Light transport probing

conventional photography

$$\underbrace{\mathbf{p}}_{n} = \mathbf{T}\,\underbrace{\mathbf{l}}_{m}$$

photo — transport matrix [Ng et al. 03] — light

$\boxed{\text{degrees of freedom} = m}$

primal-dual coding photography

$$\underbrace{\mathbf{p}}_{n} = \Pi \odot \mathbf{T}\,\underbrace{\mathbf{1}}_{m}$$

"probing matrix"

degrees of freedom $= m \times n$

primal-dual coding photography

multiply

$$\mathbf{p} = \mathbf{\Pi} \odot \mathbf{T}\,\mathbf{1}$$

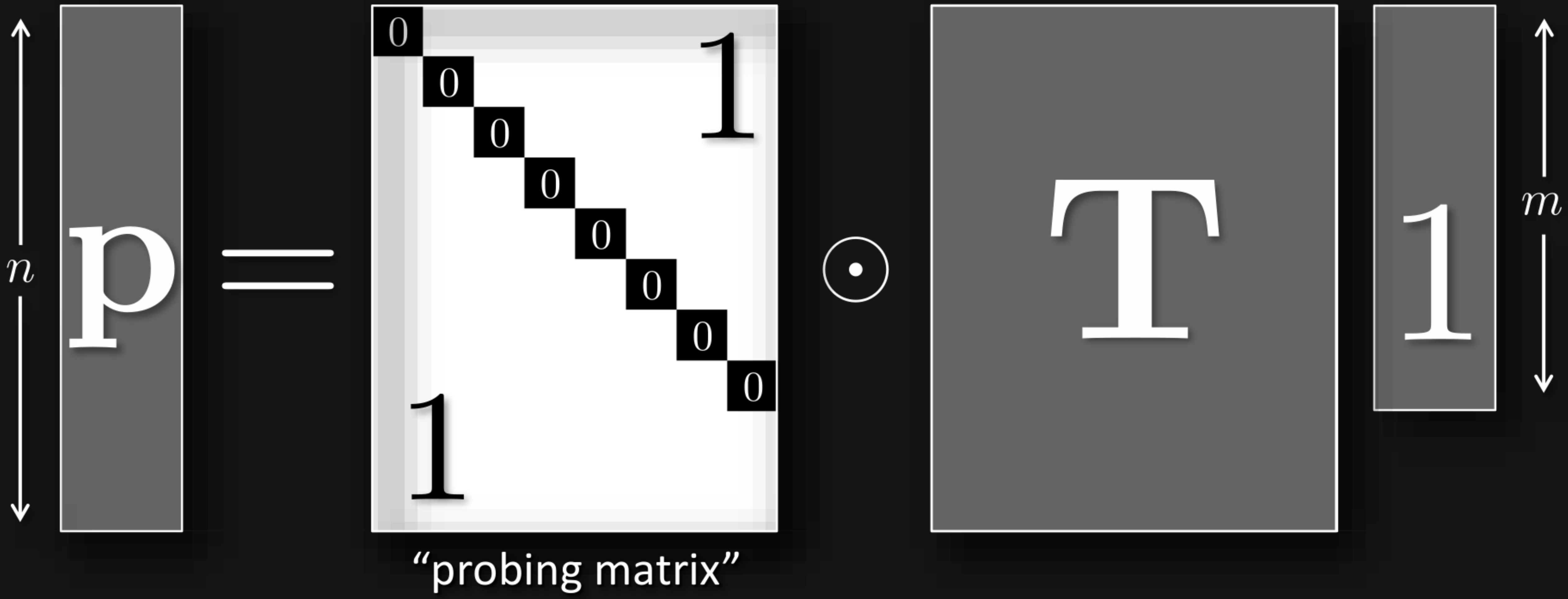
ij $\quad$ ij

n $\quad$ m

“probing matrix”

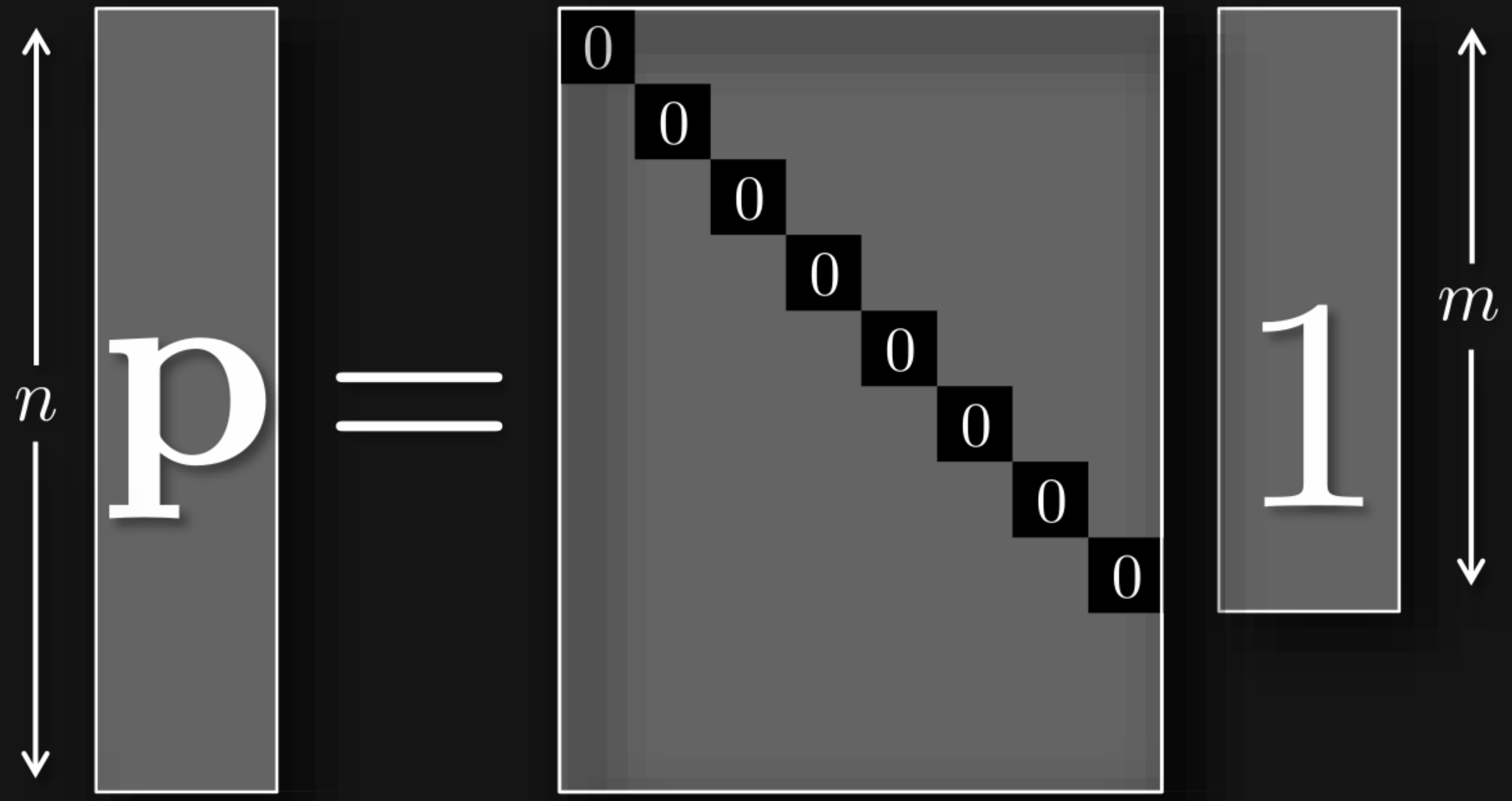
$\boxed{\text{degrees of freedom} = m \times n}$

primal-dual coding photography



degrees of freedom $= m \times n$

primal-dual coding photography



degrees of freedom $= m \times n$

$$\underbrace{\mathbf{p}}_{n} = \Pi \odot \mathbf{T}\,\underbrace{\mathbf{1}}_{m}$$

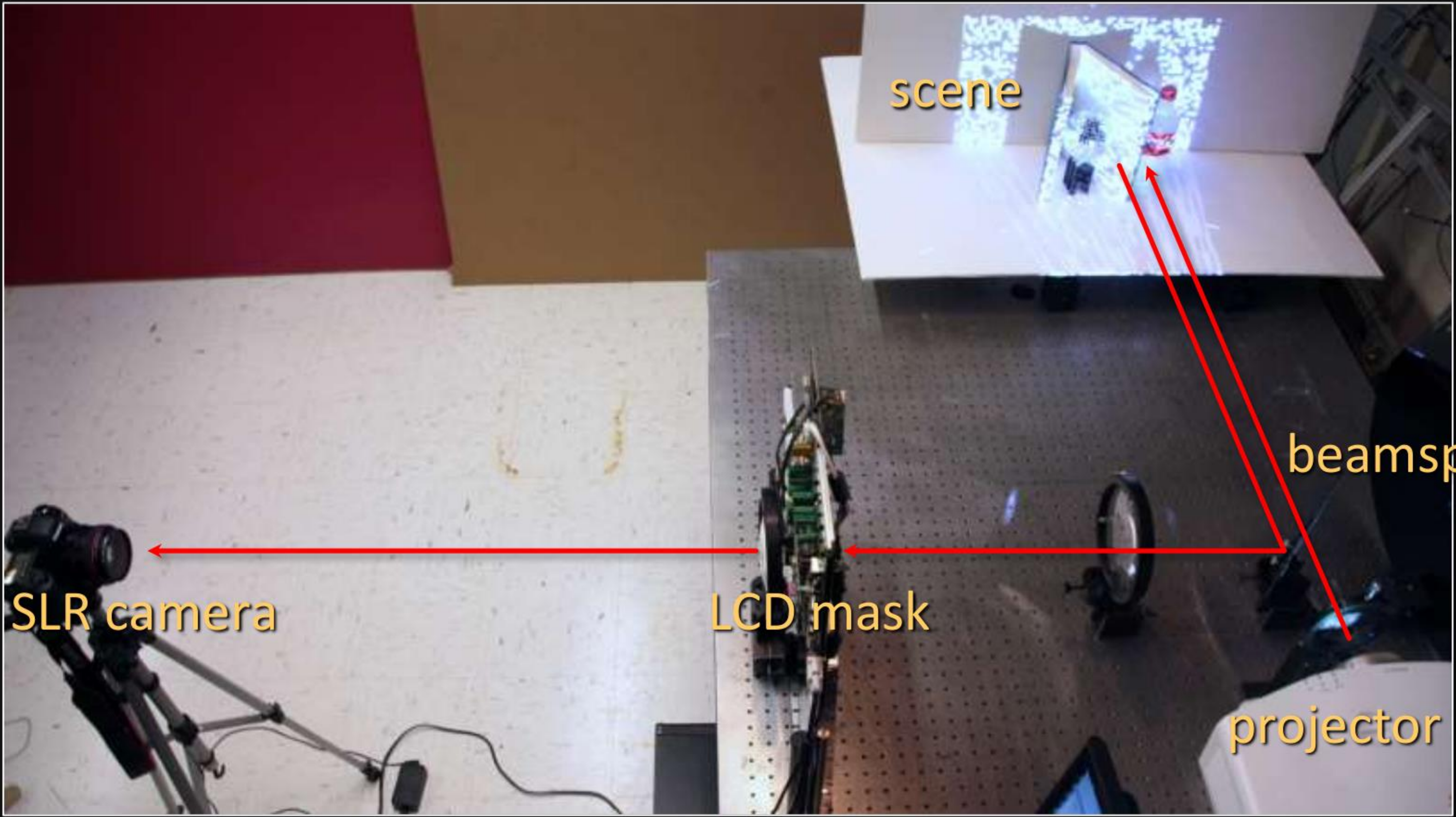
$$\mathbf{p} = \Pi \odot \mathbf{T}\,\mathbf{1}$$

$$\Pi = \sum_{i=1}^{K} \mathbf{m}_i \, \mathbf{l}_i$$

$$\mathbf{p} = \sum_{i=1}^{K} \mathbf{m}_i \odot \mathbf{T}\,\mathbf{l}_i$$

$$\Pi = \sum_{i=1}^{K} \mathbf{m}_i \, \mathbf{l}_i$$

experimental setup



$$\mathbf{p} = \sum_{i=1}^{K} \mathbf{m}_i \odot \mathbf{T}\,\mathbf{l}_i$$

n m

step 5	step 4	step 3	step 2	step 1
close shutter	repeat K times	attenuate image with vector $\mathbf{m}_i$ (dual code)	illuminate scene with vector $\mathbf{l}_i$ (primal code)	open shutter

$$\mathbf{p} = \sum_{i=1}^{K} \mathbf{m}_i \odot \mathbf{T}\,\mathbf{l}_i$$

n m

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close shutter

step 4
repeat K times

step 3
attenuate image
with vector $\mathbf{m}_i$
(dual code)

step 2
illuminate scene
with vector $\mathbf{l}_i$
(primal code)

step 1
open shutter

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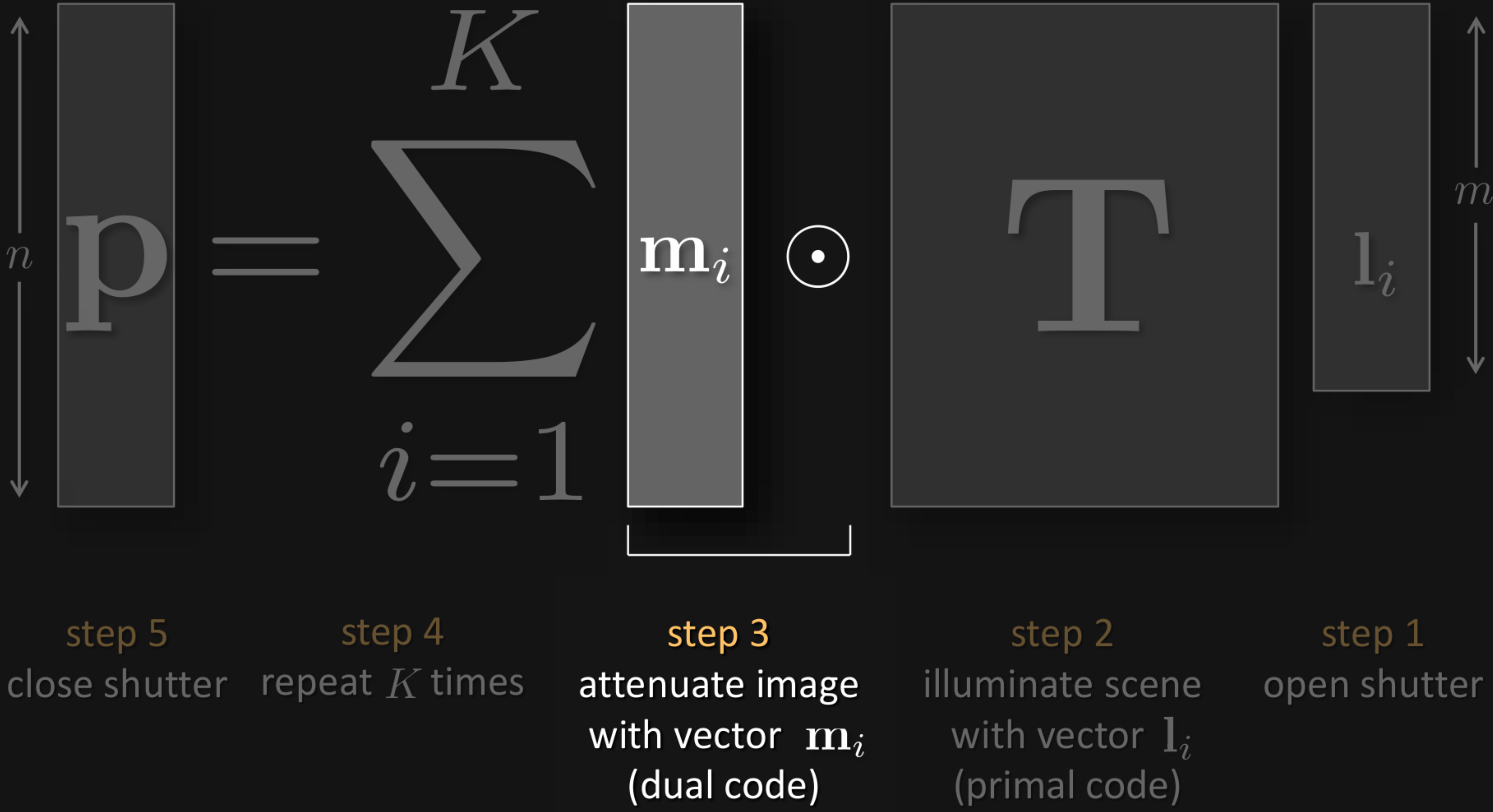
step 1
open shutter



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n
m
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close shutter
step 4
repeat K times
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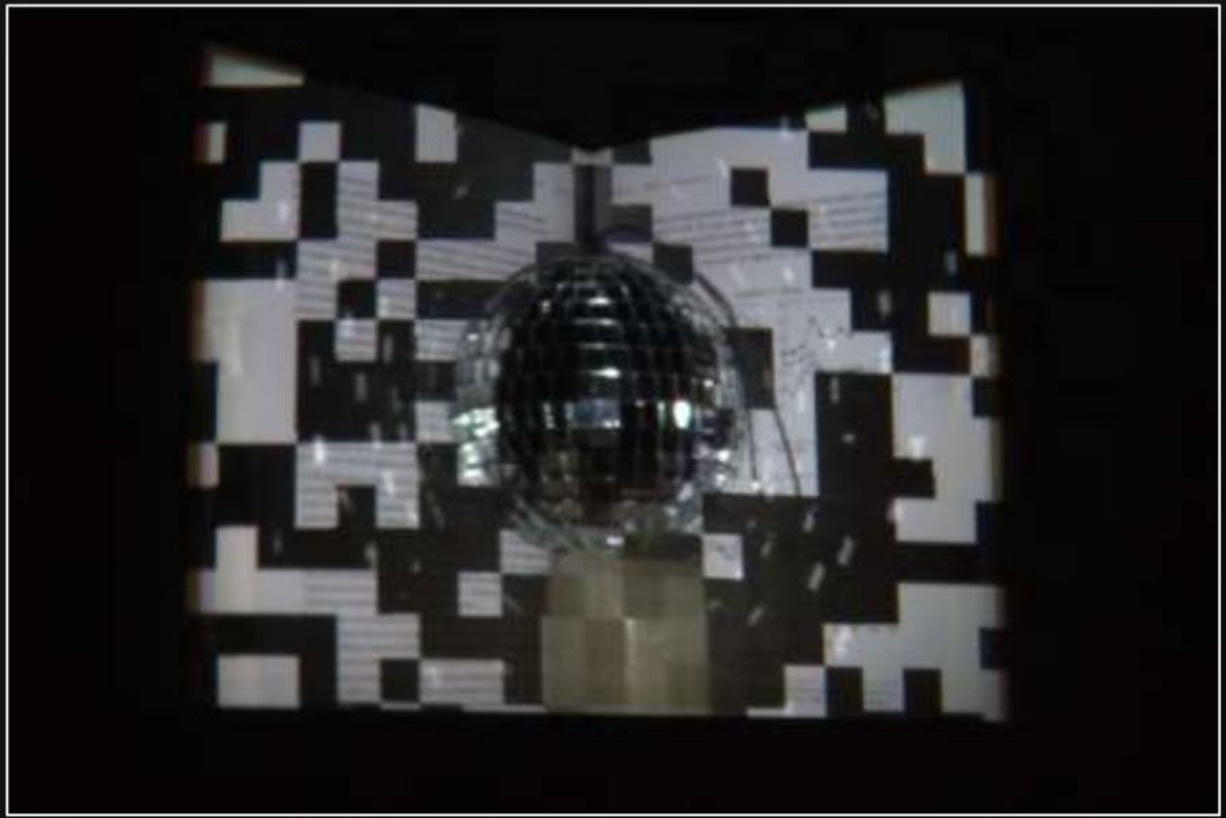
step 2
illuminate scene with vector $\mathbf{l}_i$ (primal code)

step 1
open shutter



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repeat K times

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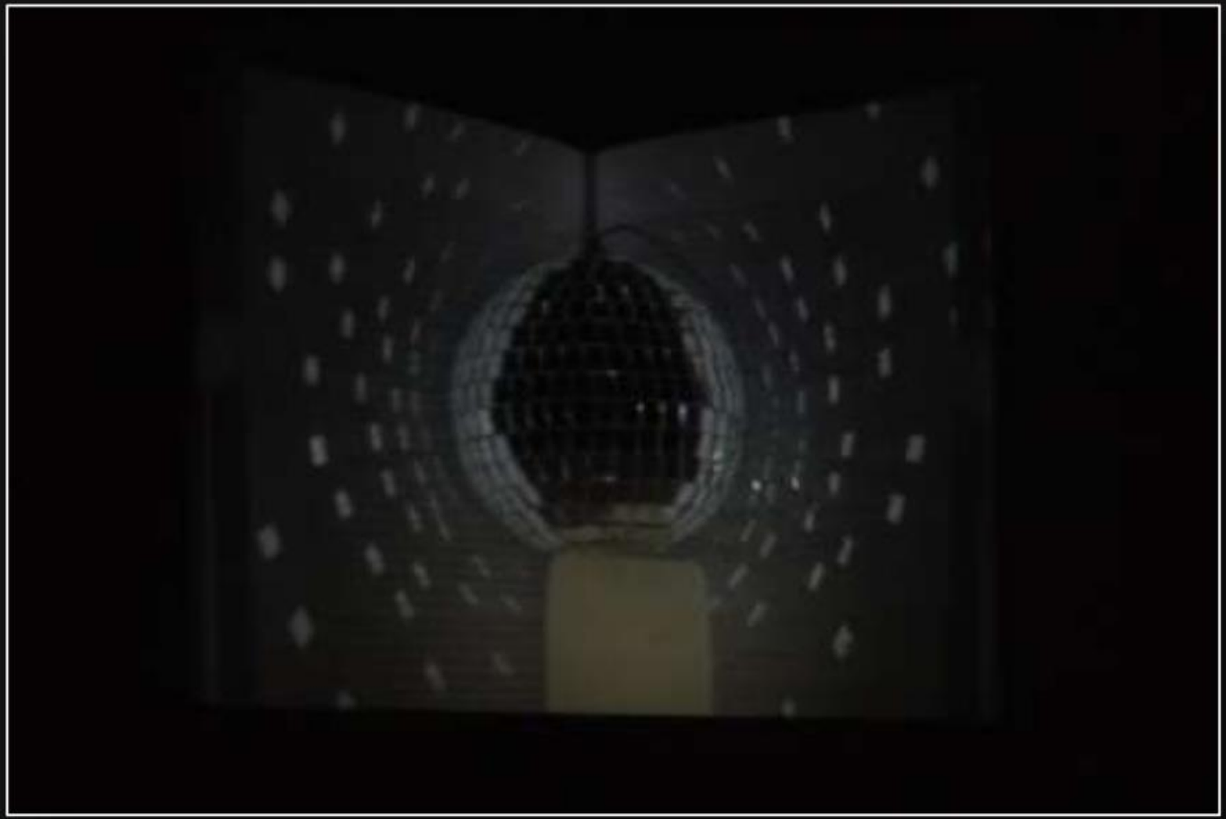
attenuate image with vector $\mathbf{m}_i$ (dual code)

step 2
illuminate scene with vector $\mathbf{l}_i$ (primal code)

step 1
open shutter

$$\sum_{i=1}^{K}$$



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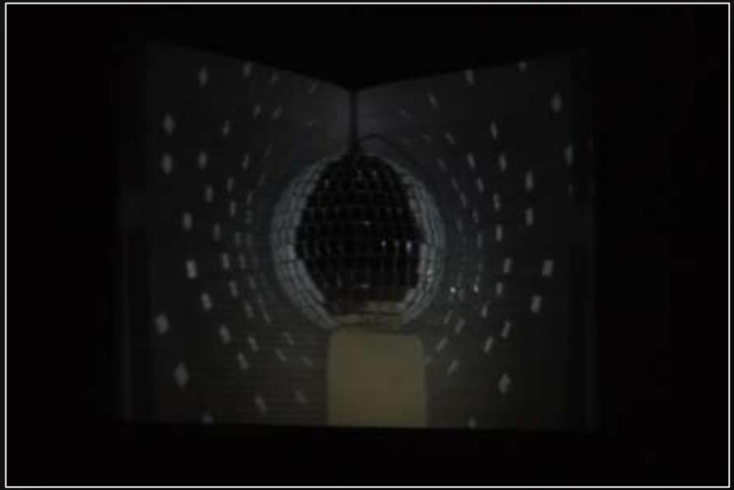

step 5
close shutter

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Rademacher primal-dual codes

stochastic diagonal estimator [Bekas et al. 07]

primal codes are Rademacher random vectors: $\mathbf{l}_i =$ random vector in $\{-1, +1\}^m$

dual codes derive from primal code: $\mathbf{m}_i = \mathbf{l}_i$

codes converge to identity probing matrix: $(\mathbf{I} \odot \mathbf{T})\mathbf{1} \approx \frac{1}{K}\sum_{i=1}^{K} \mathbf{m}_i \odot \mathbf{T}\ \mathbf{l}_i$

variance of pixel n for K primal-dual codes $= \frac{1}{K}\sum_{m=1, n\neq m}^{M} \mathbf{T}_{nm}^2$

aperture correlation (microscopy) is a diagonal estimator [Wilson et al. 96, Levoy et al. 04]

stochastic estimator for general probing

dual codes for general probing matrix $\mathbf{\Pi}$: $\mathbf{m}_i = \mathbf{\Pi}\ \mathbf{l}_i$

Direct-global separation using diagonal probing (co-axial case)

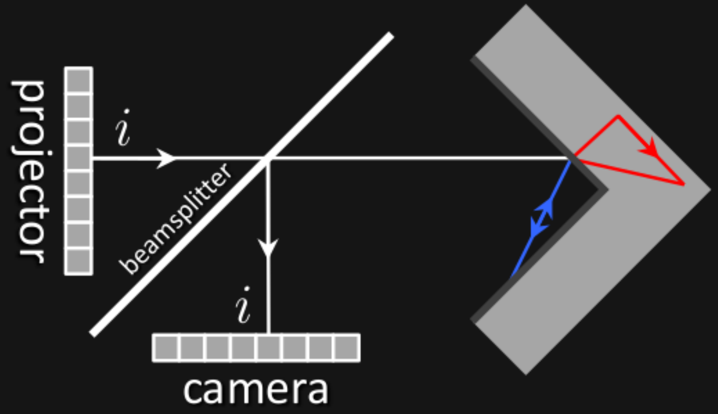
designing probing matrices

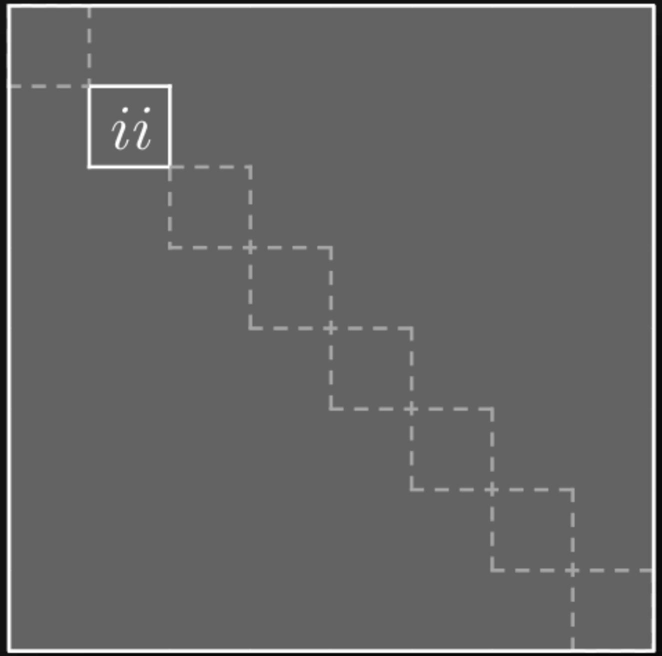
$$\mathbf{T}$$

transport matrix

designing probing matrices

Coaxial configuration: use a beamsplitter to make projector and camera effectively collocated

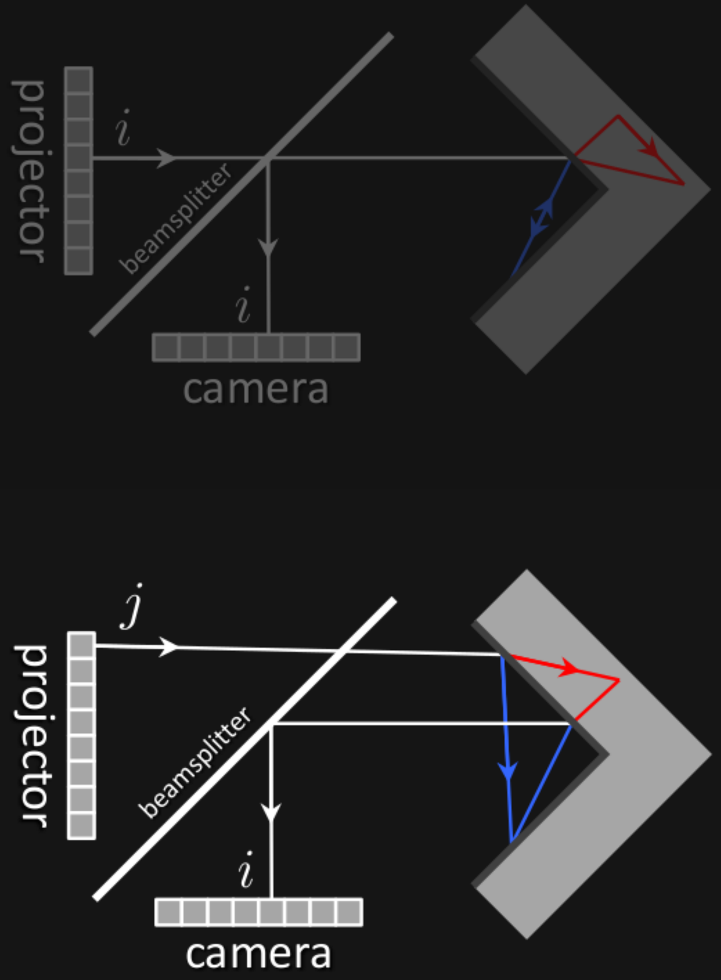


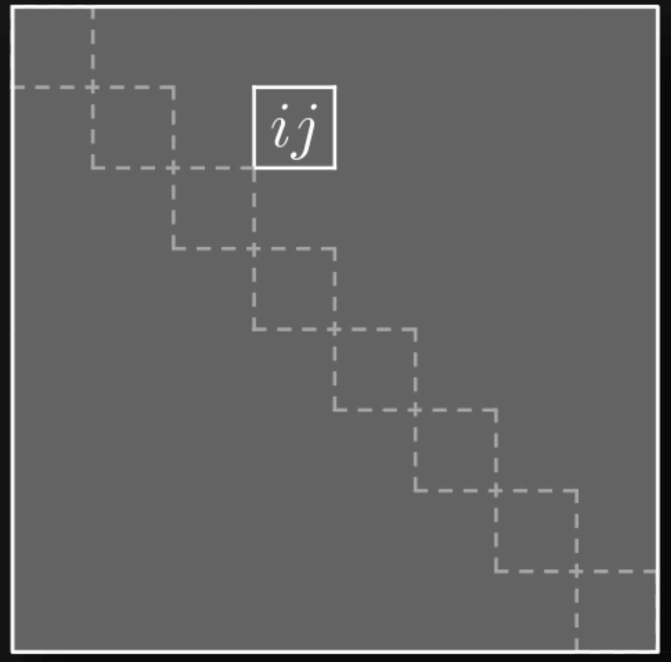


transport matrix

designing probing matrices

Coaxial configuration: use a beamsplitter to make projector and camera effectively collocated





transport matrix

coaxial example: contrast-enhancing direct light

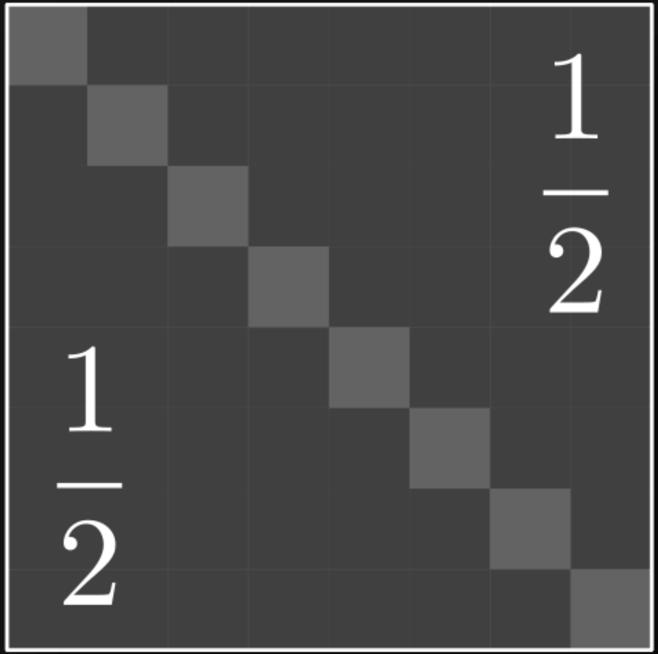
conventional photo

all light paths

coaxial example: contrast-enhancing direct light

conventional photo

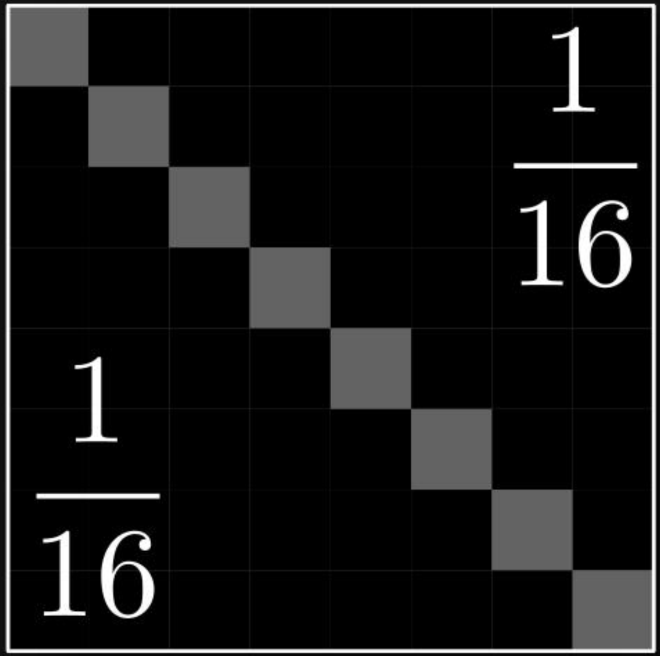
direct + ½ indirect



direct + 1/2 indirect light paths

coaxial example: contrast-enhancing direct light

conventional photo | direct + ½ indirect | direct + ¼ indirect | direct + 1/16 indirect

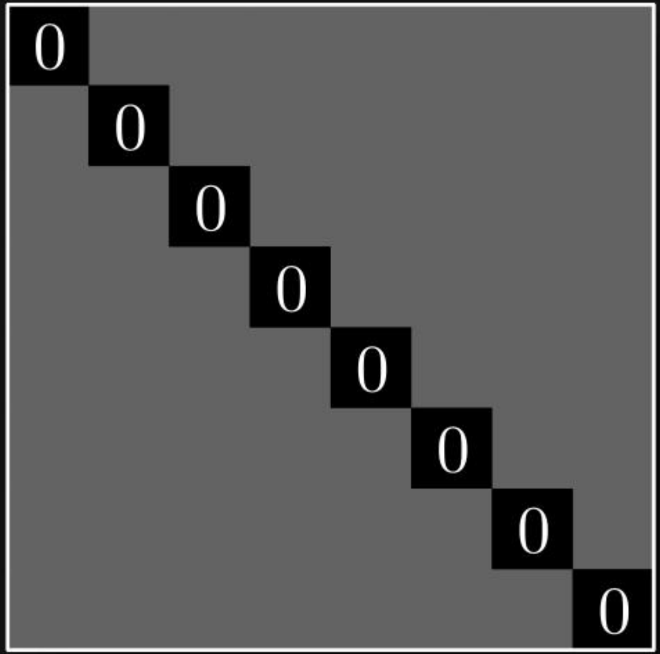


direct + 1/16 indirect light paths

coaxial example: capturing short to long range paths

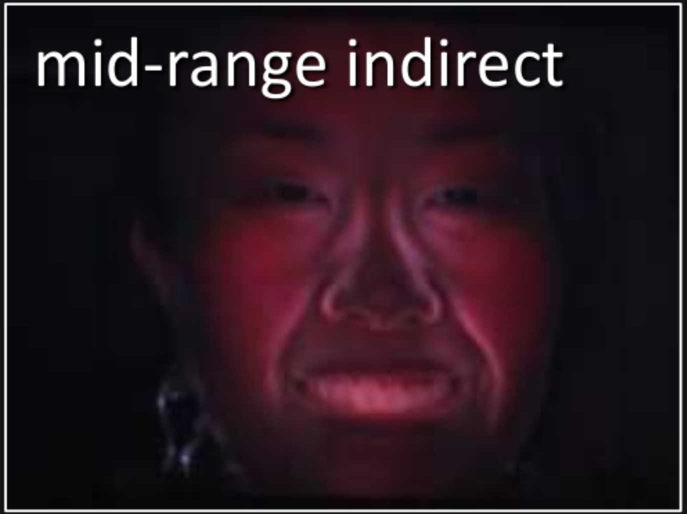
all light paths

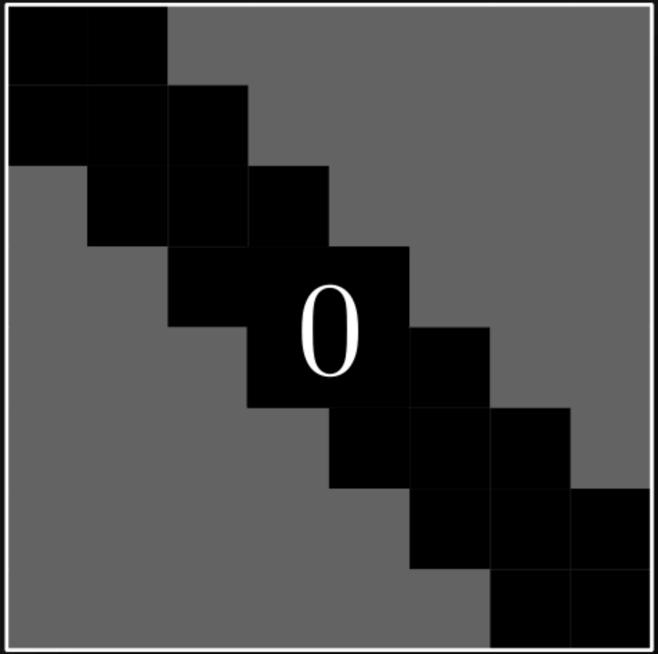
coaxial example: capturing short to long range paths



indirect light paths

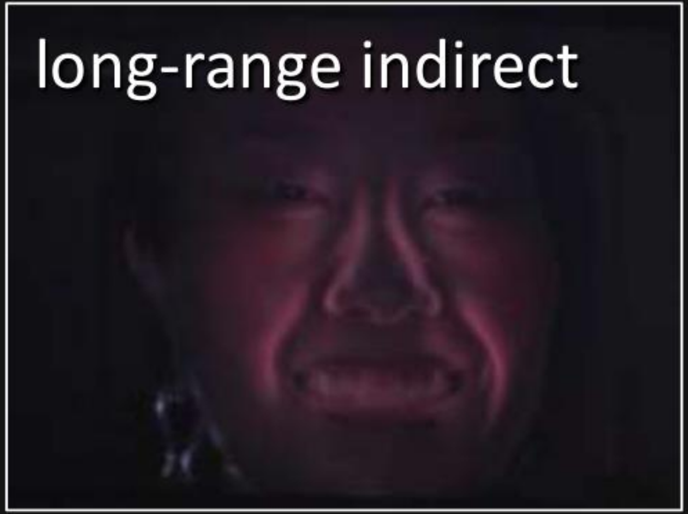
coaxial example: capturing short to long range paths

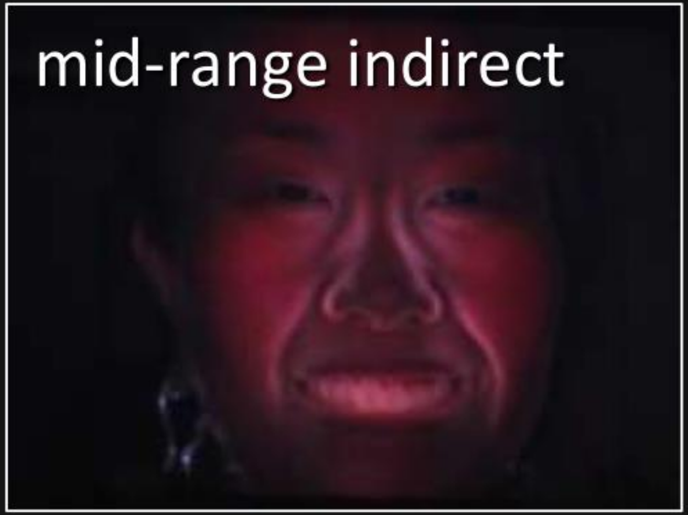


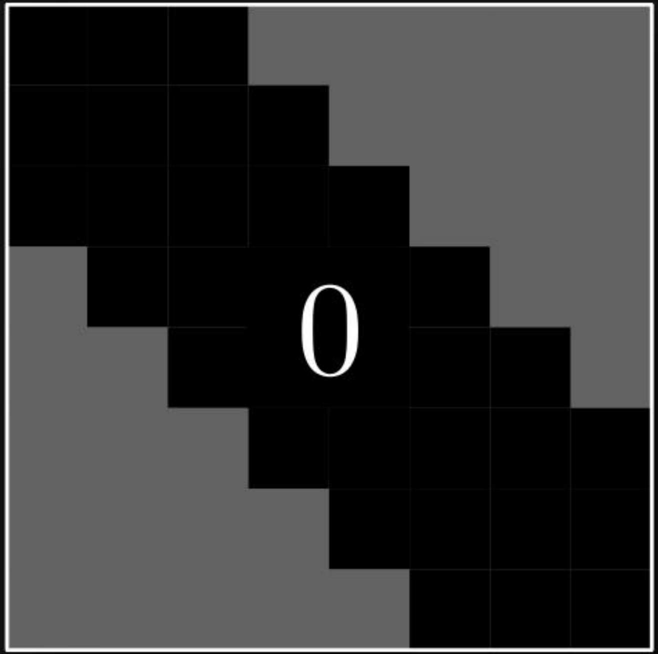


medium to long range indirect light paths

coaxial example: capturing short to long range paths





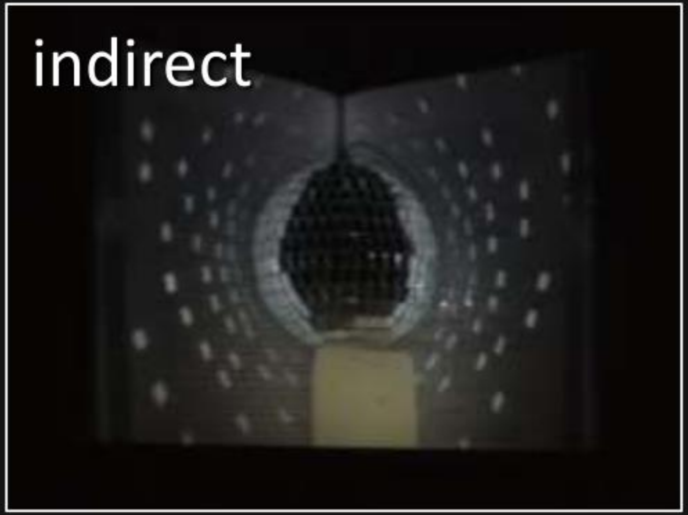


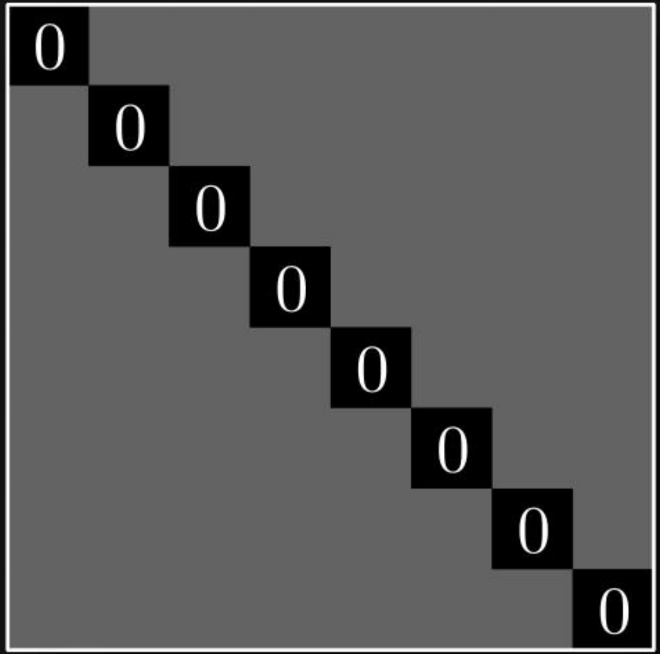
long range indirect
light paths

coaxial example: separating light transport effects

all light paths

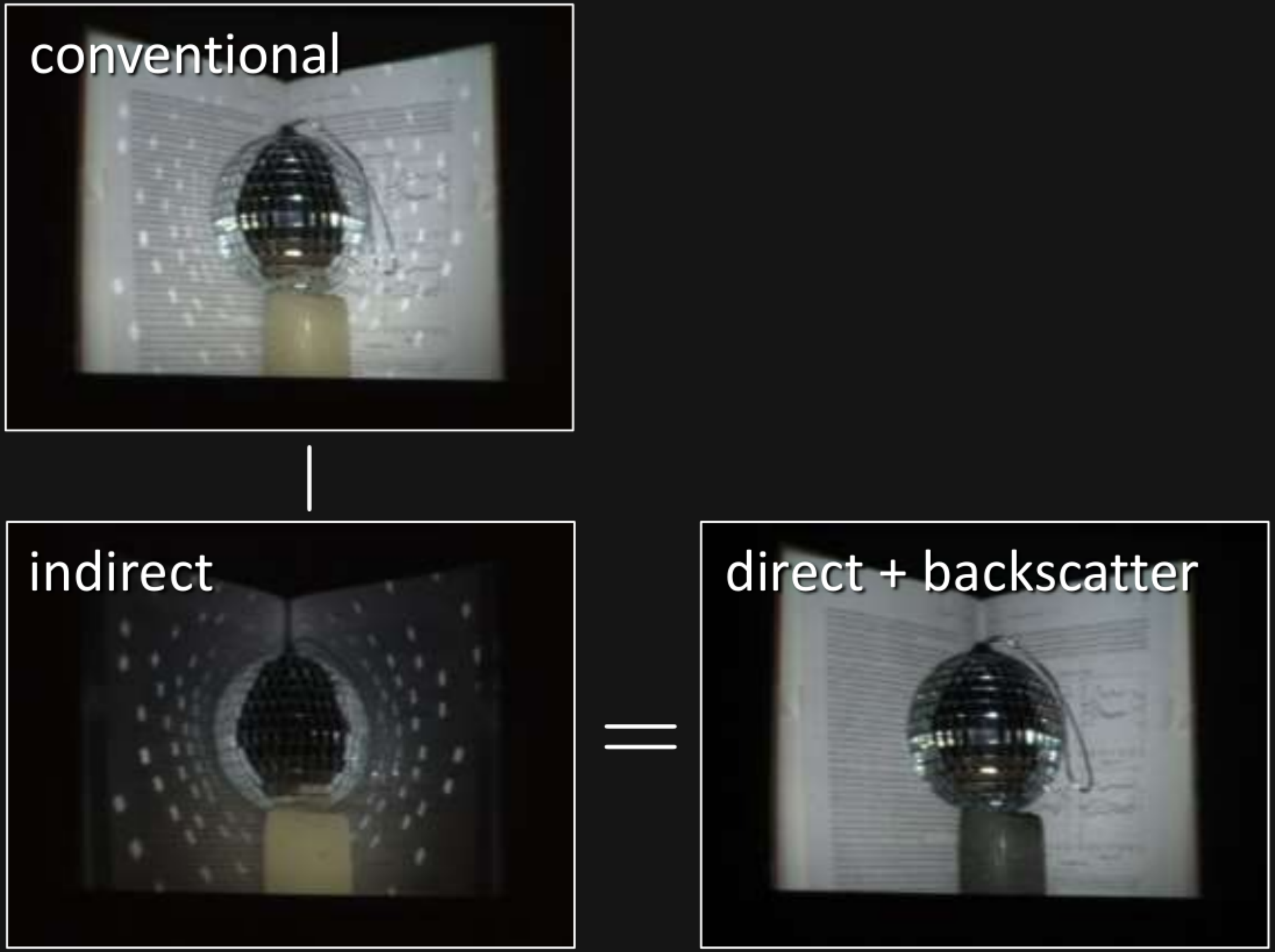
coaxial example: separating light transport effects

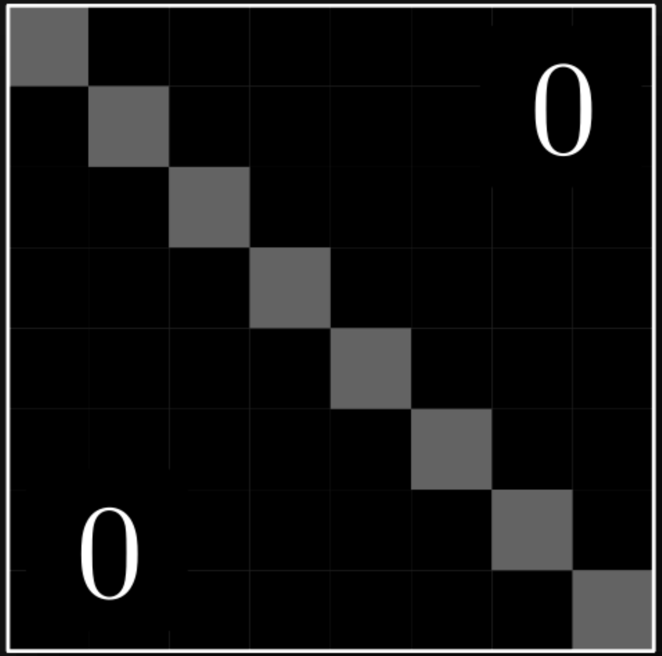




indirect light paths

coaxial example: separating light transport effects



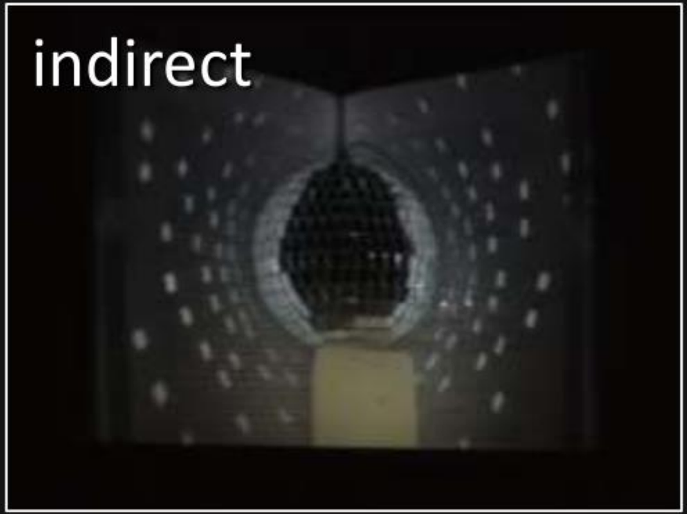


direct + back-scatter
light paths

coaxial example: separating light transport effects

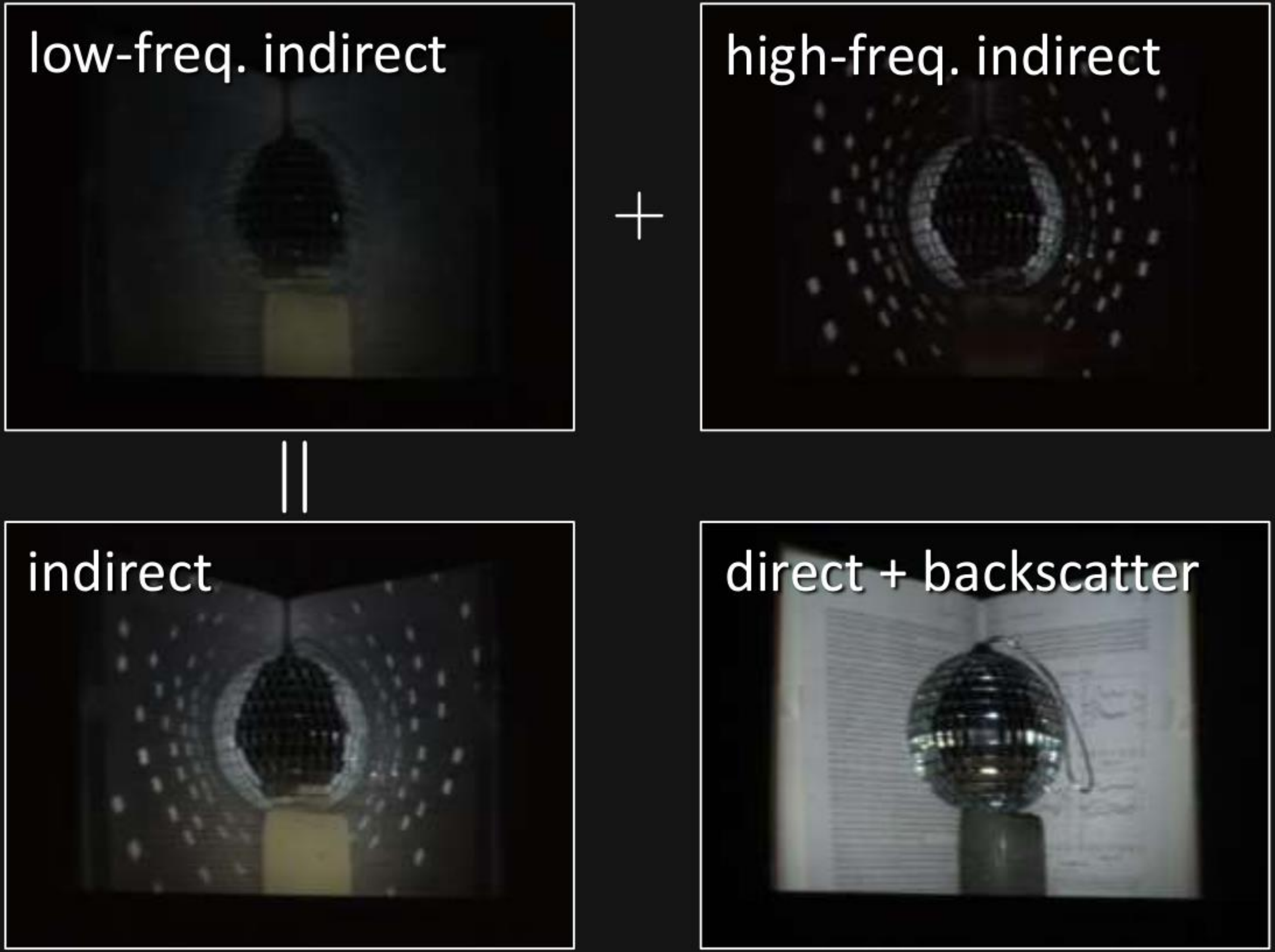

indirect [Nayar et al. 06]


direct [Nayar et al. 06]


indirect


direct + backscatter

coaxial example: separating light transport effects



What if my camera and projector are not co-axial?