Toward standardization of the DBI diagnostic

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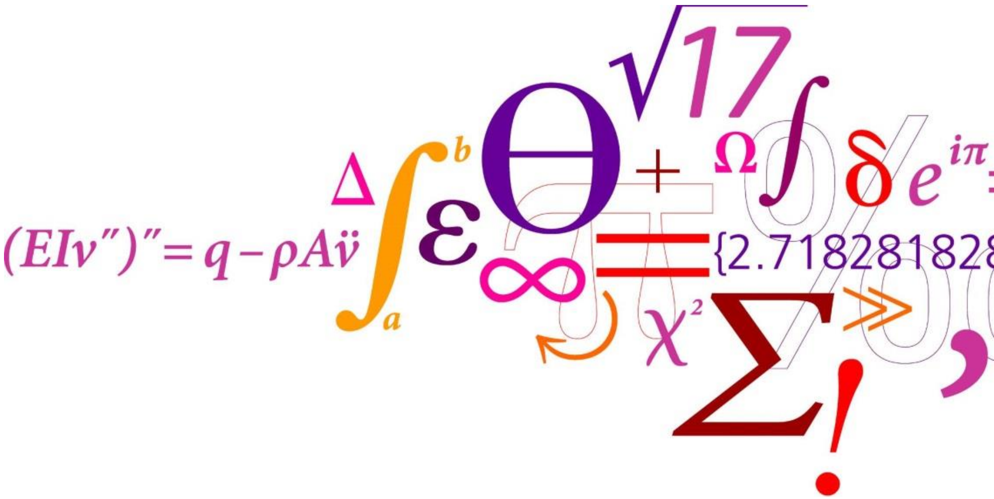

DTU Mechanical Engineering
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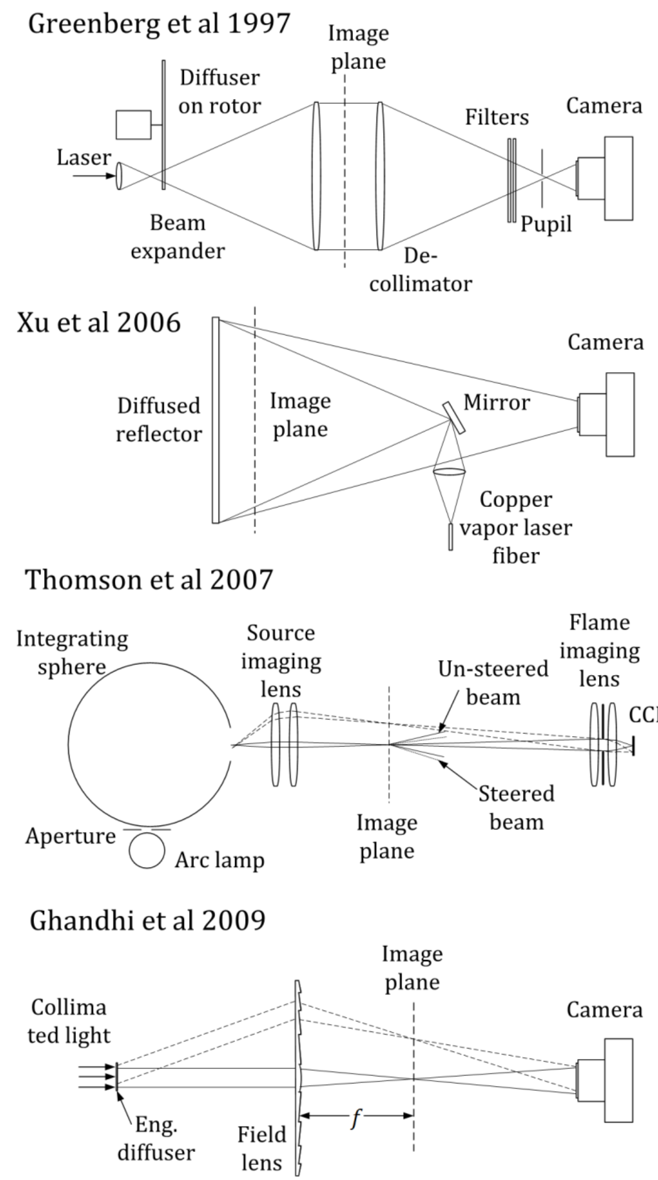
Introduction

- Extinction imaging isolates attenuation by scattering and absorption
- Diffused lighting
- Many optical setups aimed at imaging extinction
- Diffused lighting is a diffuse description



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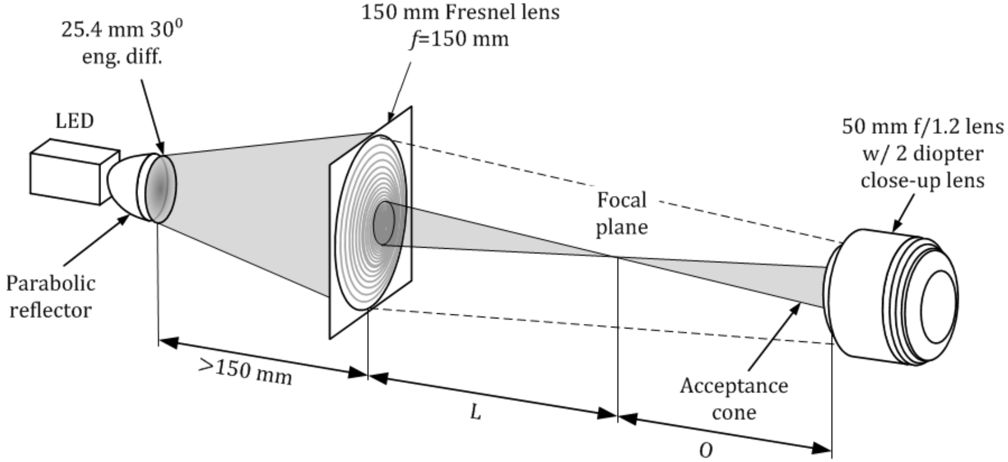
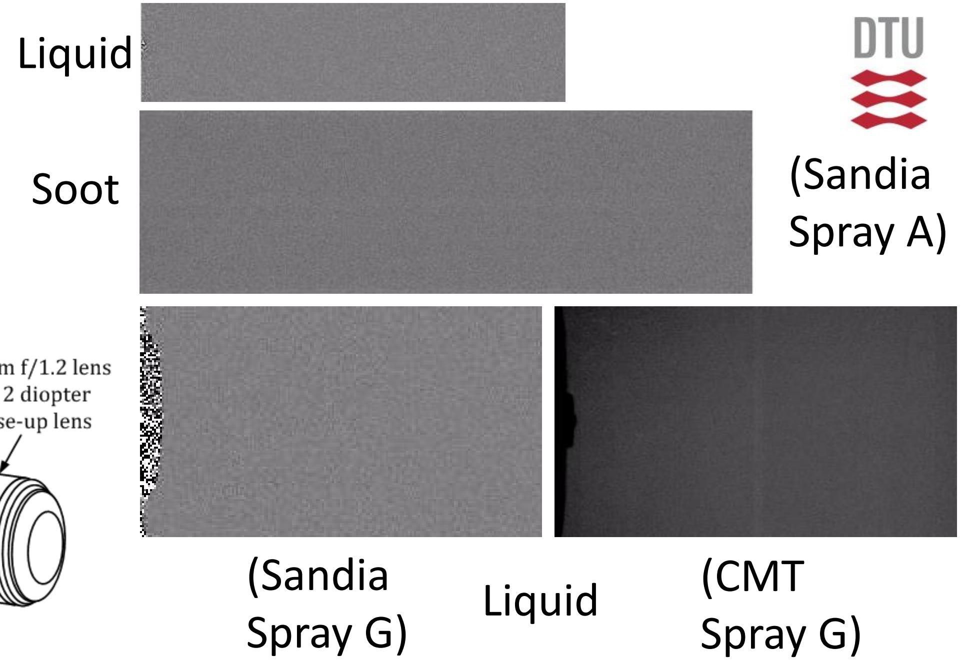
DBI applied within ECN





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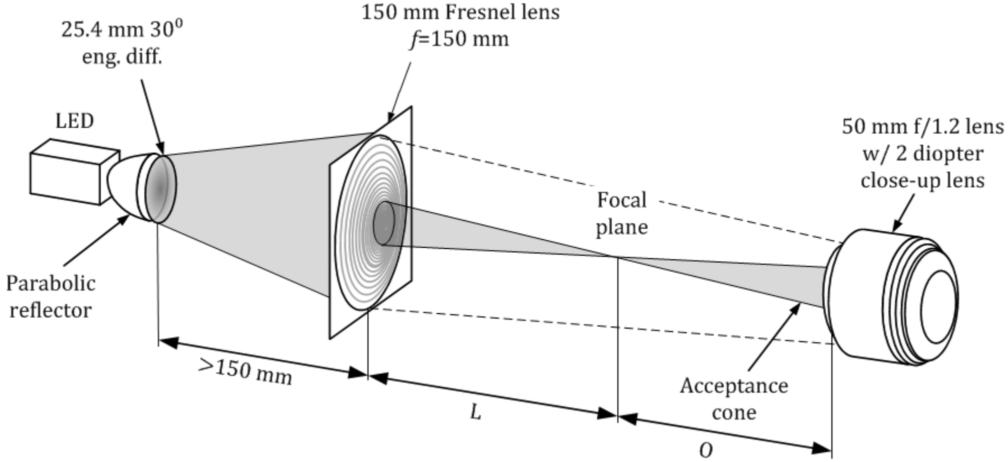
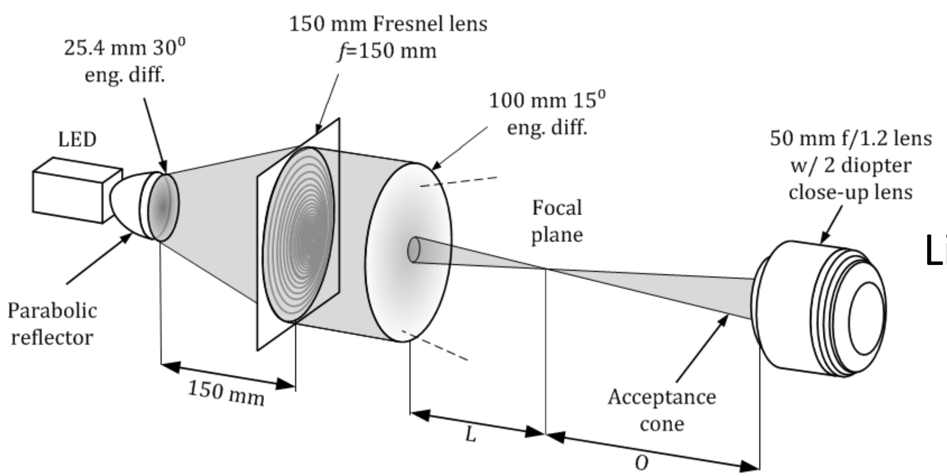
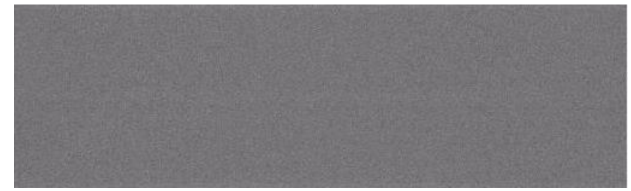


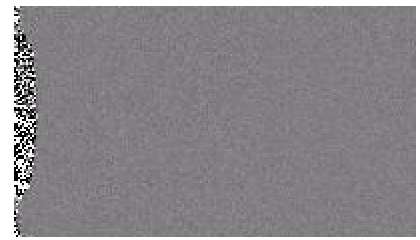


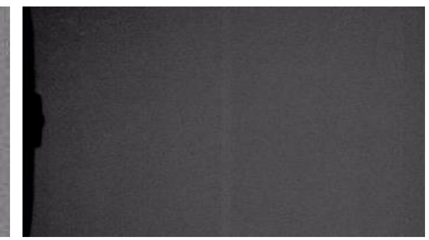
Liquid

Soot

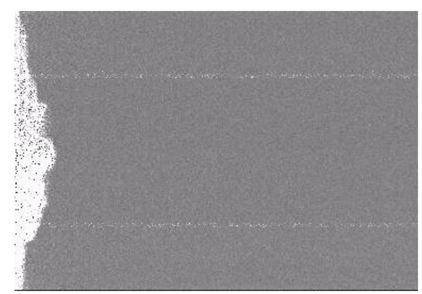


(Sandia Spray A)





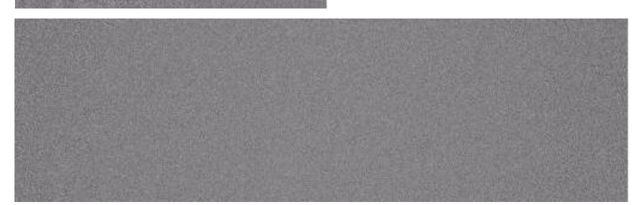
(Sandia Spray G) Liquid (CMT Spray G)



(Sandia Spray G)

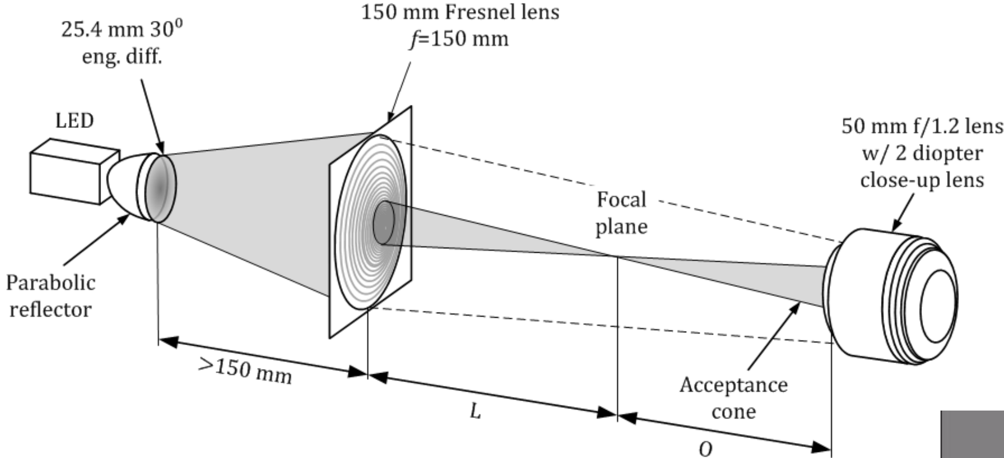
Liquid

Soot

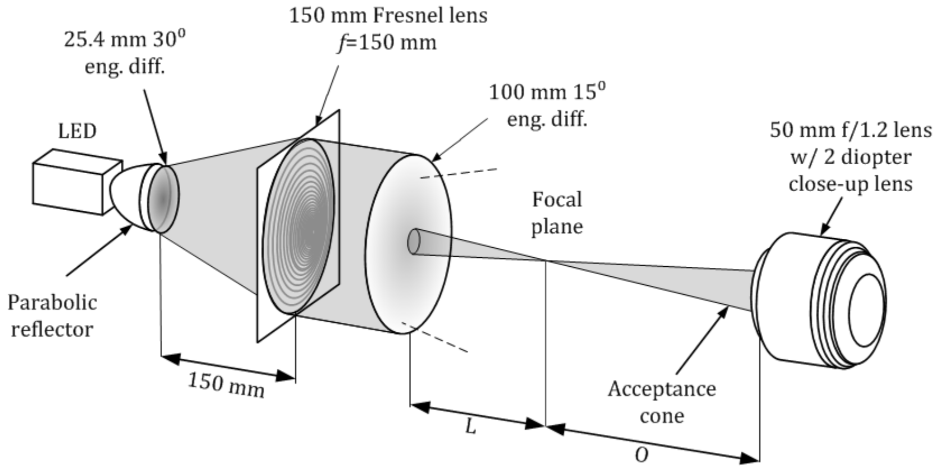


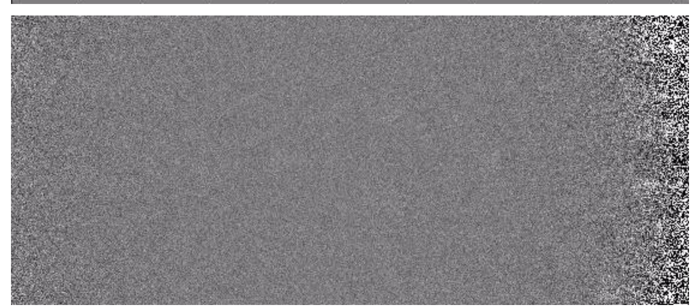
(Sandia Spray A)

DBI applied within ECN



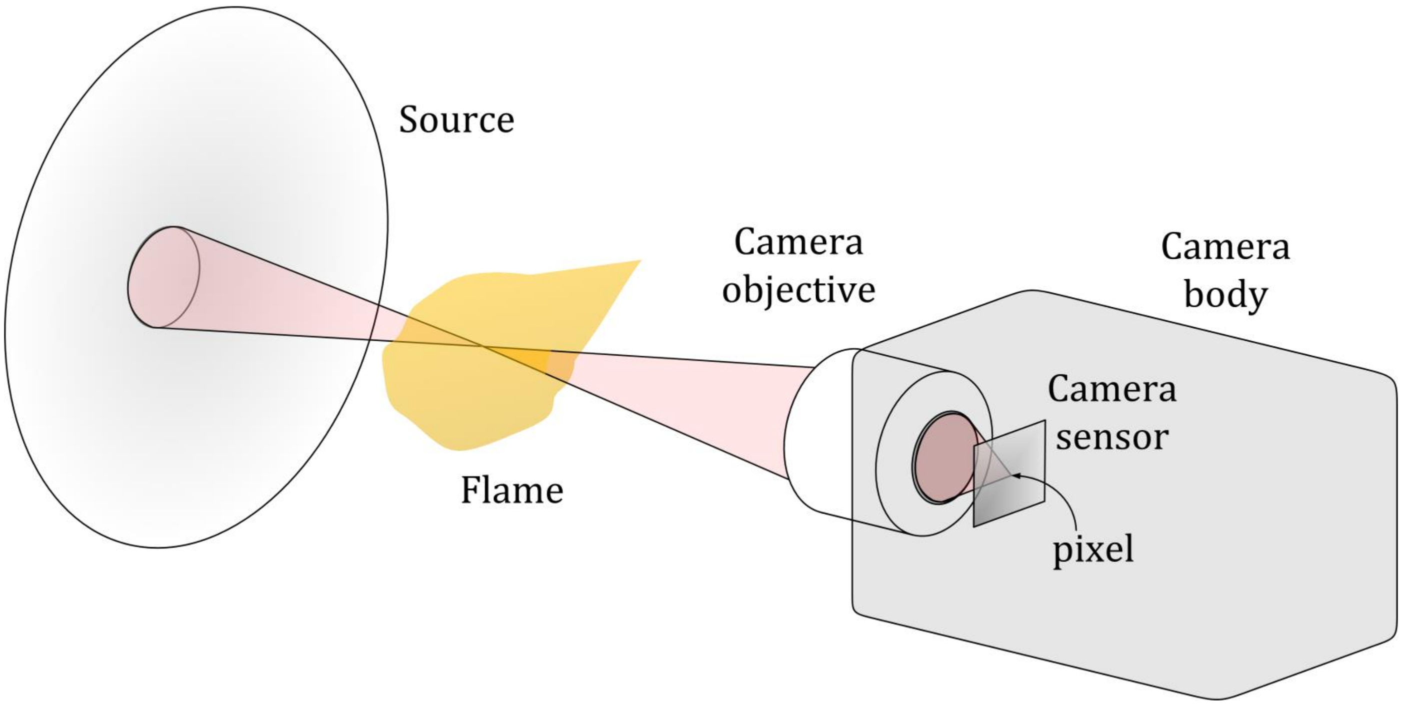
(Sandia Spray D)





(Caterpillar Spray D)

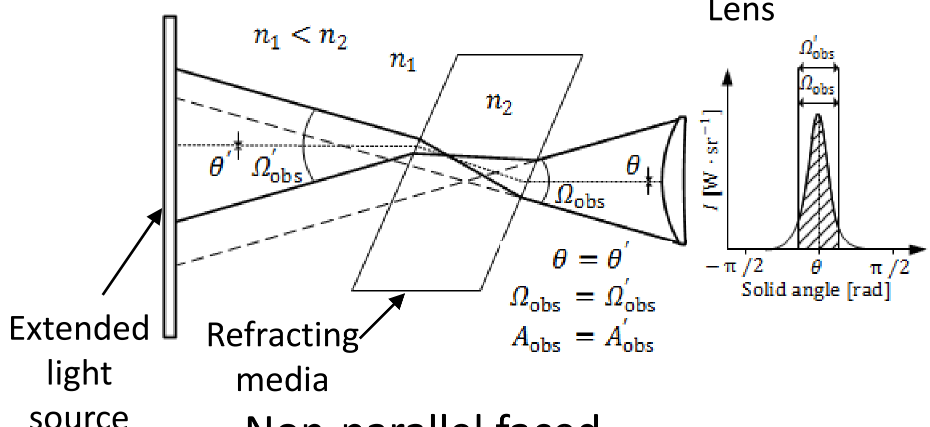
Beam steering effect



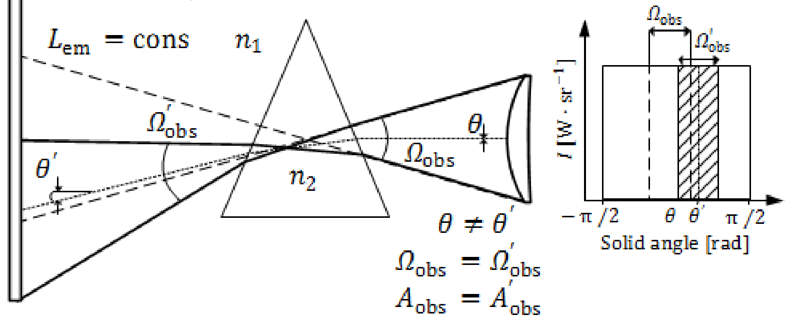
Lighting characteristics

- 3 fundamental refractive scenarios

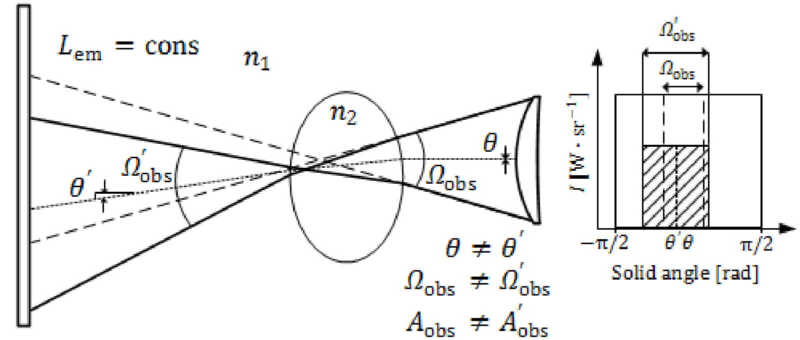
Parallel faced



Non-parallel faced



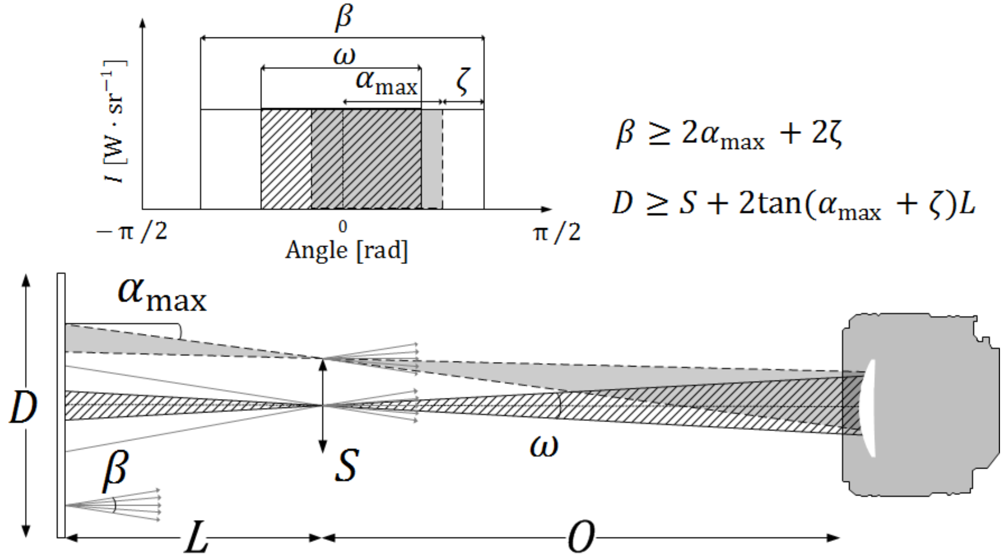
Non-planar faced



$n^2\Omega A$ and $n^2 L$ are conserved

Dimensioning for high speed

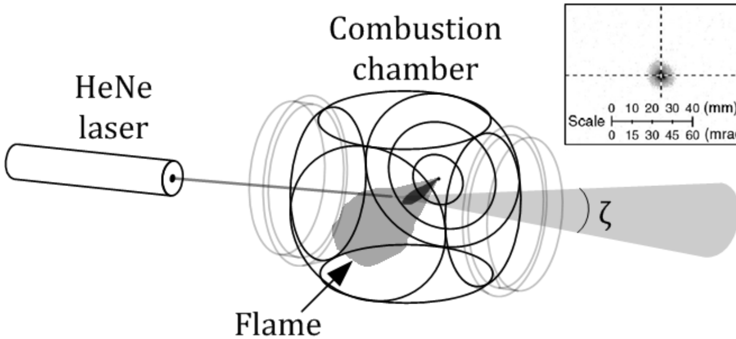
- Lambertian emitters are inefficient
- High light throughput required for high speed imaging
- Light throughput maximized with engineered diffuser
- Dimensioning according to collection optics and geometrical constraints

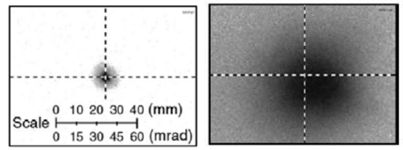


$$\beta \geq 2\alpha_{max} + 2\zeta$$

$$D \geq S + 2\tan(\alpha_{max} + \zeta)L$$

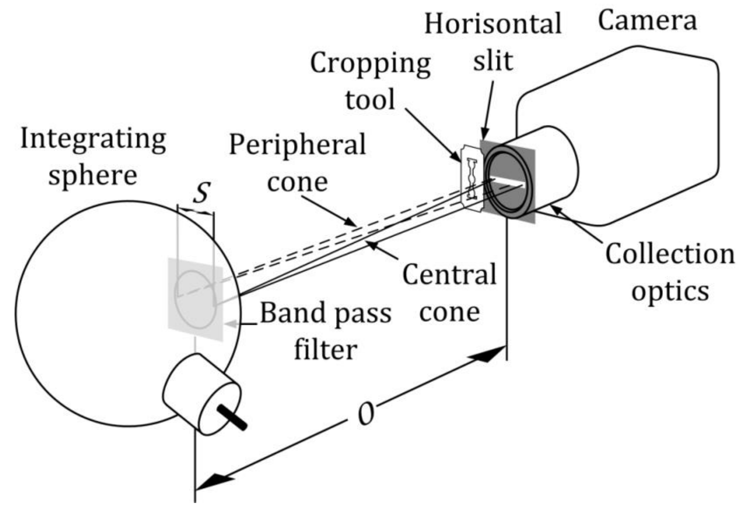
Characterization of DBI setup



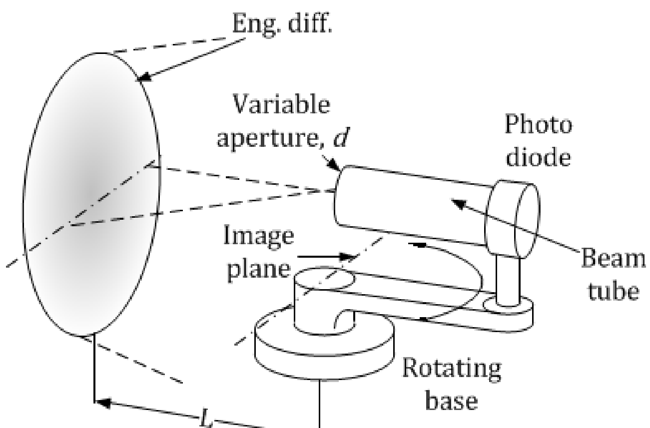


[Musculus & Pickett 2005]

- Measure the magnitude of beamsteering ζ

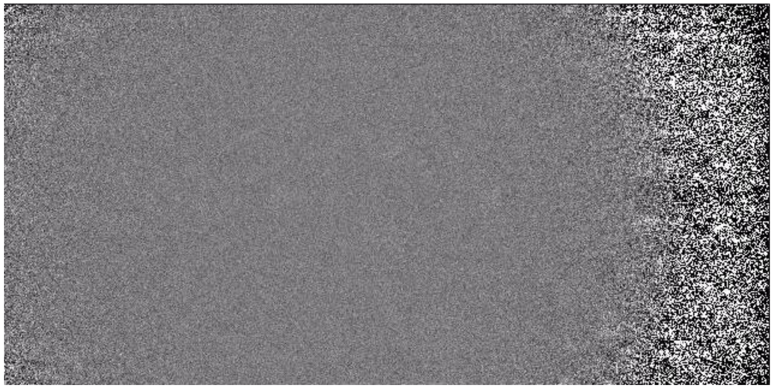


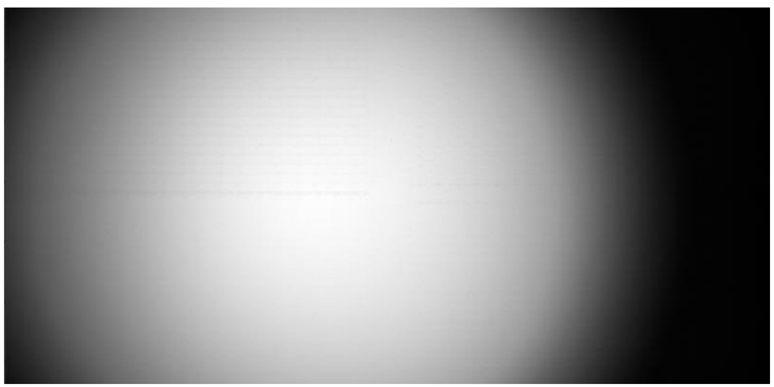
- Characterize the angles being collected from the source
- The largest angle, α_{max}, is collected at in the periphery



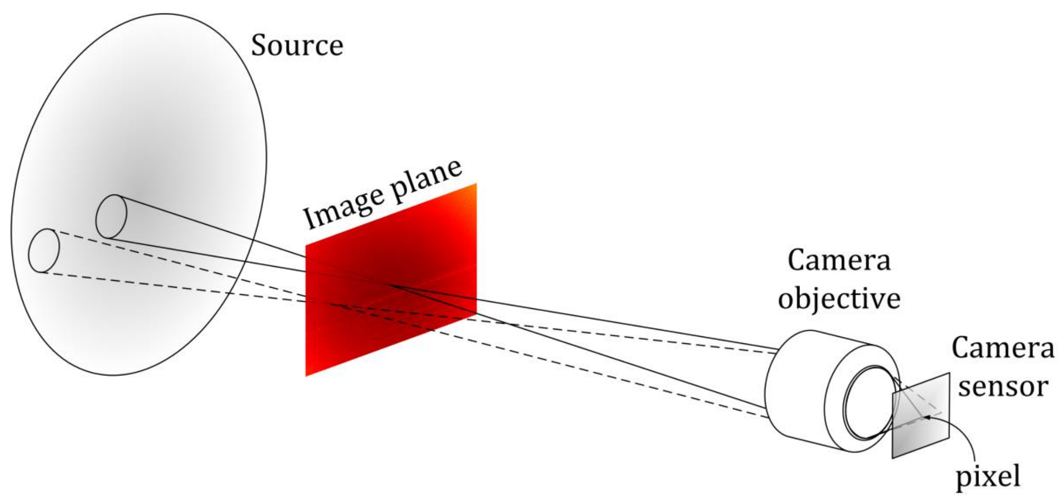
- Characterize spatial and angular uniformity
- Angular uniformity in image plane depends on angular and spatial uniformity

Revisit the CAT/Sandia measurements

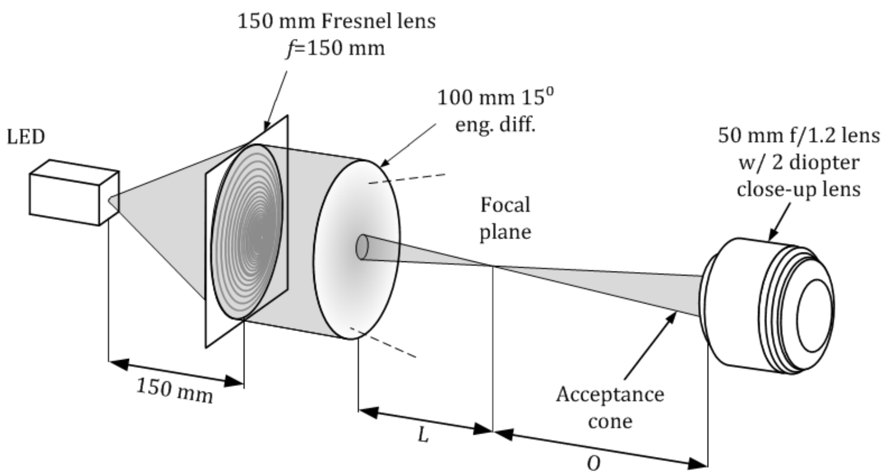


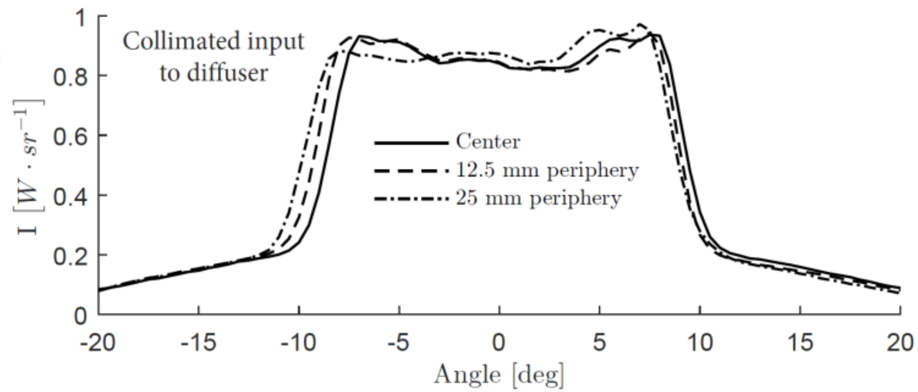


Illumination pattern
LED+parabolic
reflector

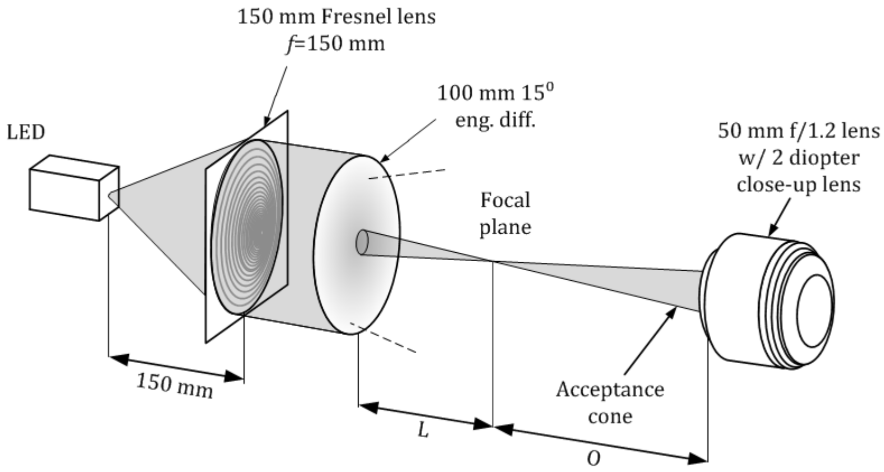


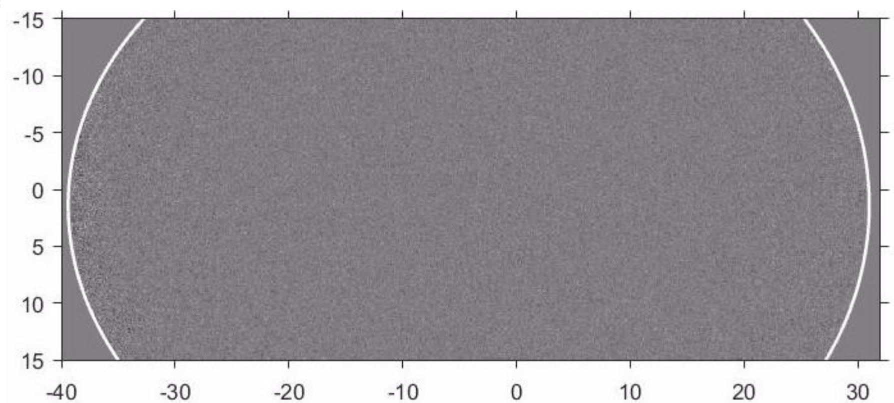
Extinction imaging





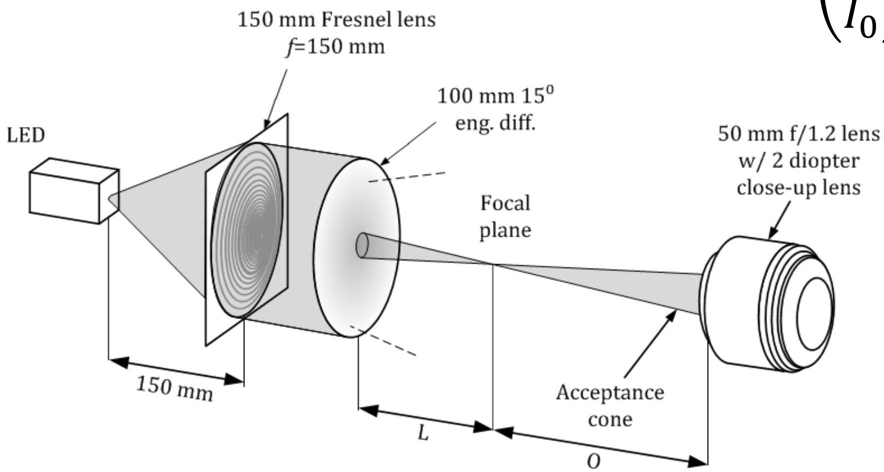
Extinction imaging

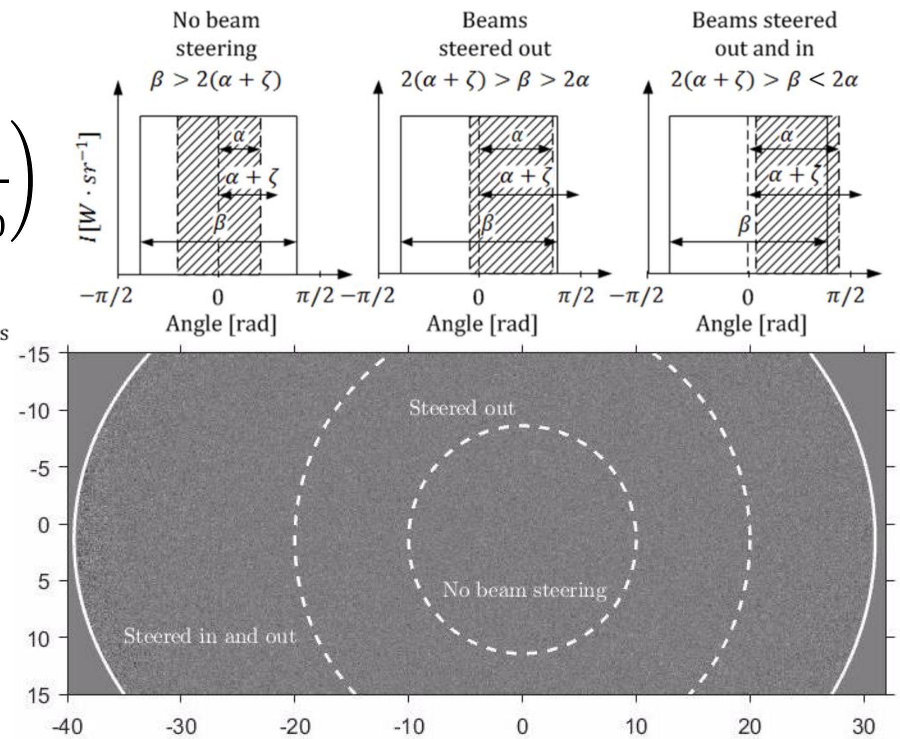




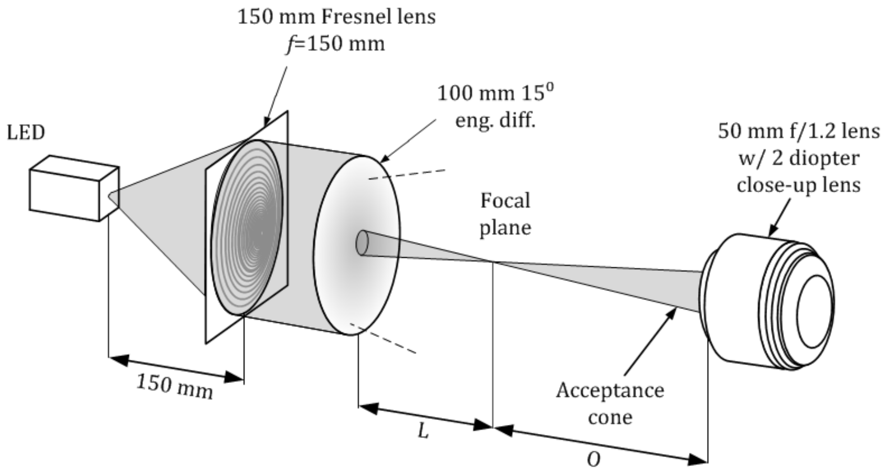
Extinction imaging

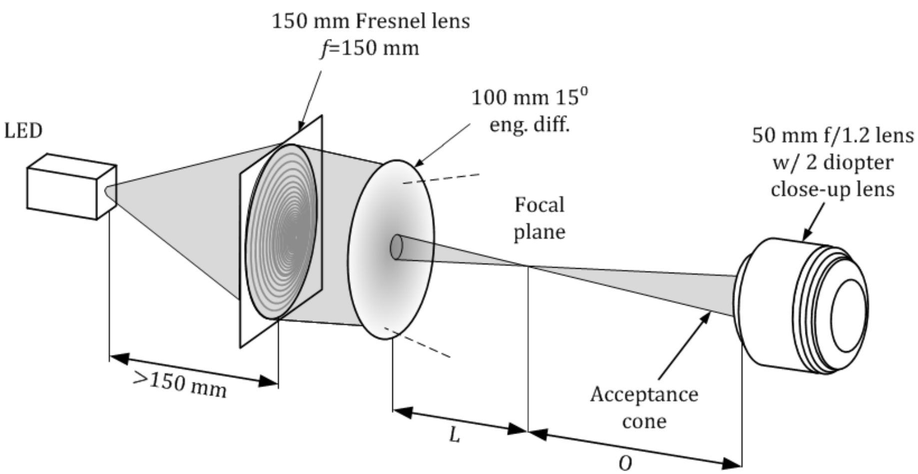
$$KL = -\ln\left(\frac{I}{I_0}\right)$$

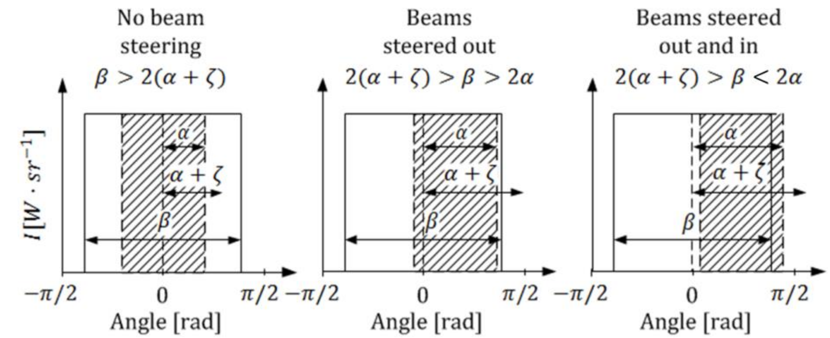


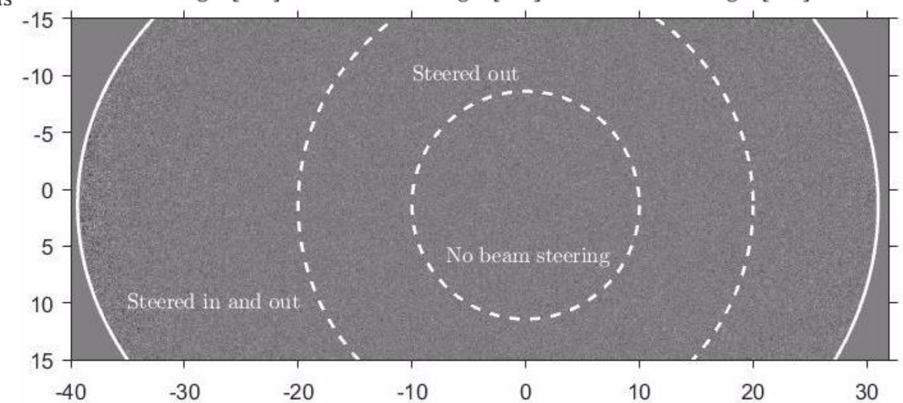


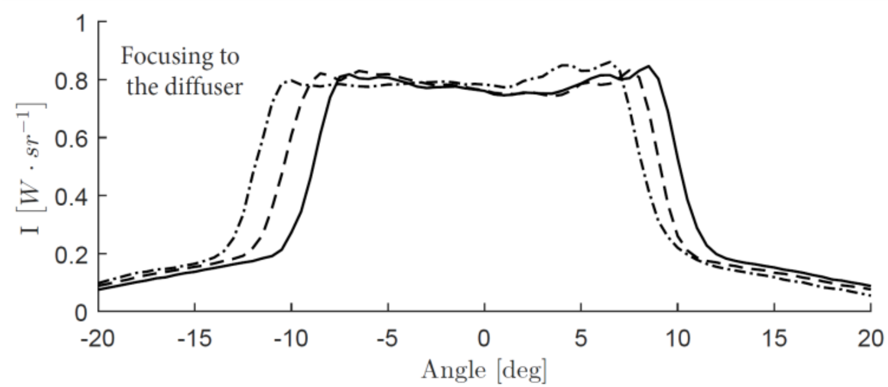
Extinction imaging











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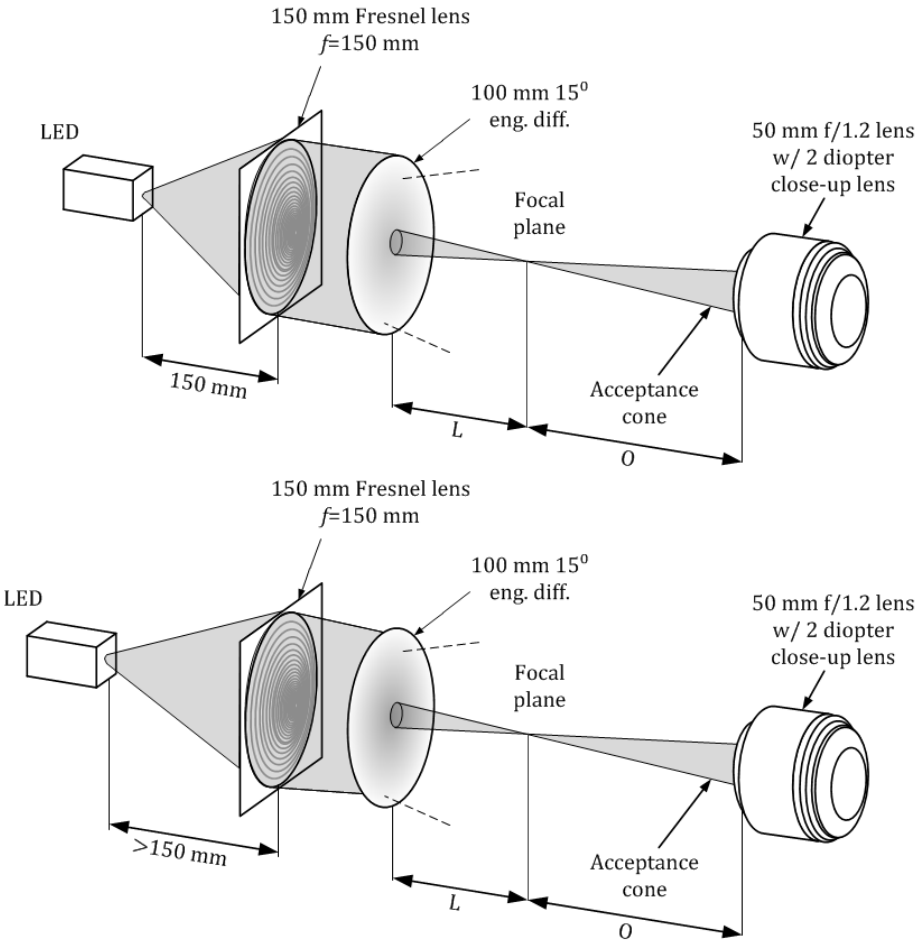
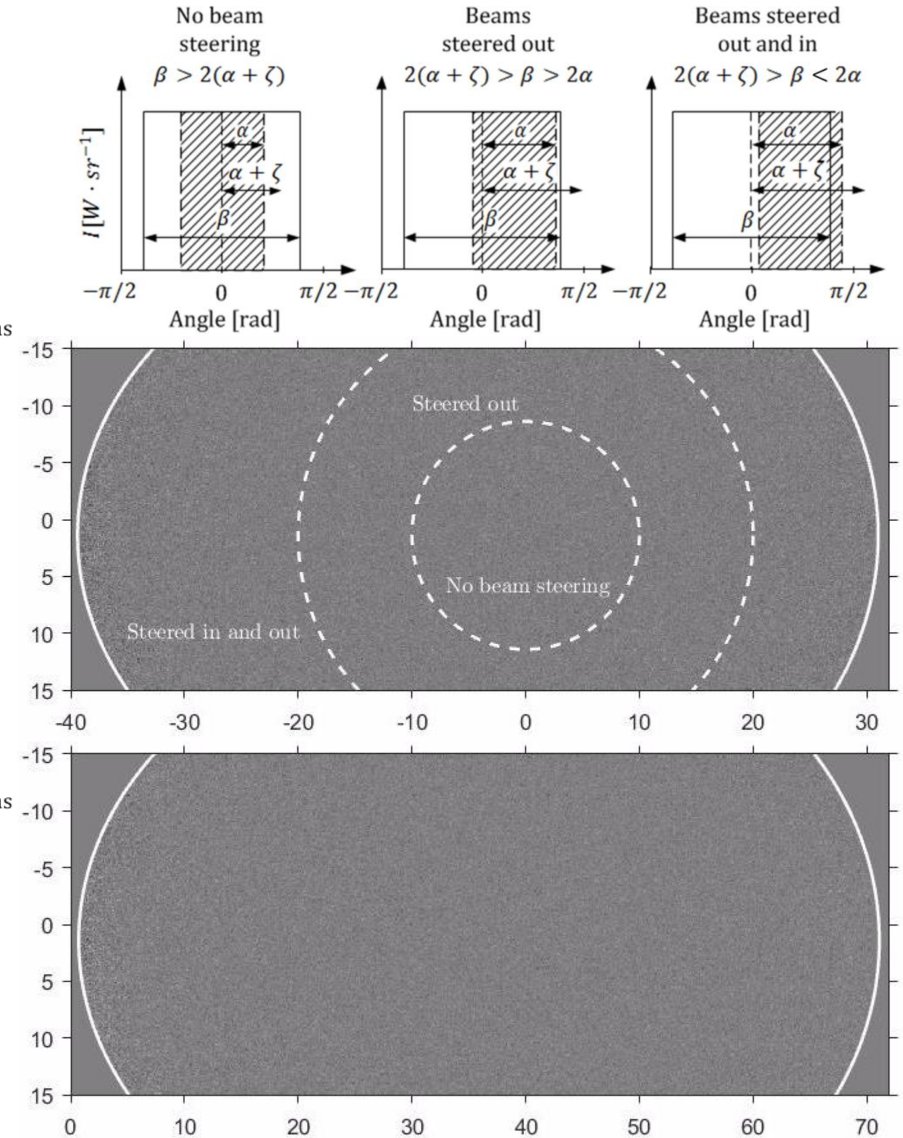
Extinction imaging





Toward standardization of the DBI diagnostic

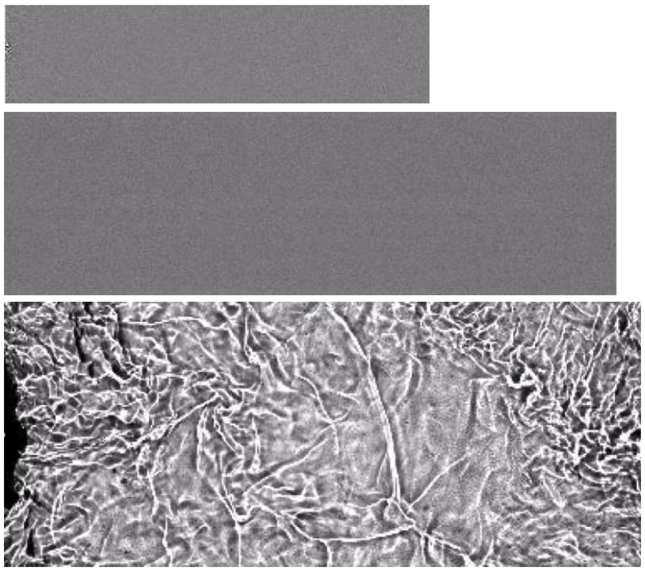
Summary

- A theoretical description of the lighting characteristics needed to eliminate beam steering
- Guide to designing an optical setup suited for high speed application
- Methods for characterizing the setup
- Respective institutions should characterize a setup suitable for application in their respective vessels

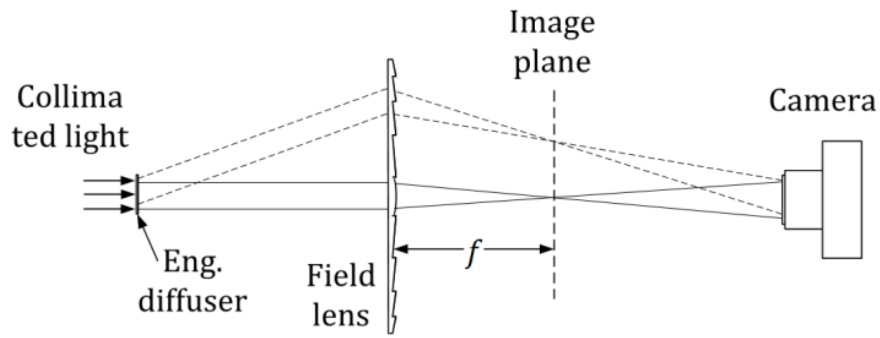
Thanks for paying my salary

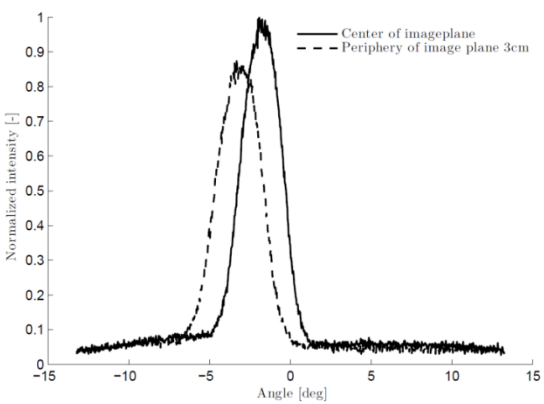
Thanks for your attention!

Revisit the measurements with previous setup



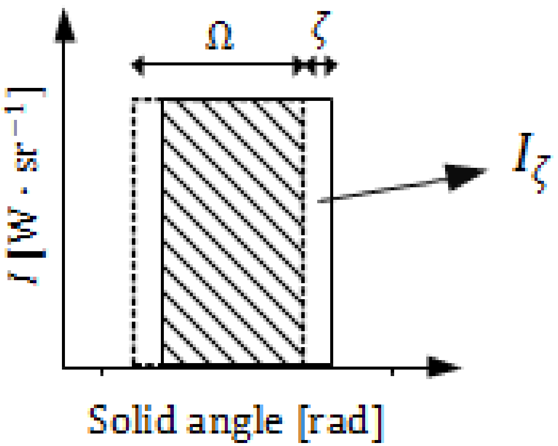
Ghandhi et al 2009





Perceived optical thickness

- Ideal source with limited angular distribution
- Solid angle of collection matching illumination
- Beam steering through non-parallel refracting media
- Larger collection angle can potentially reduce perceived optical thickness



$$KL_{app} = -\ln\left(\frac{I_0 - I_\zeta}{I_0}\right)$$

Extinction imaging of soot

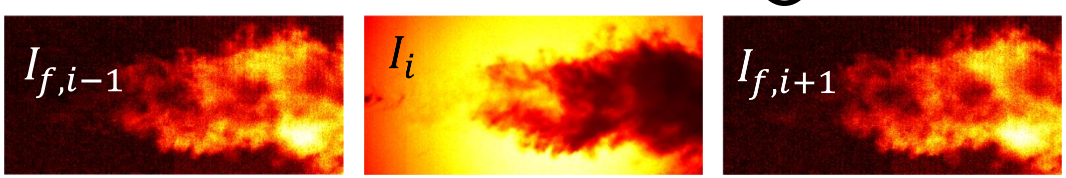
- Transmission consists of sequential and reference images
- Moving flame luminosity introduces error
- High temporal resolution and spectral filtering reduces error
- Clever post processing can further reduce error

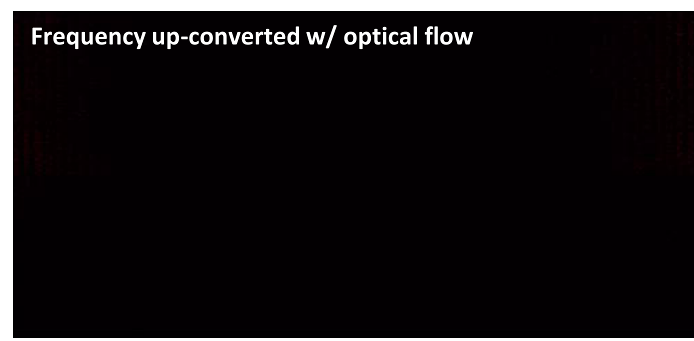
Flame and source image

Flame image

$$\tau = \frac{I - I_f}{I_0}$$

Source image





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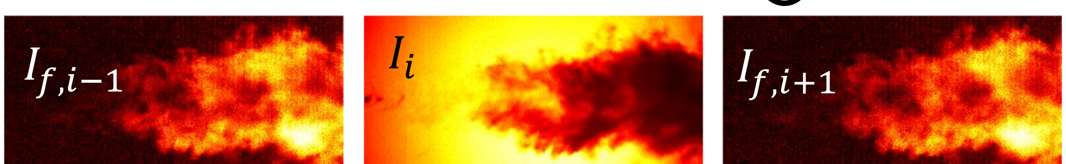
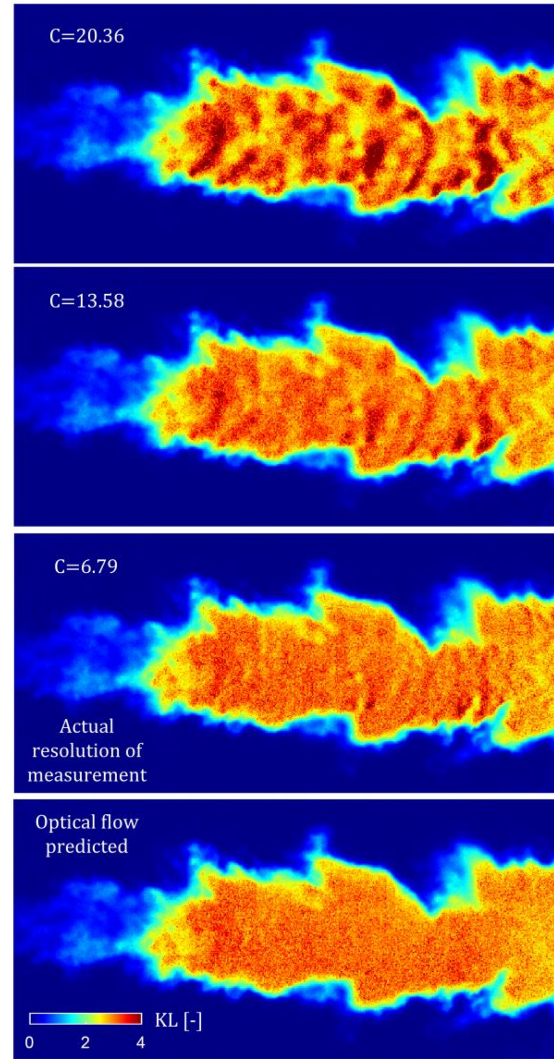
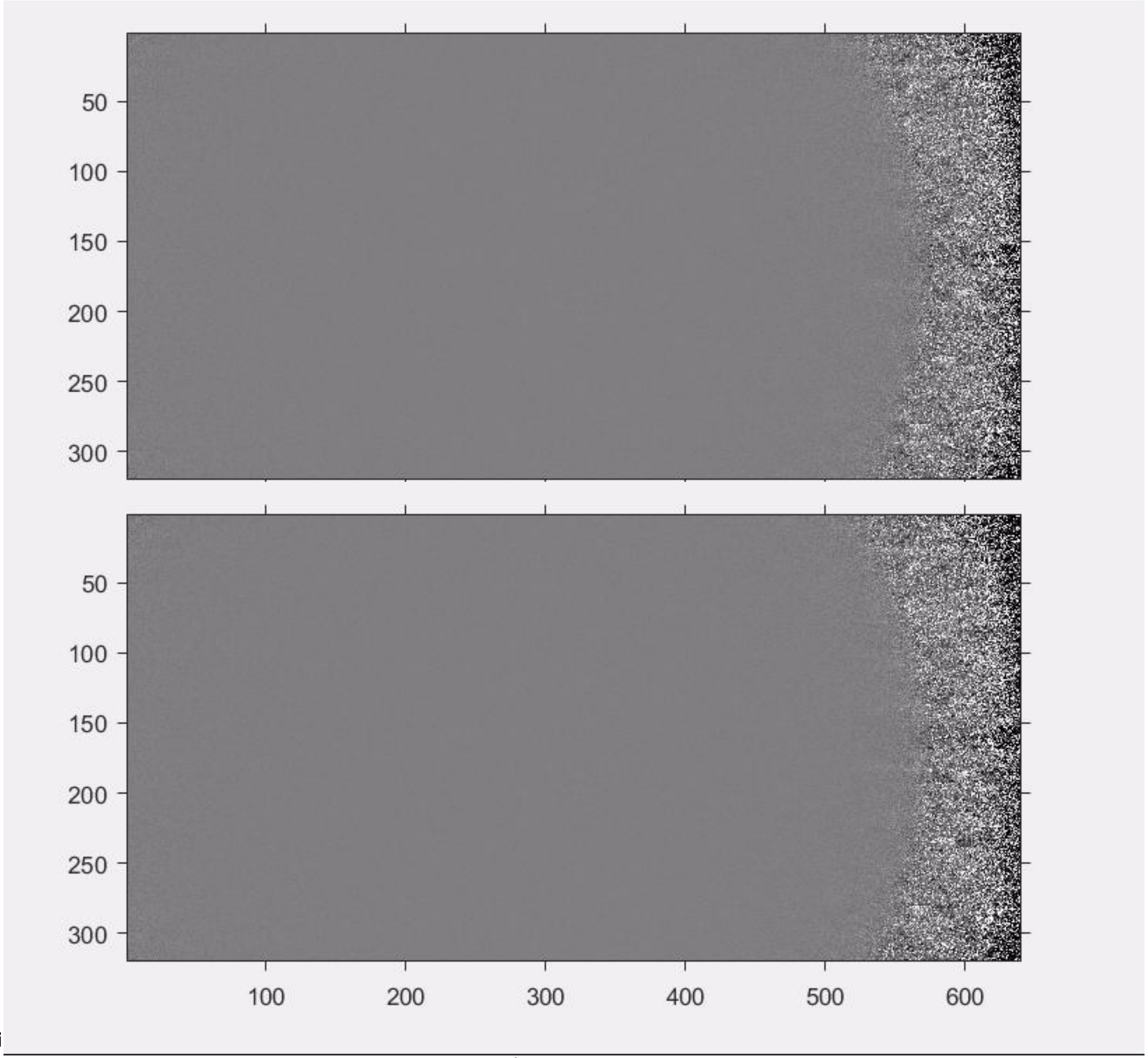




Combustion



diagnostic

Beam steering effect