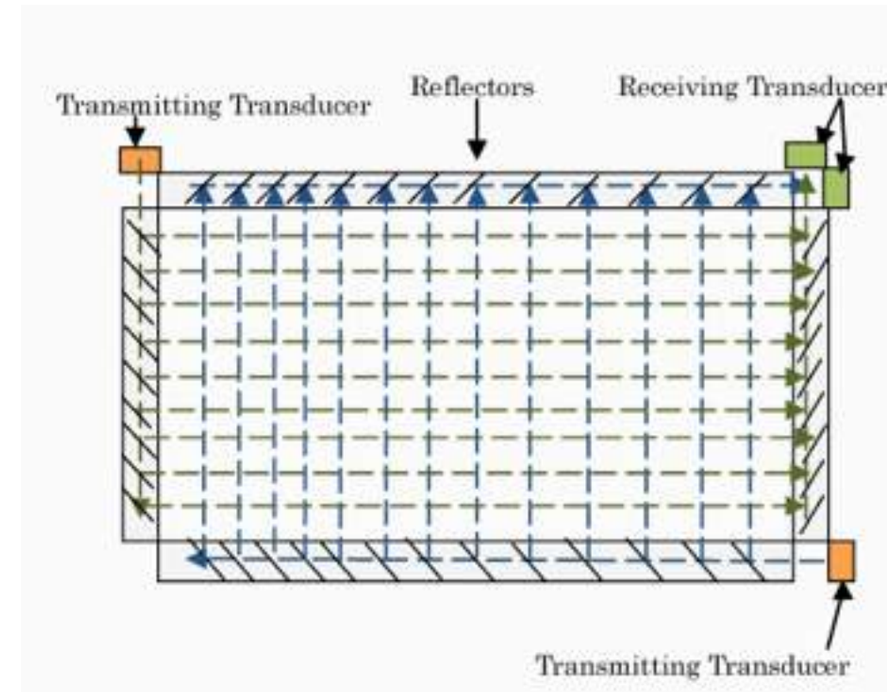
surface acoustic waves (SAW)

- basically the same as everything else just with **sound**
- **fingers in path absorb sound**
- thus you can detect them with a **microphone**





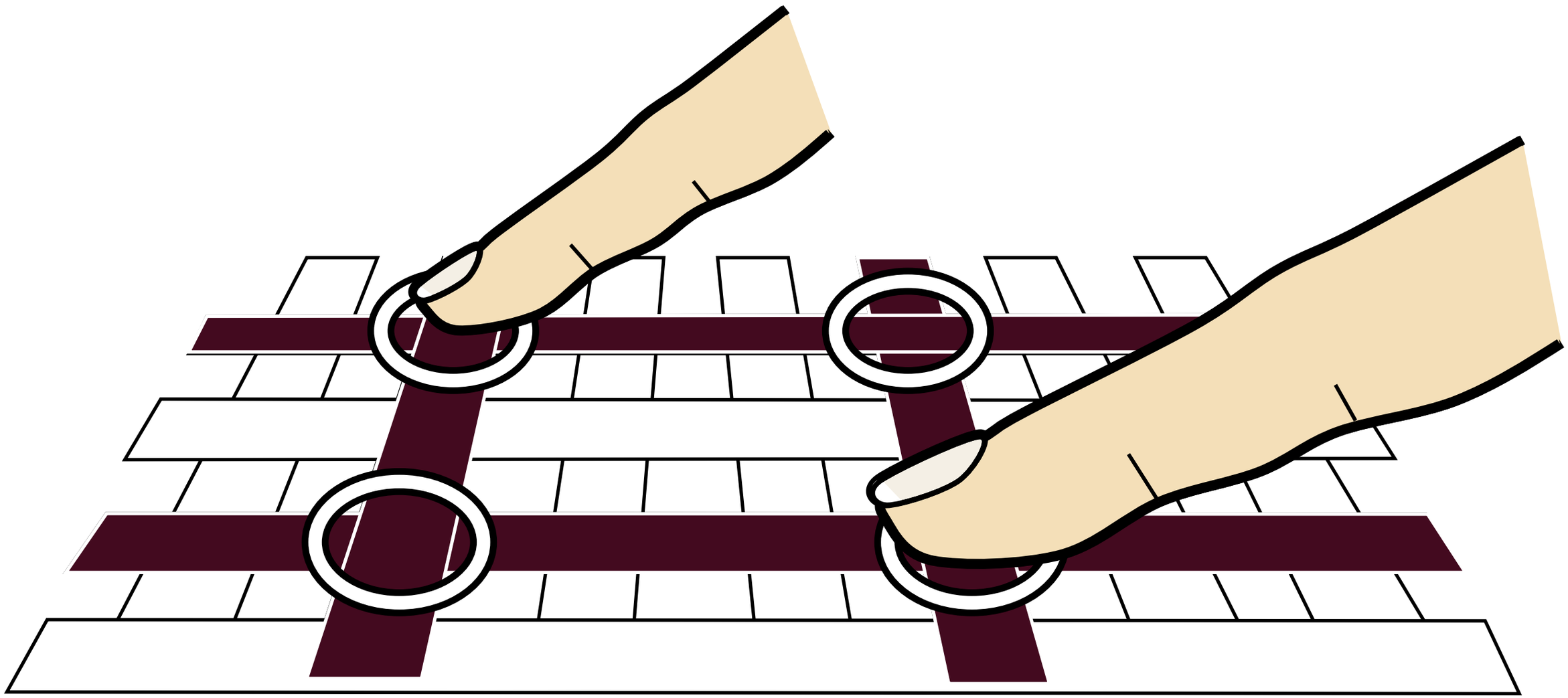




there are situations in which this grid based approach cannot correctly detect a finger's position.

how do you have to place **two fingers** to make it fail?

<30 second brainstorming>

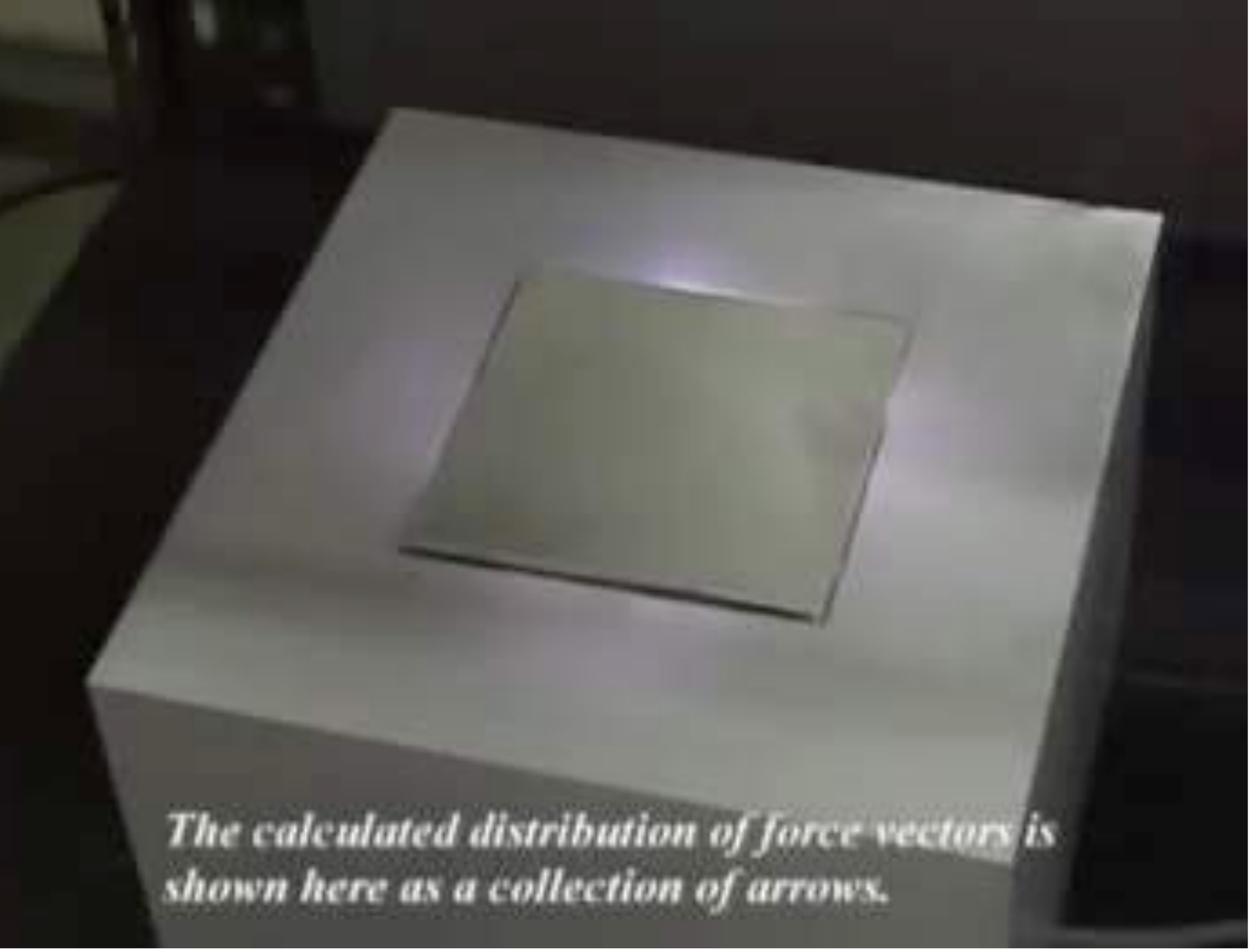


it leads to **ghosting!**

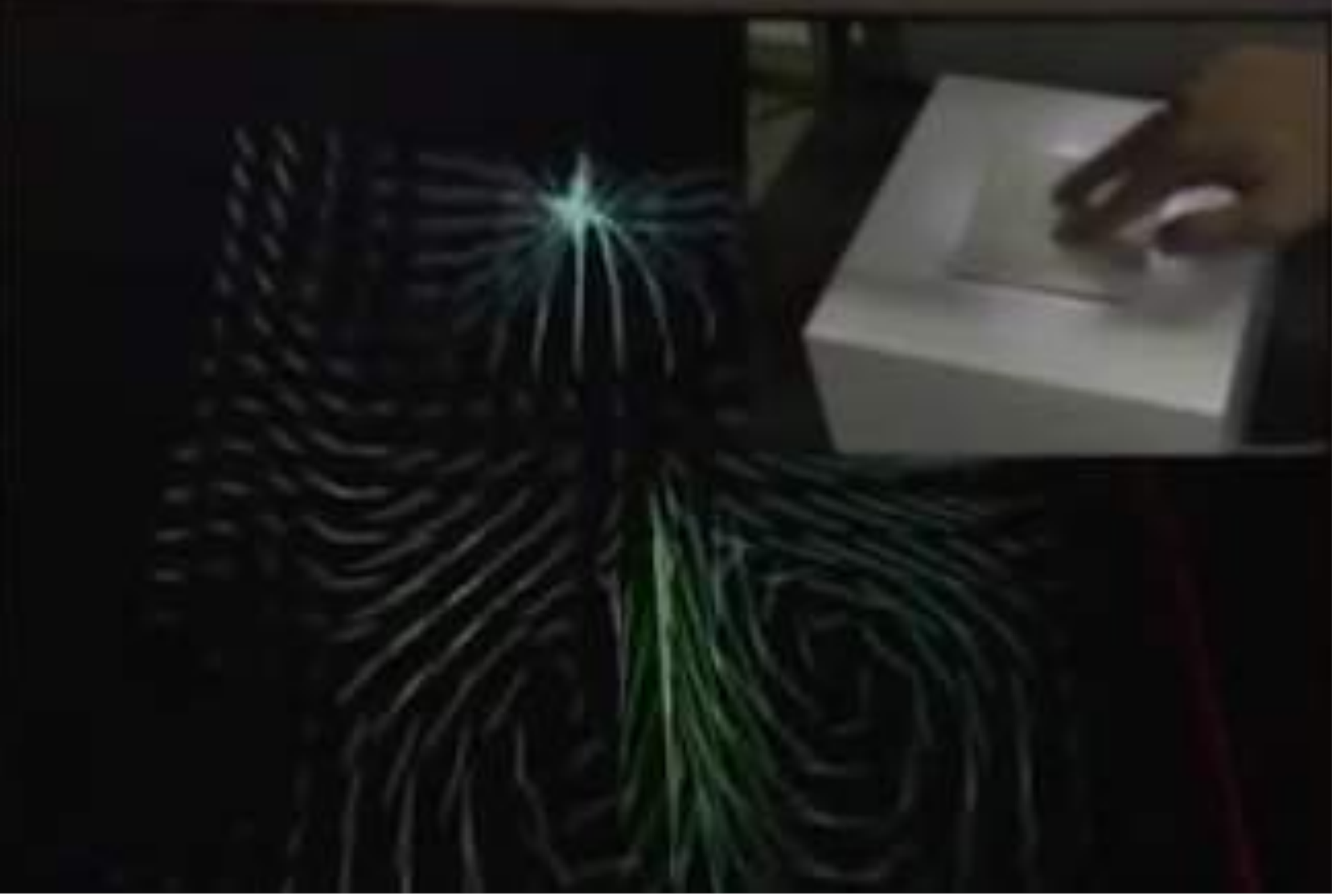
(camera-based setups don’t have this problem)

moving forward…

detecting pressure from touch…

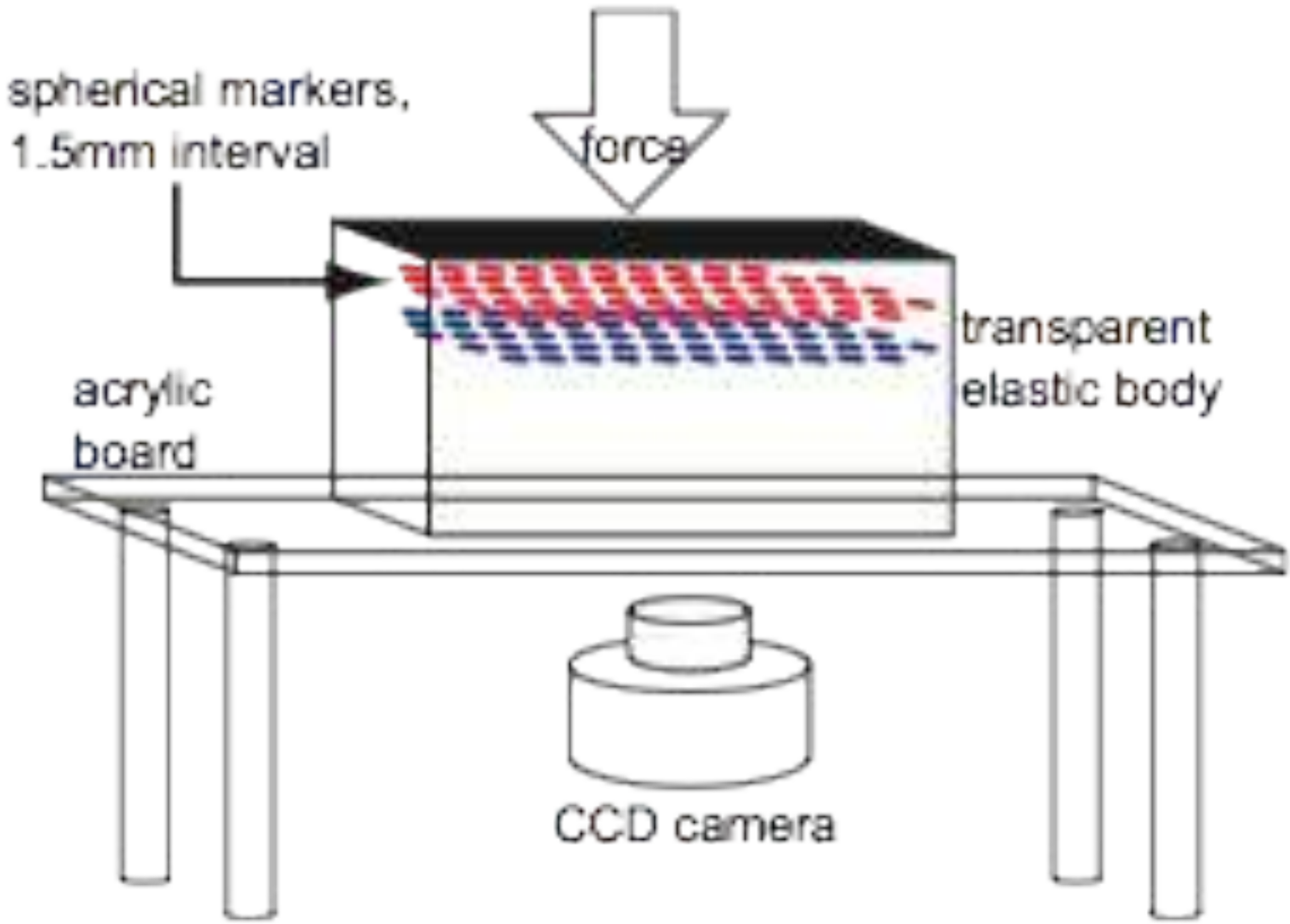


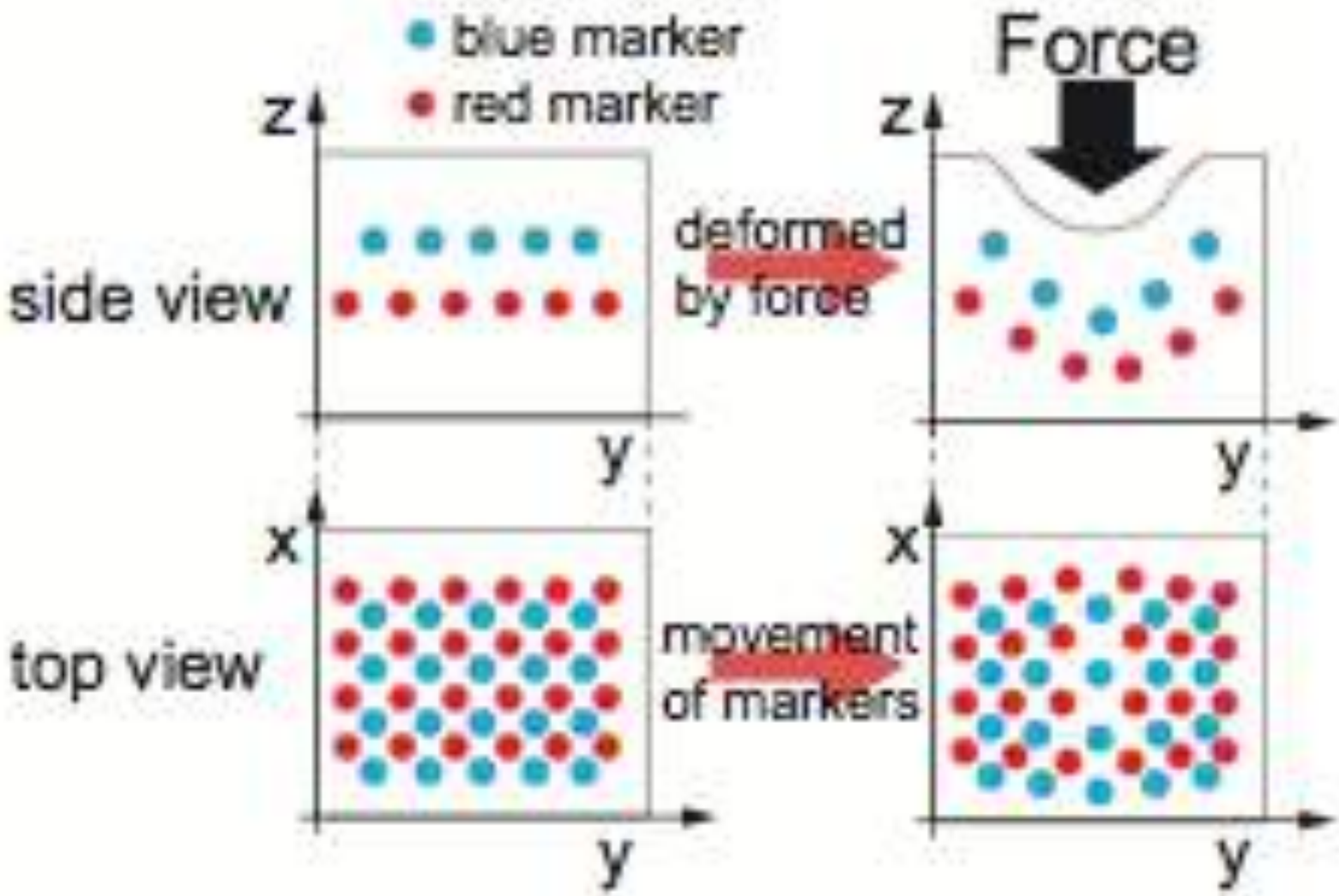
2005 GelForce



how does it work?

<30 second brainstorming>


spherical markers,
1.5mm interval
force
transparent
elastic body
acrylic
board
CCD camera


blue marker
red marker
Force
z
z
side view
deformed
by force
y
y
x
x
top view
movement
of markers
y
y

GelForce:
A Vision-based Traction Field Computer Interface

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ABSTRACT
We propose a tactile sensor based on computer vision that measures a dense traction field, or a distribution of 3D force vectors over a 2D surface, which humans also effectively sense through a dense array of mechanoreceptors in the skin. The proposed "GelForce" tactile sensor has an elegant and organic design and can compute large and structurally rich traction fields in real time. We present how this sensor can serve as a powerful and intuitive computer interface for both existing and emerging desktop applications.

ACM Categories & Subject Descriptors
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces, Haptic I/O.

Keywords
GelForce, computer vision, tactile sensor, elasticity.

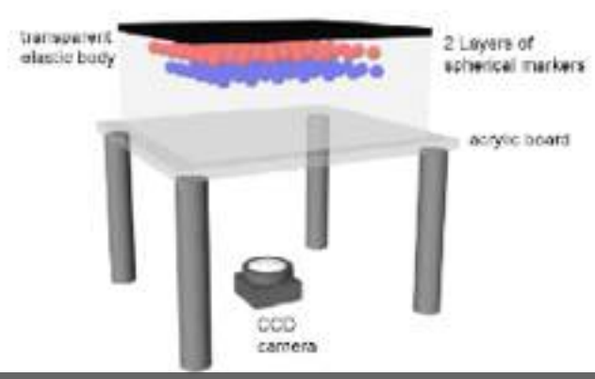


Figure 1. GelForce system design.

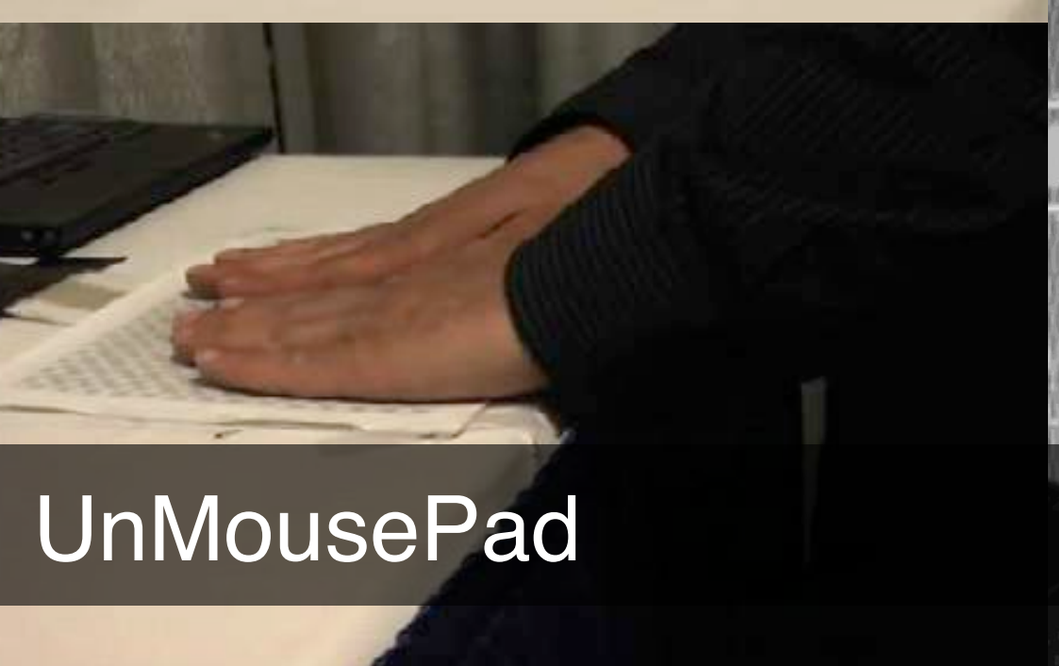
CHI 2005, April 2-7, 2005, Portland, Oregon, USA.
ACM 1-59593-002-7/05/0004.

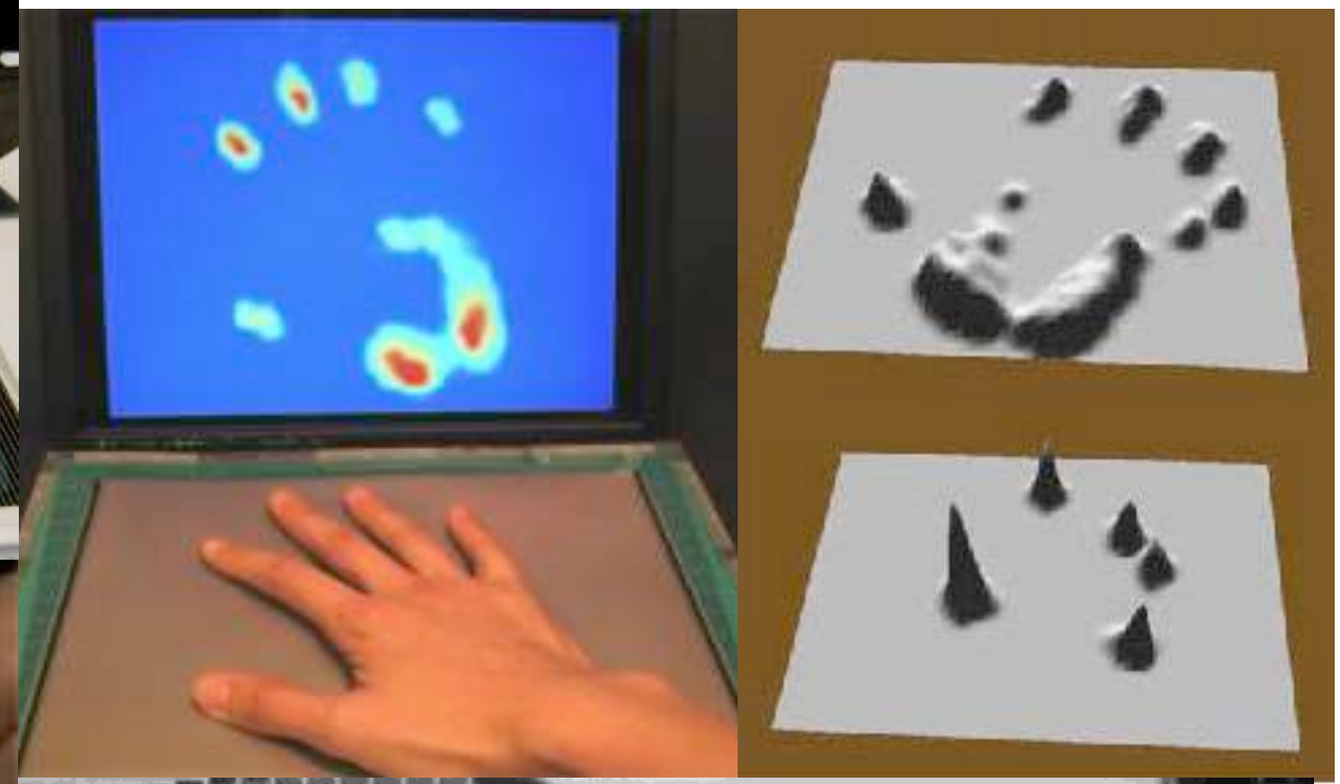
INTRODUCTION
The human sense of touch is versatile due to its high dimensionality: a dense array of mechanoreceptors in the skin composites a traction field, or a distribution of 3D force vectors over a 2D surface. This rich tactile feedback is essential for everyday tasks such as manipulating fragile objects. To realize this ability in robotics, a class of tactile sensor was recently introduced based on computer vision, in which the deformation of an elastic body is measured optically, and the applied traction is derived through elasticity theory. When computed in real time, the measured field may serve as high dimensional user input for common workstations. Here, we describe the developed sensor and propose its potential use both for common PC tasks such as point-based selection, as well as new applications that exploit the rich input of a high-dimensional vector field.

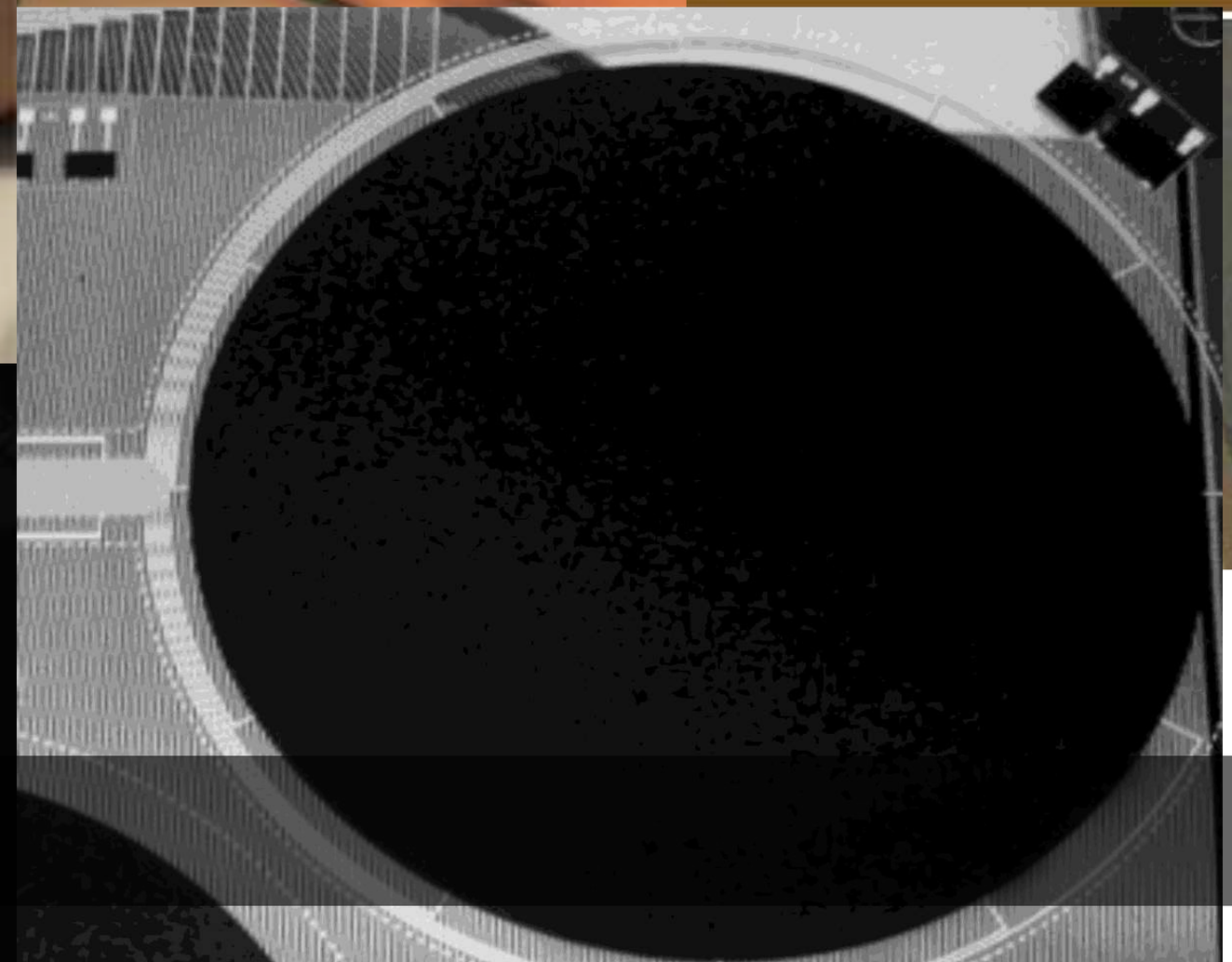
SYSTEM OVERVIEW
Traction field sensation requires the dense measurement of 3-D force vectors along a surface. This is a nontrivial extension to existing piezoelectric element arrays commonly used for touchpads, which can only measure 1D magnitude of force. The use of computer vision circumvents many problems related to sensor size and circuit complexity, and has become an emerging trend in robotics [1][2] due to the decreasing cost and size of high quality imaging systems.

Our sensor, named "GelForce", has a relatively simple system design (Figure 1), consisting of a rectangular transparent silicone body mounted over a CCD camera, which is enclosed in a black casing with internal lighting from LED's. A dense array of colored markers is arranged in the body's interior. Captured images are sent directly to a PC, and the deformation of the elastic body due to external force is measured to sub-pixel precision (equivalent to about 20 μm) by tracking the centers of mass of the markers. To obtain rich depth information with a single RGB camera, two layers of red and blue markers are positioned at

CHI 2005







UnMousePad

The UnMousePad - An Interpolating Multi-Touch Force-Sensing Input Pad

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New York University Media Research Lab

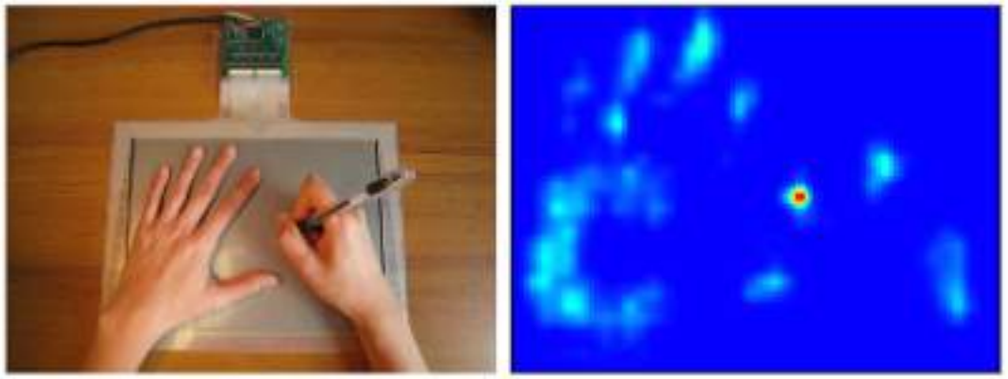

Figure 1: *Writing on an UnMousePad and the resulting force image (warmer colors represent greater pressure). The red dot corresponds to the high pressure point created by the pen tip.*

Abstract

Recently, there has been great interest in multi-touch interfaces. Such devices have taken the form of camera-based systems such as Microsoft Surface [de los Reyes et al. 2007] and Perceptive Pixel's FTIR display [Han 2005] as well as hand-held devices using capacitive sensors such as the Apple iPhone [Jobs et al. 2008]. However, optical systems are inherently bulky while most capacitive systems are only practical in small form factors and are limited in their application since they respond only to human touch and are insensitive to variations in pressure [Westerman 1999].

We have created the UnMousePad, a flexible and inexpensive multi-touch input device based on a newly developed pressure-sensing principle called Interpolating Force Sensitive Resistance. IFSR sensors can acquire high-quality anti-aliased pressure images at high frame rates. They can be paper-thin, flexible, and transparent and can easily be scaled to fit on a portable device or to cover an entire table, floor or wall. The UnMousePad can sense three orders of magnitude of pressure variation, and can be used to distinguish multiple fingertip touches while simultaneously tracking pens and styli with a positional accuracy of 87 dpi, and can sense the pressure distributions of objects placed on its surface.

In addition to supporting multi-touch interaction, IFSR is a general pressure imaging technology that can be incorporated into shoes, tennis racquets, hospital beds, factory assembly lines and many other applications. The ability to measure high-quality pressure images at low cost has the potential to dramatically improve the way that people interact with machines and the way that machines interact with the world.

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ACM Reference Format
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CR Categories: H.5.2 [Information interfaces and presentation]: User Interfaces—Input devices and strategies;

Keywords: Multi-Touch Devices, Input Devices, Sensors, Mobile and Personal Devices, FSR, IFSR

1 Introduction

Multi-touch input has been an active area of research for over two decades [Buxton et al. 1985] but has always suffered from the absence of an easily available high-quality touch input device that is accurately responsive to pressure and can scale inexpensively to large or small form factors. For this reason, exciting user interfaces developed in the lab have appeared on CNN [Han 2005], but not on everyone's desks, computer screens, table-tops, walls and floors. What has been needed - and lacking - is an inexpensive, flexible and sensitive *touch imaging* technology, capable of capturing even subtle variations in gesture.

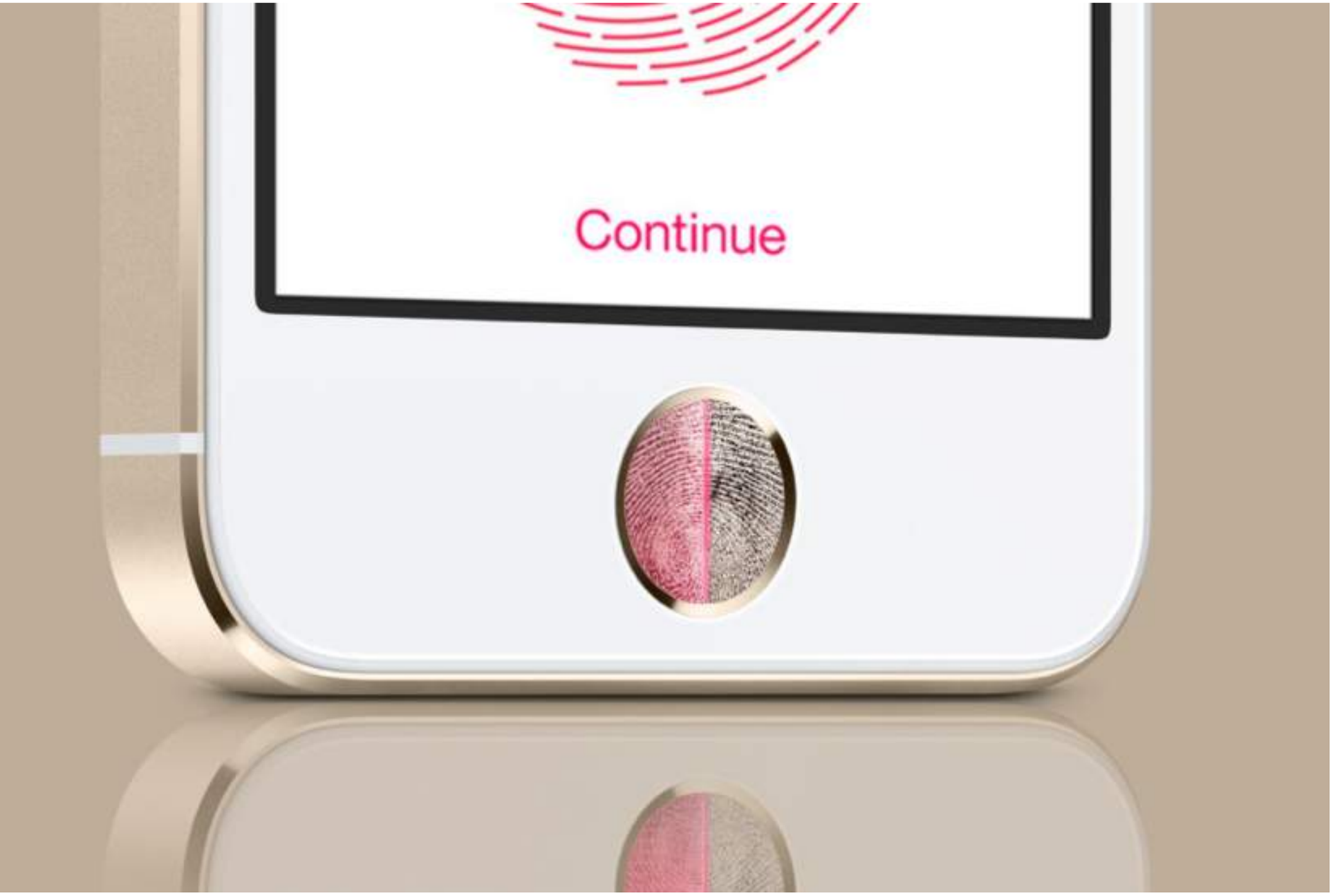
The UnMousePad is a novel form of input sensor that enables inexpensive multi-touch pressure acquisition. It can accurately measure entire images of pressure with continuous bilinear interpolation, permitting both high-frame-rate and high-quality imaging of spatially variant pressure upon a surface.

Though the use of force-variable resistors at multiple points of contact is not new [Malacaria 1998], previous work in this area has focused mainly on arrays of discrete and independent sensors. The key difference between the UnMousePad and previous technologies is the newly developed principle of Interpolating Force Sensitive Resistance (IFSR), which closely mimics the multi-resolution properties of human skin, in which the position of a touch can be detected at finer scale than the discrimination of multiple touches.

The development of the UnMousePad and other IFSR based sen-

SIGGRAPH 2009

user identification on each touch



what if we had **finger print** detection on the entire screen?

<30 second brainstorming>


Fiberio is the first **secure** multitouch table

Fiberio: A Touchscreen that Senses Fingerprints

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ABSTRACT
We present Fiberio, a rear-projected multitouch table that identifies users biometrically based on their fingerprints *during* each touch interaction. Fiberio accomplishes this using a new type of screen material: a large fiber optic plate. The plate *diffuses* light on transmission, thereby allowing it to act as projection surface. At the same time, the plate *reflects* light specularly, which produces the contrast required for fingerprint sensing. In addition to offering all the functionality known from traditional diffused illumination systems, Fiberio is the first interactive tabletop system that authenticates users during touch interaction—unobtrusively and securely using the biometric features of fingerprints, which eliminates the need for users to carry any identification tokens.

Author Keywords
Touchscreens; multitouch; user identification; fingerprints.

ACM Classification Keywords
H5.2 [Information interfaces and presentation]: User Interfaces. Input devices & strategies.

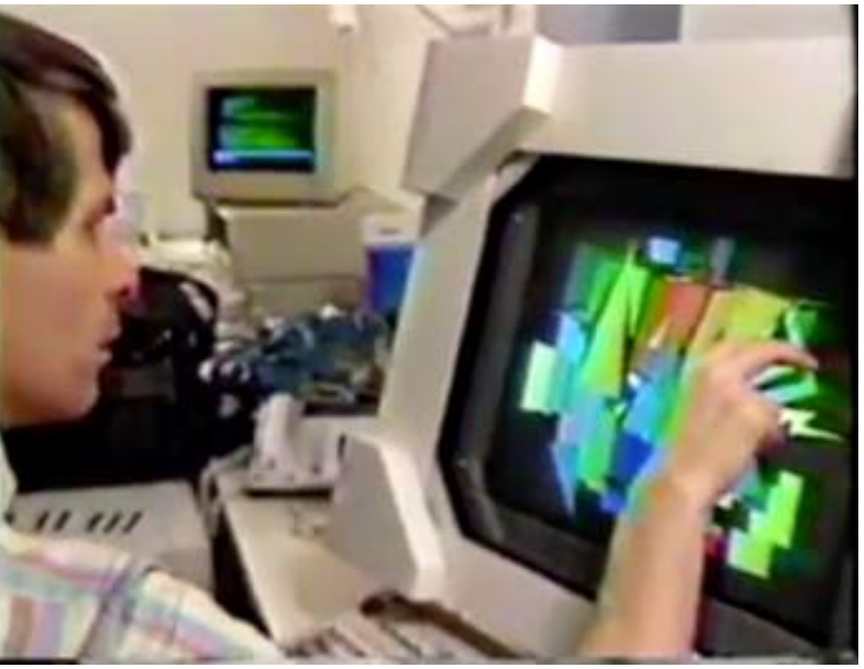
INTRODUCTION
Several researchers have proposed techniques that allow

Figure 1: ***Fiberio*** **is a rear-projected tabletop system that identifies users based on their fingerprints** ***during each***

let’s zoom out

towards more natural user interaction!
use your hands to interact.

1963



1986

2007

let’s take a **5 minute break!**

end.