

Computational Photography



Dr. Irfan Essa

Professor

School of Interactive Computing



Study the basics of computation and its impact on the entire workflow of photography, from capturing, manipulating and collaborating on, and sharing photographs.

What is Computational Photography (Part 1)?



Dr. Irfan Essa

Professor

School of Interactive Computing

Computational Photography and its comparison to traditional photography and digital photography.



Lesson Objectives

- ★ Describe in your own words what is computational photography by appropriately using the terms *illumination, digital sensors, actuators, optics, rays, pixels, smart lights, image, and display*; and
- ★ Correctly identify the appropriate sequence of the six (6) fundamental elements of computational photography in a diagram.



http://commons.wikimedia.org/wiki/File:Rolleiflex_minidigi.jpg

What is Photography?



<http://commons.wikimedia.org/wiki/File:Photography.jpg>

What is Photography?



*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

Photography is the [art](#), [science](#), and practice of creating durable [images](#) by recording [light](#) or other [electromagnetic radiation](#), either chemically by means of a light-sensitive material such as [photographic film](#), or electronically by means of an [image sensor](#).^[1] Typically, a [lens](#) is used to [focus](#) the light reflected or emitted from objects into a [real image](#) on the light-sensitive surface inside a [camera](#) during a timed [exposure](#). The result in an electronic image sensor is an [electrical charge](#) at each [pixel](#), which is [electronically processed](#) and stored in a [digital image file](#) for subsequent display or processing.

<http://en.wikipedia.org/wiki/Photography>



What is **Photography?**

*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

Photography is the [art](#), [science](#), and practice of creating durable [images](#) by recording [light](#) or other [electromagnetic radiation](#), either chemically by means of a light-sensitive material such as [photographic film](#), or electronically by means of an [image sensor](#).^[1] Typically, a [lens](#) is used to [focus](#) the light reflected or emitted from objects into a [real image](#) on the light-sensitive surface inside a [camera](#) during a timed [exposure](#). The result in an electronic image sensor is an [electrical charge](#) at each [pixel](#), which is [electronically processed](#) and stored in a [digital image file](#) for subsequent display or processing.

<http://en.wikipedia.org/wiki/Photography>

What is **Photography?**



art

science

practice

*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

Photography is the [art](#), [science](#), and practice of creating durable [images](#) by recording [light](#) or other [electromagnetic radiation](#), either chemically by means of a light-sensitive material such as [photographic film](#), or electronically by means of an [image sensor](#).^[1] Typically, a [lens](#) is used to [focus](#) the light reflected or emitted from objects into a [real image](#) on the light-sensitive surface inside a [camera](#) during a timed [exposure](#). The result in an electronic image sensor is an [electrical charge](#) at each [pixel](#), which is [electronically processed](#) and stored in a [digital image file](#) for subsequent display or processing.

<http://en.wikipedia.org/wiki/Photography>

What is **Photography?**



art

science

light (etc.)

practice

*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

Photography is the [art](#), [science](#), and practice of creating durable [images](#) by recording [light](#) or other [electromagnetic radiation](#), either chemically by means of a light-sensitive material such as [photographic film](#), or electronically by means of an [image sensor](#).^[1] Typically, a [lens](#) is used to [focus](#) the light reflected or emitted from objects into a [real image](#) on the light-sensitive surface inside a [camera](#) during a timed [exposure](#). The result in an electronic image sensor is an [electrical charge](#) at each [pixel](#), which is [electronically processed](#) and stored in a [digital image file](#) for subsequent display or processing.

<http://en.wikipedia.org/wiki/Photography>

What is **Photography?**



art

science

light (etc.)

images

practice

*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

Photography is the [art](#), [science](#), and practice of creating durable [images](#) by recording [light](#) or other [electromagnetic radiation](#), either chemically by means of a light-sensitive material such as [photographic film](#), or electronically by means of an [image sensor](#).^[1] Typically, a [lens](#) is used to [focus](#) the light reflected or emitted from objects into a [real image](#) on the light-sensitive surface inside a [camera](#) during a timed [exposure](#). The result in an electronic image sensor is an [electrical charge](#) at each [pixel](#), which is [electronically processed](#) and stored in a [digital image file](#) for subsequent display or processing.

<http://en.wikipedia.org/wiki/Photography>

What is **Photography?**



art

science

practice

light (etc.)

chemically

images

electronically

*photo-graphy --
"drawing with light"*

<http://commons.wikimedia.org/wiki/File:Photography.jpg>

What is Computational Photography?

What is Computational Photography?



+



=



Camera 2.0
(Frankencamera)
Adams et al., 2010

What is Computational Photography?



+



=



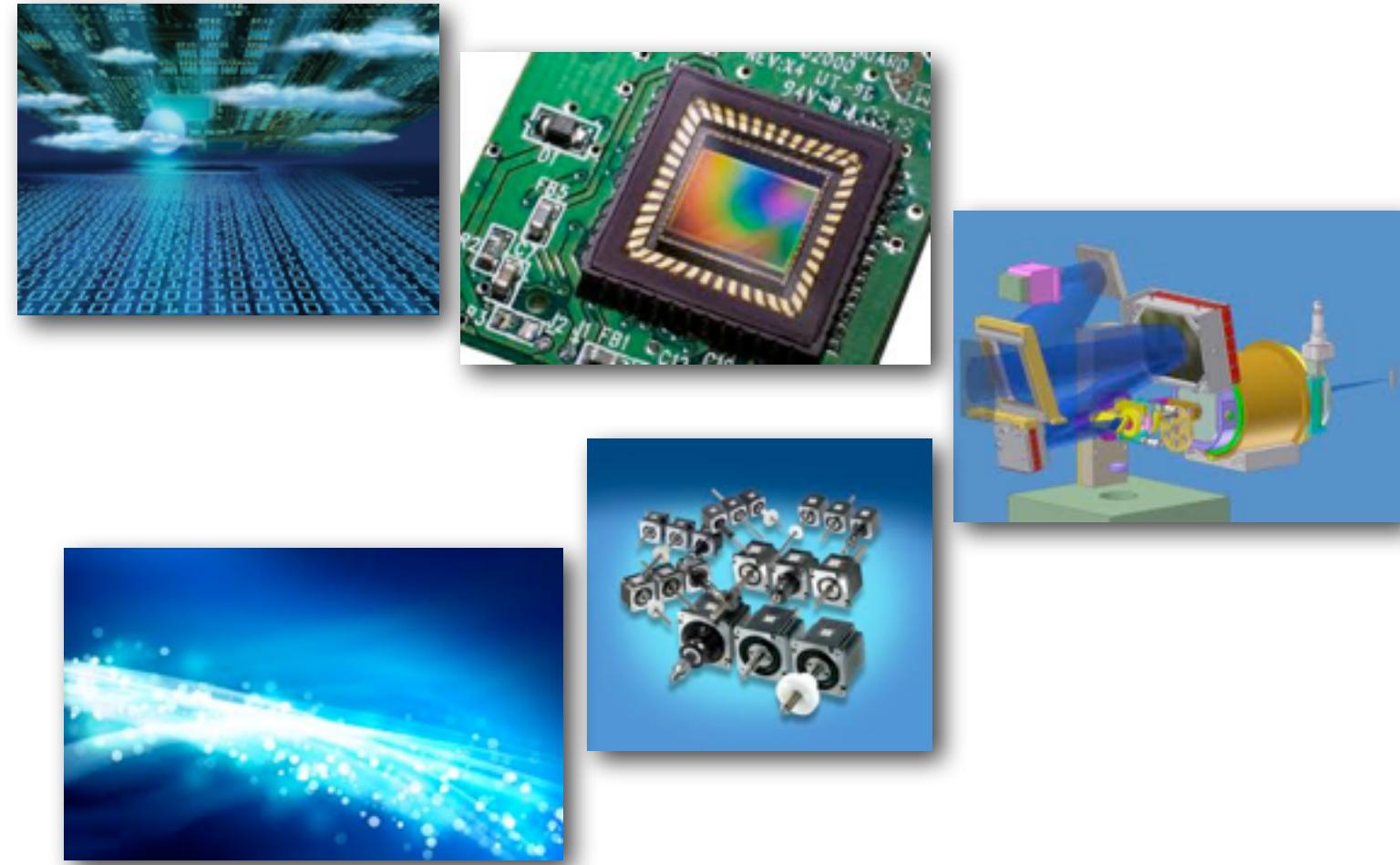
Camera 2.0
(Frankencamera)
Adams et al., 2010



• • •

Computational Photography Combines:

- ★ computing,
- ★ digital sensors,
- ★ modern optics,
- ★ actuators, and
- ★ smart lights
- ★ strategies to “escape” the limitations
of traditional film cameras



Limitations of Traditional Film Cameras

★ Debatable, but...

- chemicals / darkroom,
- 12-24-36 pictures / roll,
- no instant gratification,
- + sensitivity of film +



Computational Photography Enables Imaging

★ Unbounded Dynamic Range

★ Variable

- Focus
- Depth of Field
- Resolution
- Lighting
- Reflectance



★ Supports and Enhances the Medium of Photography



Elements of Computational Photography



3D Scene

Elements of Computational Photography



3D Scene

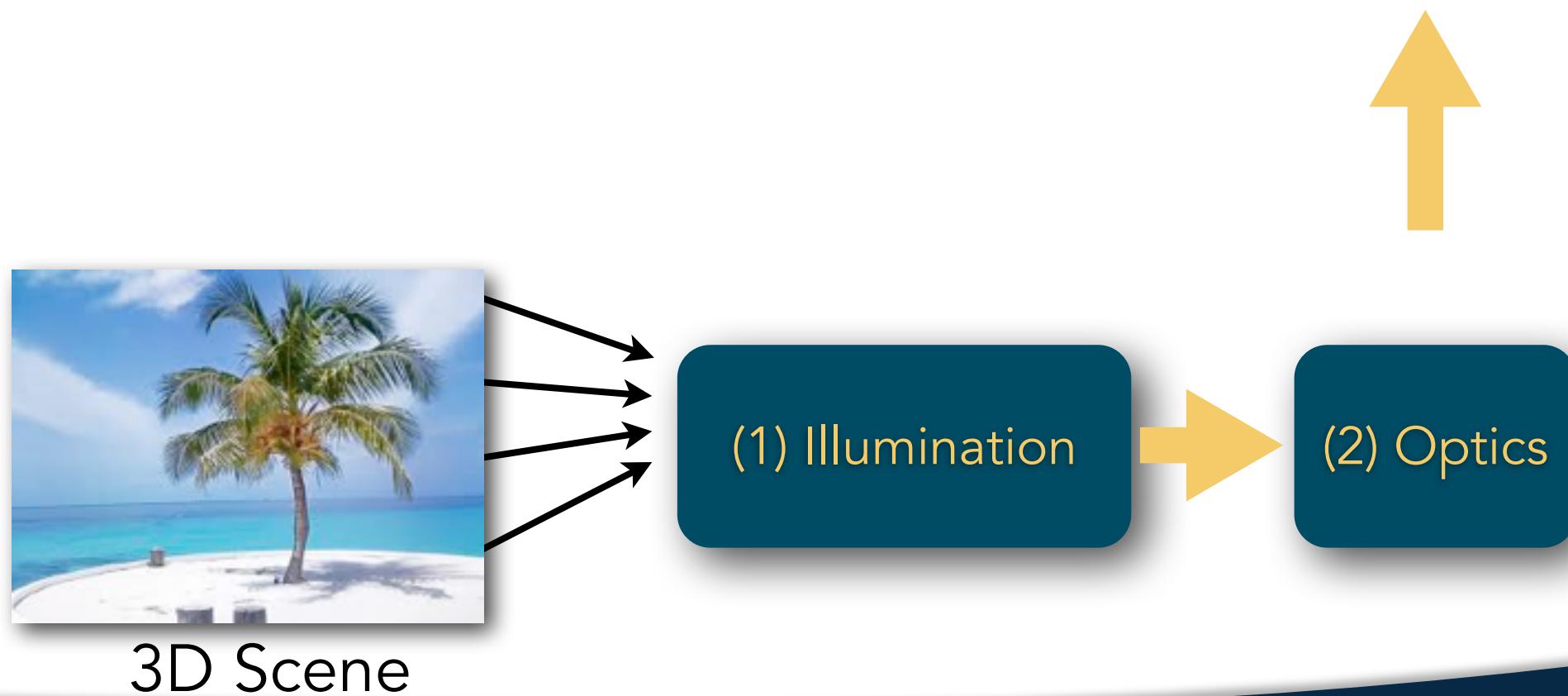
Elements of Computational Photography

1. Illumination



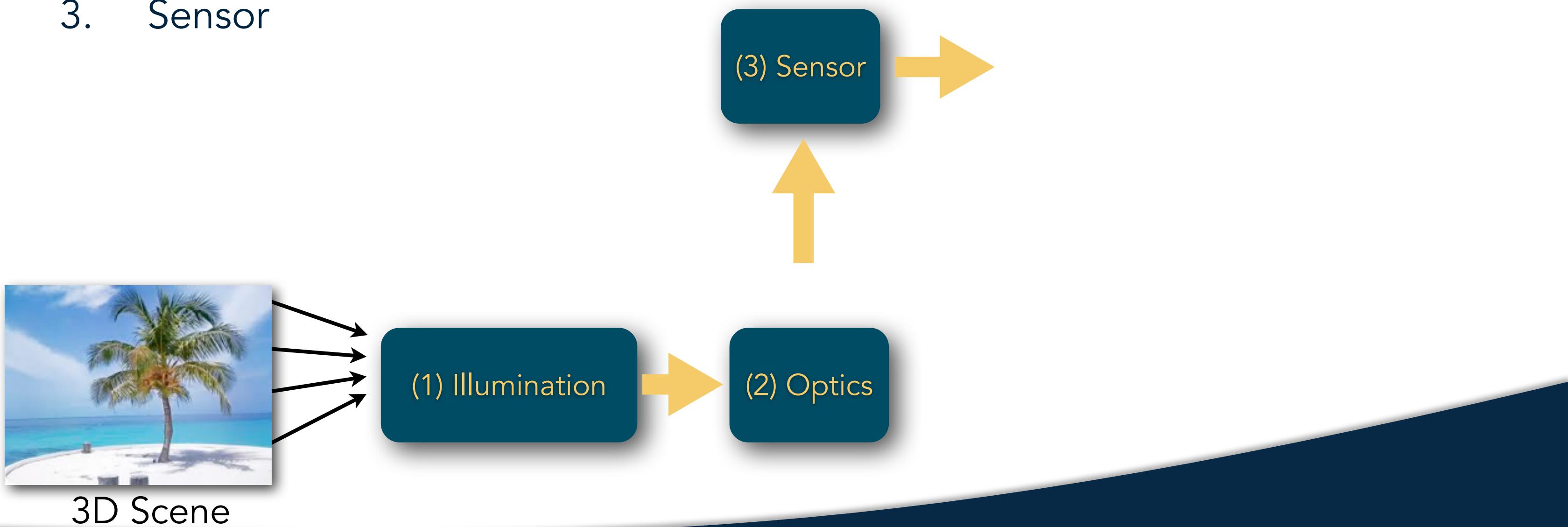
Elements of Computational Photography

1. Illumination
2. Optics



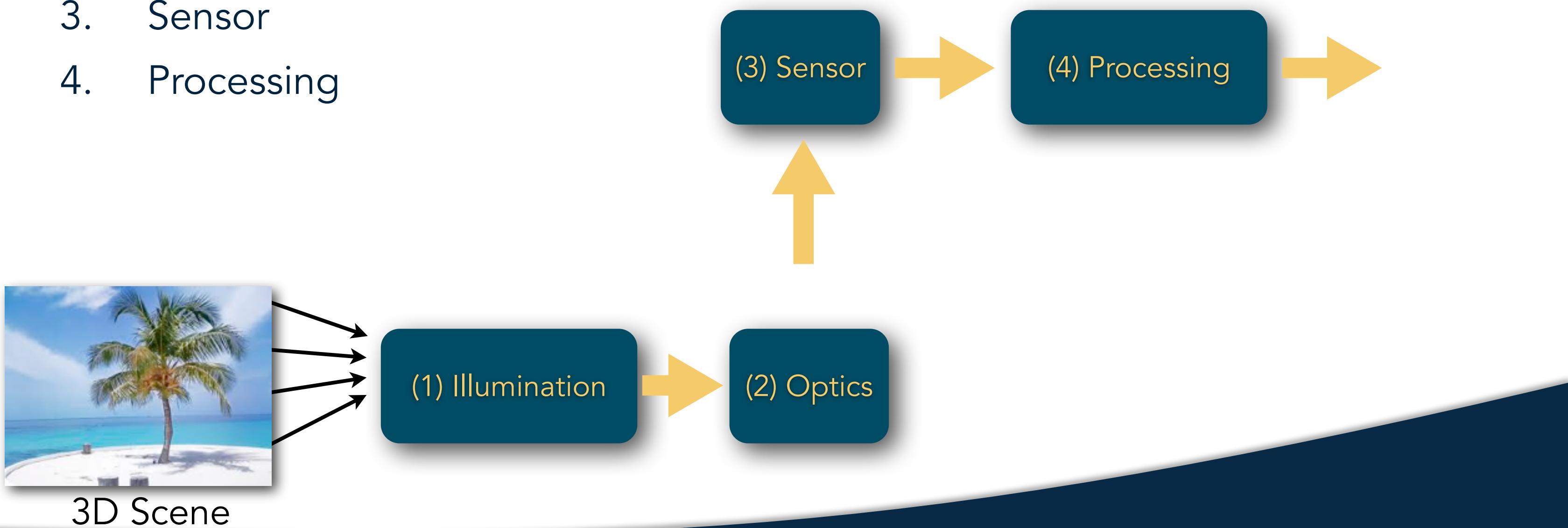
Elements of Computational Photography

1. Illumination
2. Optics
3. Sensor



Elements of Computational Photography

1. Illumination
2. Optics
3. Sensor
4. Processing

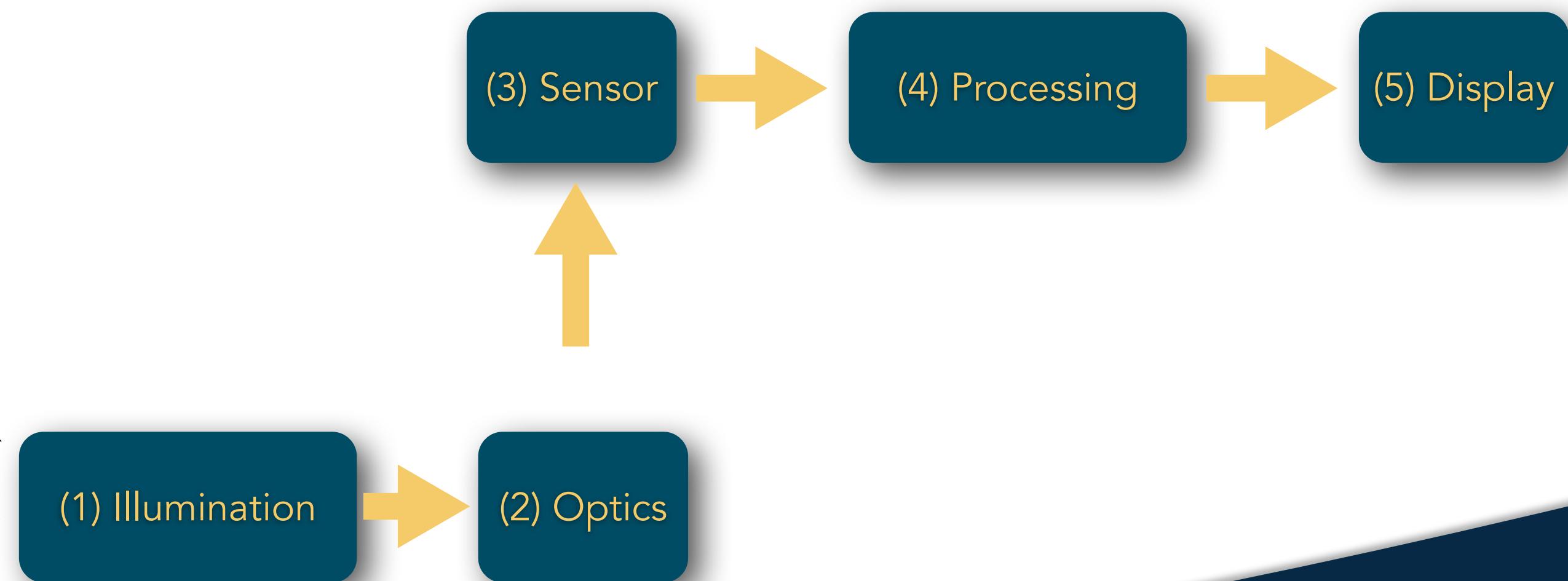


Elements of Computational Photography

1. Illumination
2. Optics
3. Sensor
4. Processing
5. Display



3D Scene



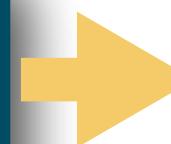
Elements of Computational Photography

1. Illumination
2. Optics
3. Sensor
4. Processing
5. Display
6. User: Sharing/Consuming



3D Scene

(1) Illumination



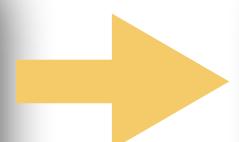
(2) Optics



(3) Sensor



(4) Processing



(5) Display

(6) User



Elements of Computational Photography

1. Illumination
2. Optics
3. Sensor
4. Processing
5. Display
6. User: Sharing/Consuming



3D Scene

A. Computation can be embedded in all aspects of these elements to support photography



(6) User



(5) Display

Computational Photography (Rays to Pixels)

3D Scene



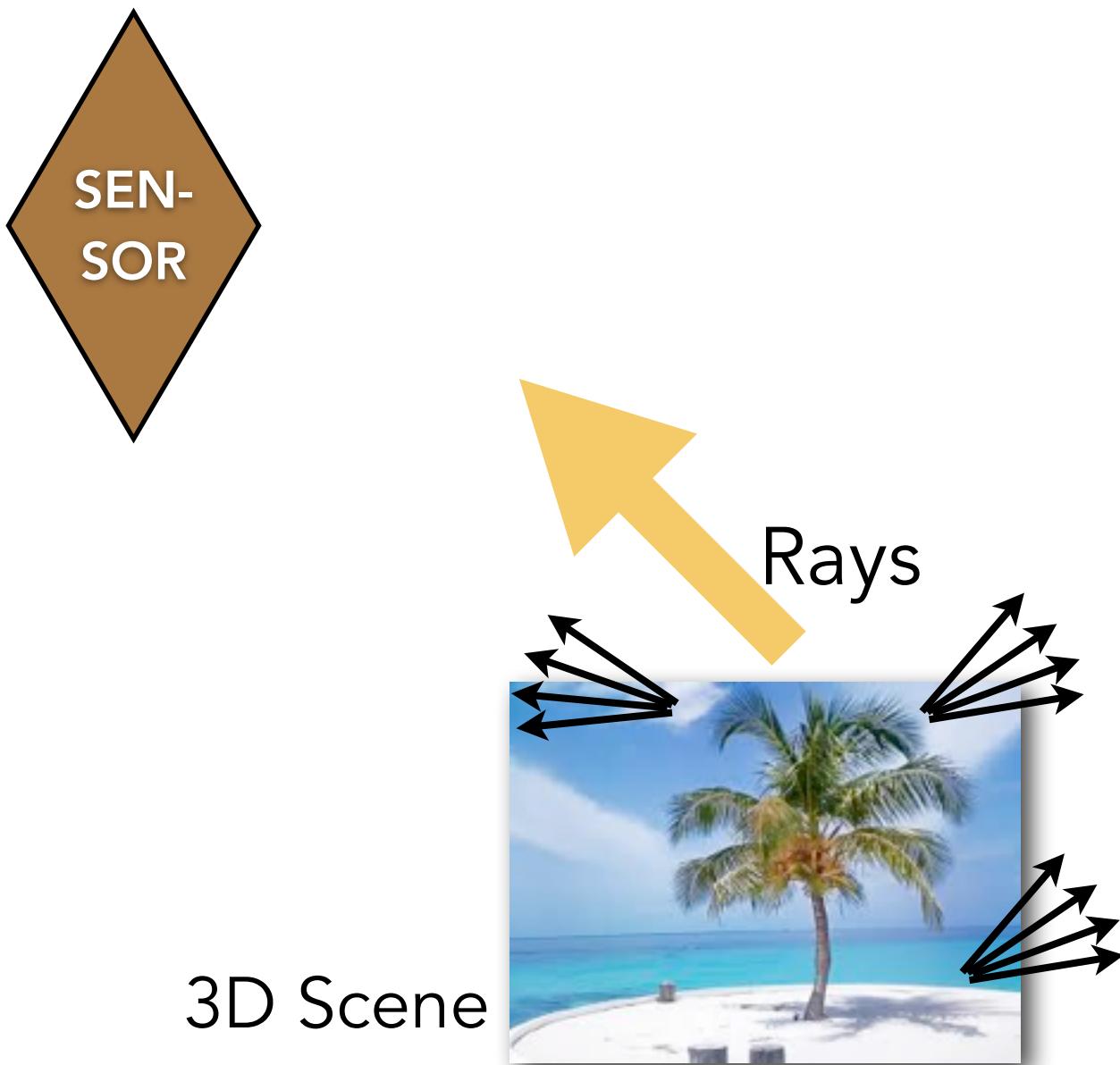
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)



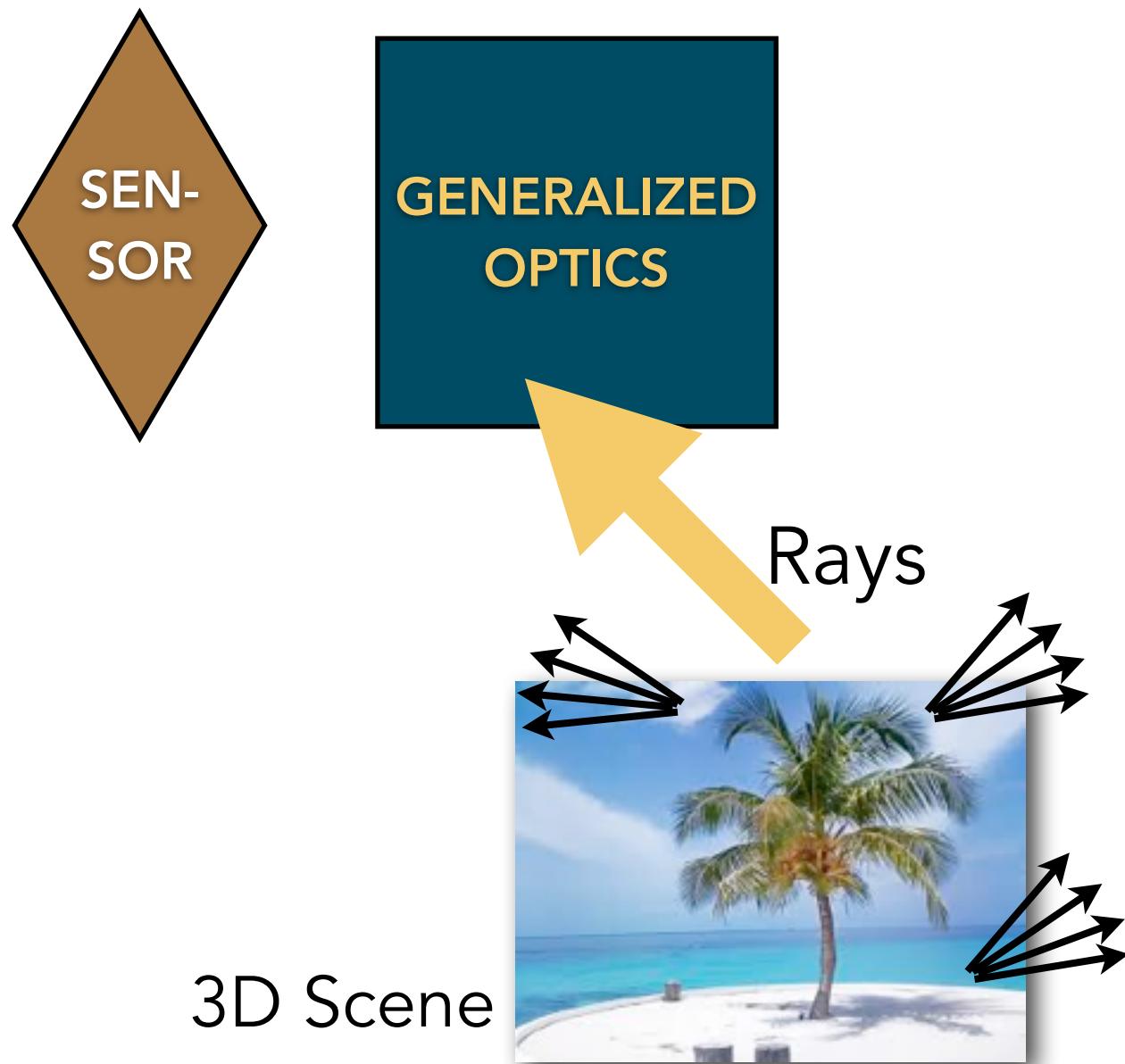
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)



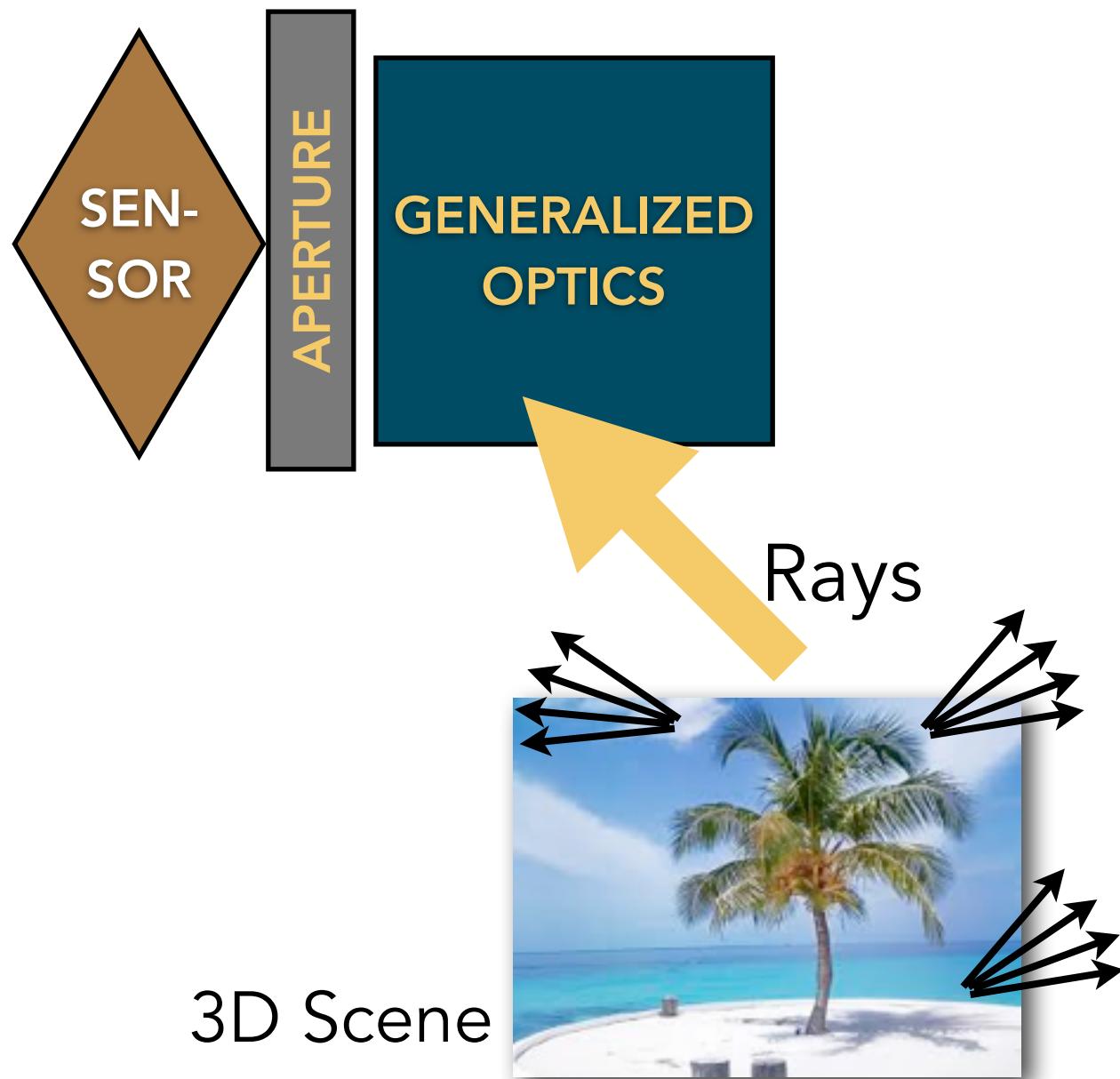
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)



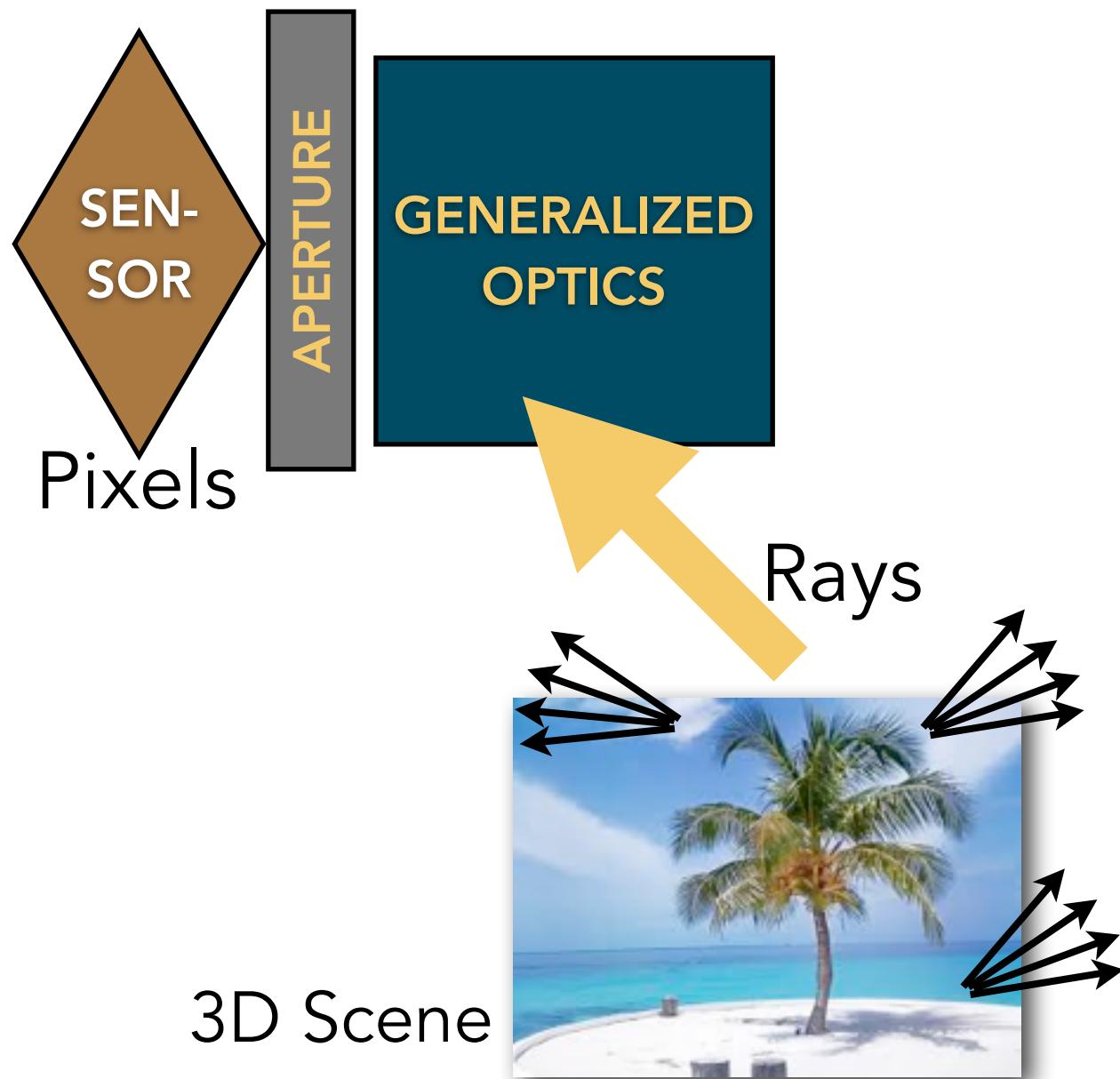
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)



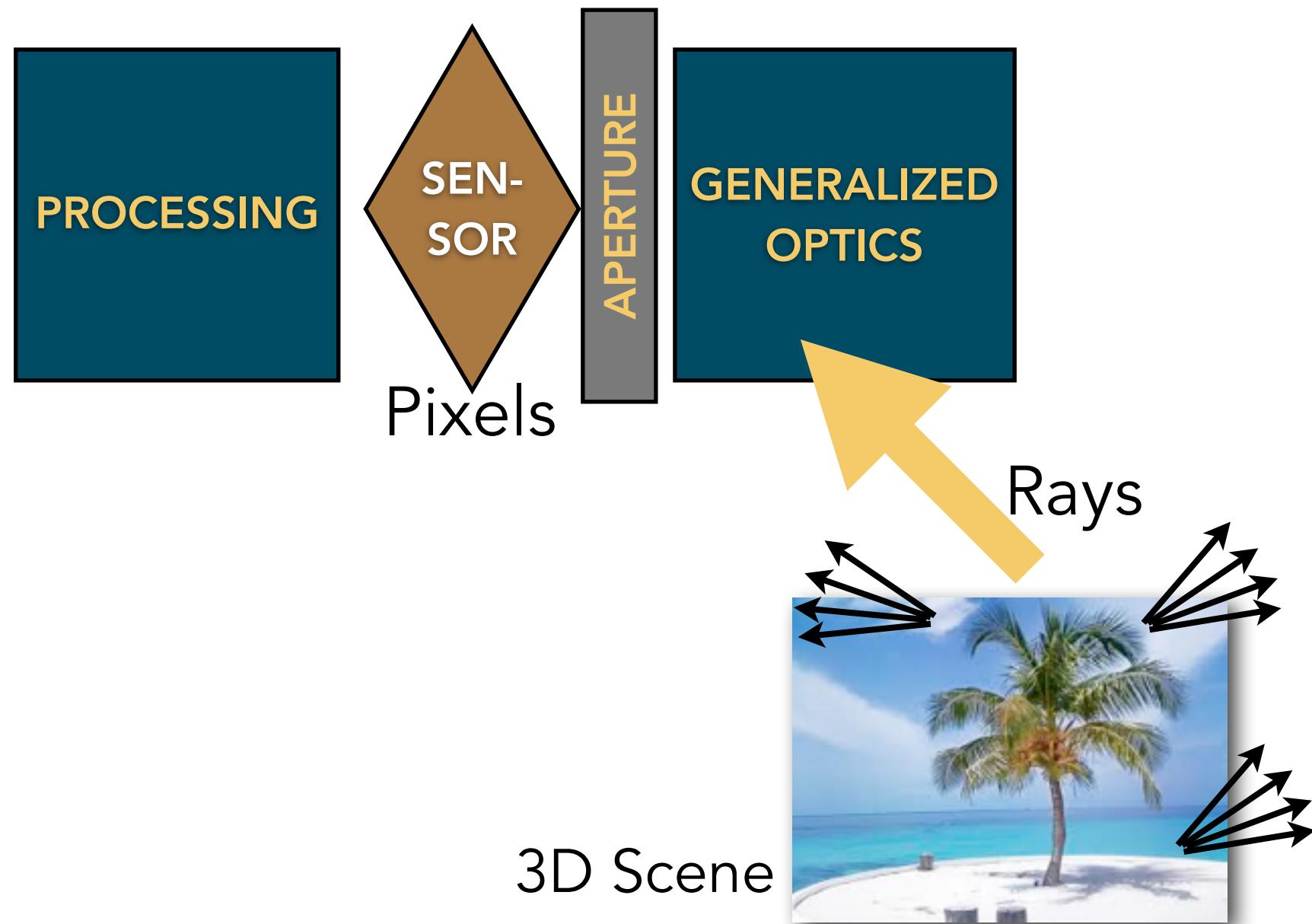
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)



Schematic motivated by Nayar and Raskar

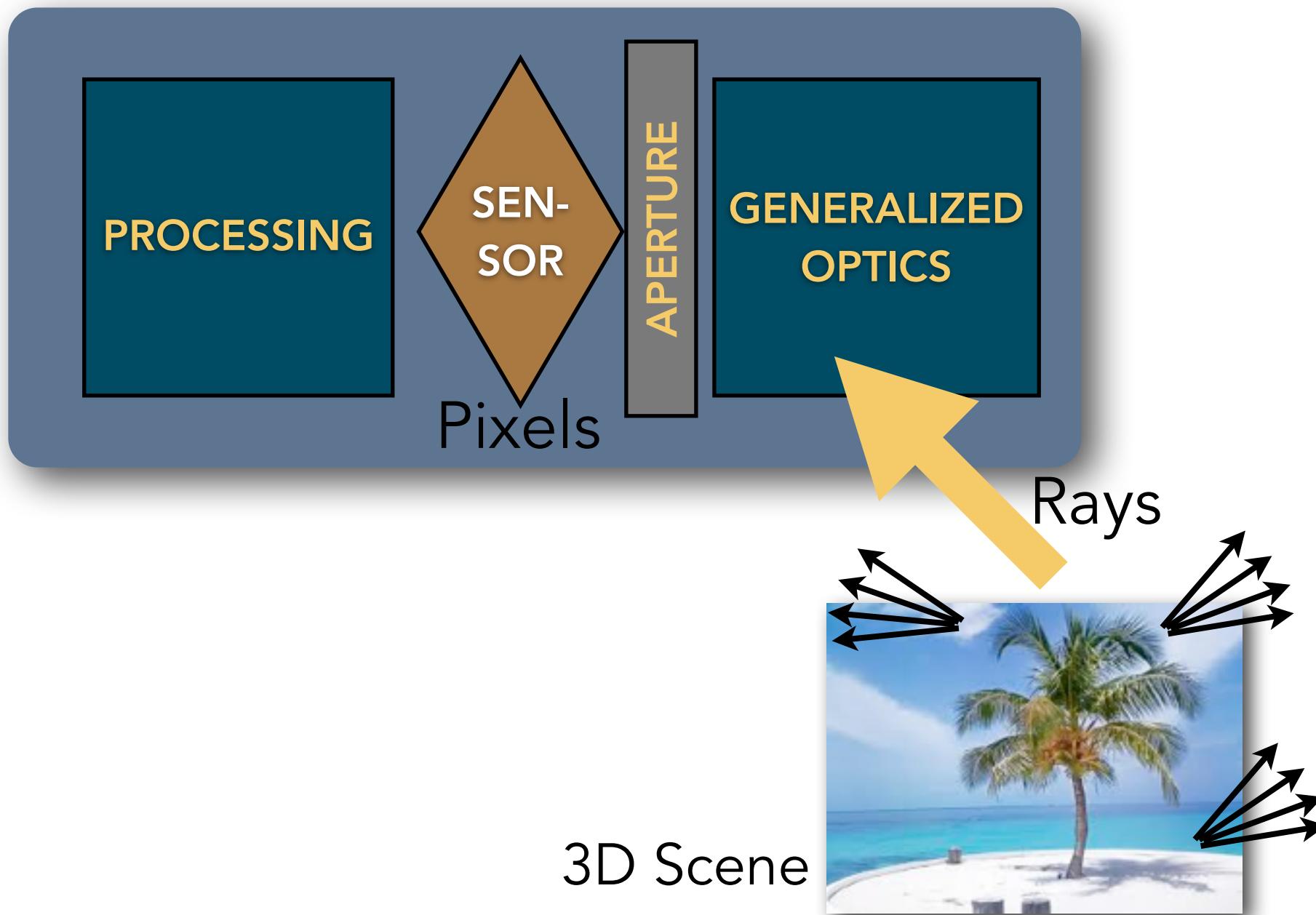
Computational Photography (Rays to Pixels)



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

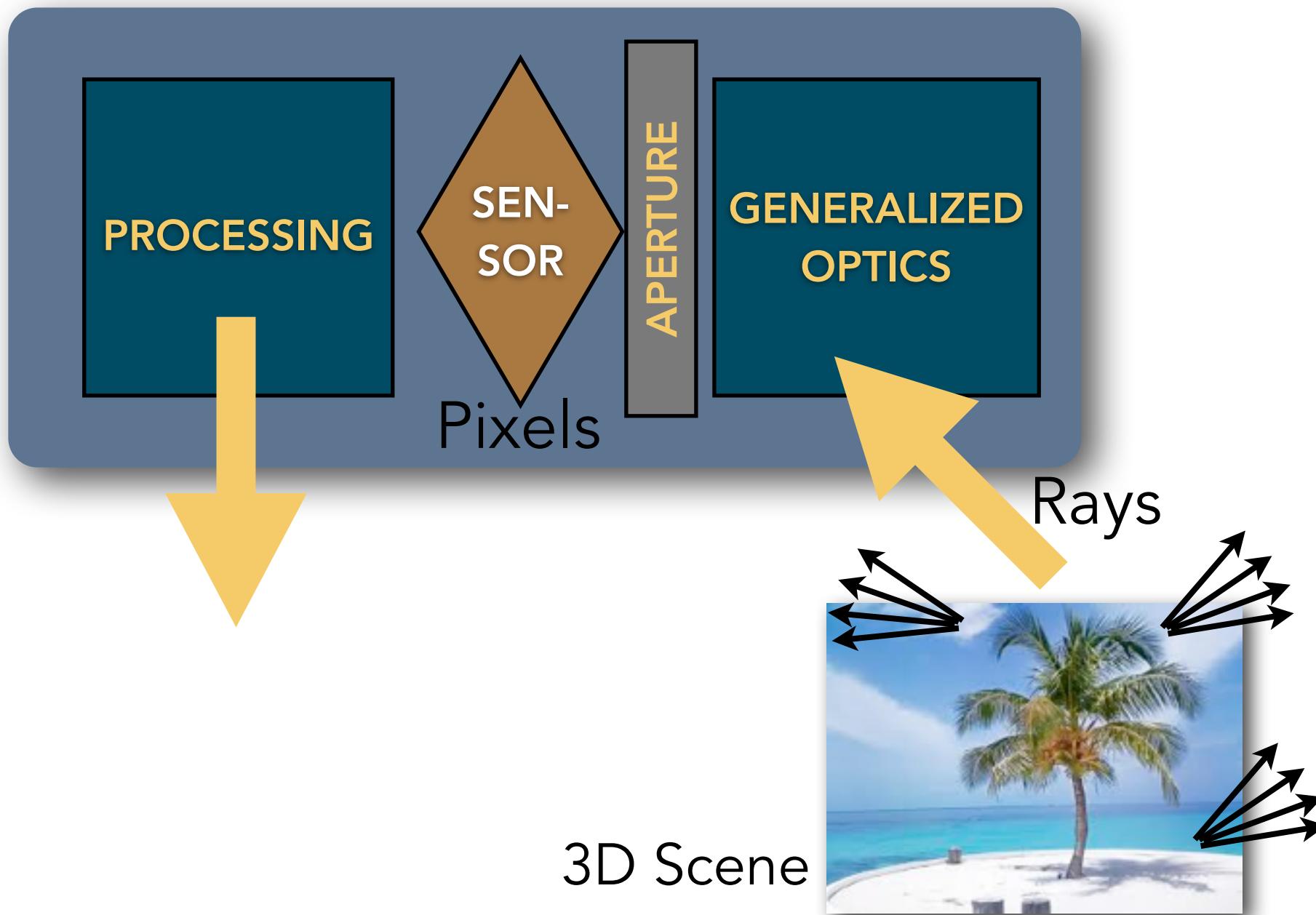
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

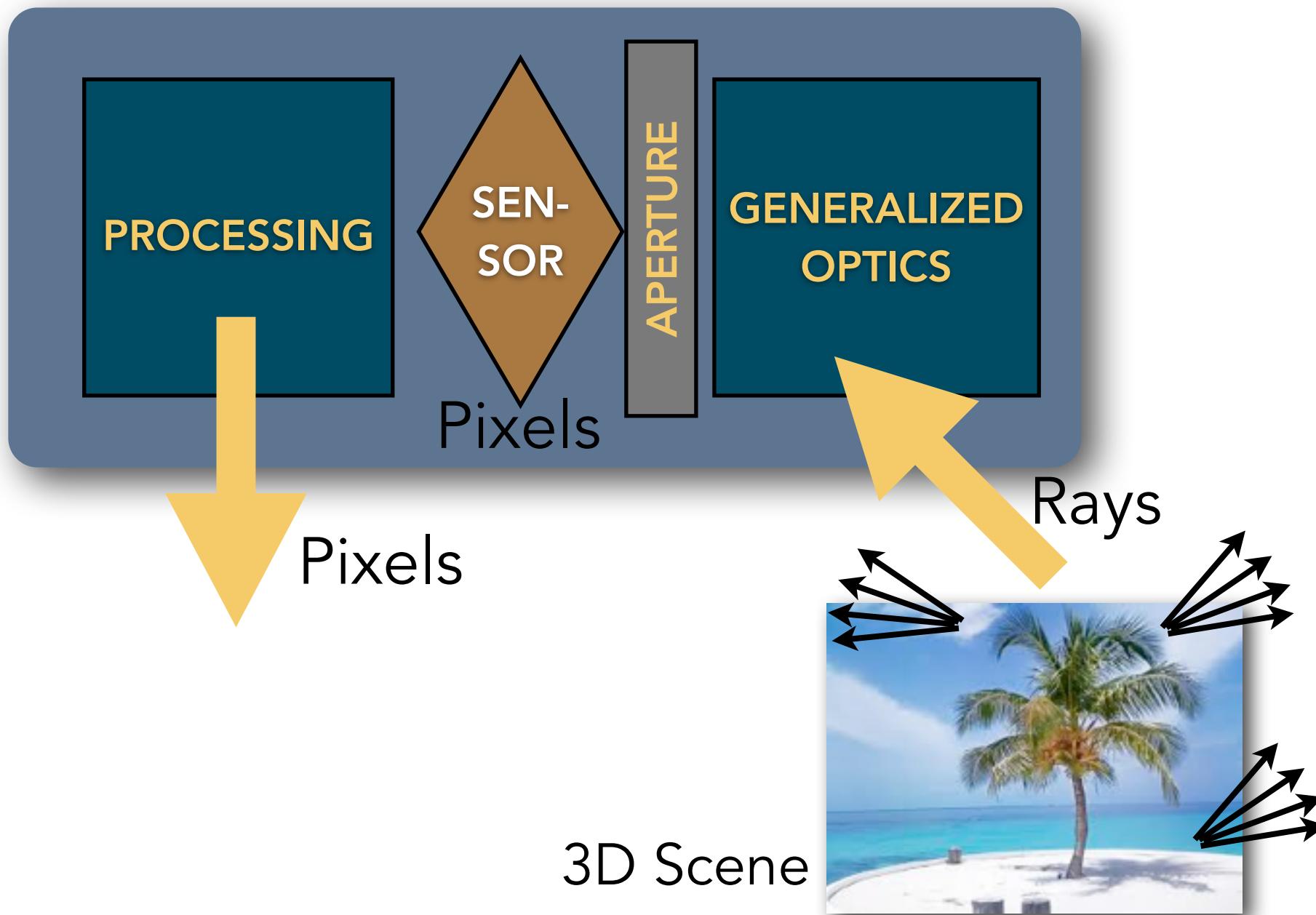
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

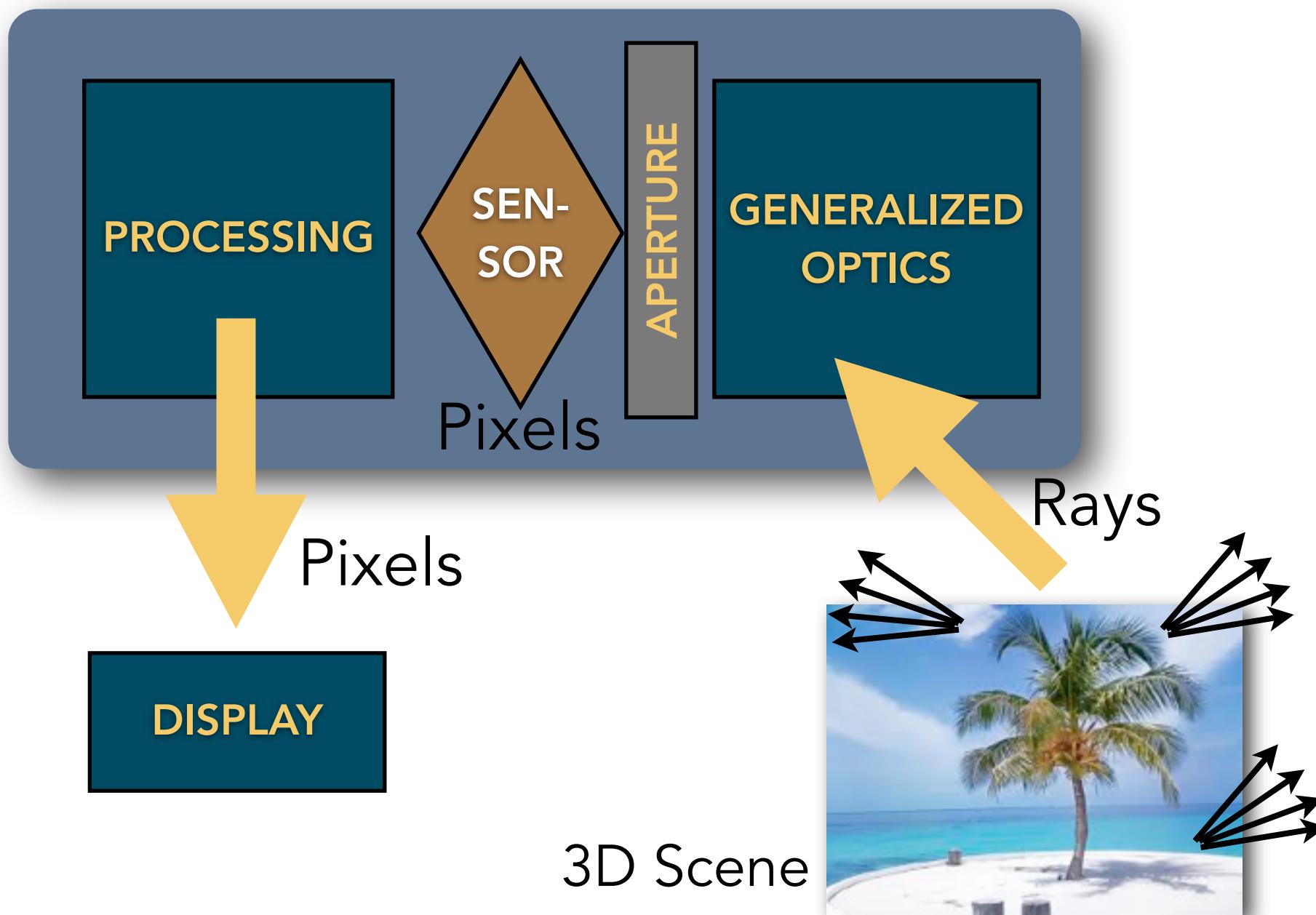
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

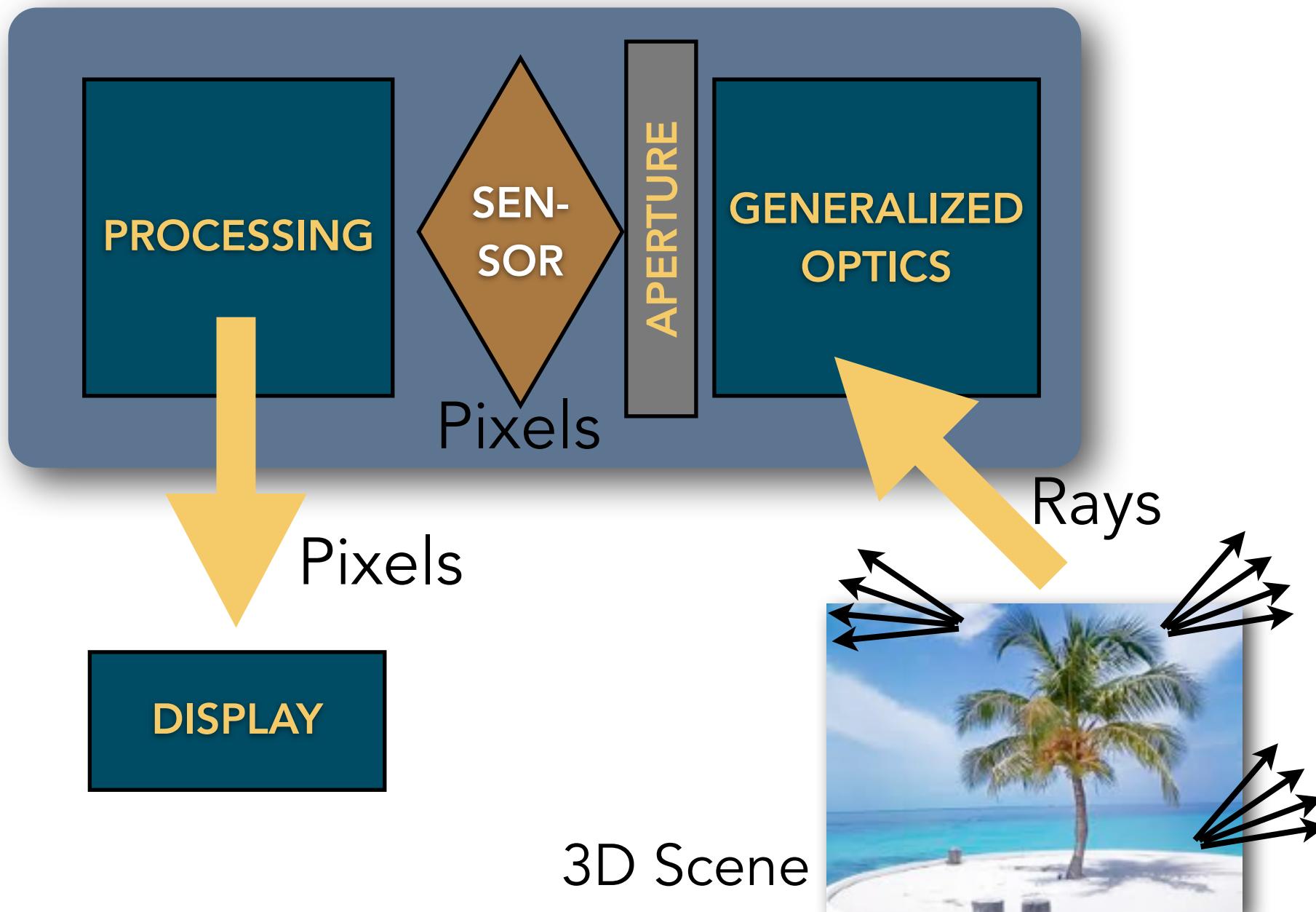
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

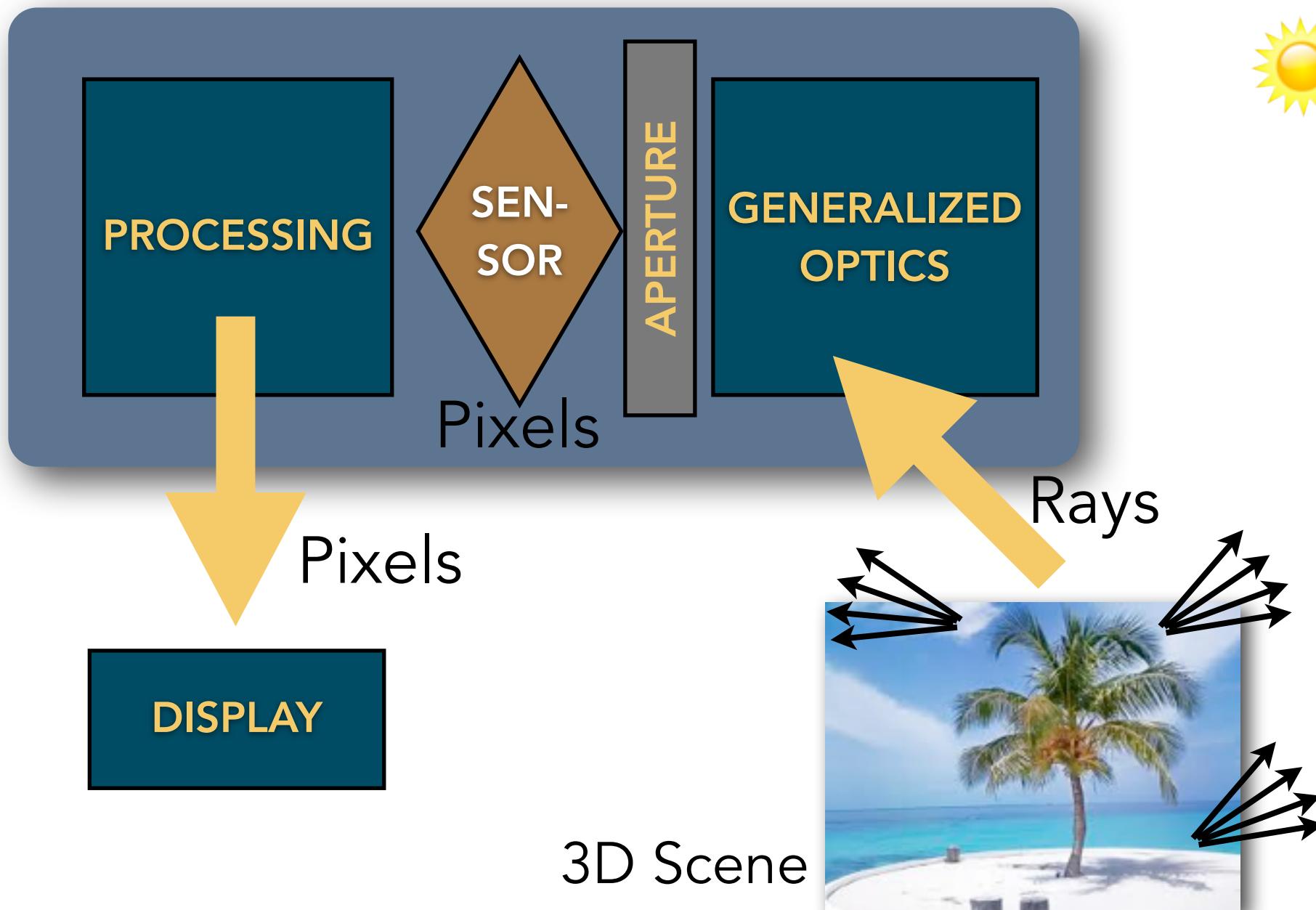
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

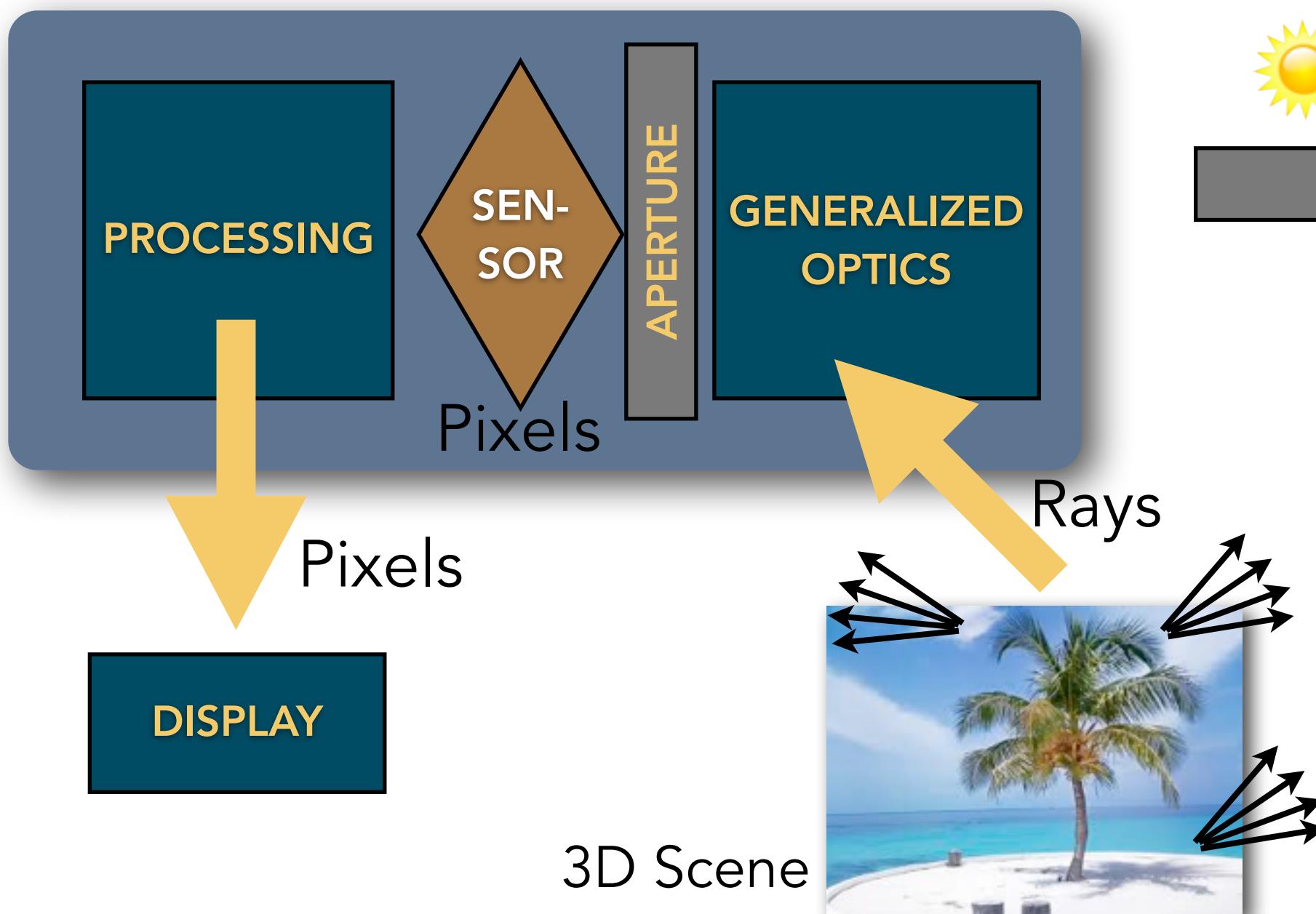
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

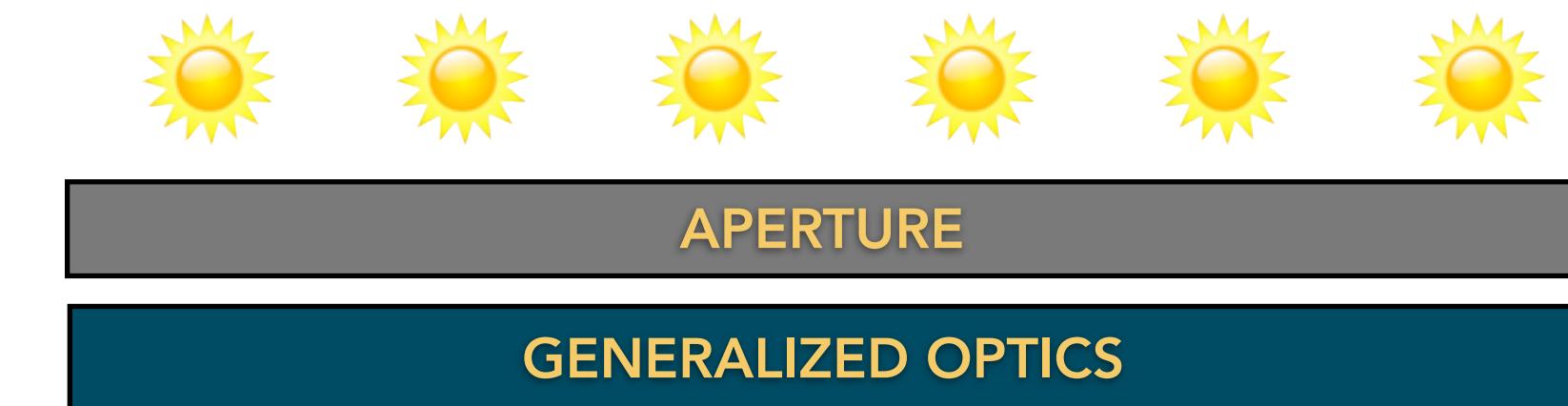
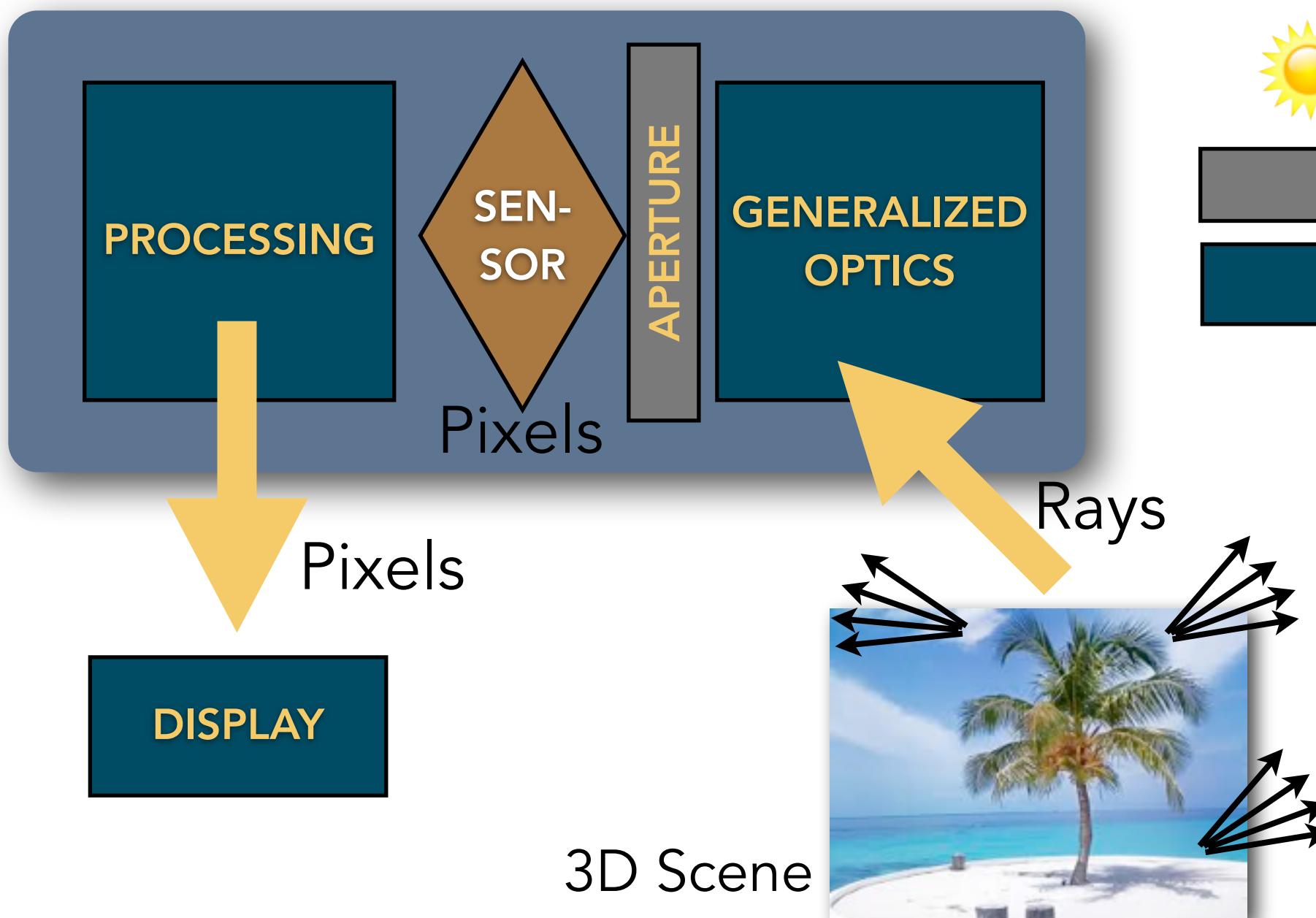
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

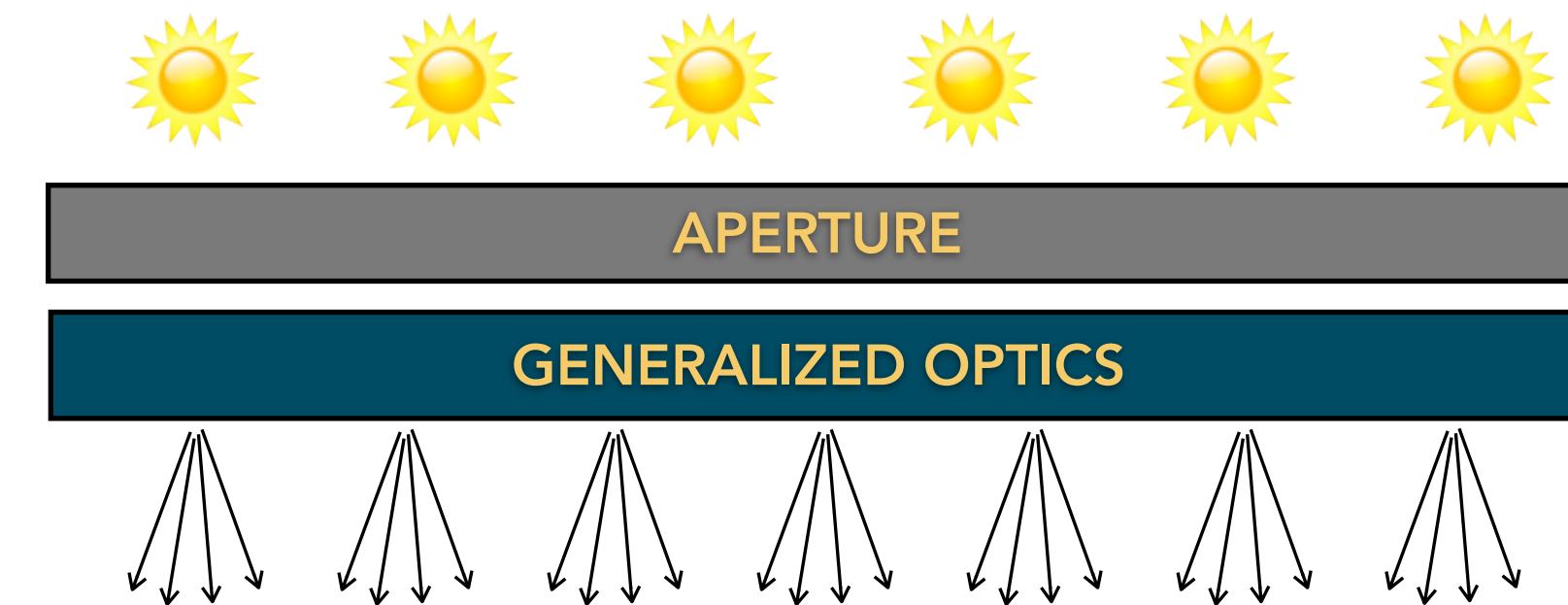
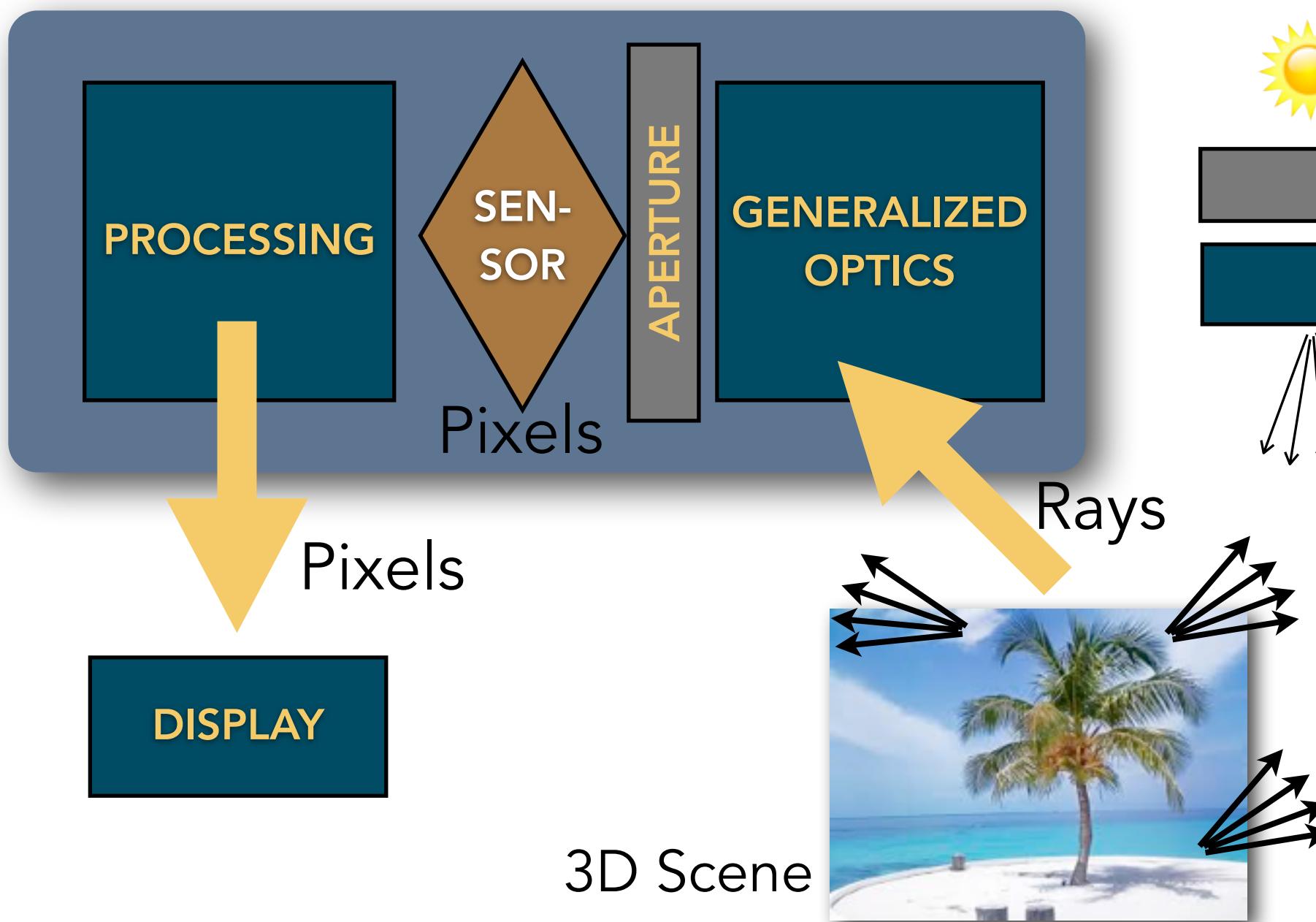
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

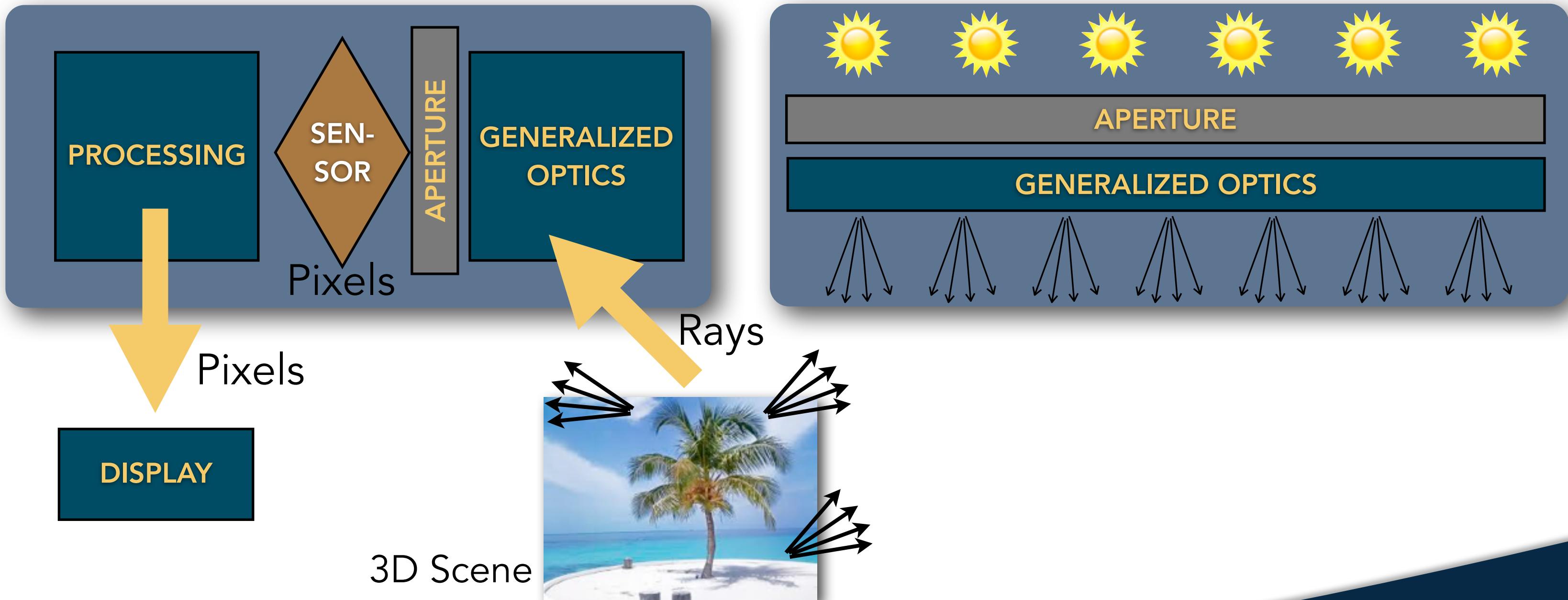
Novel Camera



Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

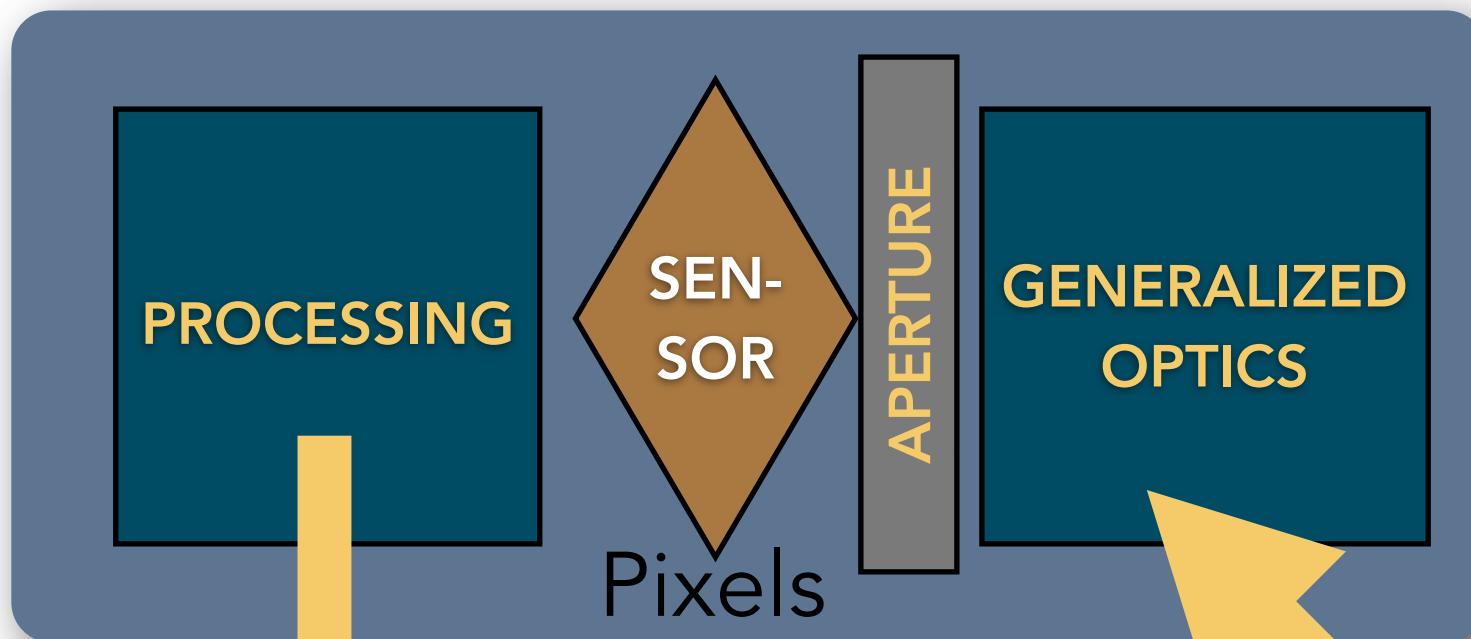
Novel Camera



Schematic motivated by Nayar and Raskar

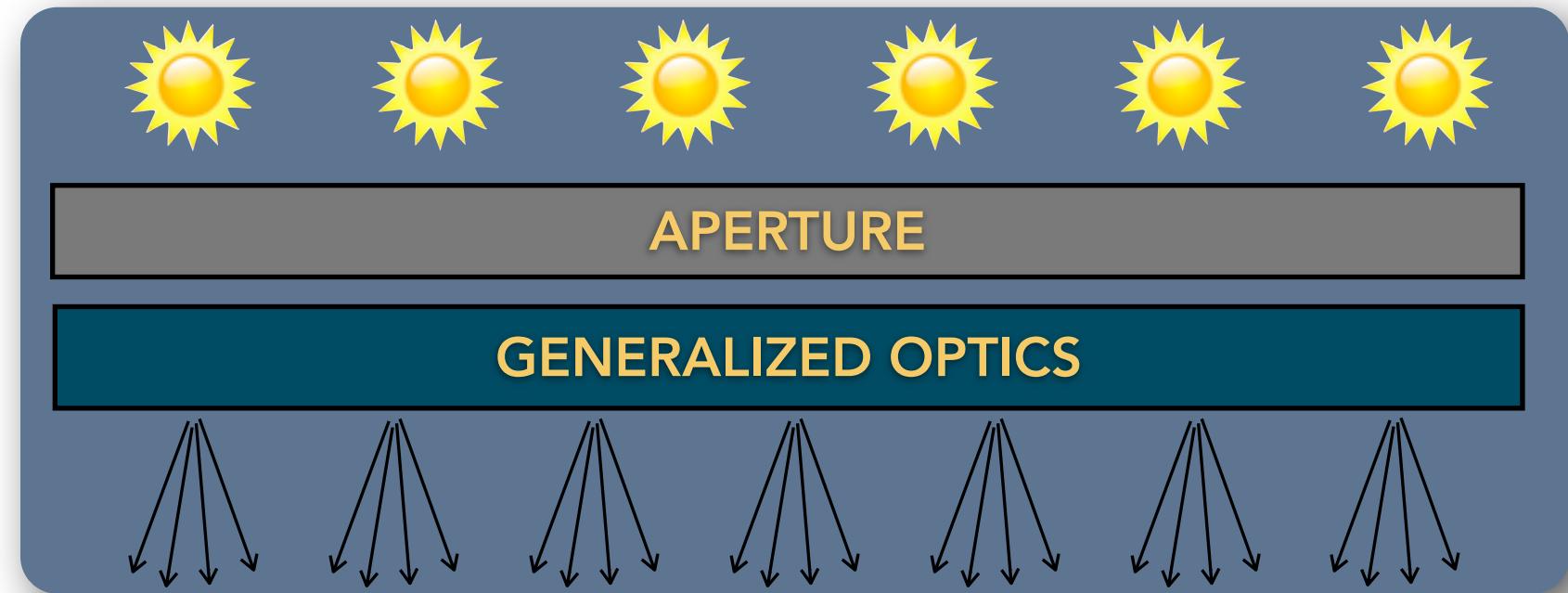
Computational Photography (Rays to Pixels)

Novel Camera



Pixels

Novel Illumination

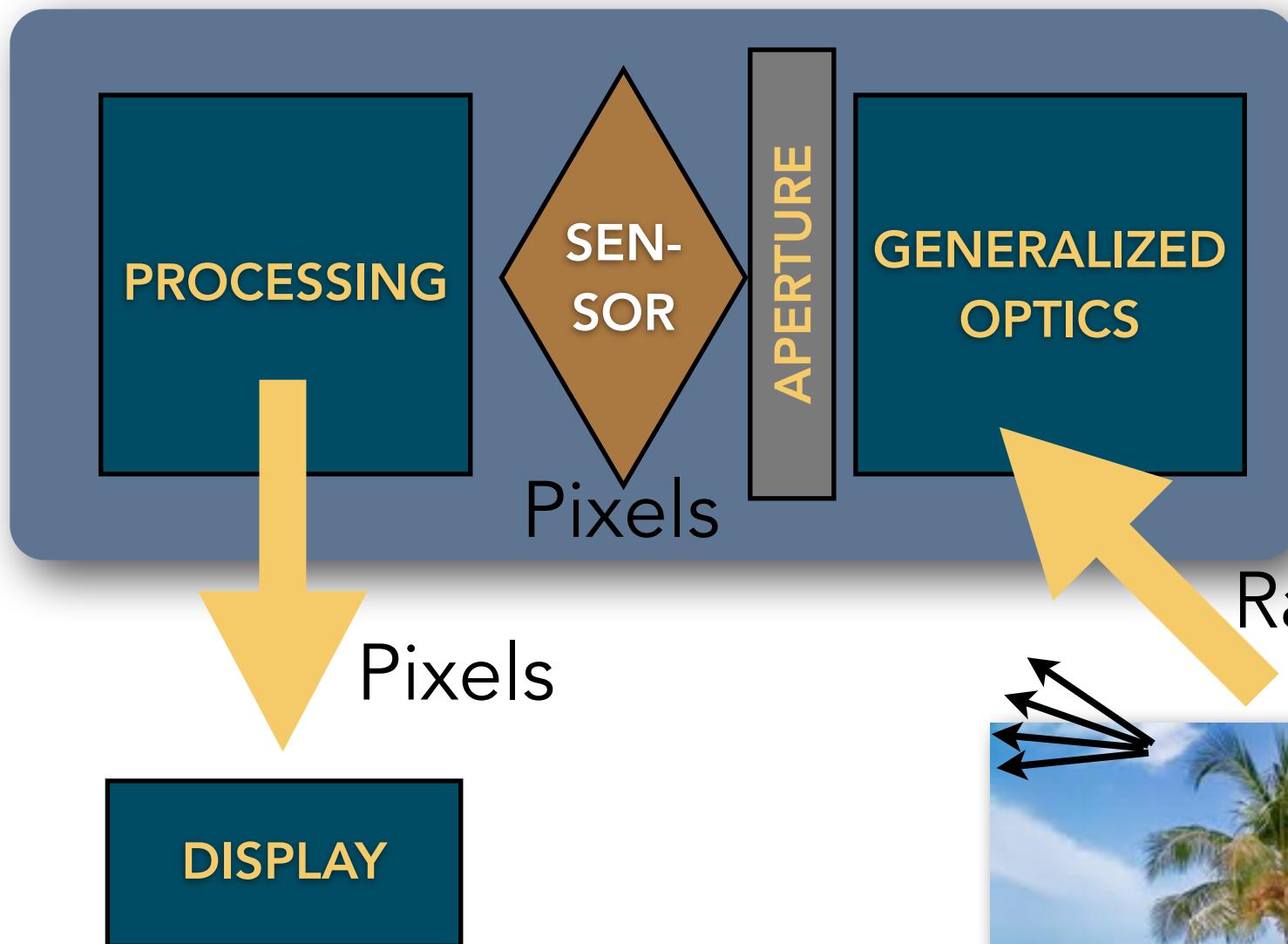


3D Scene

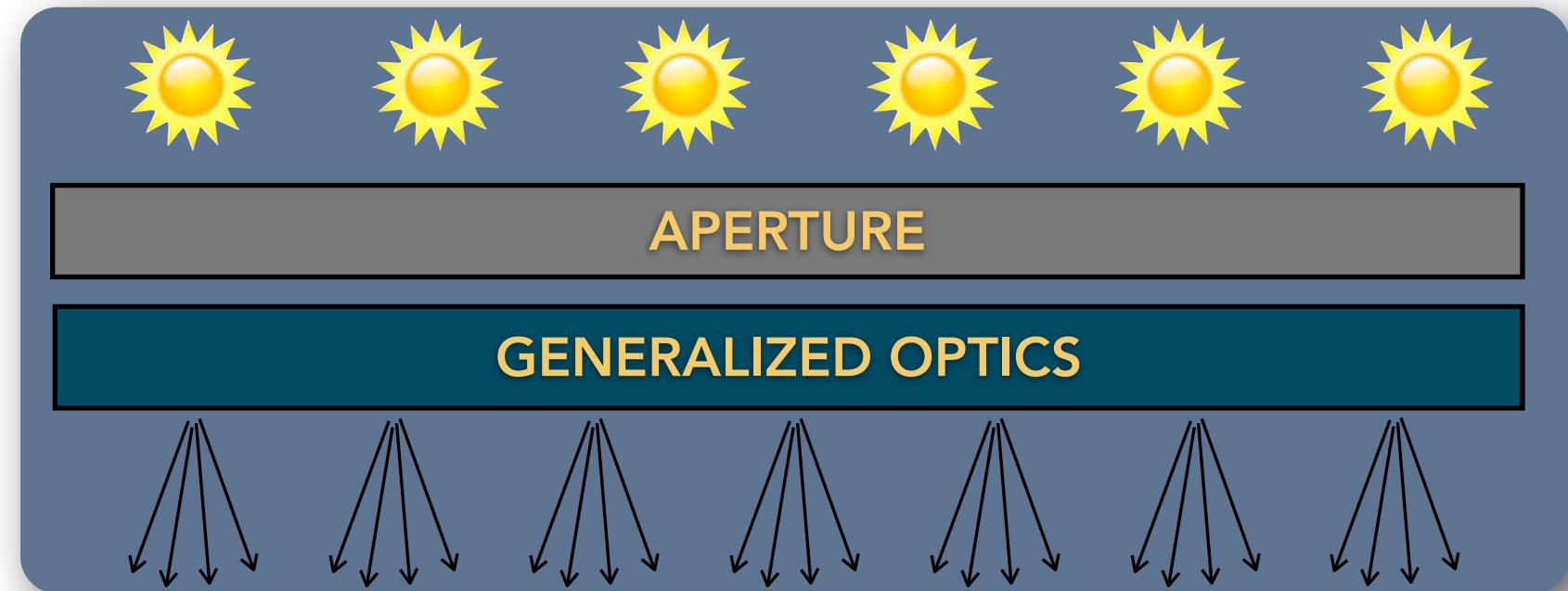
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

Novel Camera



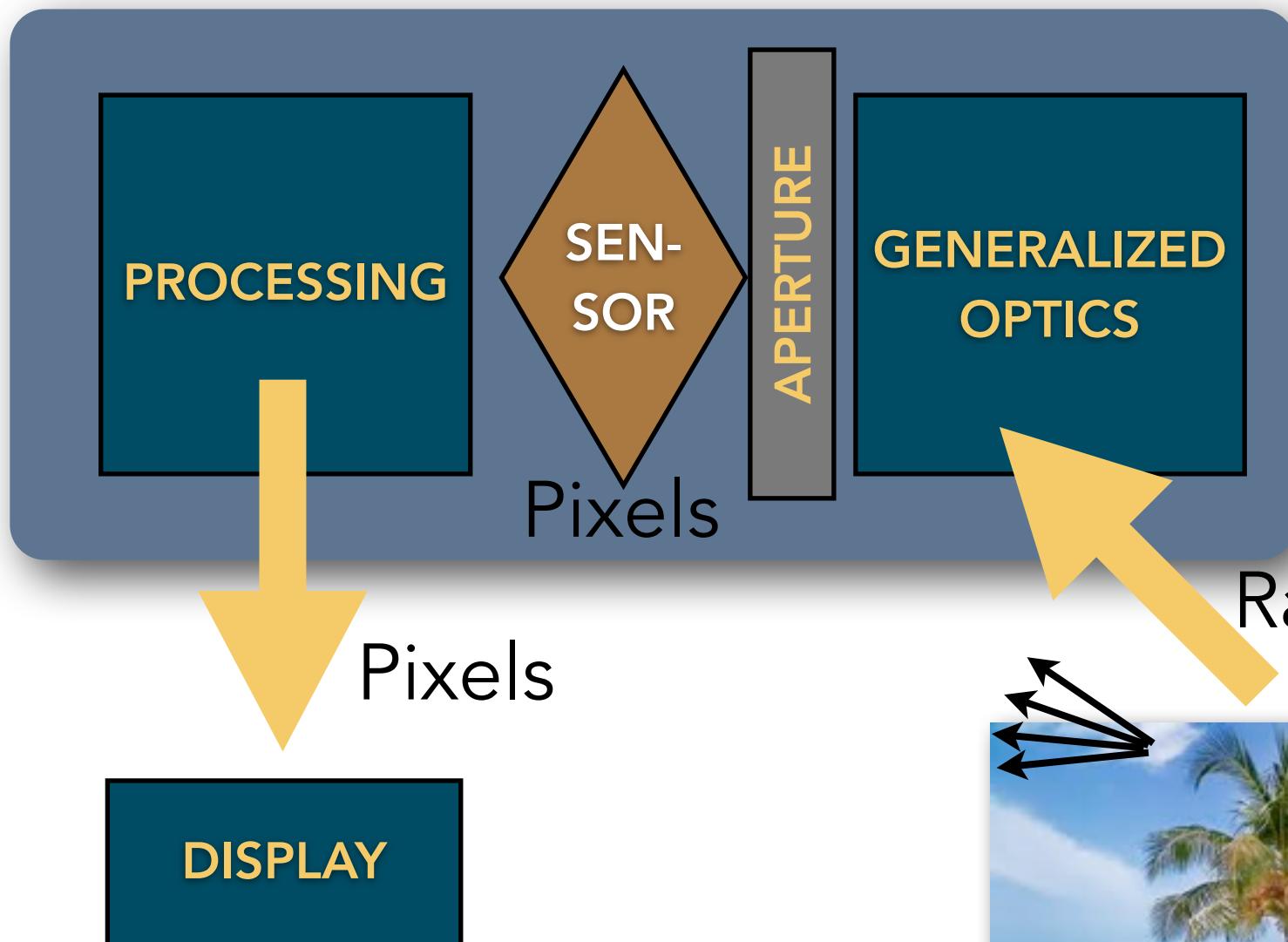
Novel Illumination



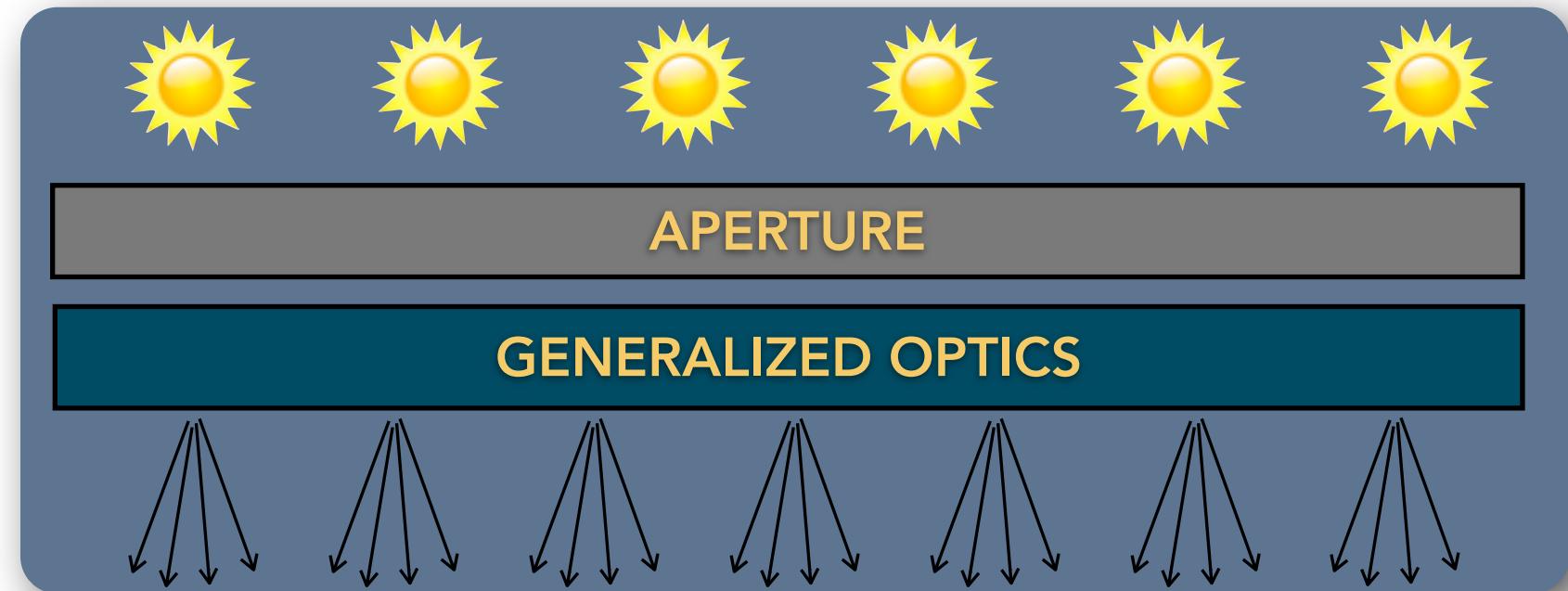
Schematic motivated by Nayar and Raskar

Computational Photography (Rays to Pixels)

Novel Camera



Novel Illumination



Schematic motivated by Nayar and Raskar

Summary

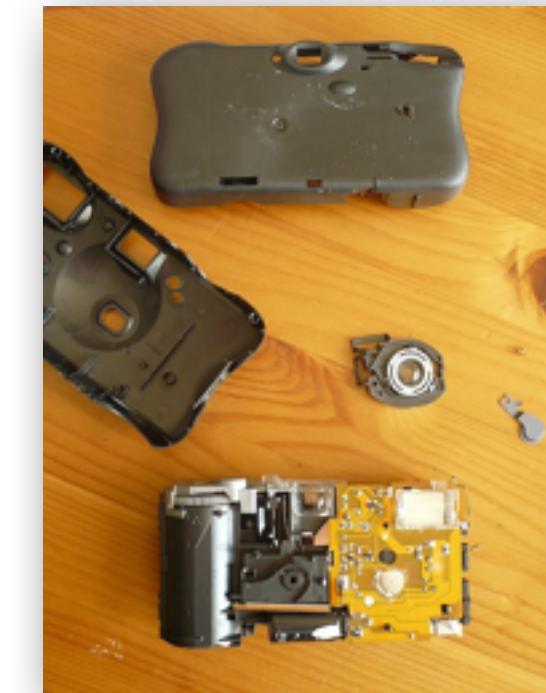
- ★ Discussed how Computational Photography “computationalizes” the entire workflow of photography
- ★ Showed the process of converting rays to pixels
- ★ Provided the terms associated with generalizing control (actuation) of elements: *illumination, optics/aperture, sensor, processing, display, and sharing*
- ★ Emphasized how Computational Photography “Enhances” the photographic processing



http://commons.wikimedia.org/wiki/File:Water_droplet_blue_bg05.jpg

Next Class

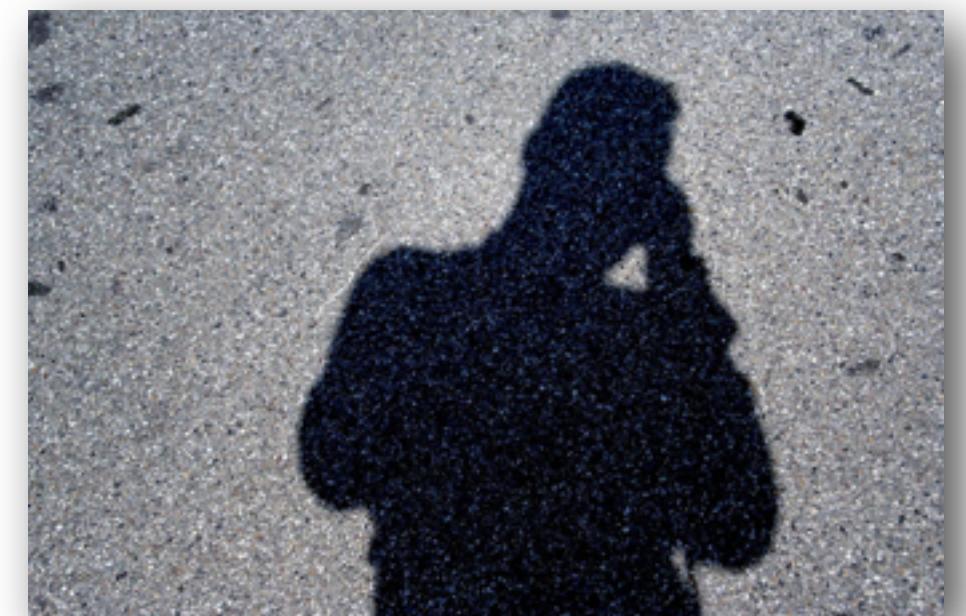
- ★ Look at a specific example of Computational Photography
- ★ A deeper dive, with brief details about how “computationalizing” the different elements of Computational Photography can generate novel images.

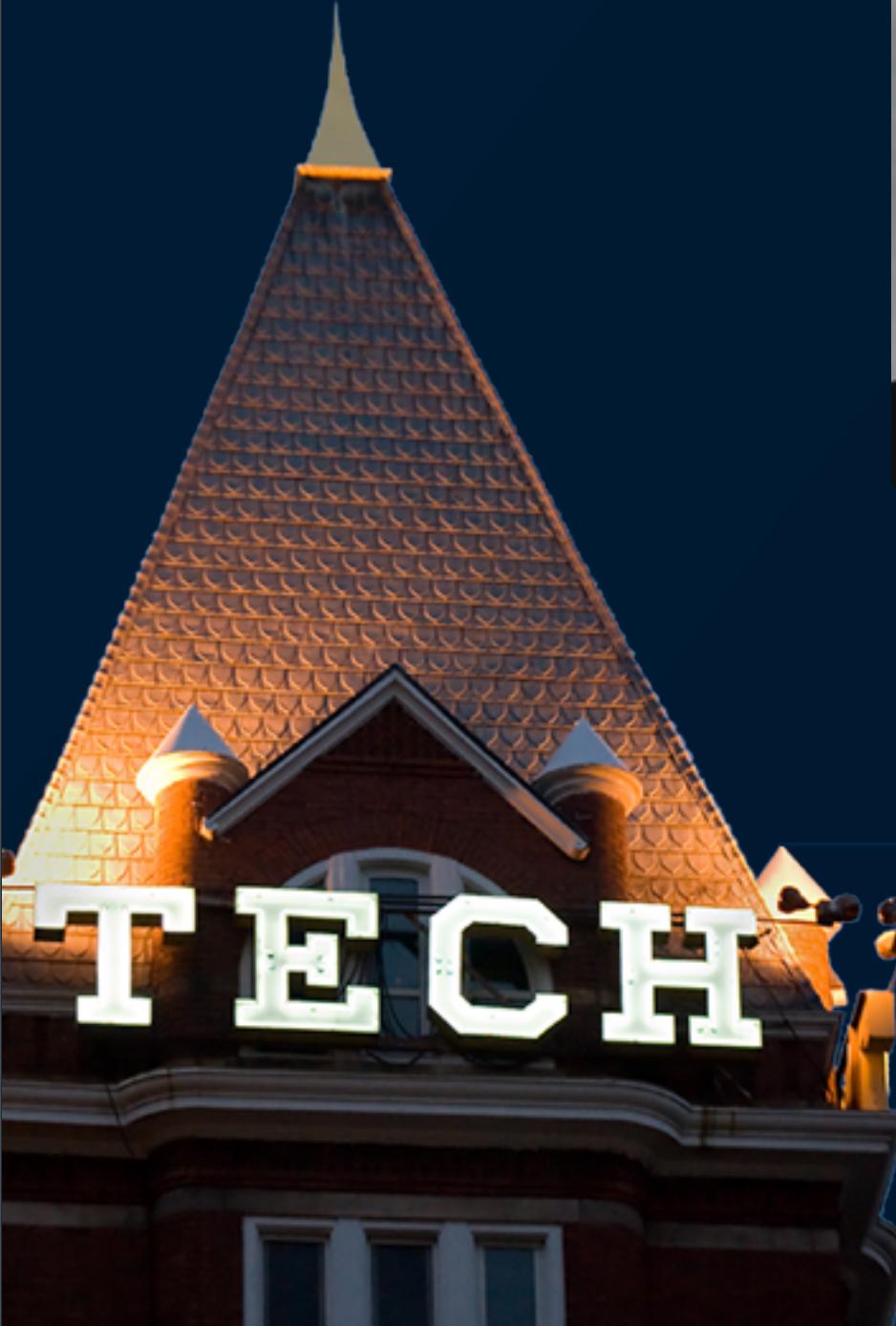


<http://www.flickr.com/photos/heredragons/2479043774/>

Credits

- ★ Adams, Talvala, Park, Jacobs, Ajdin, Gelfand, Dolson, Vaquero, Baek, Tico, Lensch, Matusik, Pulli, Horowitz, Levoy (2010) "The Frankencamera: An Experimental Platform for Computational Photography", In SIGGRAPH 2010
- ★ Some schematics motivated by Shree Nayar, Ramesh Raskar, and Jack Tumblin.
- ★ Images
 - <http://www.flickr.com/photos/neneonline/231886965/>
 - <http://www.flickr.com/photos/heredragons/2479043774/>





Computational Photography



Dr. Irfan Essa

Professor

School of Interactive Computing

Study the basics of the impact of computation on the entire workflow of photography, from how images are captured, manipulated and collaborated on, and shared.