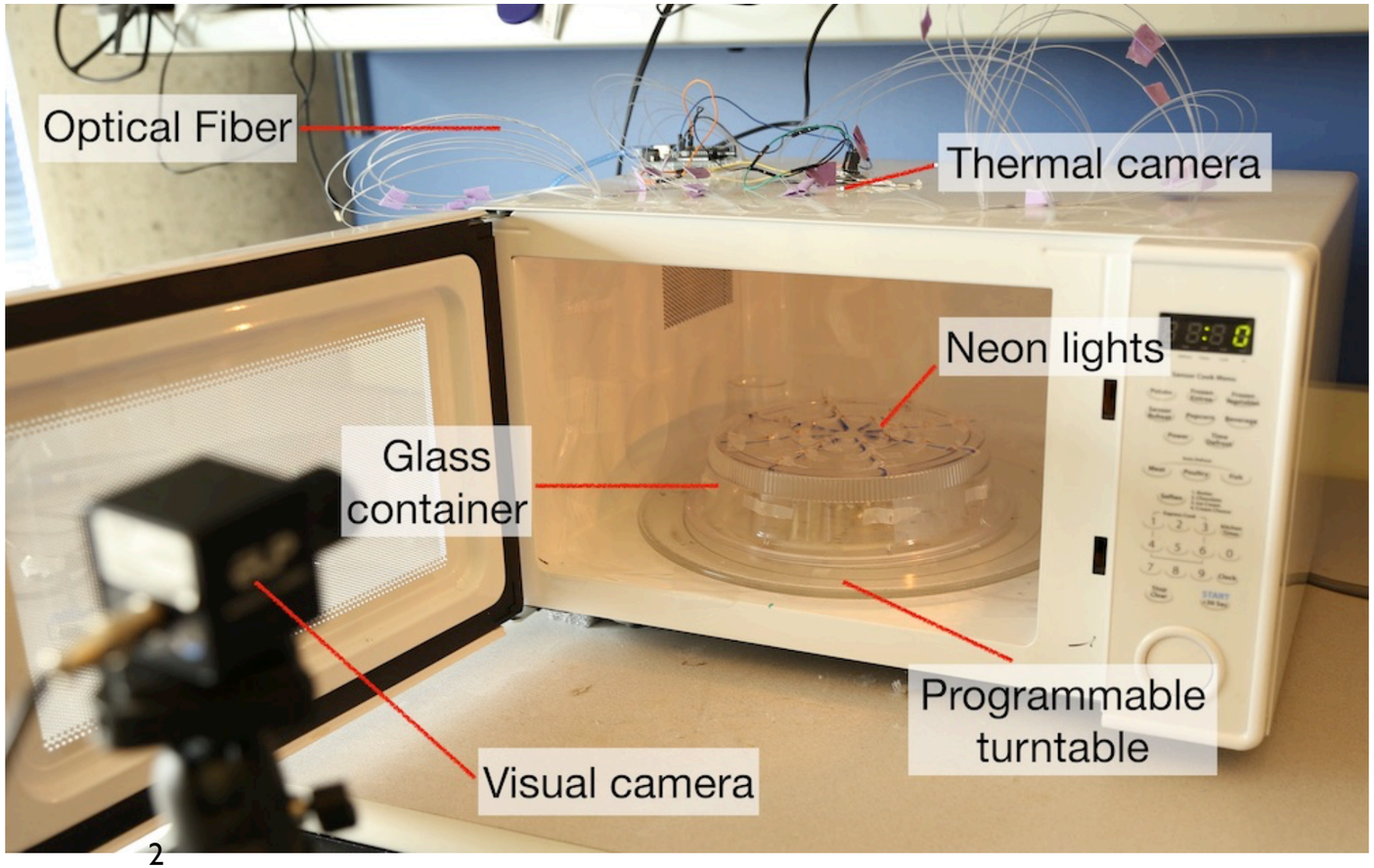

SHARP
Carousel
Sensor Cook Menu
Potato
Frozen Entree
Frozen Vegetables
Sensor Reheat
Popcorn
Beverage
Power
Time Defrost
Meat
Poultry
Fish
Soften
Express Cook
1
2
3
Kitchen Timer
4
5
6
0
7
8
9
Clock
Stop Clear
START
+30 Sec

Software Defined Cooking (SDC)
using a microwave oven

Haojian Jin
Jingxian Wang
Swarun Kumar
Jason Hong

Carnegie Mellon University



Cooking is the **application of heat** to ingredients to transform them via chemical and physical reactions

Jeff Potter. Cooking for Geeks: Real Science, Great Hacks, and Good Food.

Cooking is the **application of heat** to ingredients to transform them via chemical and physical reactions

SDC = programmable heating

heat the food in a software-defined thermal trajectory (recipe).

Jeff Potter. Cooking for Geeks: Real Science, Great Hacks, and Good Food.

overcooking the fat,

without burning the meat.

https://www.huffpost.com/entry/bacon-mistakes-how-to-cook_n_3111706

Software-defined Cooking Recipe

Cooked = Temperature x Time x Space

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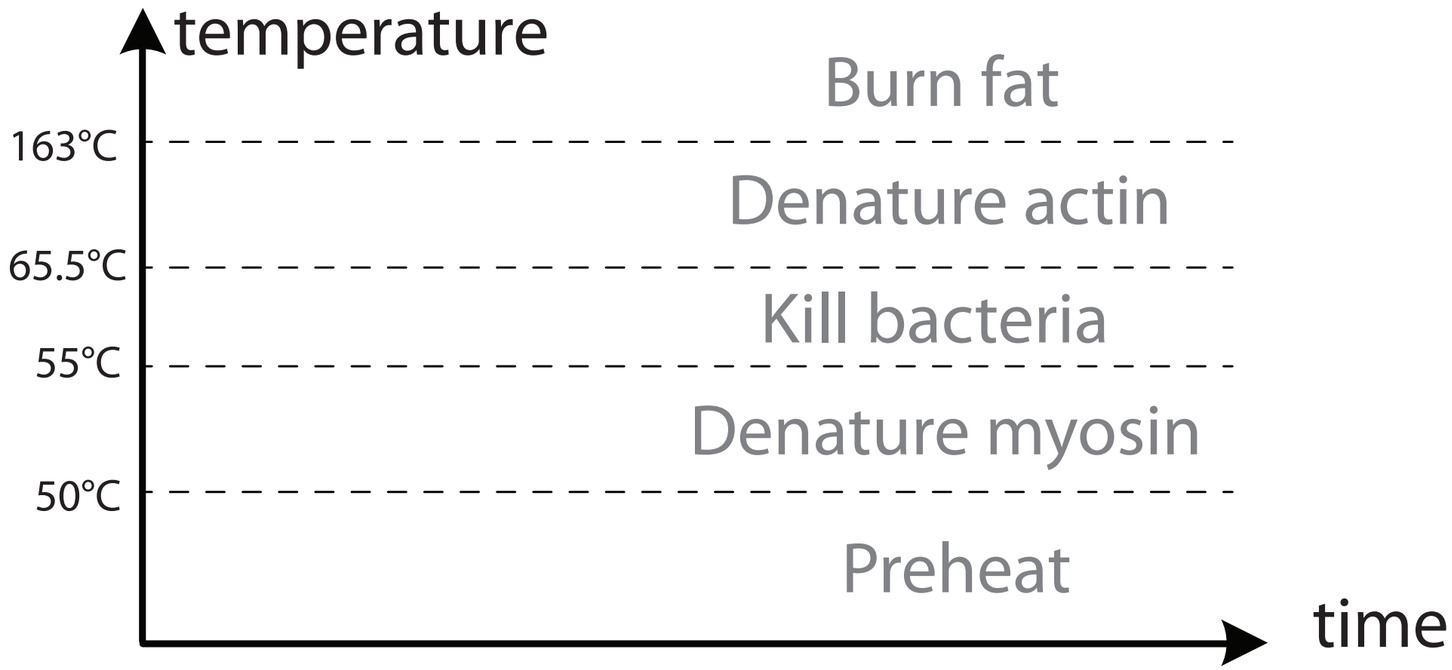
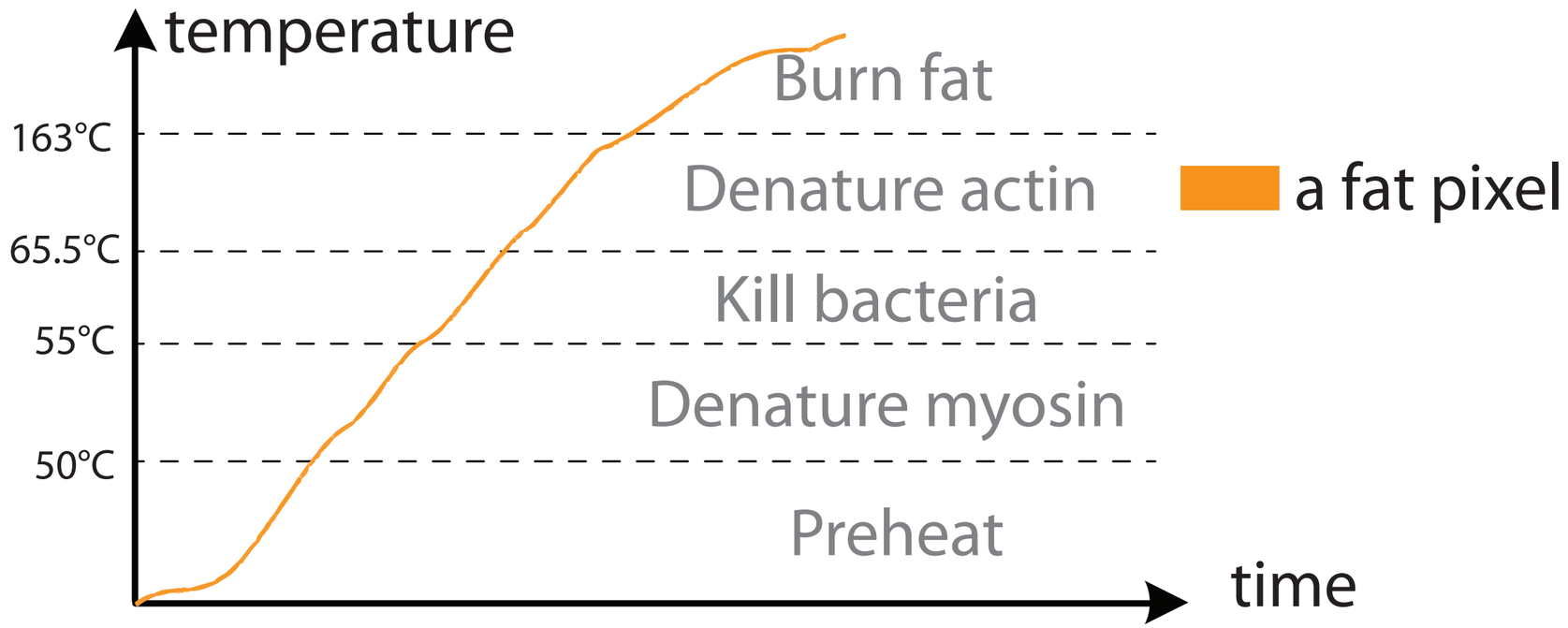


Software-defined Cooking Recipe

Cooked = Temperature x **Time** x Space



Software-defined Cooking Recipe

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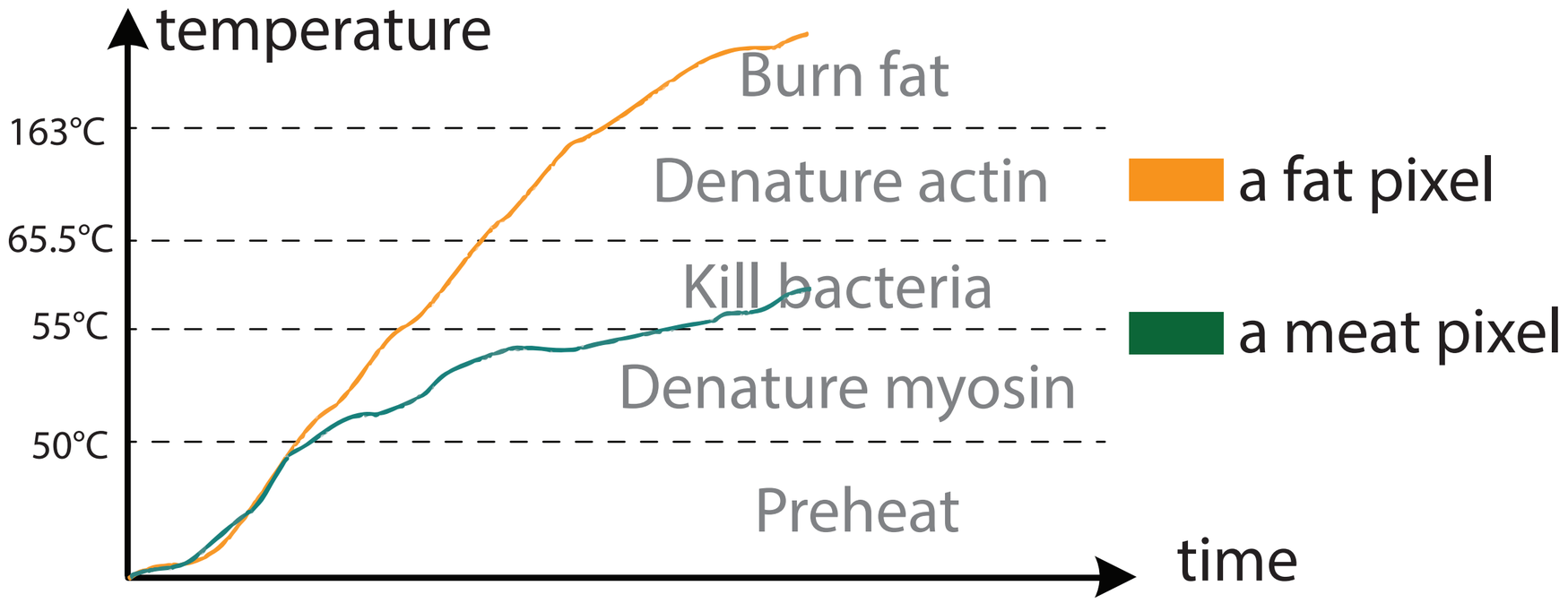

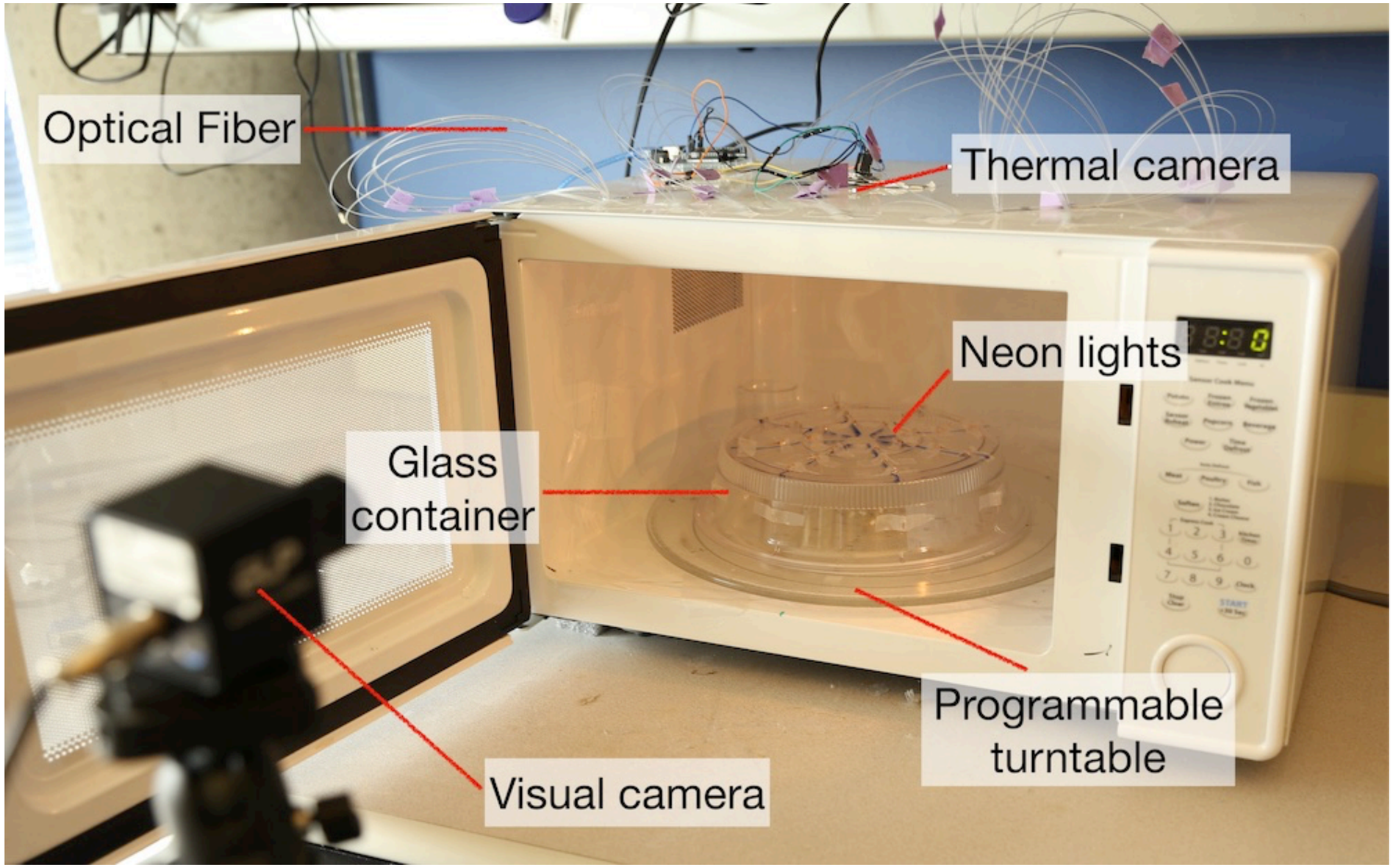

SDC (software-defined cooking): a novel low-cost **closed-loop** system that can **sense** and **control** heating at a **fine-grained** resolution.

SDC (software-defined cooking): a novel low-cost **closed-loop** system that can **sense** and **control** heating at a **fine-grained** resolution.

Spoiler alert

No Turntable

Default Turntable

high heat

SDC Uniform Heating

SDC Arbitrary Heating

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SDC Uniform Heating

SDC Arbitrary Heating


third most popular domestic heating method (after baking and grilling)
ZUCCHERO
SALE
CAFFE
VIKING

Today's Microwave: a **blunt heating** device

reheating leftovers

uneven & **unpredictable** heating

Microwave can only heat food **blindly**

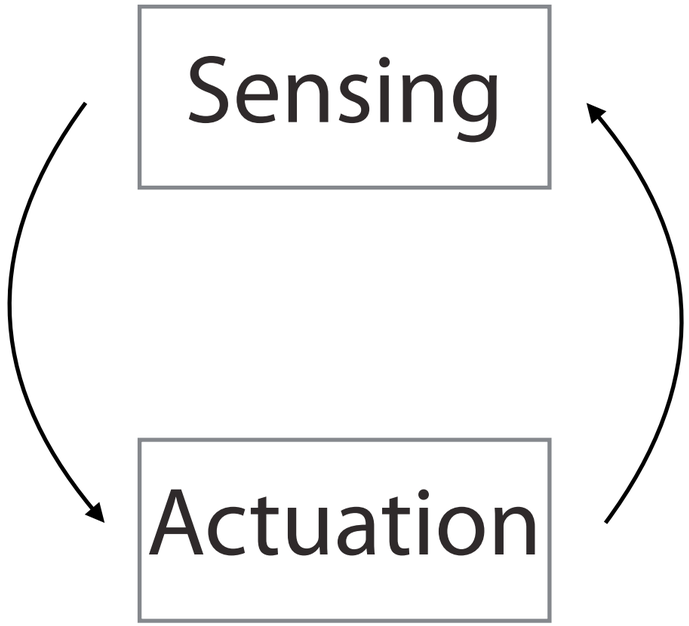
1 Don’t know how much heat each food pixel has absorbed.

2 Have no way to actuate heating on a specific food pixel.

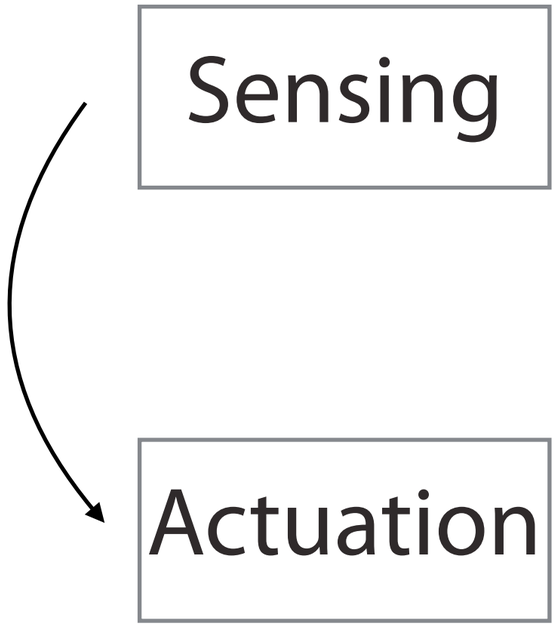
A **closed-loop** system to heat **smartly**

1 ~~Don't know how much heat each food pixel has absorbed.~~

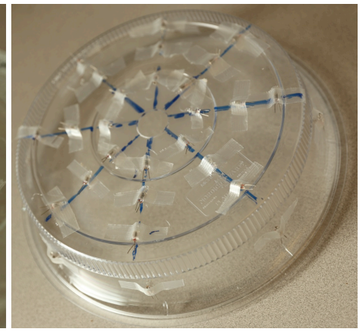
2 ~~Have no way to actuate heating on a specific food pixel.~~

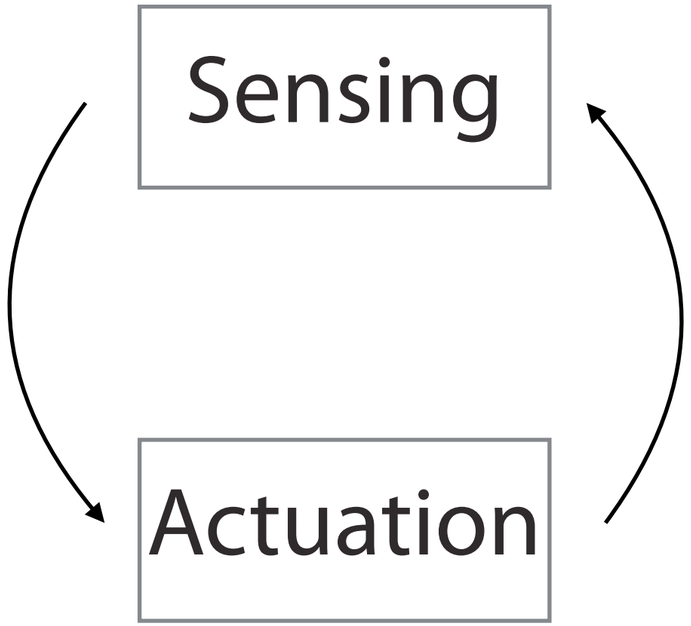


A **closed-loop** system to heat **smartly**



A **closed-loop** system to heat **smartly**





Heat Sensing

Sensing related work (1)

Most electronics & batteries are not microwave-safe.

Sensing related work (2)

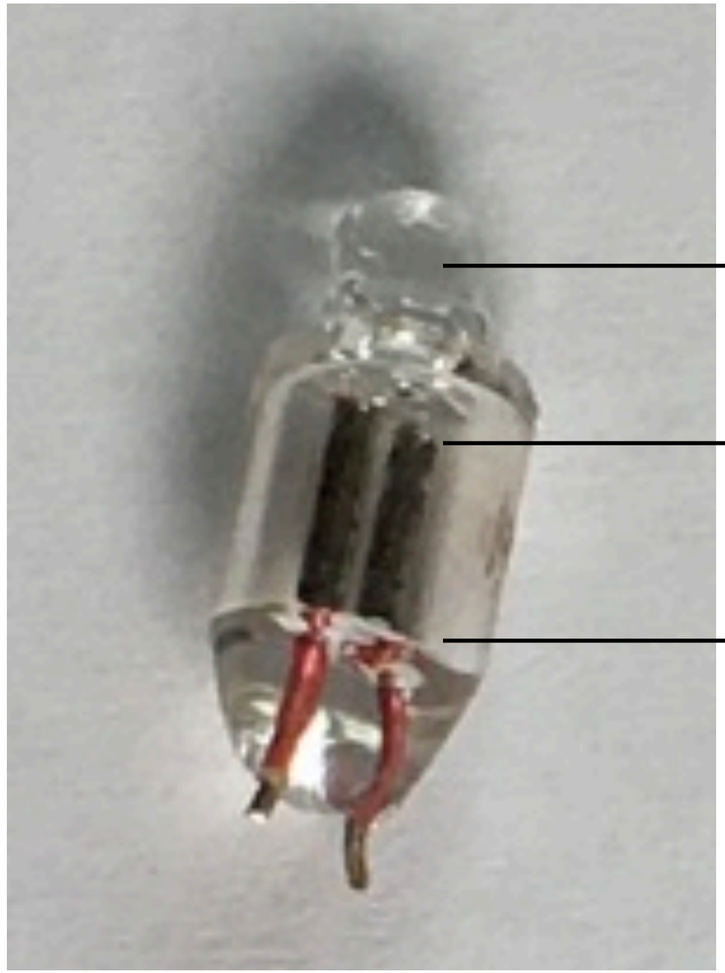
Microwave Synthesis Workstation

8 temperature sensors

$ 86,000+

Specialized microwave-safe sensors are
delicate and expensive.

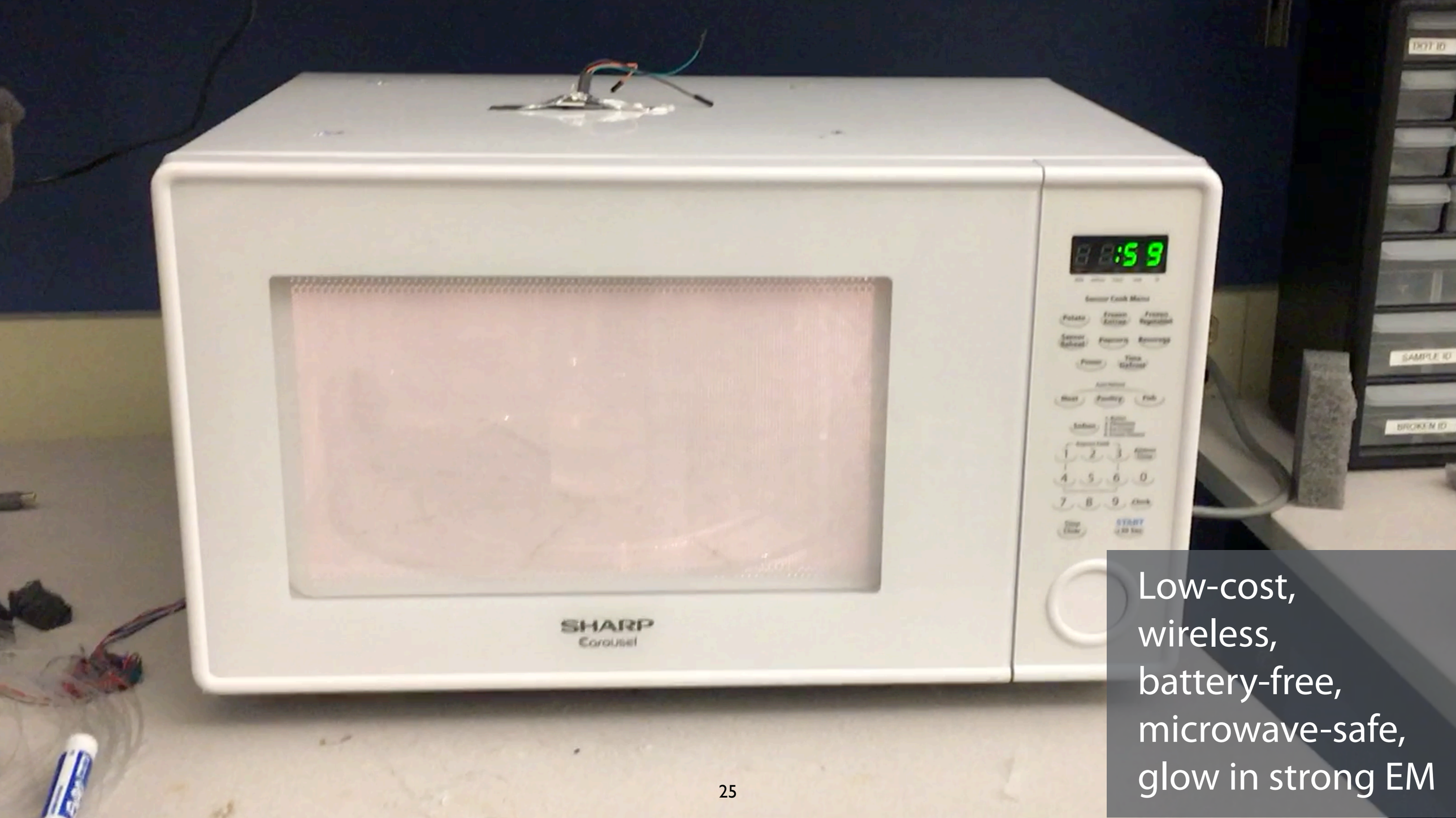
Neon lights



Glass

Electrodes

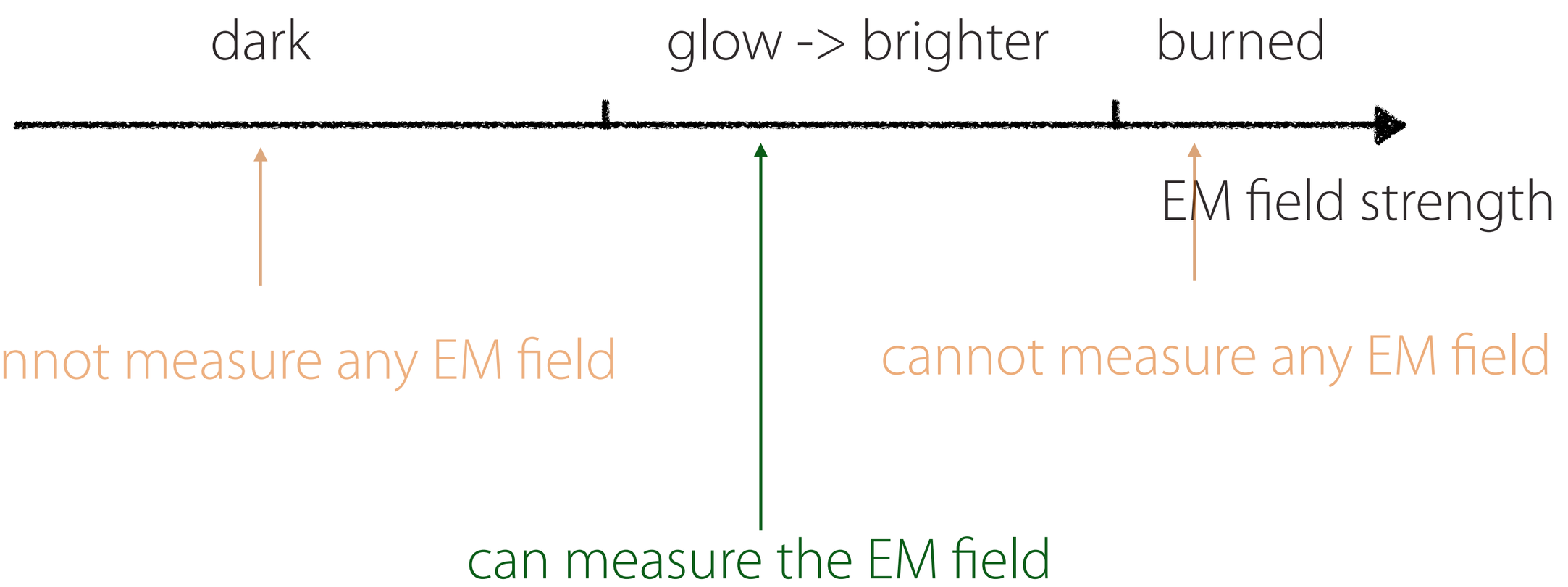
Low-pressure
Neon gas mixture



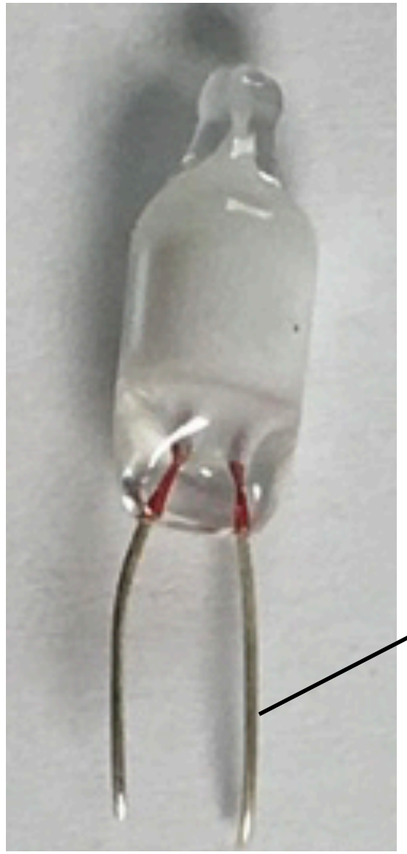
Low-cost,
wireless,
battery-free,
microwave-safe,
glow in strong EM

Programming EM sensitivity

Programming EM sensitivity



Programming EM sensitivity



Wires as the antenna for energy harvesting

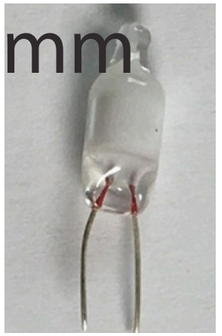
Glowing principles => Paper

Programming EM sensitivity

0 mm

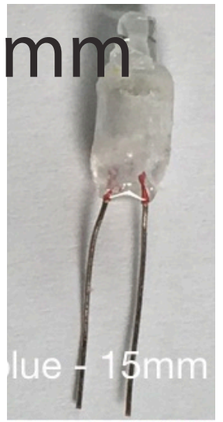
dark glow -> brighter burned

7.5 mm



dark glow -> brighter burned

15 mm



dark glow -> brighter burned

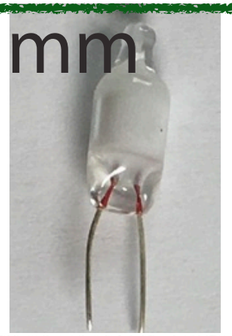
EM field strength

Programming EM sensitivity

0 mm

dark glow -> brighter burned

7.5 mm



dark glow -> brighter burned

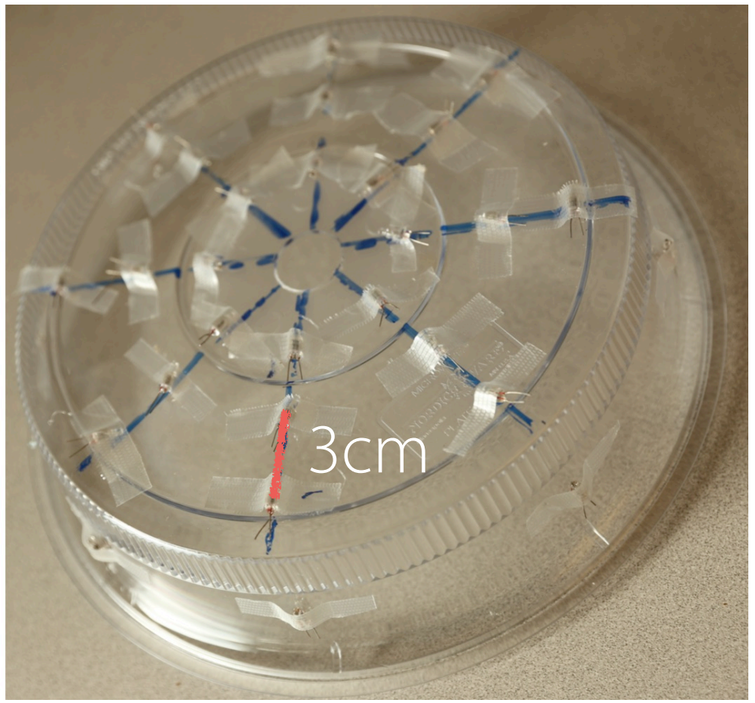
15 mm

dark glow -> brighter burned

EM field strength

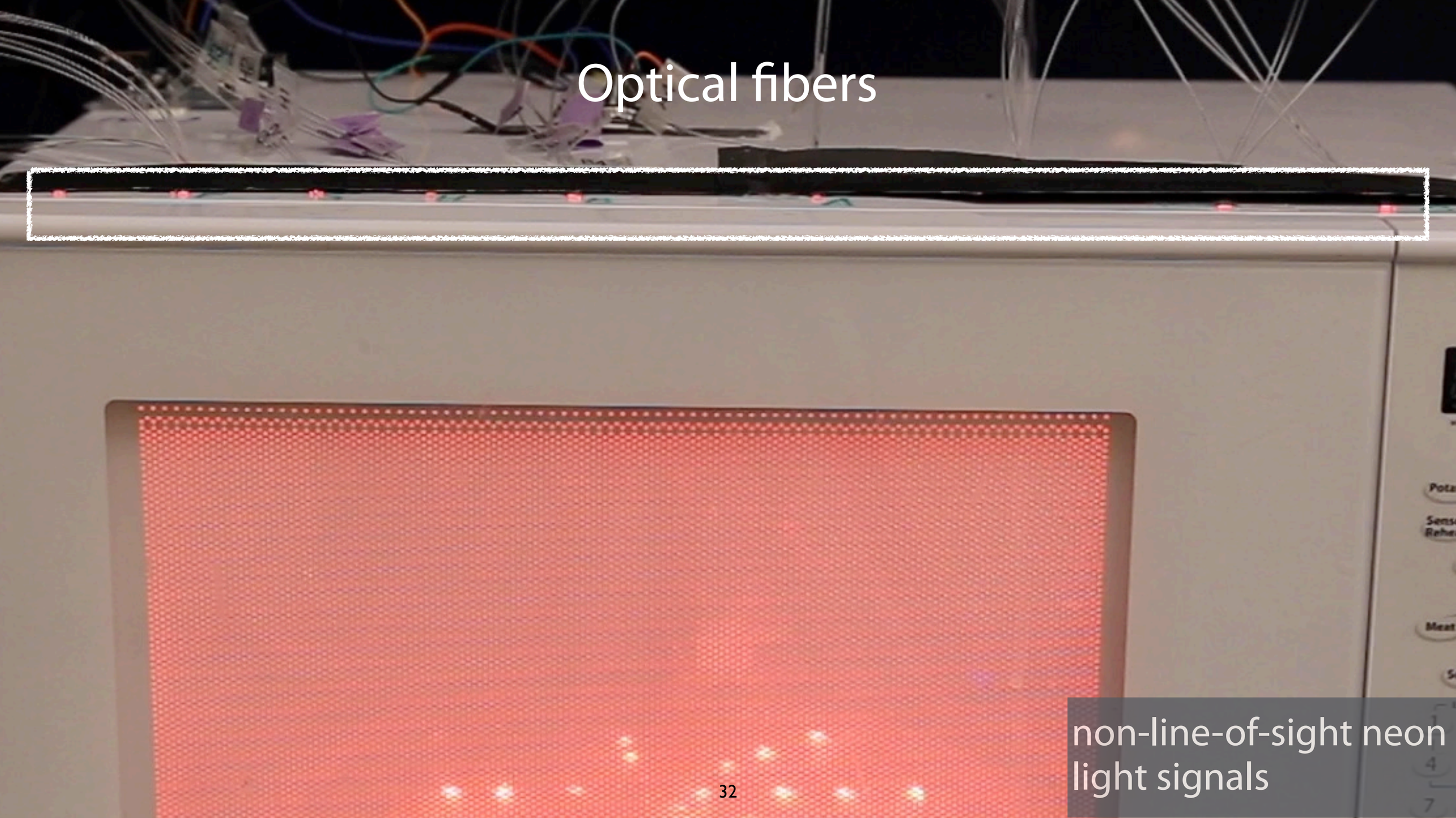
Placement of Neon Lights

turntable with 32 neon lights



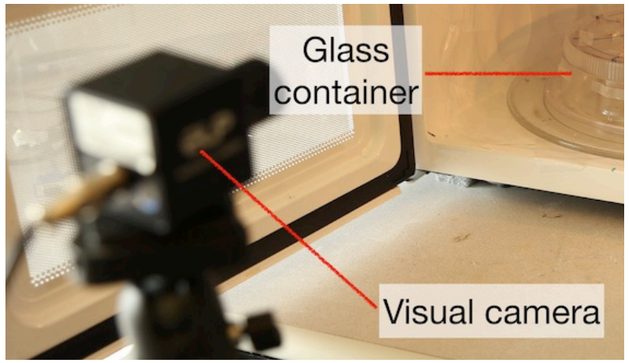
cover with 32 neon lights

Optical fibers

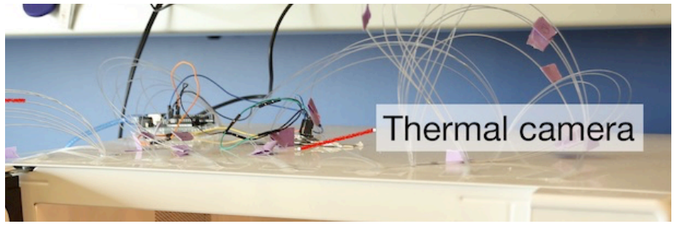


non-line-of-sight neon light signals

Sensors



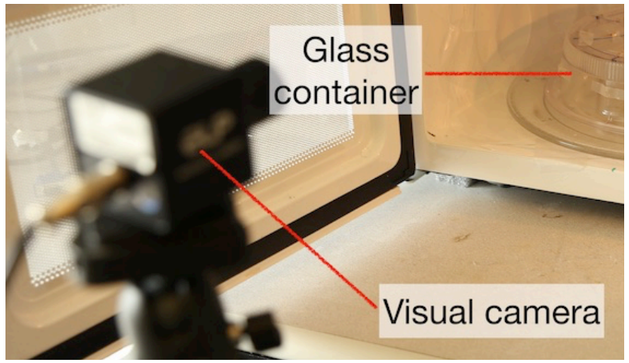
A web cam



A thermal cam

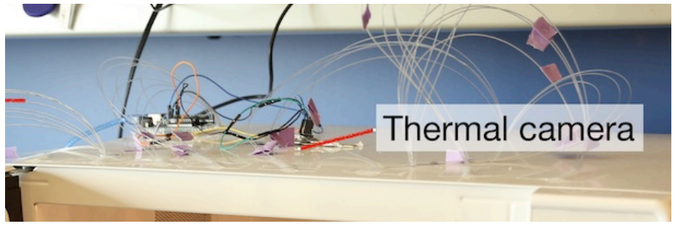
Sensors

Raw data



A web cam

3D EM field



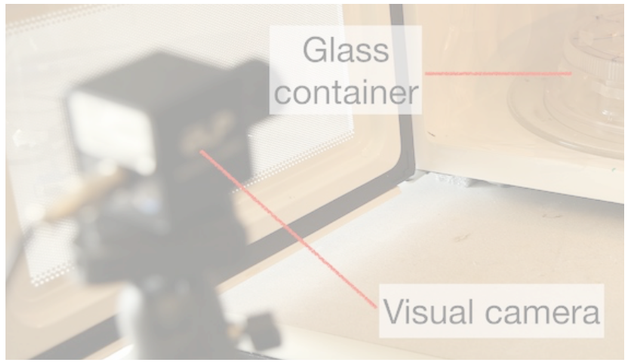
A thermal cam

raw temperature

Sensors

Raw data

Output



A web cam

3D EM field

A thermal cam

raw temperature

extended kalman filter

Temperature P

Gradient P’

Heat Actuation

Actuation related work

turn table for **blind** rotation

non-uniform and **unpredicatable**

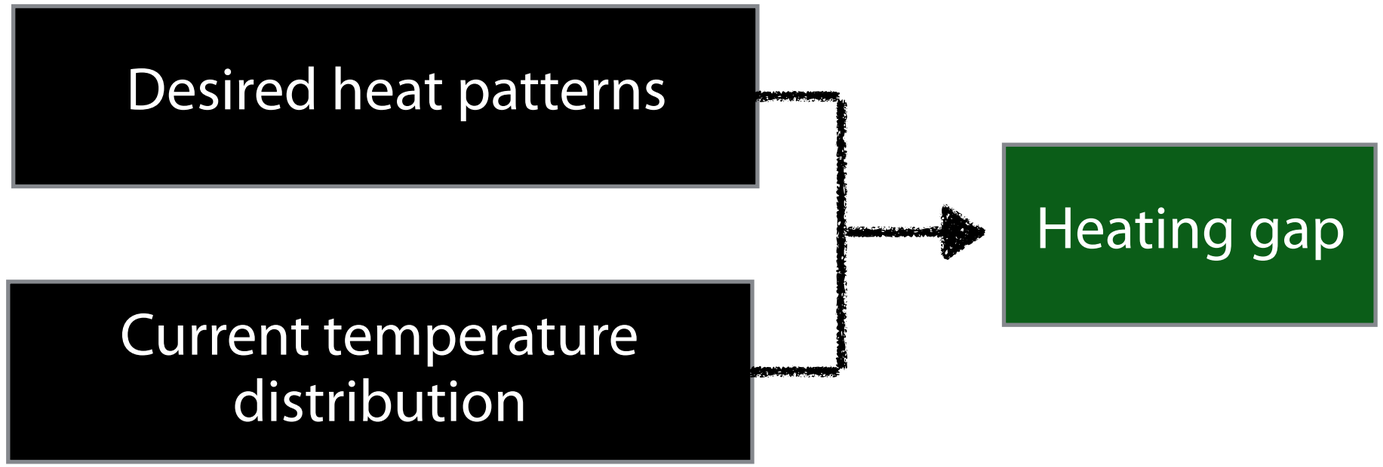
A closed-loop turntable

Desired heat patterns from software-defined recipes

Current temperature distribution from Sensors

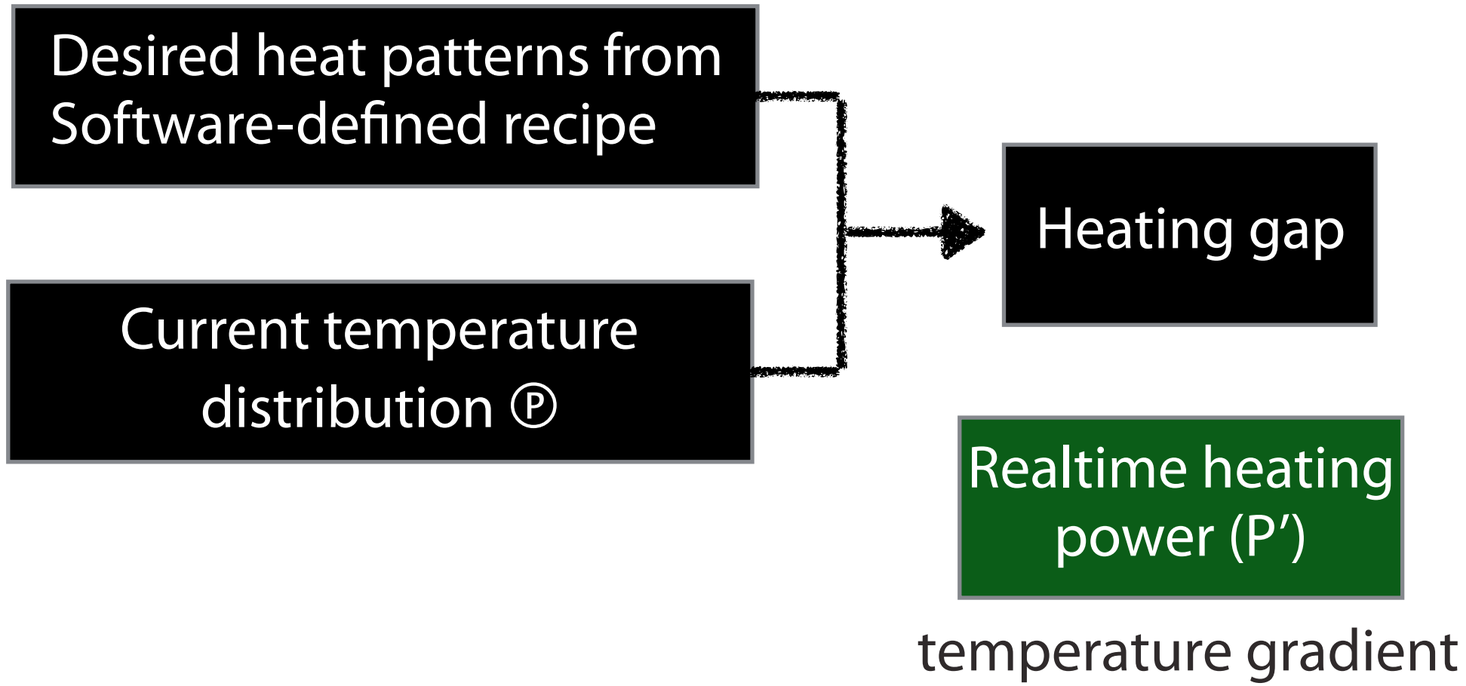
at time t

A closed-loop turntable



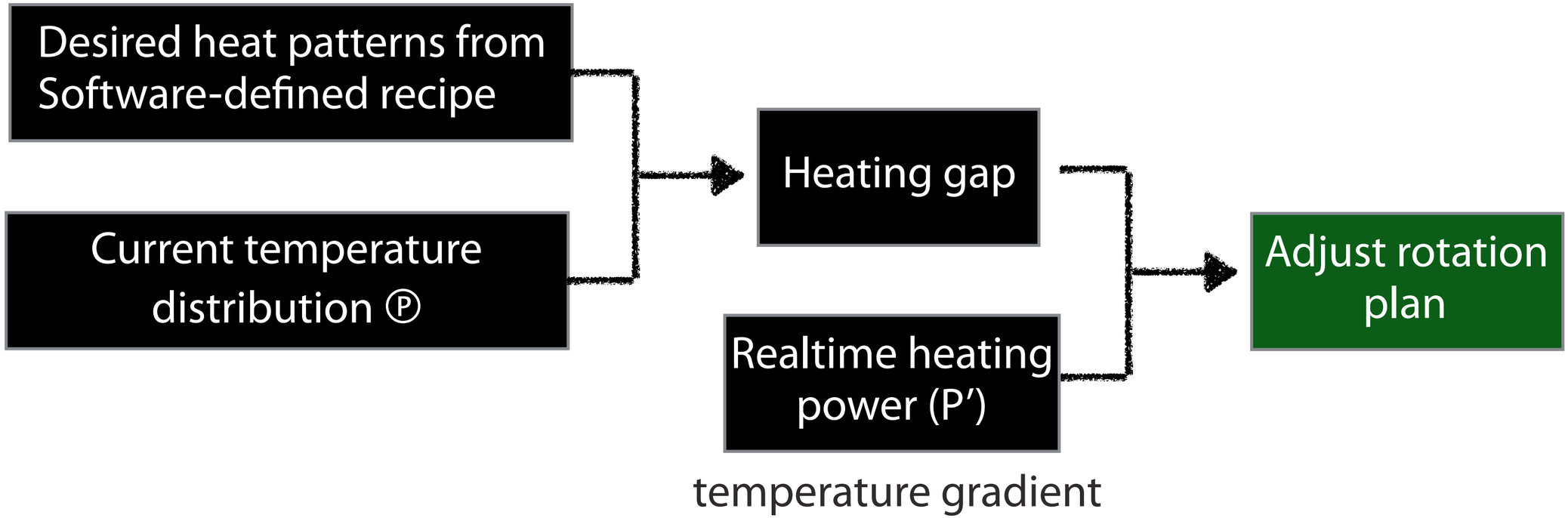
at time t

A closed-loop turntable



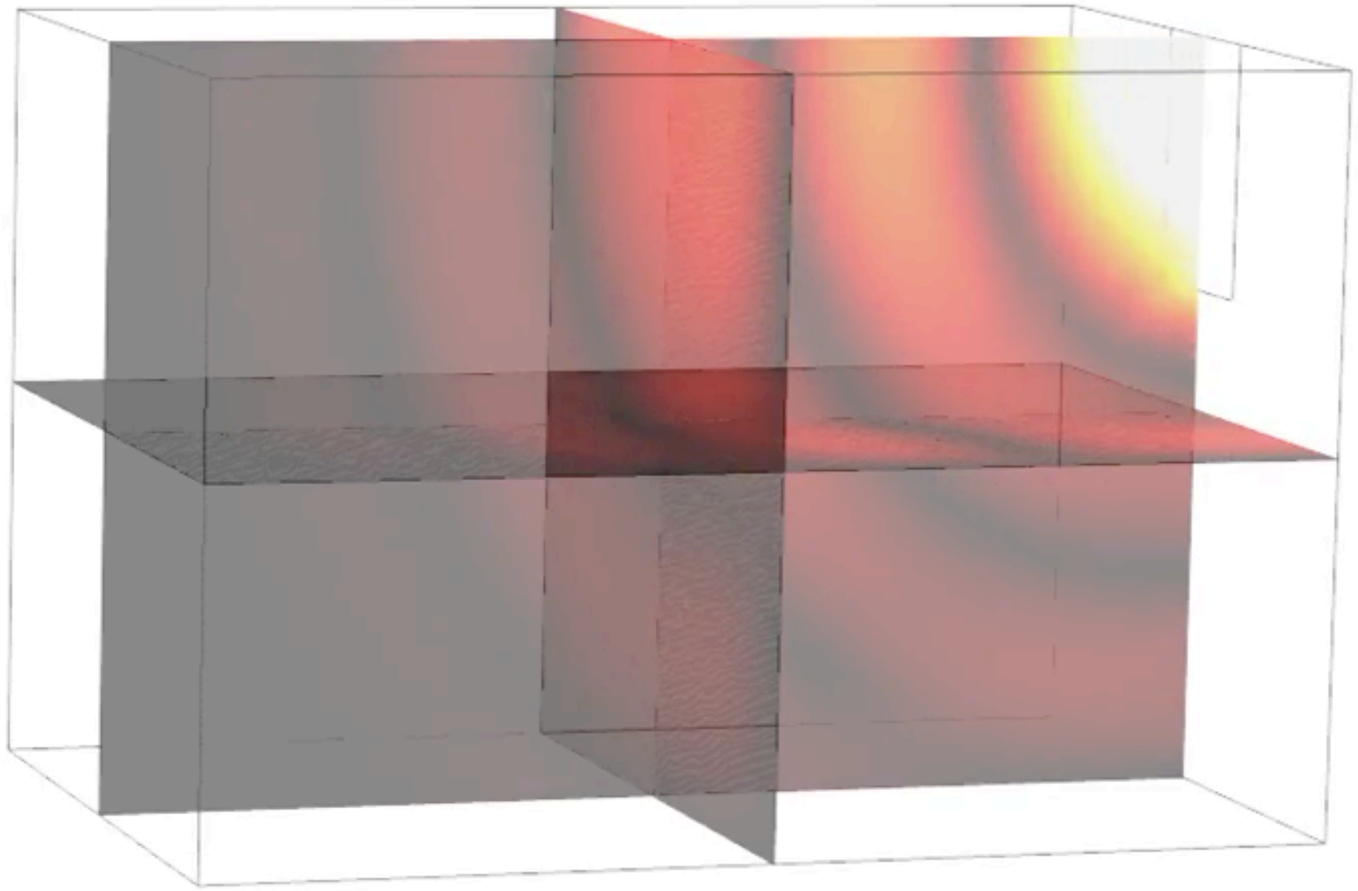
at time t

A closed-loop turntable



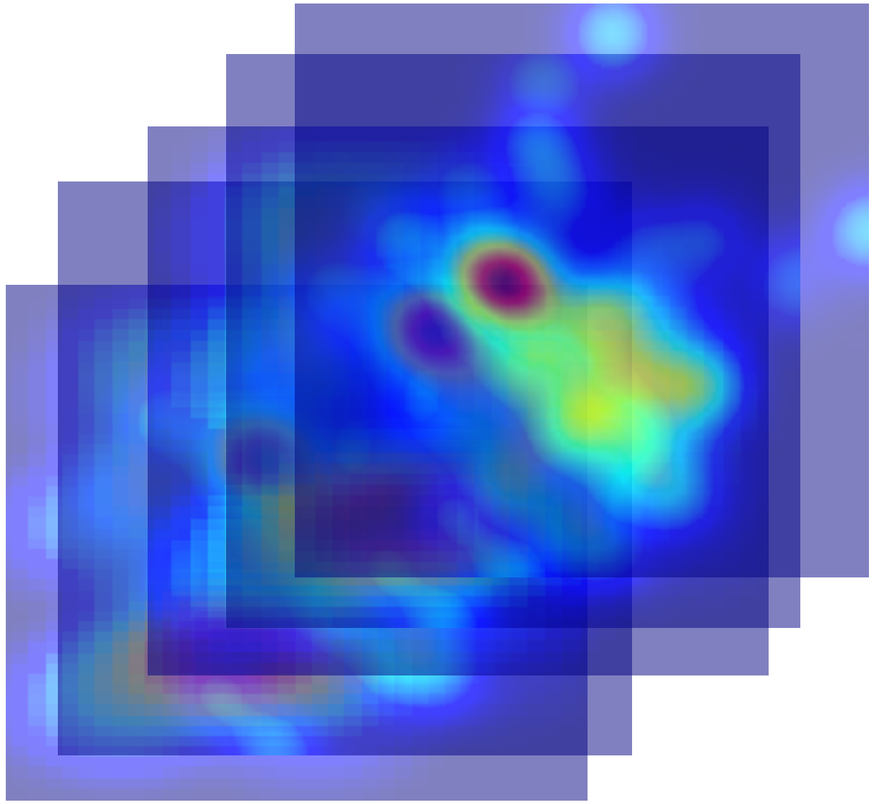
at time t

Heating patterns from 3D standing waves



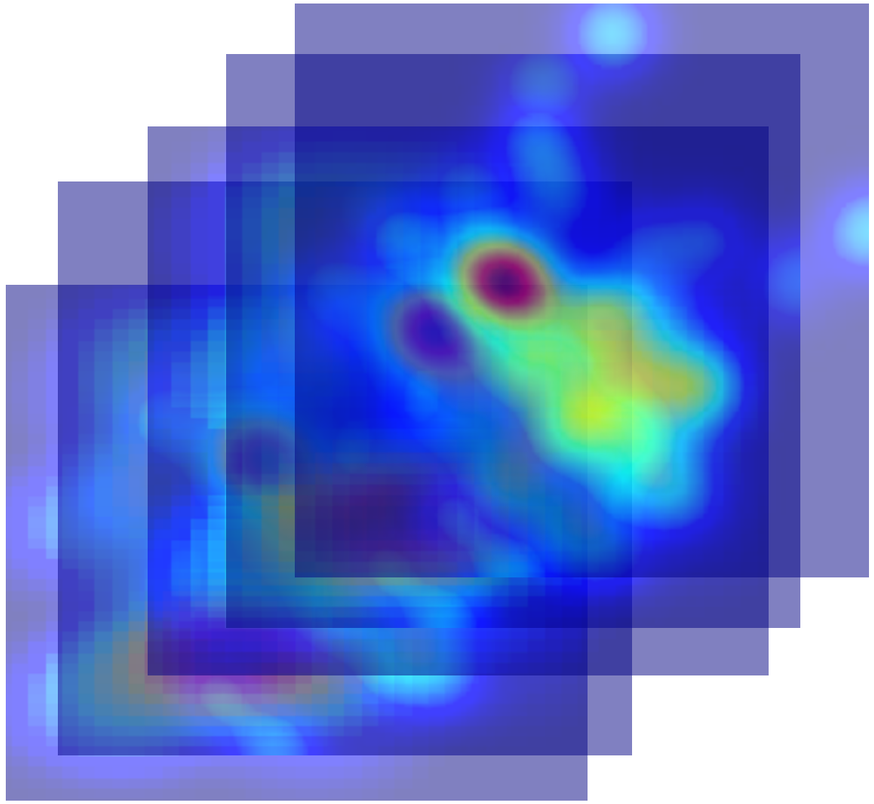
Microwave cannot heat
individual pixels independently.

Determining the rotation plan



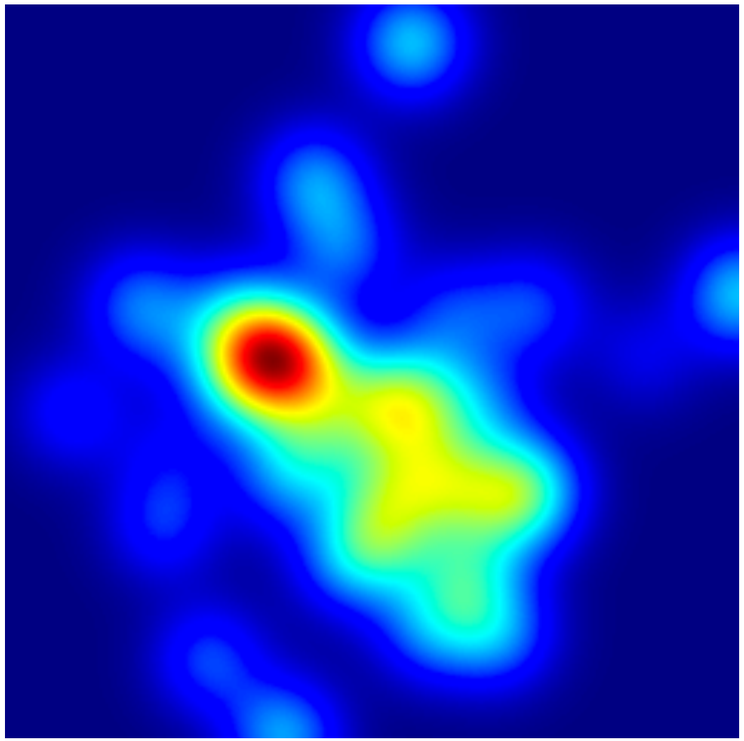
Realtime heating power (P’)

Determining the rotation plan



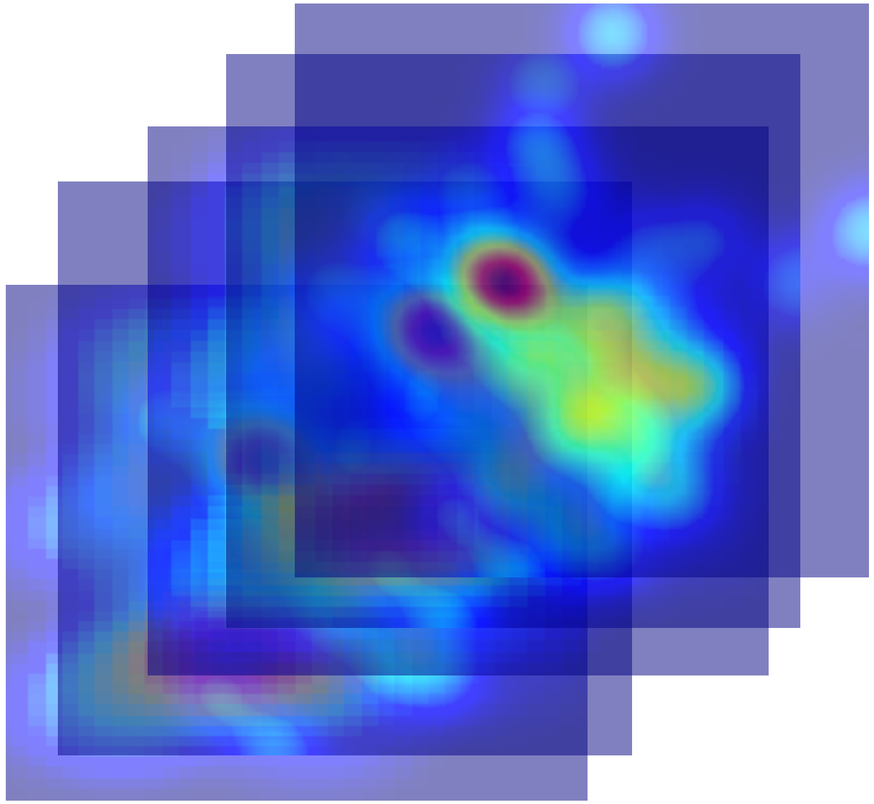
Realtime heating power (P’)

=



Heating gap

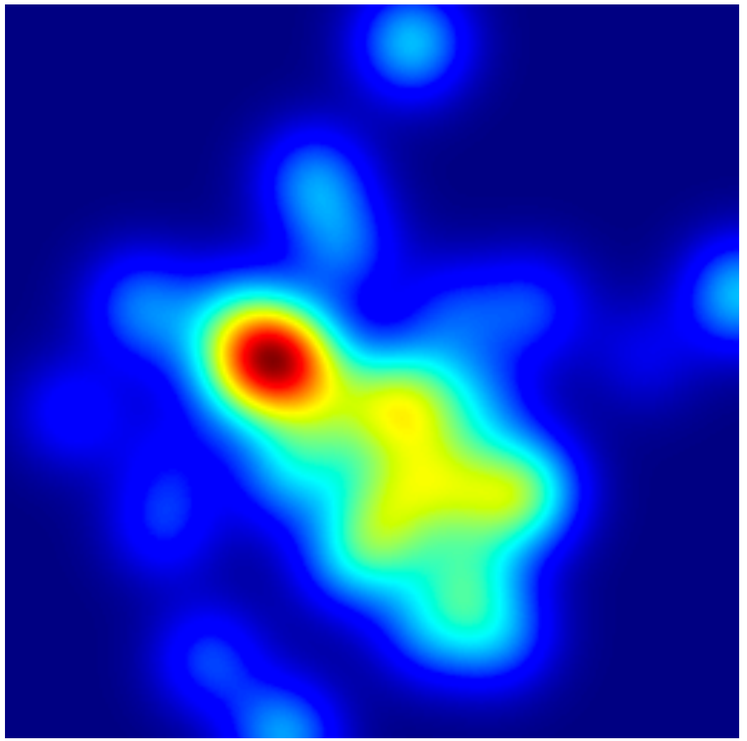
Determining the rotation plan



Realtime heating power (P')

=

a knapsack problem



Heating gap

Optimization details => Paper

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Default Turntable

SDC Uniform Heating

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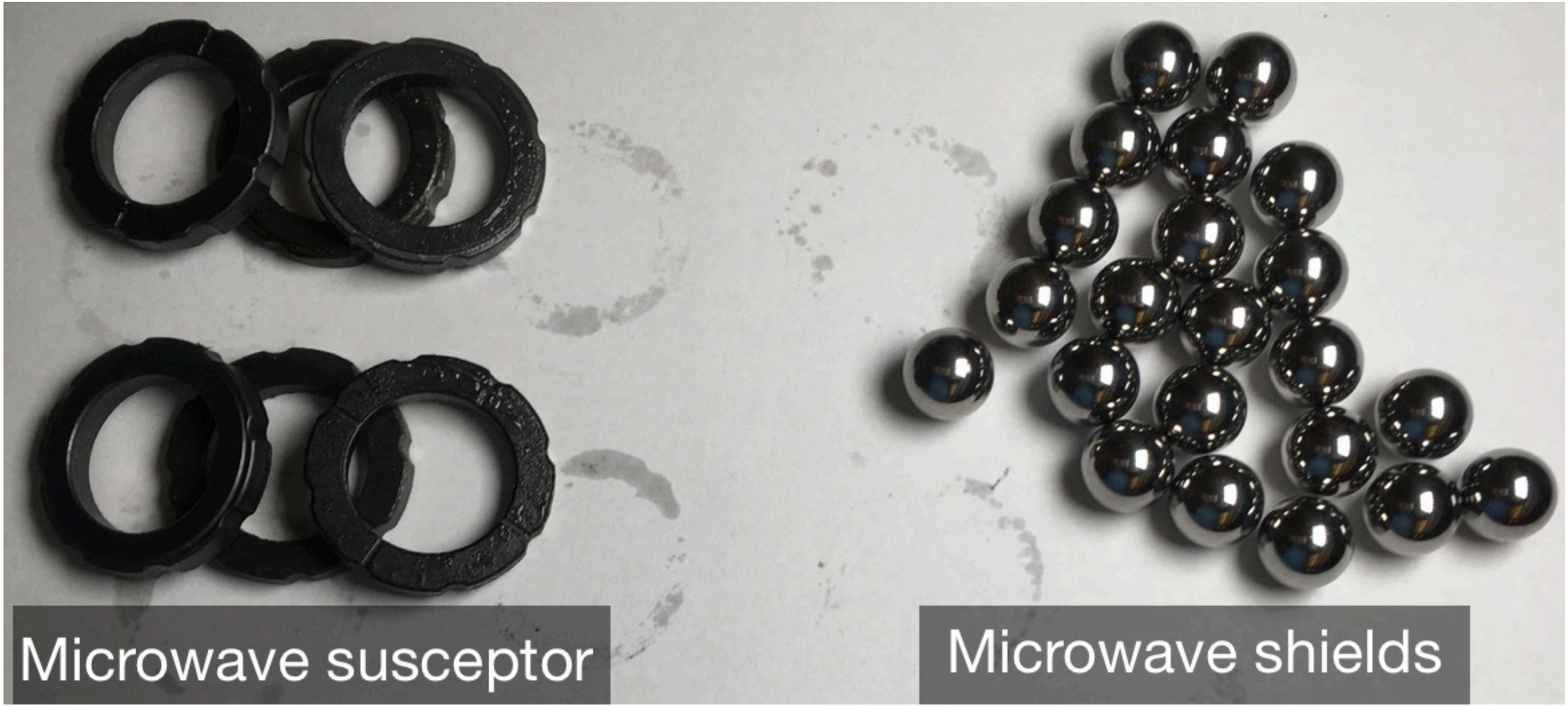
SDC Uniform Heating

SDC Arbitrary Heating

Microwave accessories



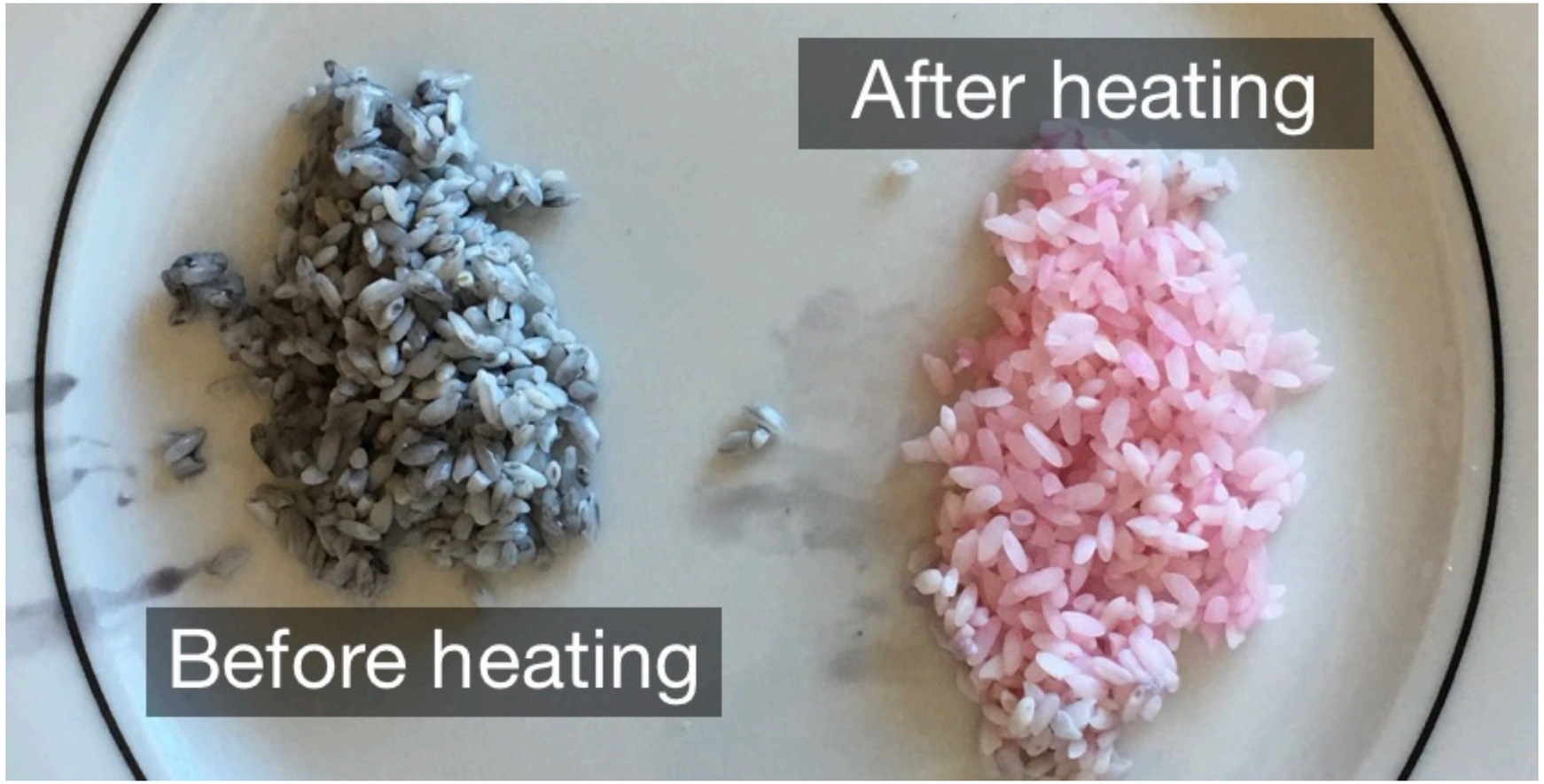
Details => Paper

patterned microwave susceptor

ensure **coverage** through SDC

Evaluation

Evaluation apparatus



thermal-chromatic pigment + rice

reusable

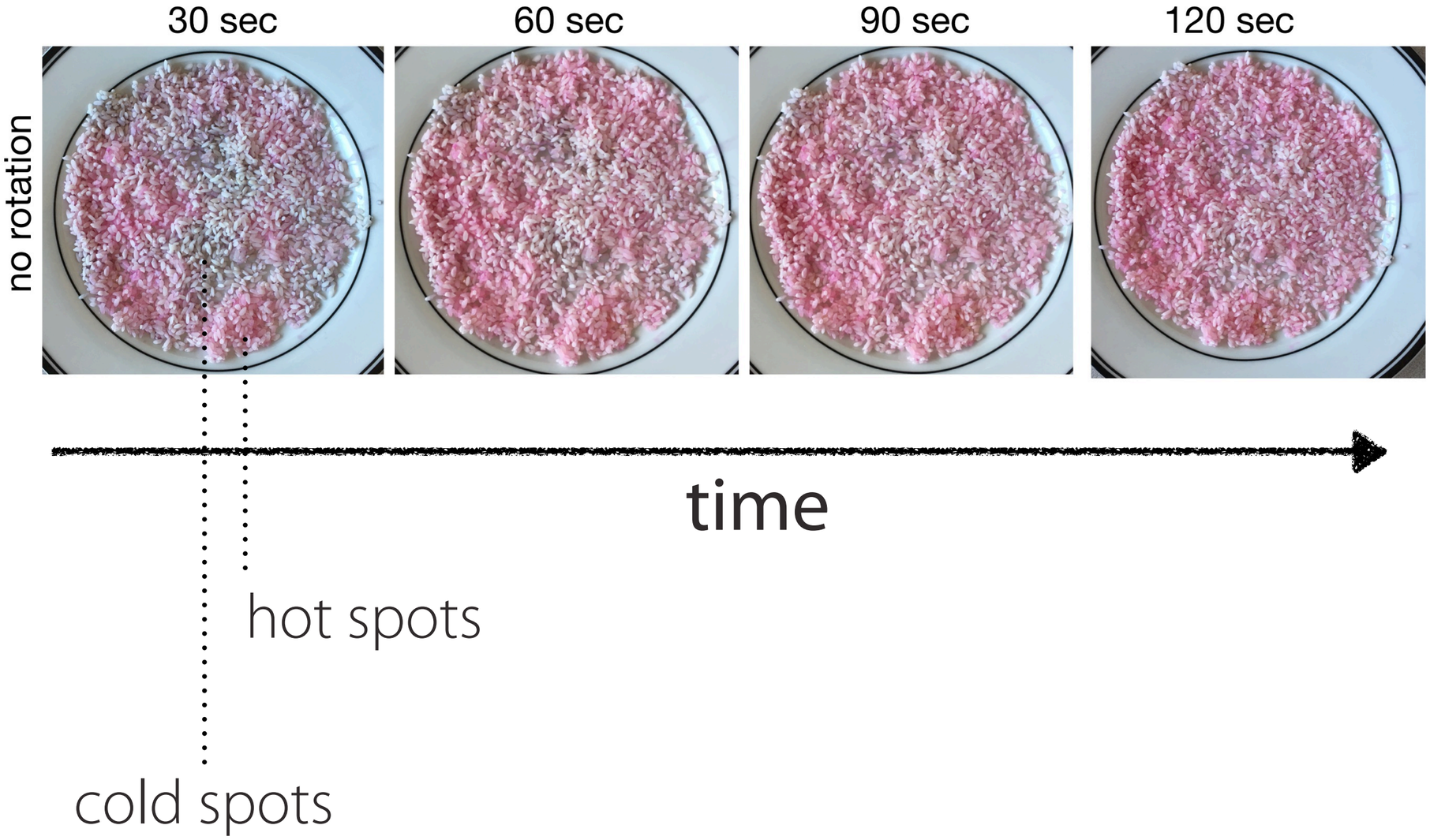
turn pink if p > 31°C

The room temperature is at 20°C.

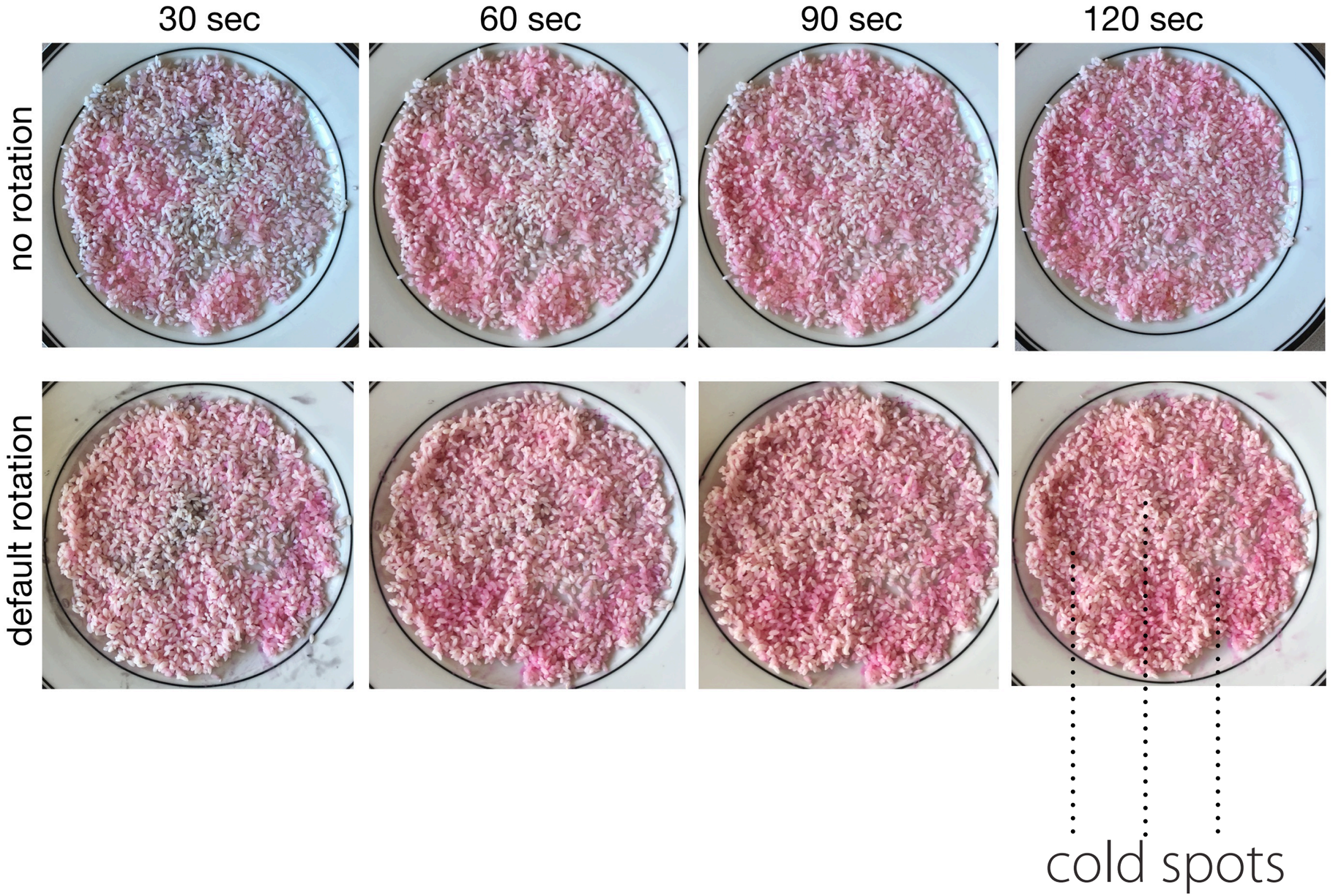
Uniform heating

heat the rice in a plate **uniformly** to 60°C in 2 minutes.

Baselines: microwave oven w/o turntable



Uniform Heating



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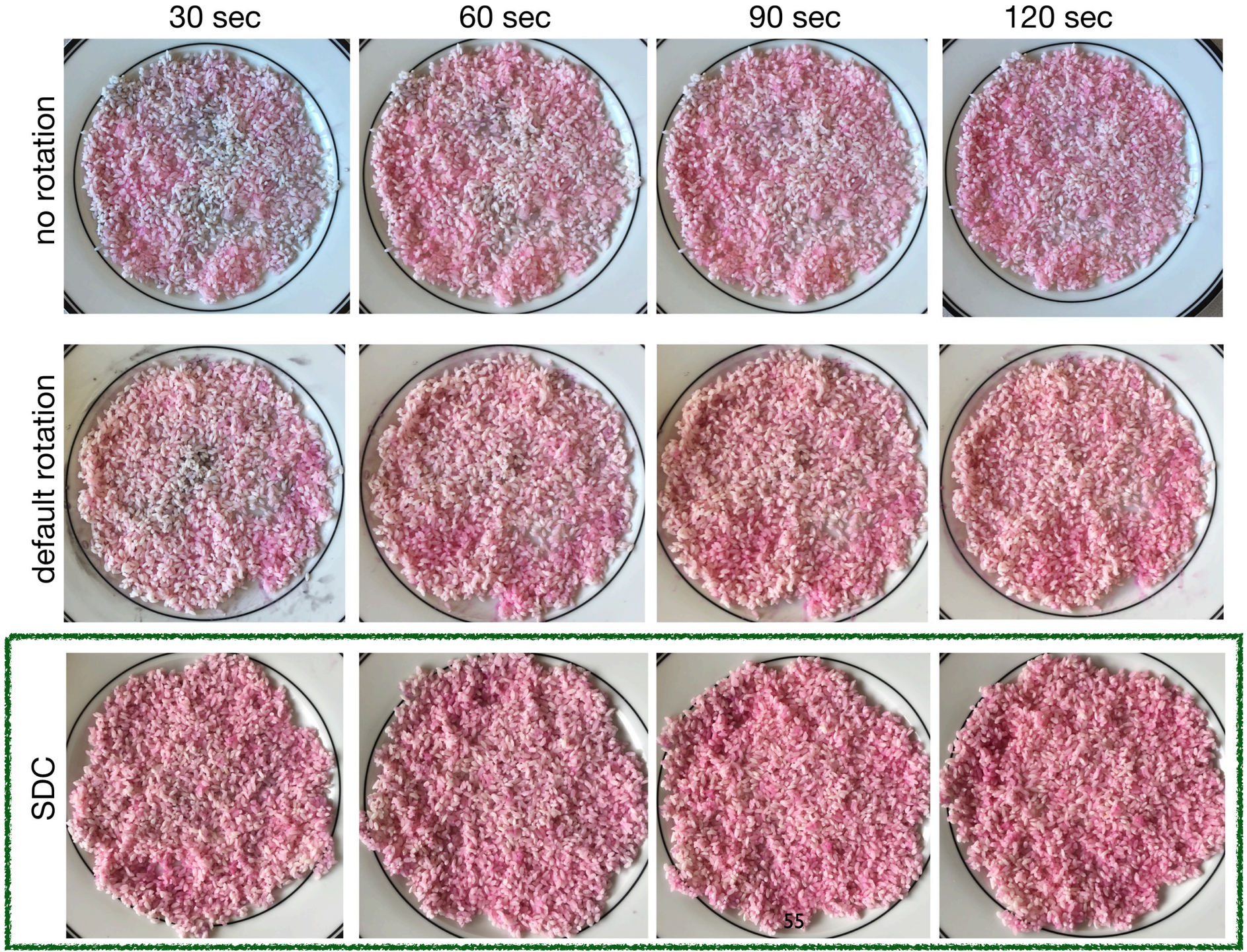


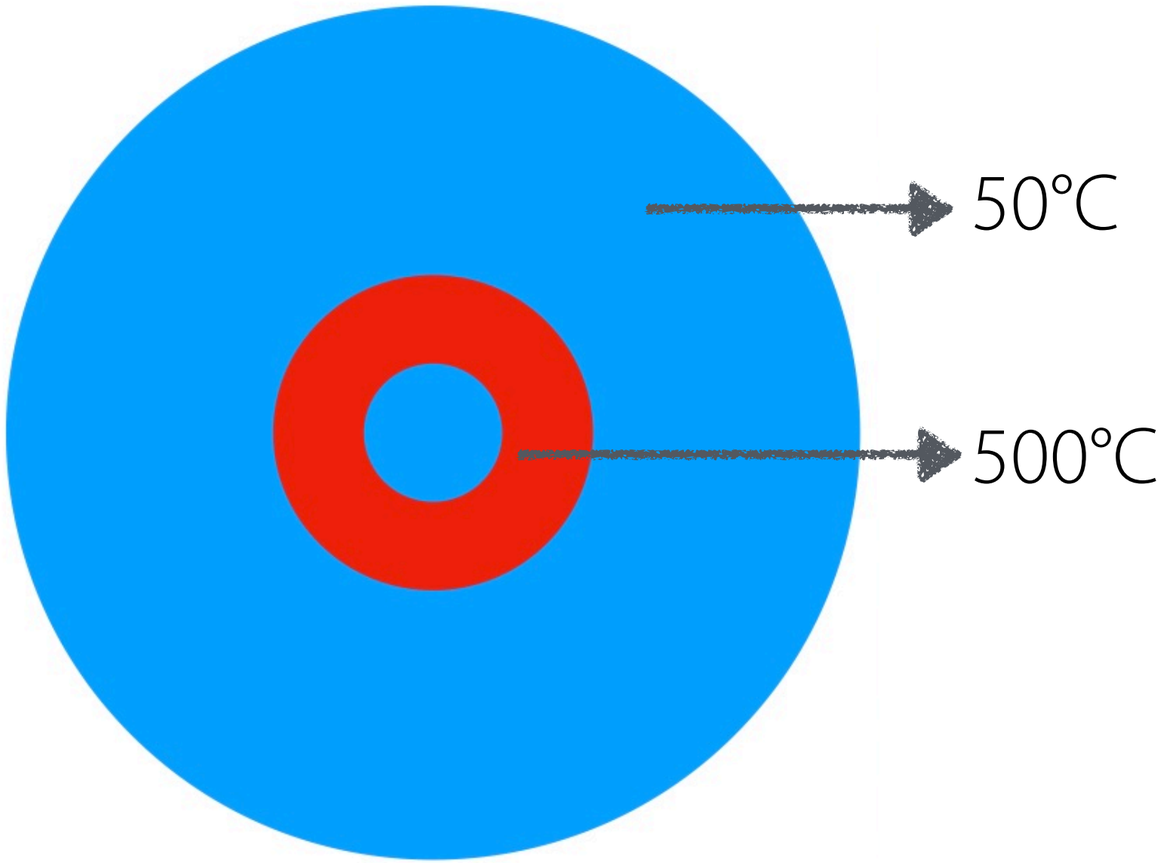
Uniform Heating

Uniform heating

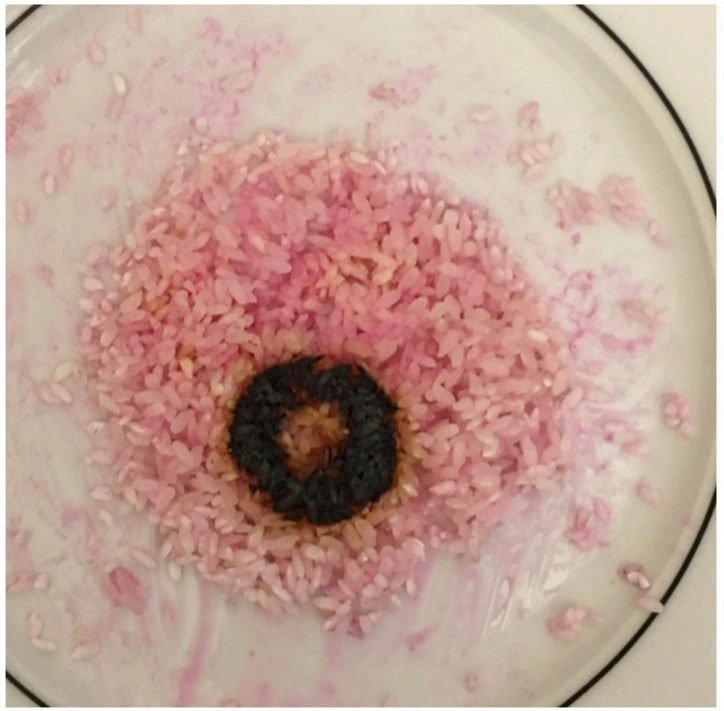
improve the **thermal heating uniformity** by **633%**
compared to microwaves with a blind turntable.

More quantitative results => Paper

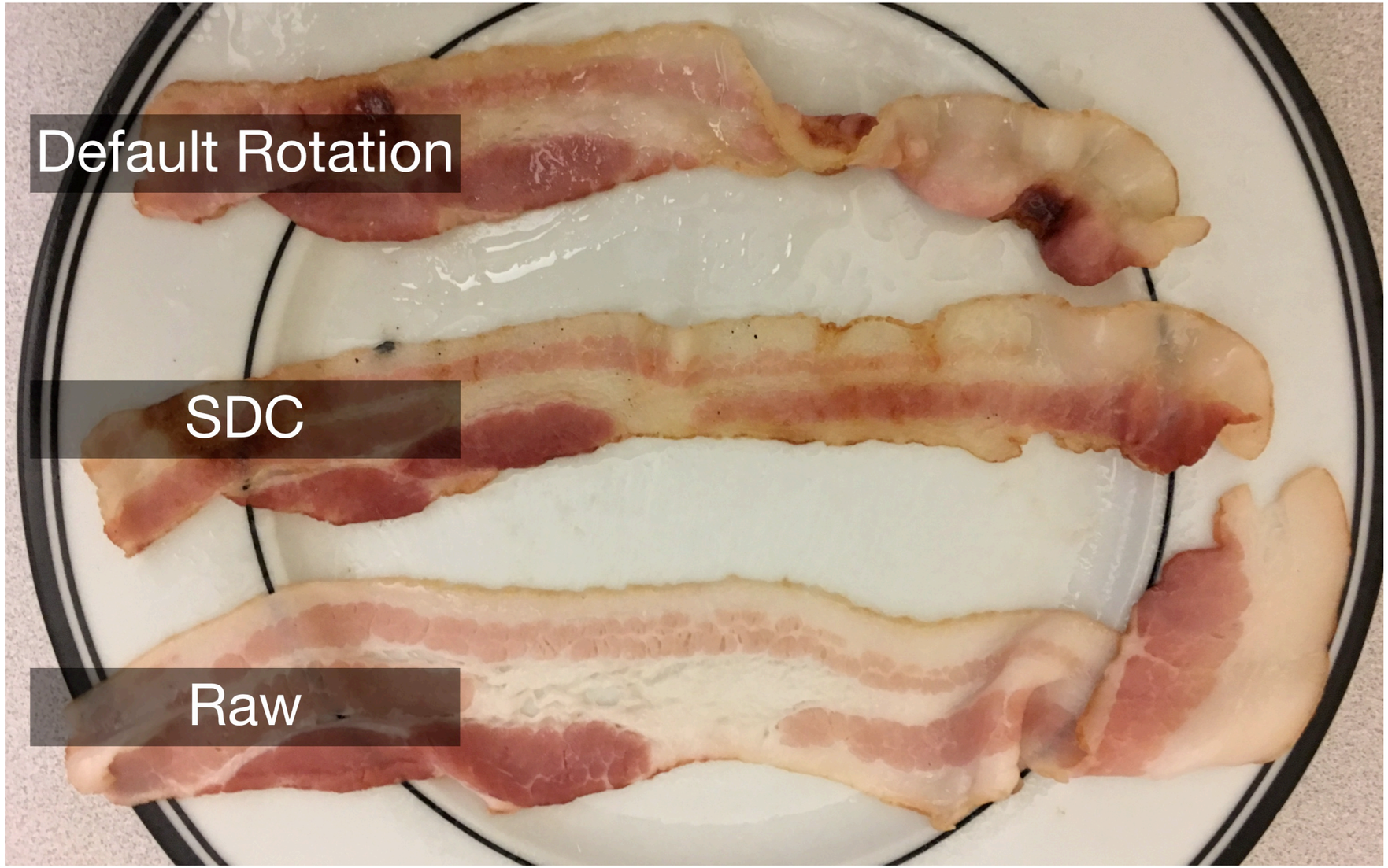
Arbitrary heating



with a microwave susceptor ring



App: Cooking bacon



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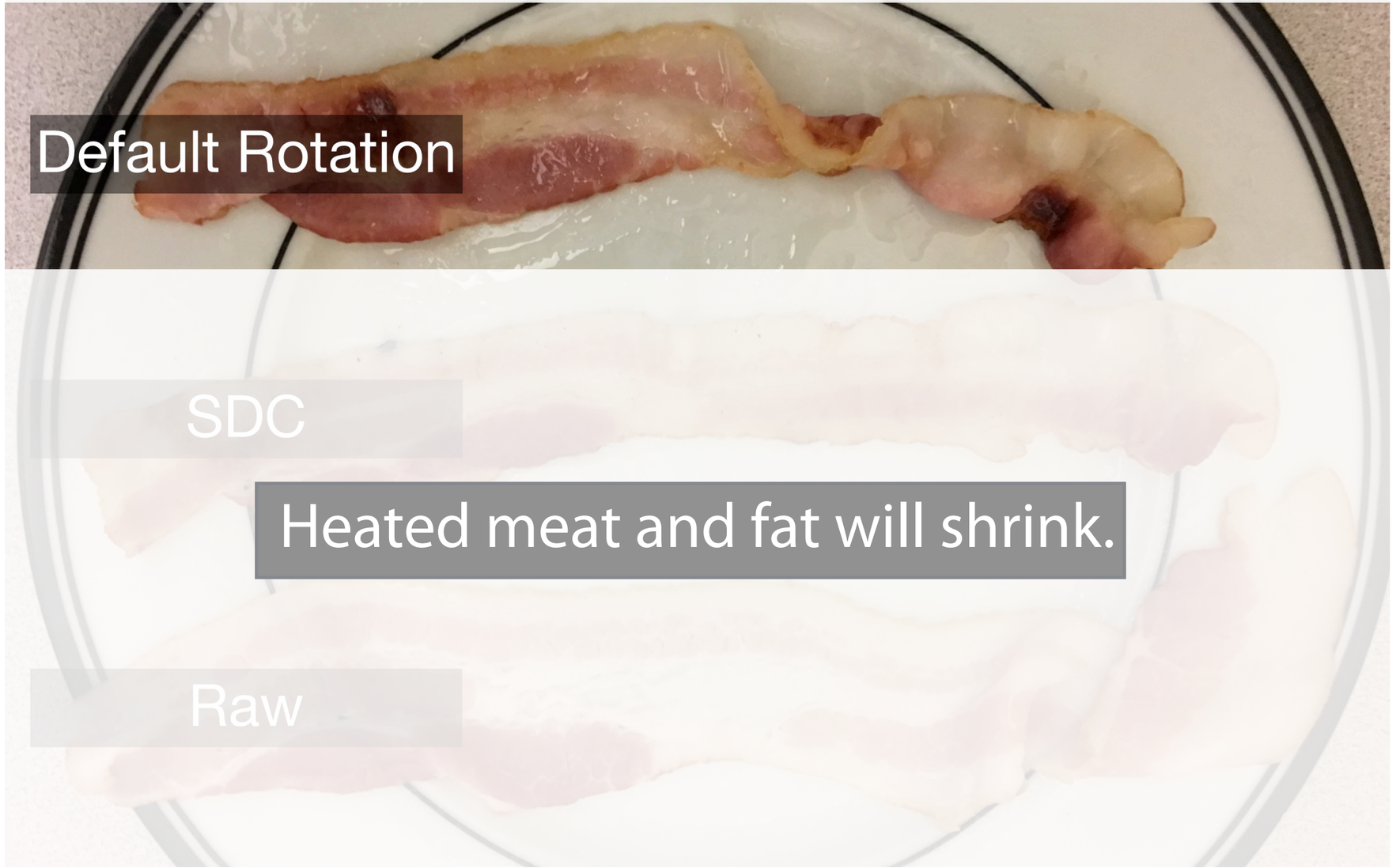

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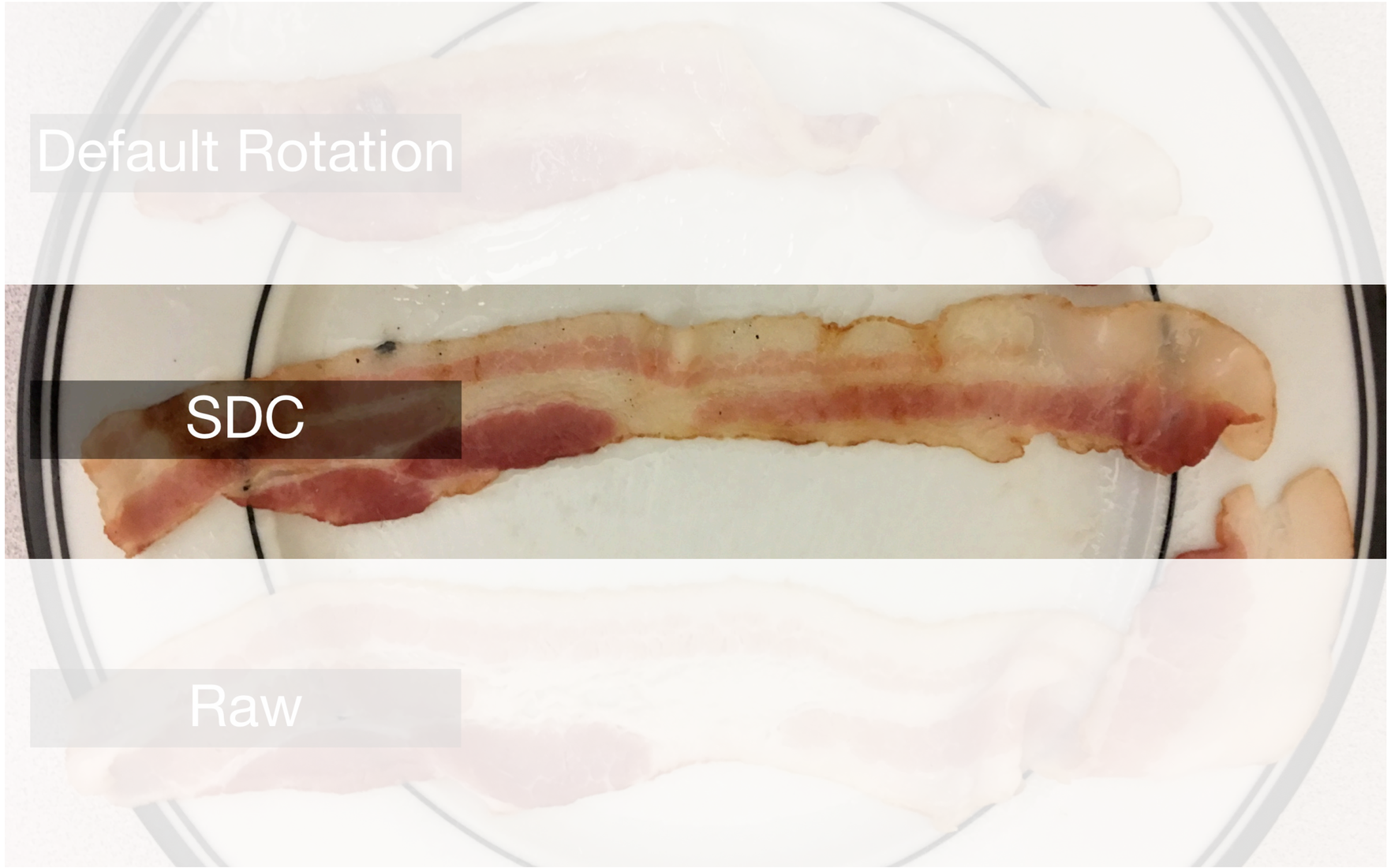


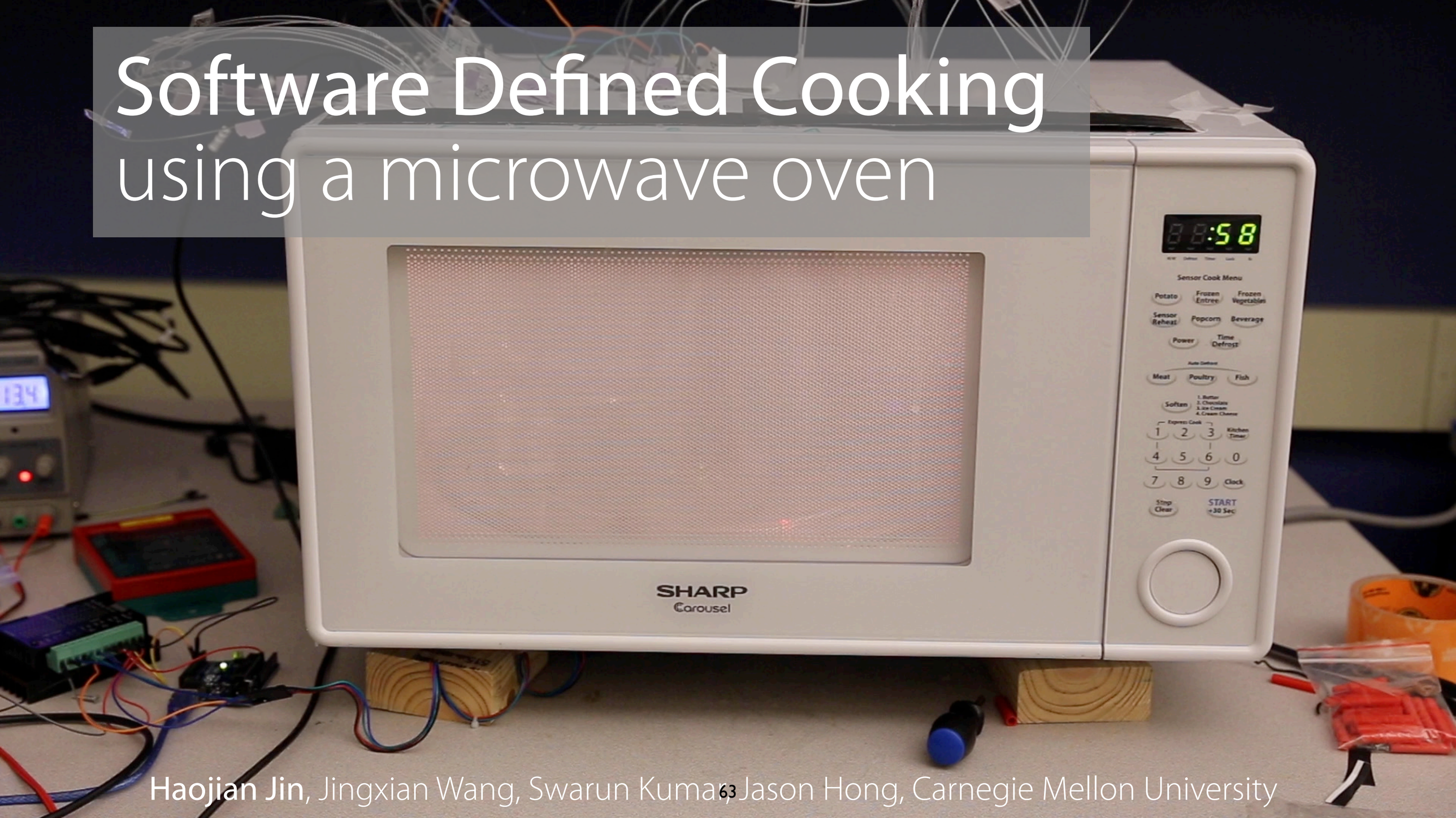
More apps => Paper

Limitations

1. SDC cooking is slower.
2. Some heating patterns might be infeasible.
3. Not sure if it's more delicious. :-)

Future work

1. 6 DoF turntable
2. Higher frequency microwave + beamforming
3. Replacing neon lights with rectifiers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