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## Convergence Real-Virtual thanks to Optics & Computer Sciences

Xavier Granier

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***Convergence Real-Virtual  
thanks to  
Optics & Computer Sciences***

**Xavier Granier**



# Spatial Augmented Reality

[Ridel – Reuter – Granier]

La torcia rivelatrice

Con un dito ridai ai marmi i colori antichi.

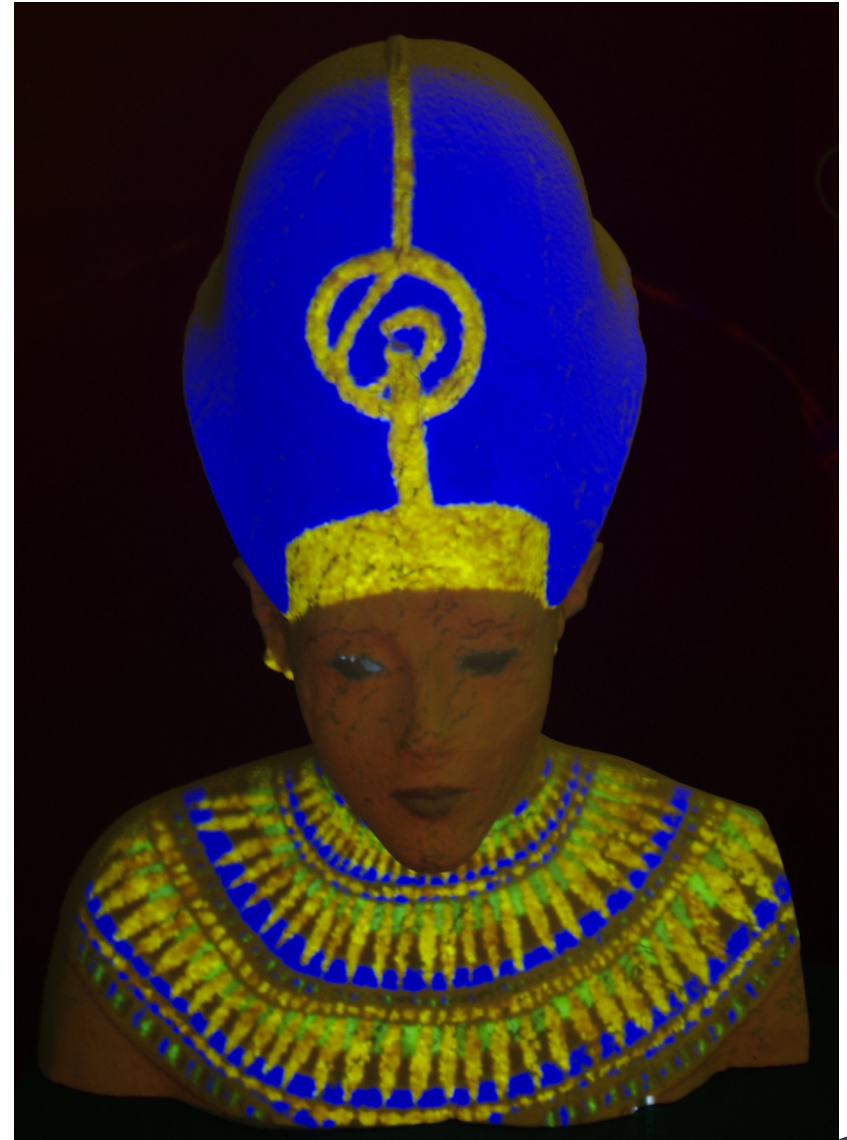
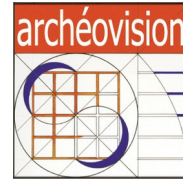
The revealing torch

Give back the marbles their ancient colors with your finger.



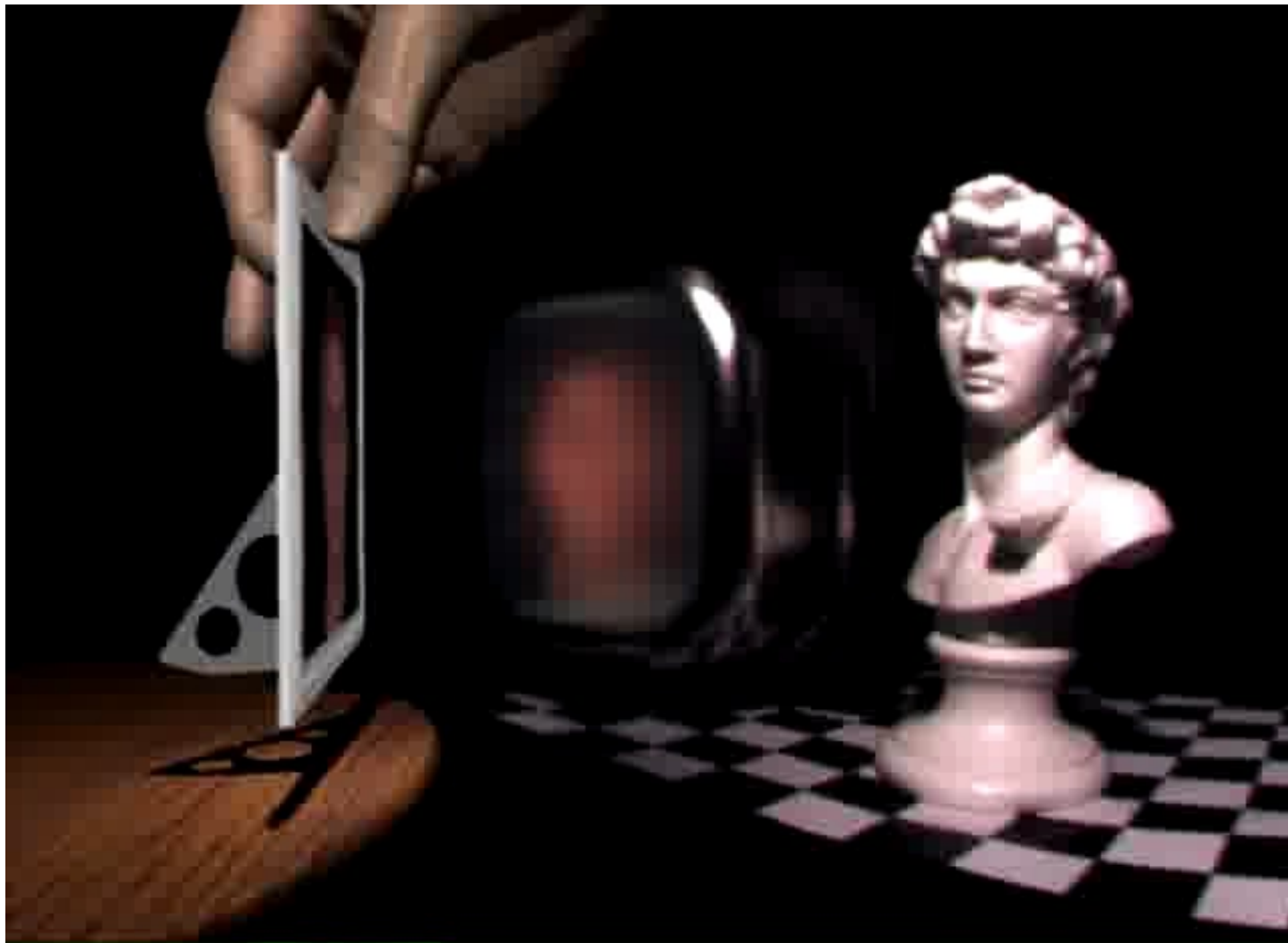
**Mercati di Traiano  
Museo dei Fori Imperiali**

# Convergence between real & virtual



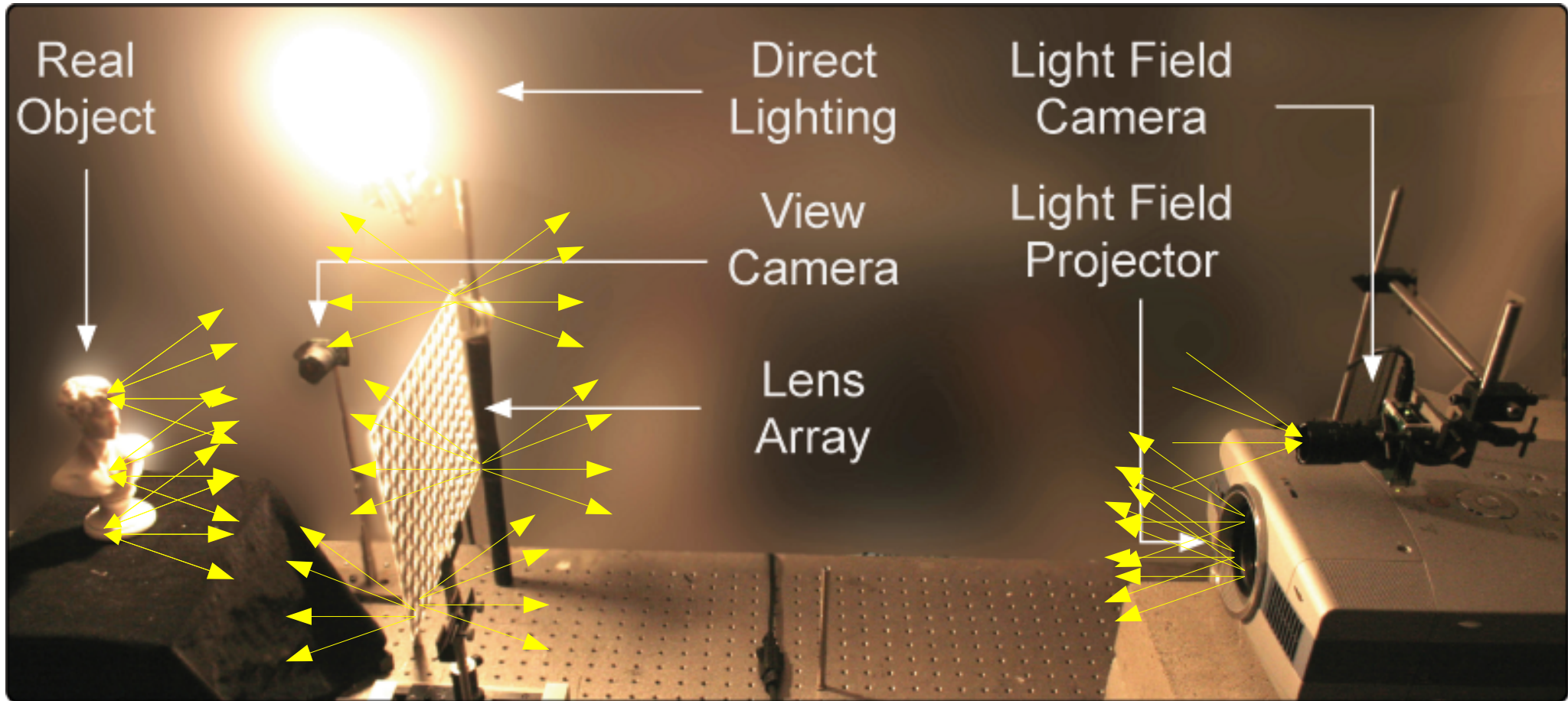
[Ridel – Reuter – Granier 2014]

# Convergence between real & virtual



Columbia University 2008  
Sino-French Symposium 2015

# A unique representation in a hybrid systems

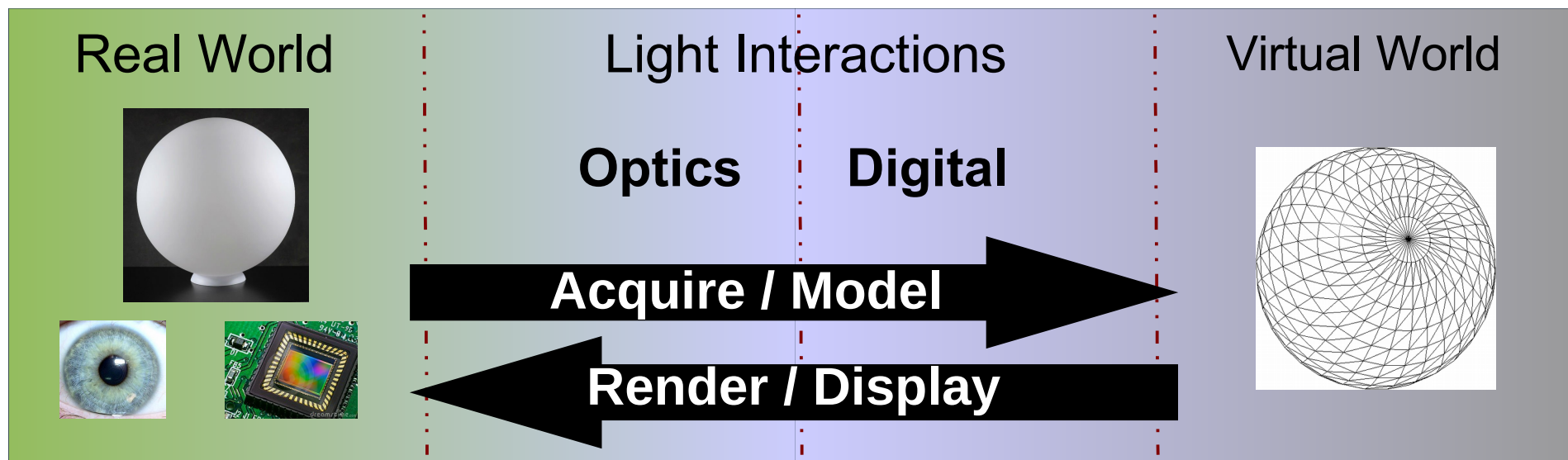


Cossairt – SIGGRAPH 2008

# Convergence Real-Virtual

A **global but specialized view** of light interactions

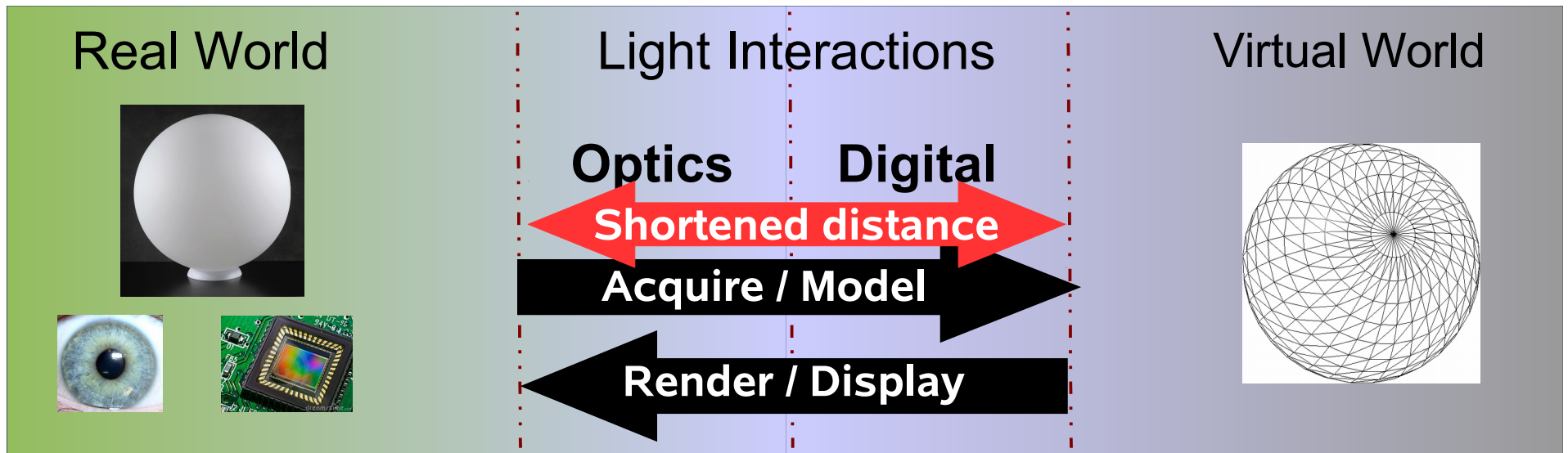
- ◉ **Real World:**
  - ◉ Physics and Optics laws
  - ◉ Sensors characteristics (physical & human)
- ◉ **Virtual World:** models & algorithms



# Convergence Real-Virtual

A **global but specialized view** of light interactions

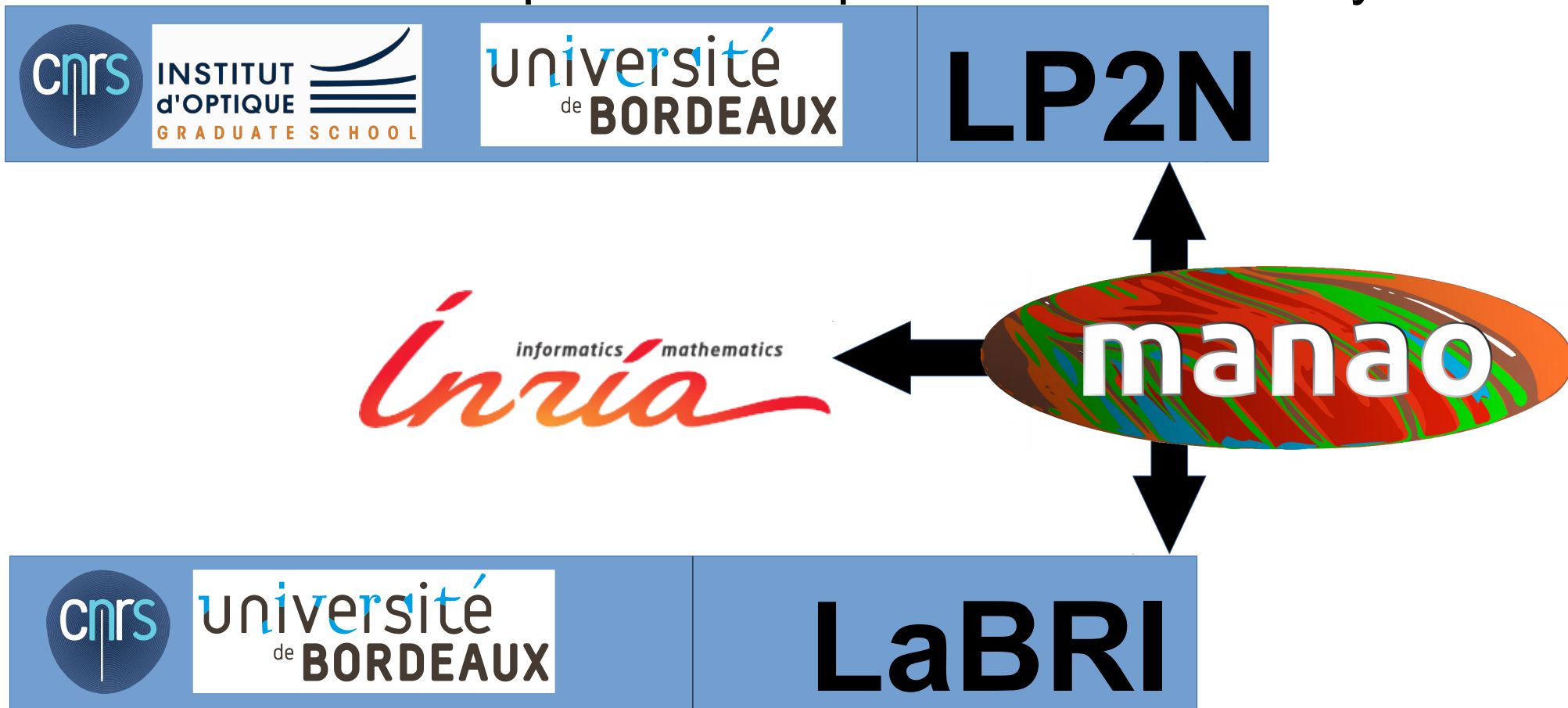
- ◉ **Real World:**
  - ◉ Physics and Optics laws
  - ◉ Sensors characteristics (physical & human)
- ◉ **Virtual World:** models & algorithms





# MANAO team-project: a bridge

Axe IV: Computational Optics & Mixed Reality



Team: Image & Sound

Group: Acquisition & Visualization

# 玛瑙科研组在哪里？



# Convergence Optics & Computers

## 4 Challenges

### 1. Simulation

### 2. Tools for design & Co-design

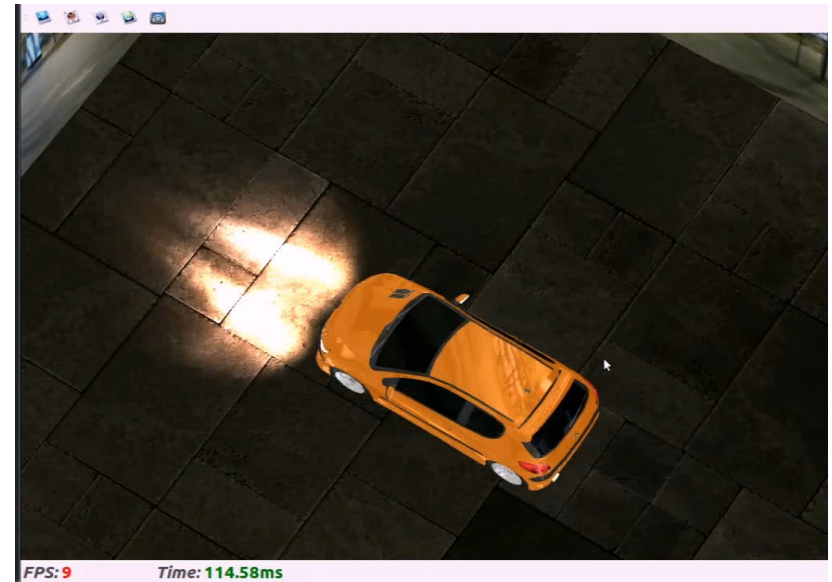
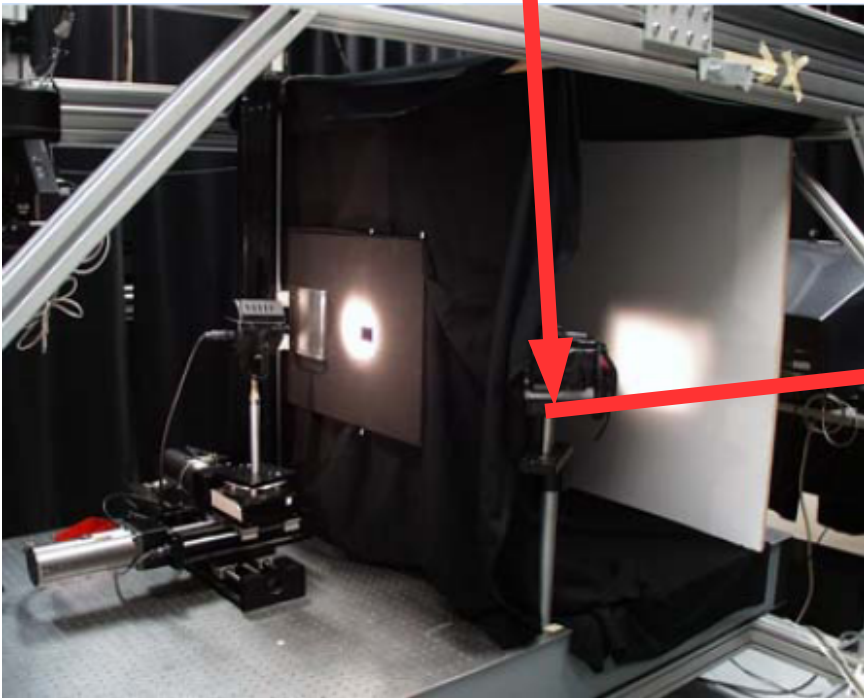
### 3. Hybrid systems

### 4. Certifications

- *Systems, tools*
- *Simulations*

# Interactive simulation of transfers

$$L(p \rightarrow \vec{o}) = L_e(p \rightarrow \vec{o}) + \int_{\Omega} \rho(\vec{\omega} \rightarrow p \rightarrow \vec{o}) \langle \vec{n} \cdot \vec{\omega} \rangle L(\vec{\omega} \rightarrow p) d\vec{\omega}$$



$$L(u, v, s, t) = \sum_{ij} I_{ij}(s, t) \frac{d^2}{\cos^2 \varphi} \phi_{ij}(u, v)$$

[Lu – Pacanowski – Granier 2015]

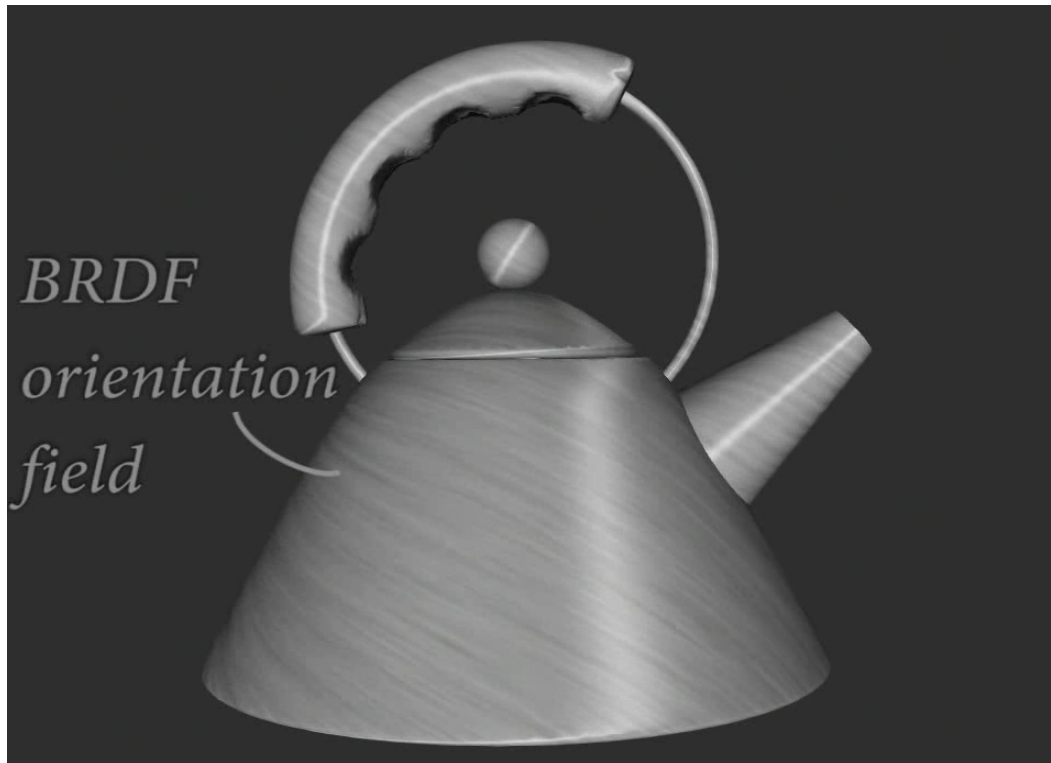
# Conception : BRDF orientation field

- **Theoretical analysis**

- *BRDF orientation field*
- *Highlight tangent field*

- **Optimization**

- *Orientation field*
- *To obtain highlights*



[Raymond – Barla – Guennebaud  
– Pacanowski – Granier 2014]

# Co-Design High-dimensional Imaging

Computer  
Graphics

Computer  
Vision

High-D  
images

synthesis

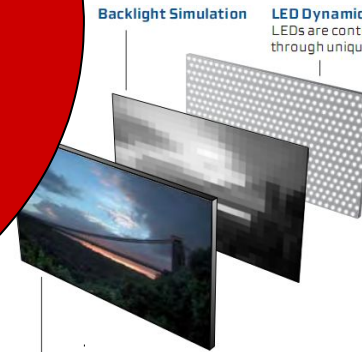
analysis

capture

display

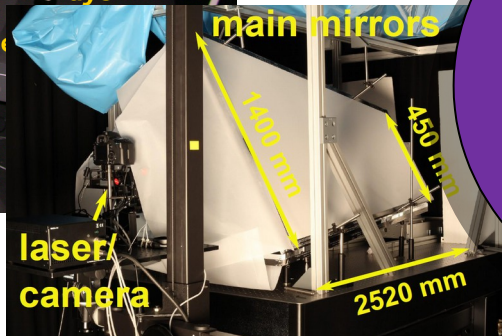
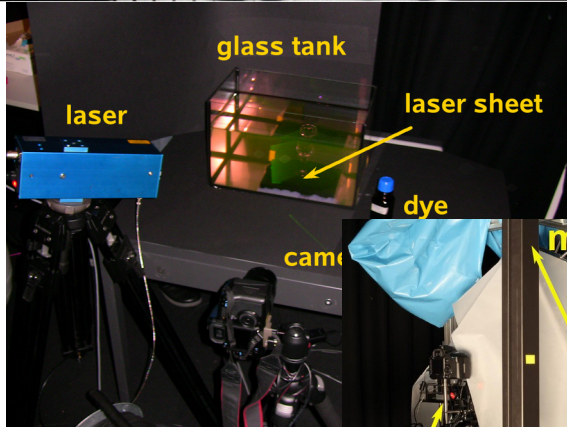
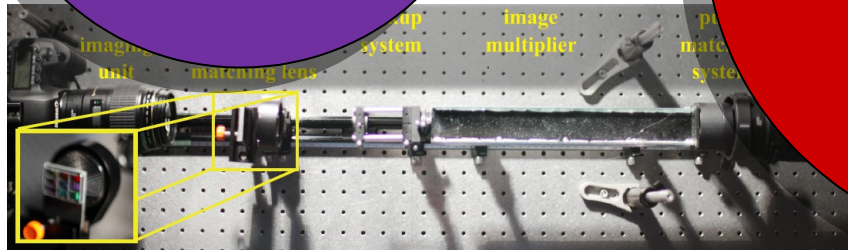
Optics

Backlight Simulation LED Dynamic Backlight  
LEDs are controlled through unique signals.



Dolby Inc.

LCD Provides color, resolution, and contrast. Contrast and image created by combining LED and LCD images.

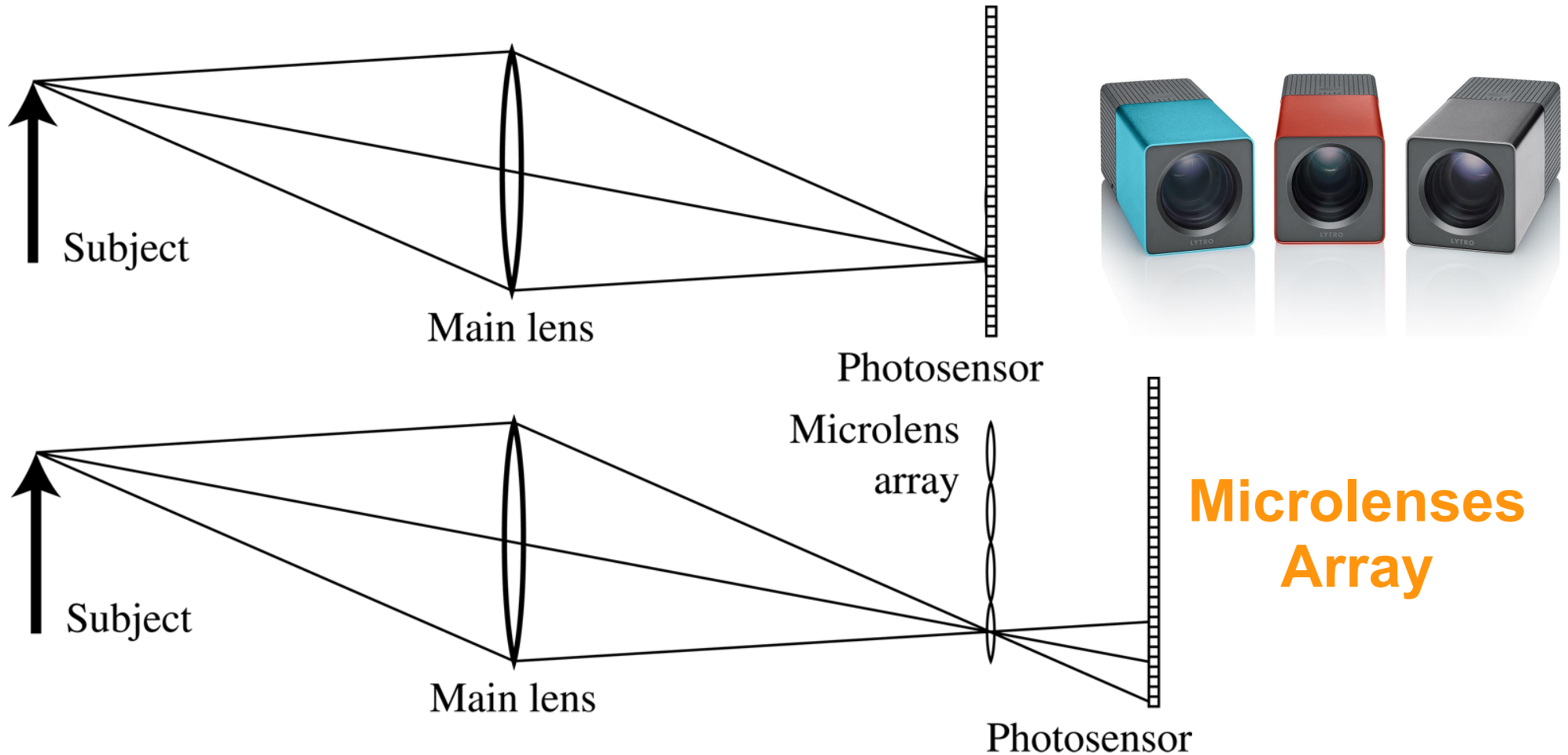


# Light-Field Acquisition



**Lytro**

# Light-Field Acquisition



SIGGRAPH 2005 & TR 2005-02: Ng, Levoy, Brédif, Duval, Horowitz & Hanrahan



# Co-design: Plenoptique Imaging



[Manakov – Retrepo – Ihrke 2013]

# Generalized plenoptic imaging

- **Many copies of the same view**

- *HDR*
- *Spectral Imaging*
- ....

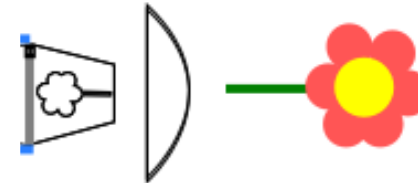
- **Many view-points**

- *Light-Field*

- ...  $L(x, y, z, \vec{l}, \lambda, \vec{\psi}, t)$

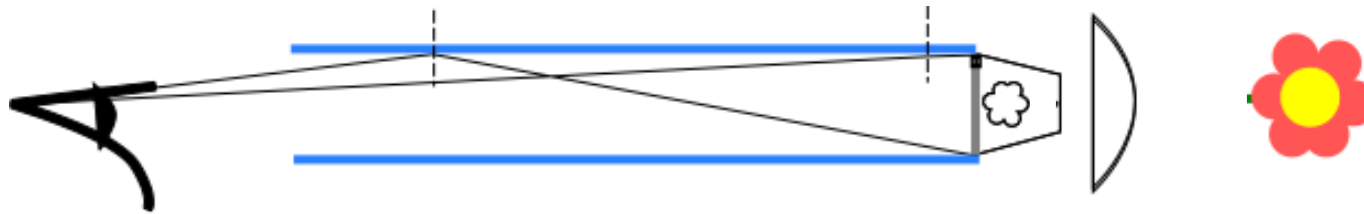
# How to make many copies

- **Directly a diffuser**



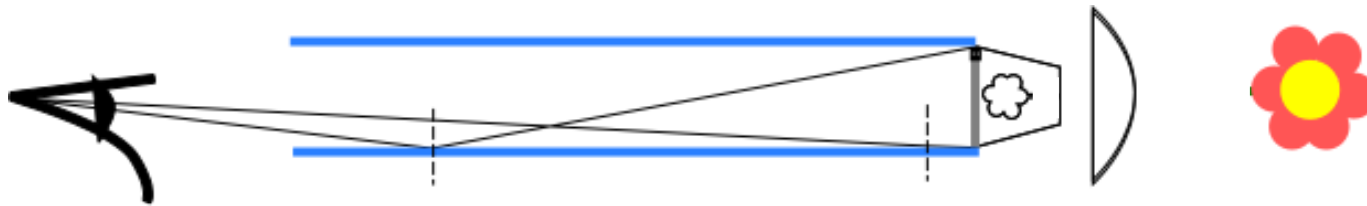
# How to make many copies

- ... and after a reflection



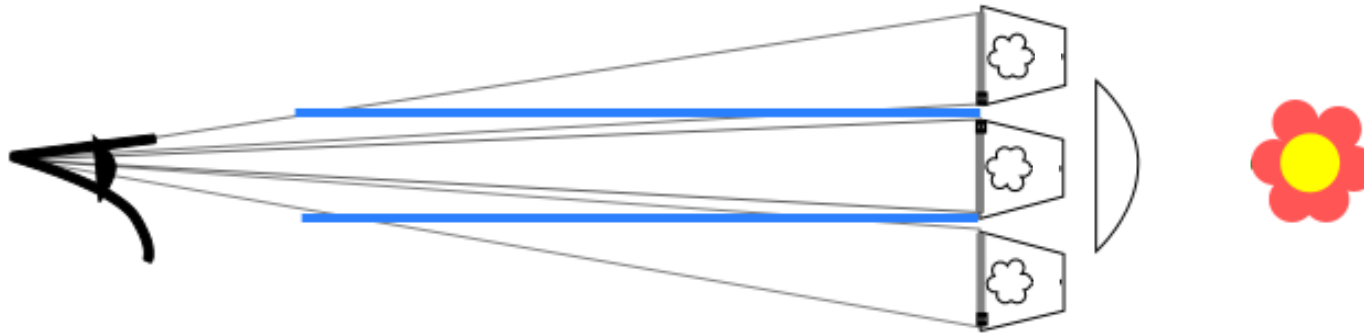
# How to make many copies

- ... and another one

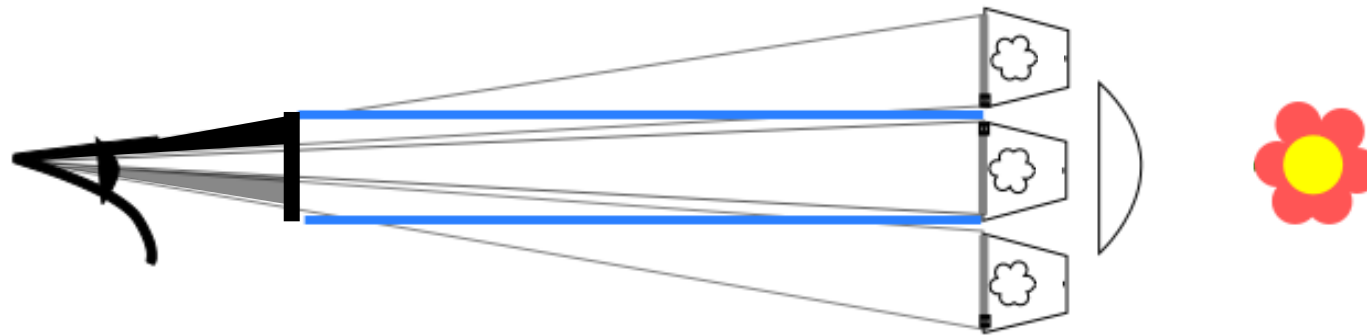


# How to make many copies

- Many virtual copies of the diffuser



# Application 1: HDR Imaging



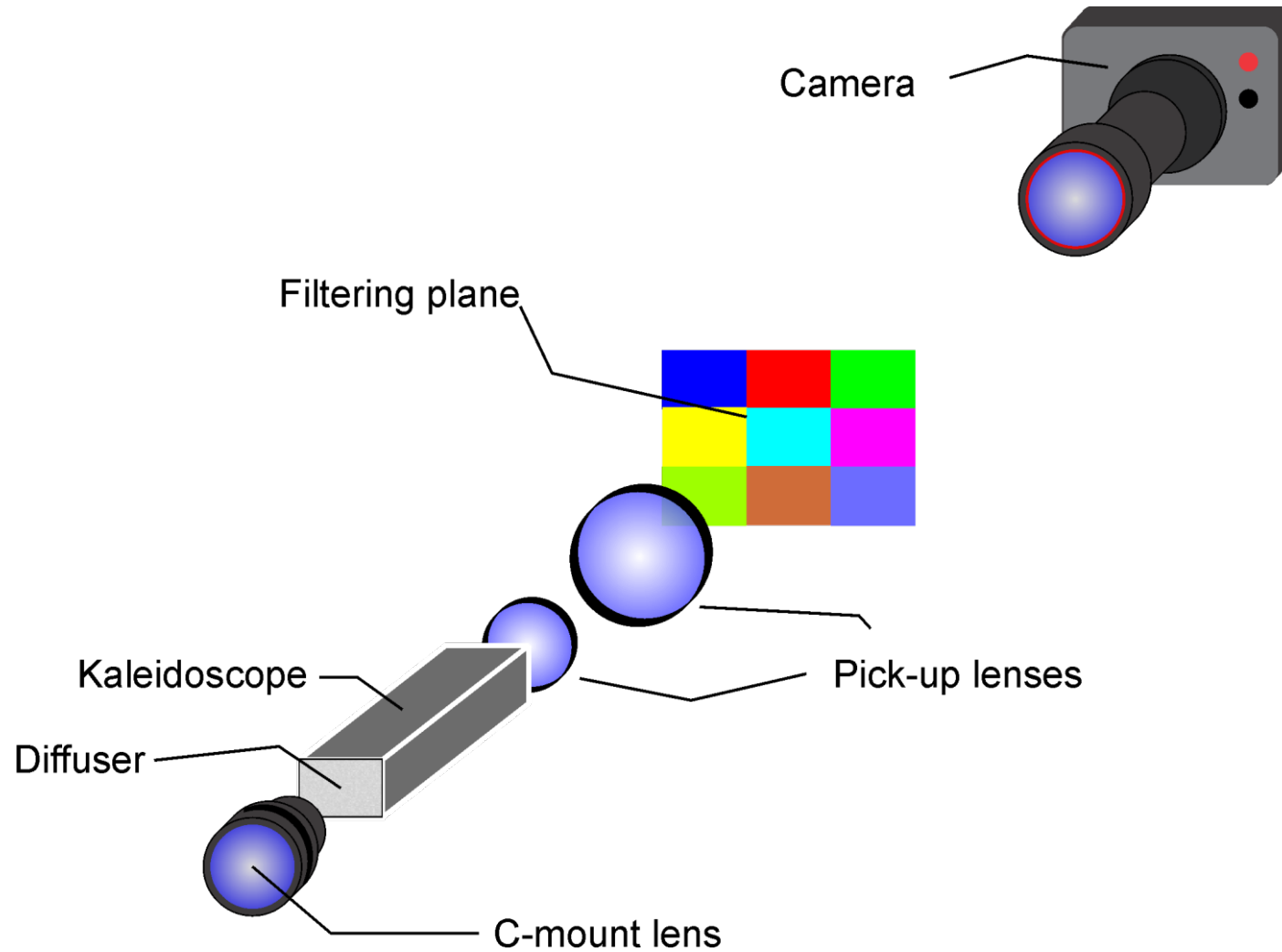
Neutral  
Density  
Filters

# Application 1: HDR Imaging

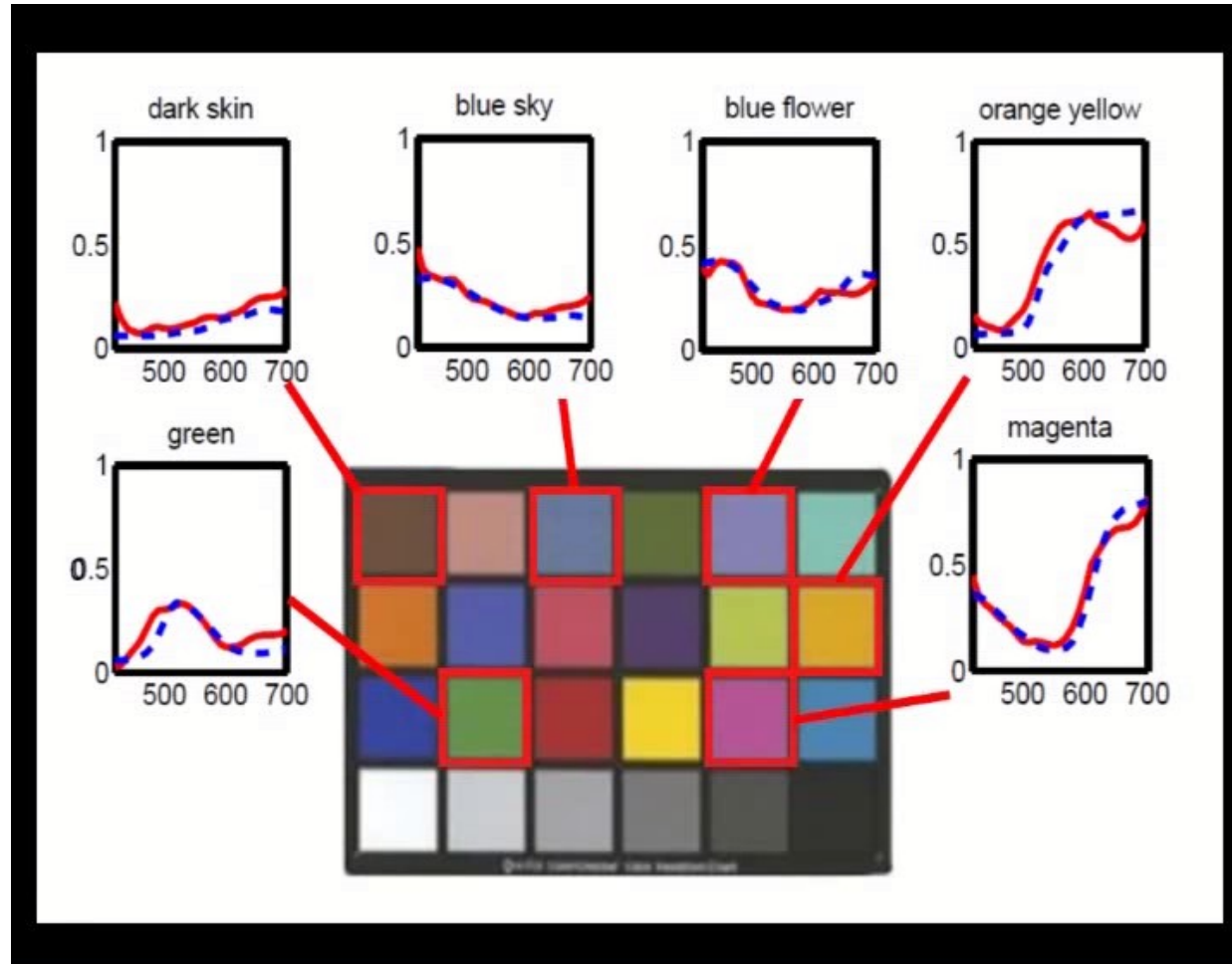




# Application 2: Spectral Imaging



# Application 2: Spectral Imaging



# Imagerie plénoptique généralisée

- **Many copies of the same view**

- *HDR*

- *Spectral Imaging*

- ....

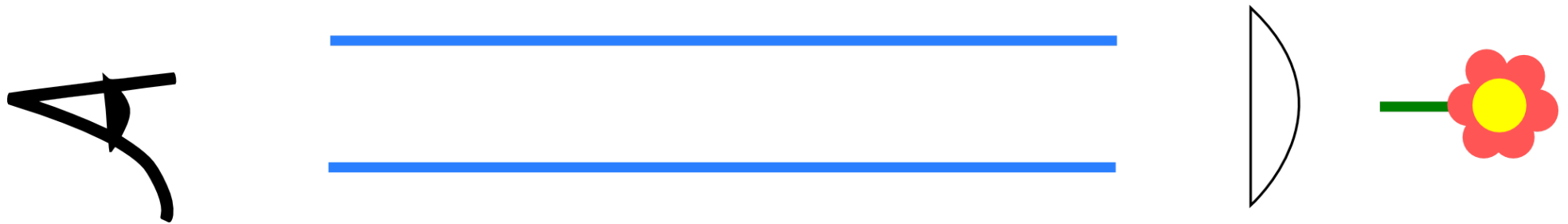
- **Many view-points**

- *Light-Field*

- ...  $L(x, y, z, \vec{l}, \lambda, \vec{\psi}, t)$

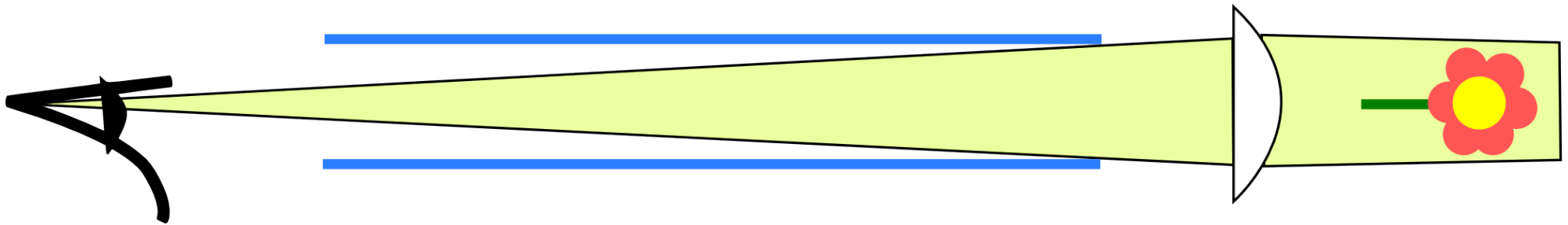
# How to make many viewpoints

- Remove the diffuser



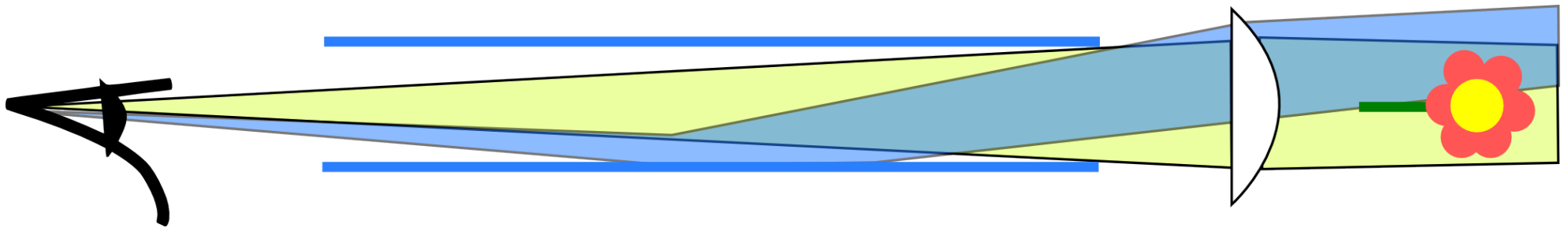
# How to make many viewpoints

- **Direct view point**



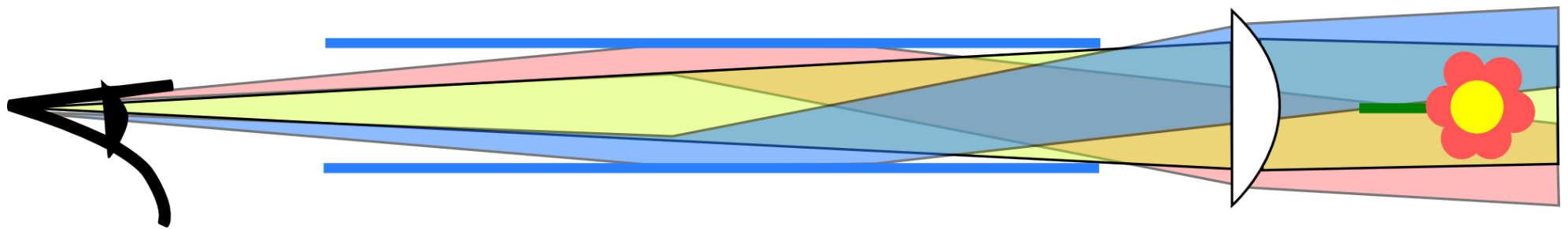
# How to make many viewpoints

- ... and after a reflection



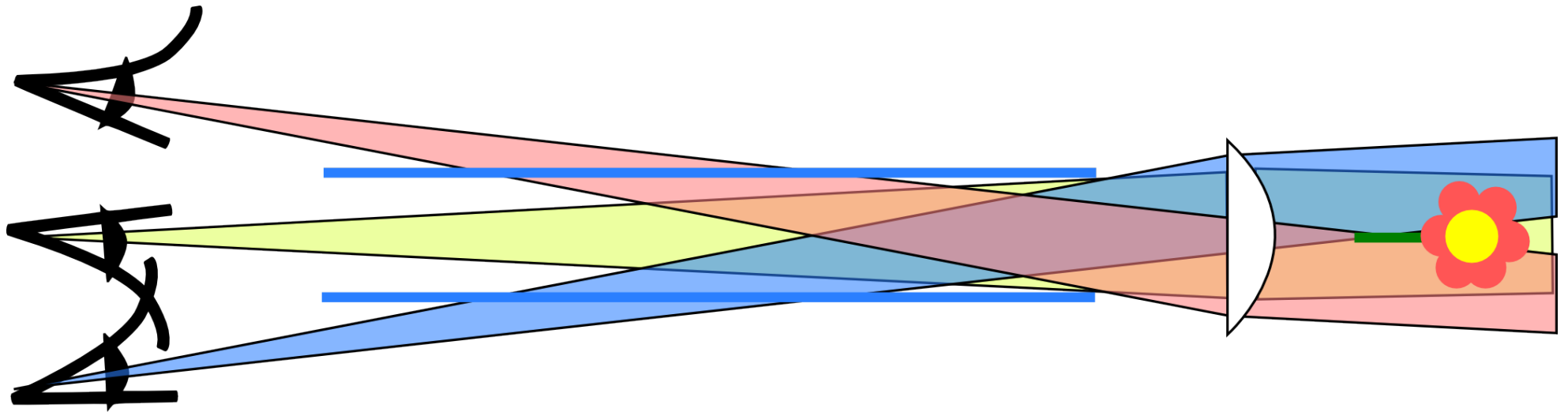
# How to make many viewpoints

- ... and another one



# How to make many viewpoints

- **Virtual view points**





# Resulting Image



# Application 3: Light field



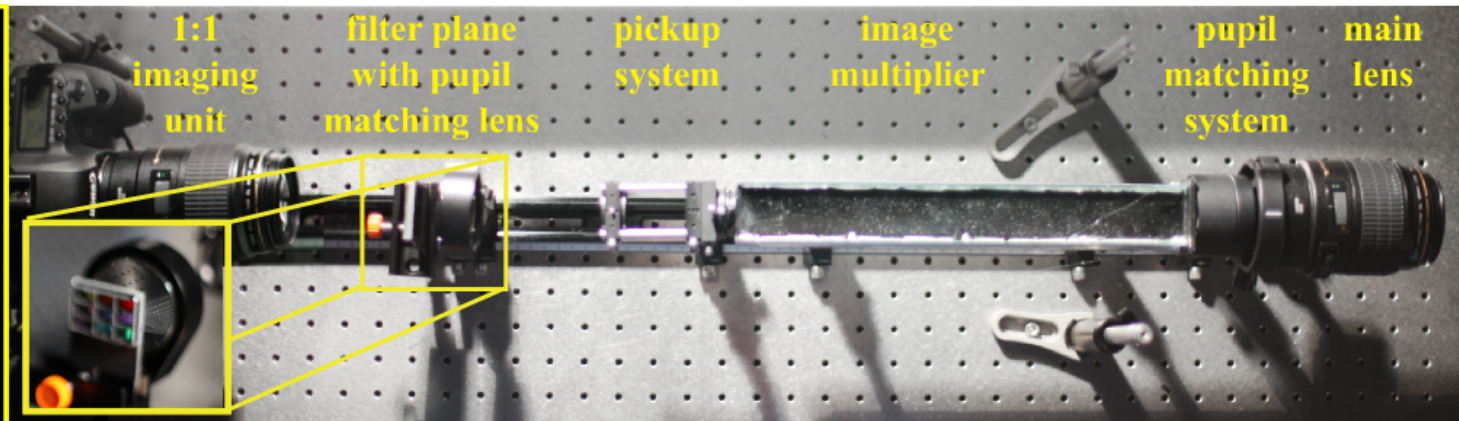
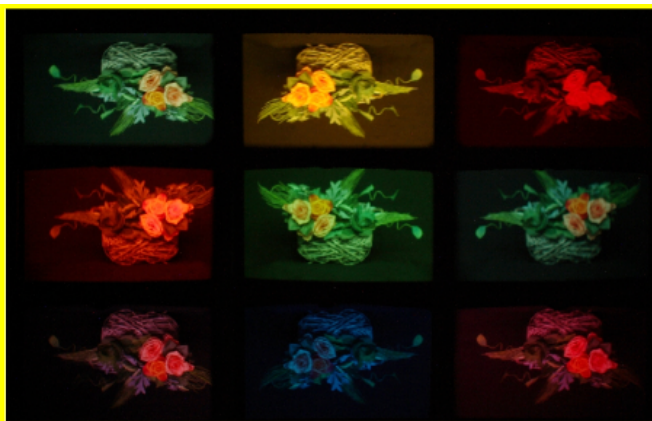
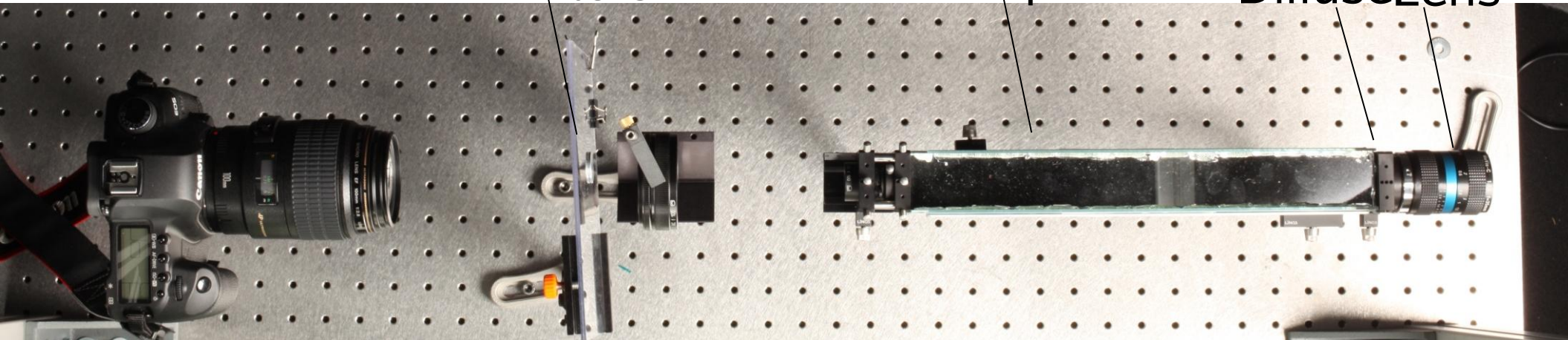
# Reconfigurable Plenoptic Camera

Camera

Filters

Kaleidoscope

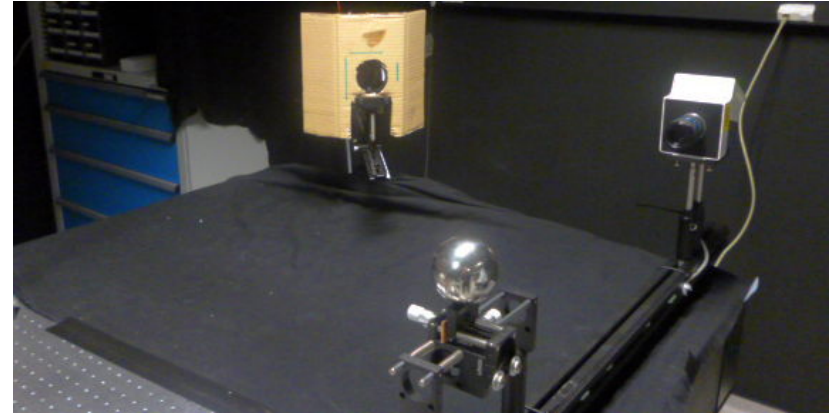
Diffuse Lens



# COEL : Computational Optical Experimentation Lab

- **Experimentation platform**

- *Prototyping hybrid systems*
- *Optical and mechanical components*
- *Controlable lighting*
- *Computer resources*

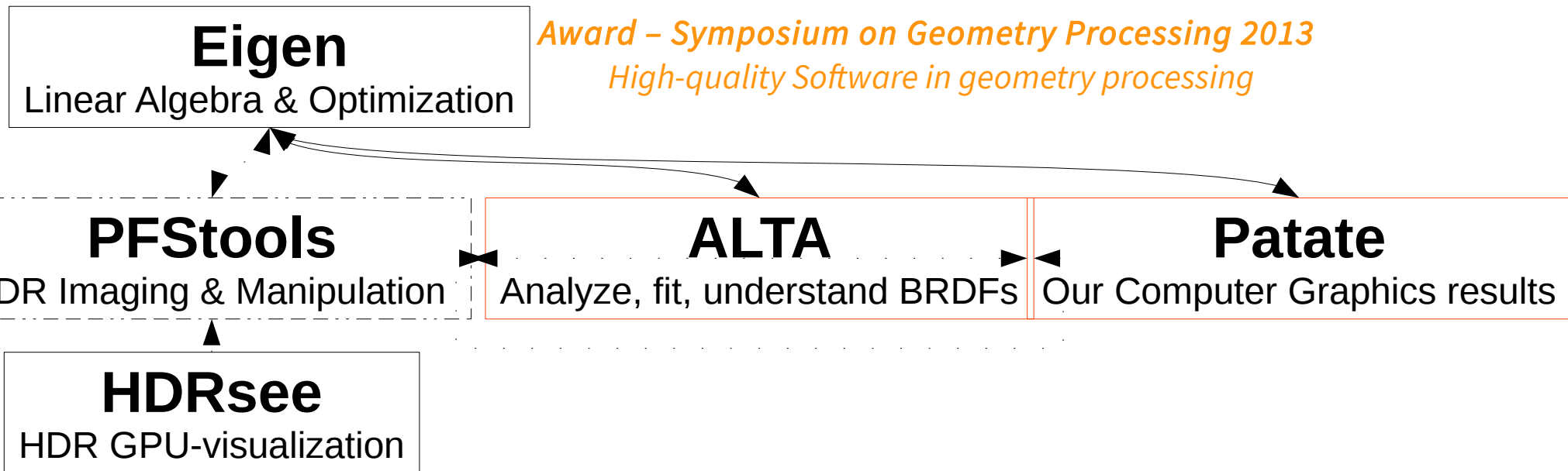


- **Common effort**

- *Optic (LP2N)*
- *Computer Science (Inria)*



# Software ecosystem



- **For companies & academies**

- *Historical : Eigen, PFStools, HDRsee*
- *Recents : ALTA, Patate*

# Certification - ALTA library

- Open-source C++ Library
  - Models comparisons (fitting)
  - Data analysis
- Plugins
  - Easy to extend
  - Connections (BRDF Explorer)
- Scripting
- Alpha version
  - Open Data format (MERL, ASTM)
  - Non-linear approximation
  - Rational functions
  - Analytic BRDFs
  - Moment analysis



[Pacanowski – Guennebaud – Barla 2014]

# Conclusion

- **Convergence of Virtual - Real Worlds**
  - *From Acquisition to Display*
  - *Need of hybrid tools: Optics + Computer sciences*
- **Challenges**
  1. *Simulation*
  2. *Tools for design & Co-design*
  3. *Hybrid systems*
  4. *Certifications*