Probing coherence properties of X-rays radiation sources: the Heterodyne Near Field Speckle approach

«PhD 1st year Workshop»

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University of Milan, Department of Physics

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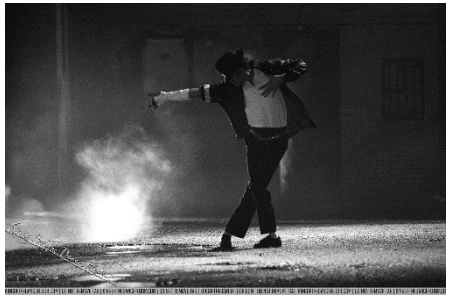
UNIVERSITÀ DEGLI STUDI DI MILANO

INFN
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

SPARC

X-rays third generation sources



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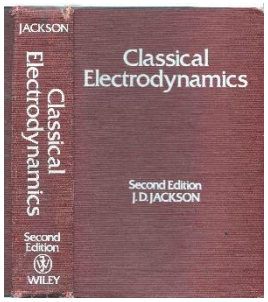

«…accelerated charges emit electromagnetic radiation»

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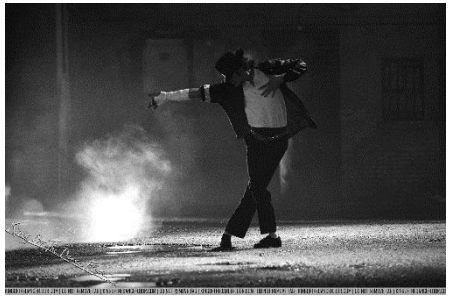

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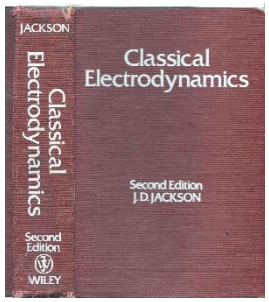

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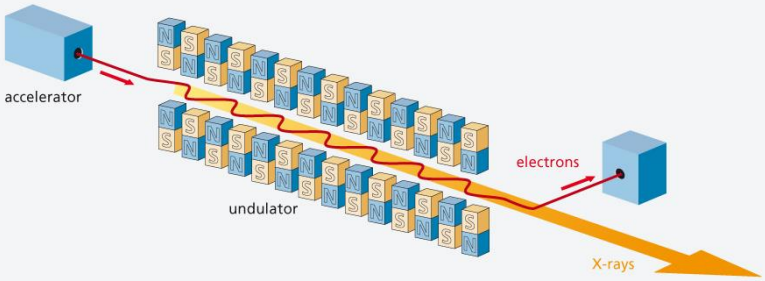
Wigglers and undulators



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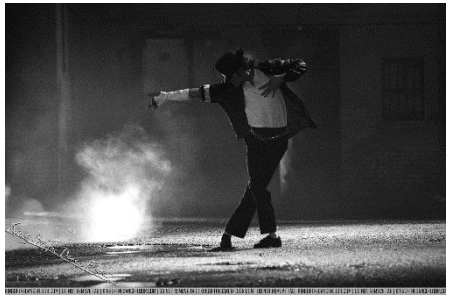

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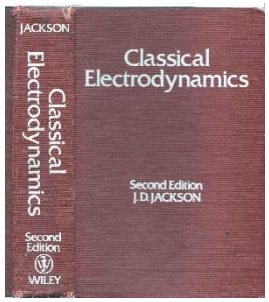

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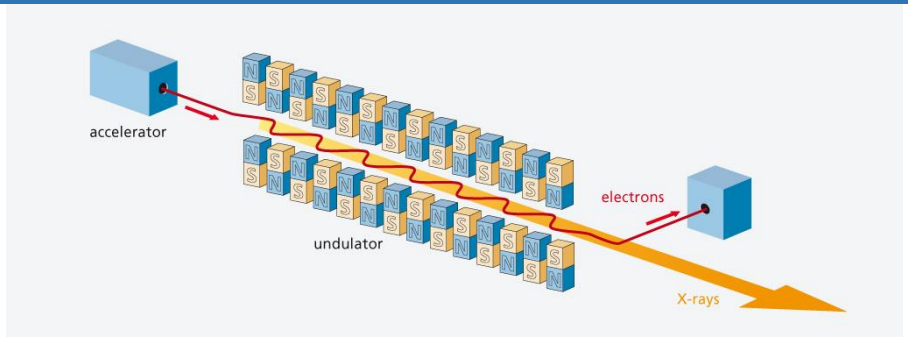
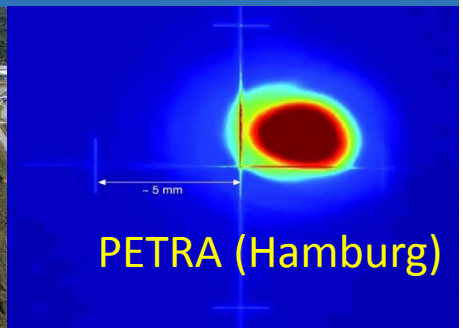


Synchrotrons

Free Electron Lasers (FELs)



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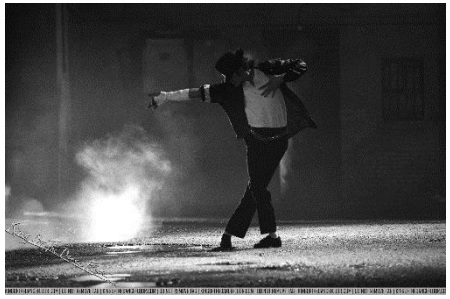

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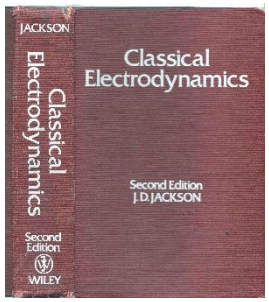

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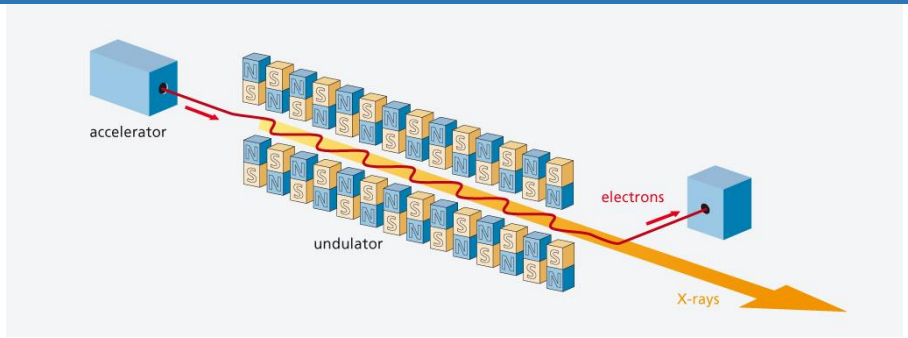

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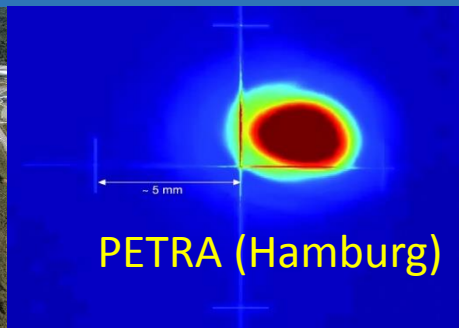
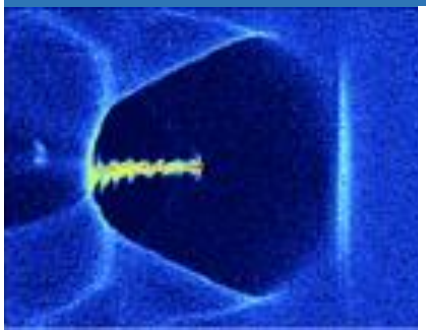
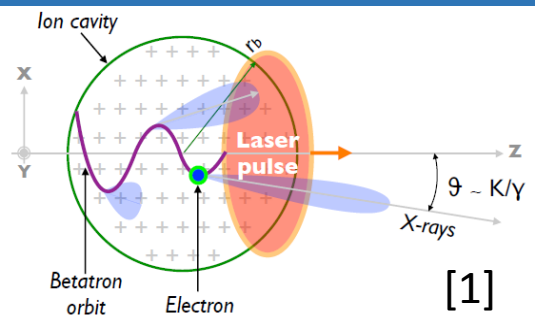


Laser Wake Field Acceleration

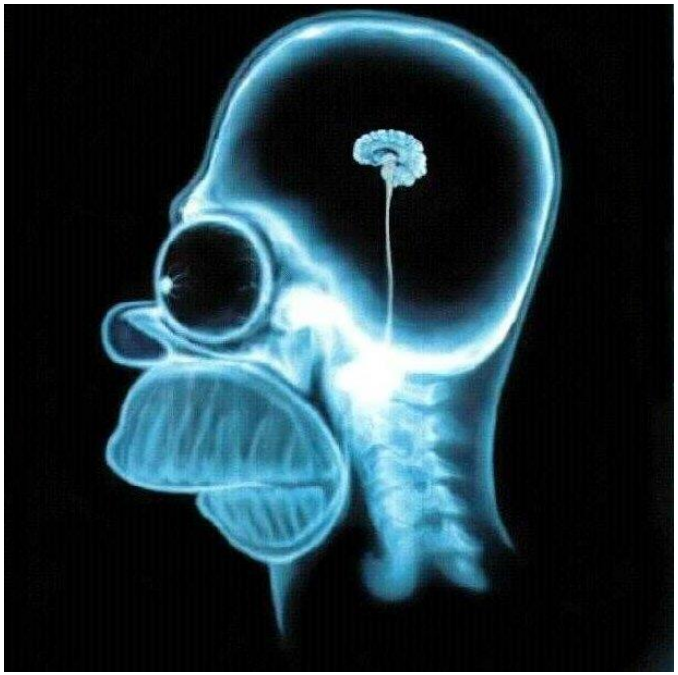




[1]

[1] S. Corde *et al.*, Femtosecond X-rays from laser-plasma accelerators, *Rev. Mod. Phys.* **85** (2013)

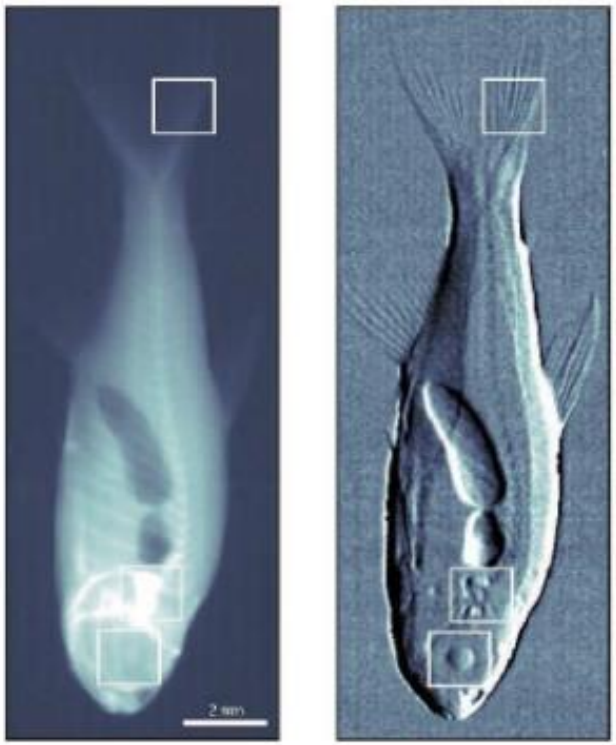
Why are X-rays so important?



X-ray imaging

Why are X-rays so important?

HMM, FIIIIIIISH !!!



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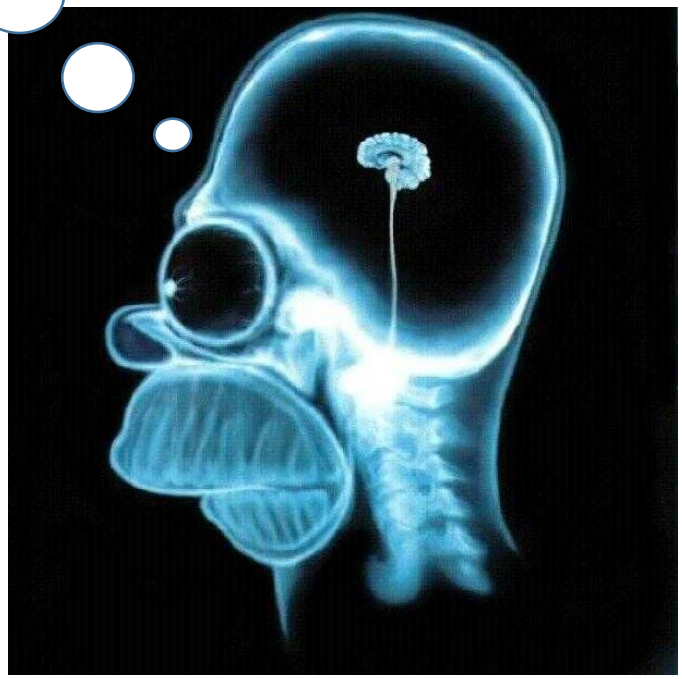

X-ray phase contrast imaging

X-ray imaging

[1] F. Pfeiffer *et al.*,Phase retrieval and differential phase-contrast imaging with low-brilliance X-ray sources, *Nature Phys.* **2** (2006)

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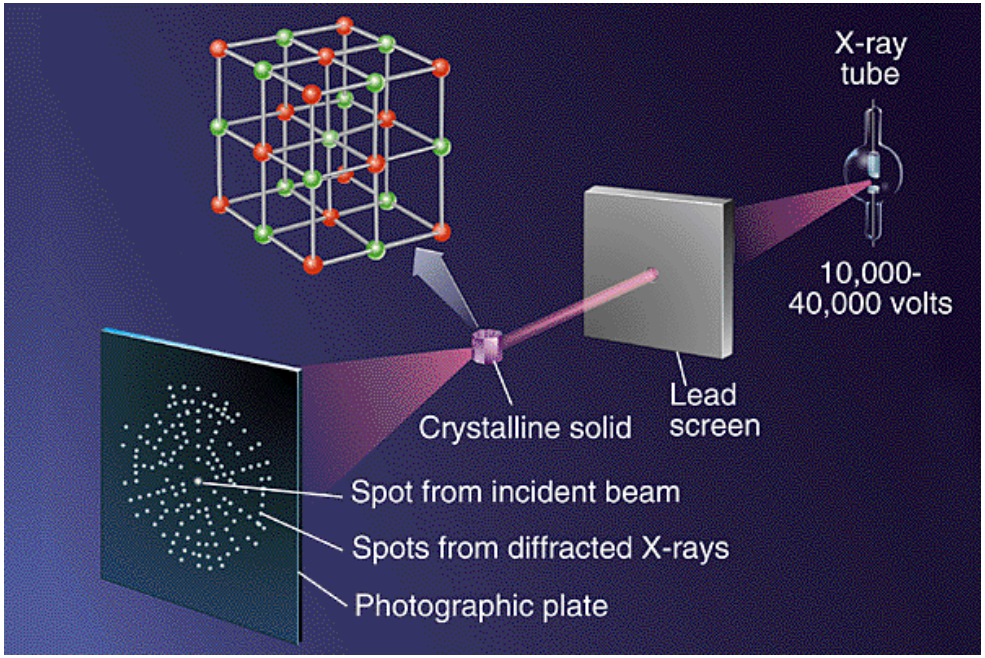
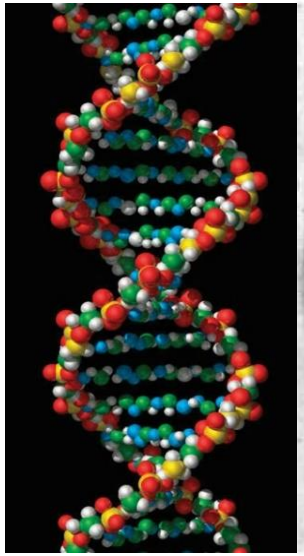
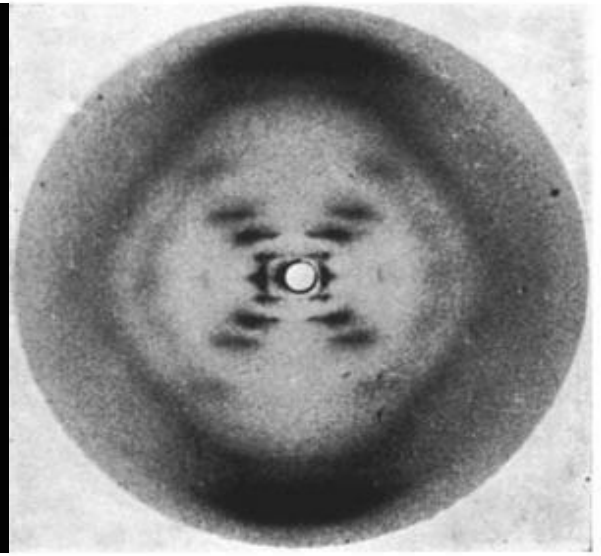
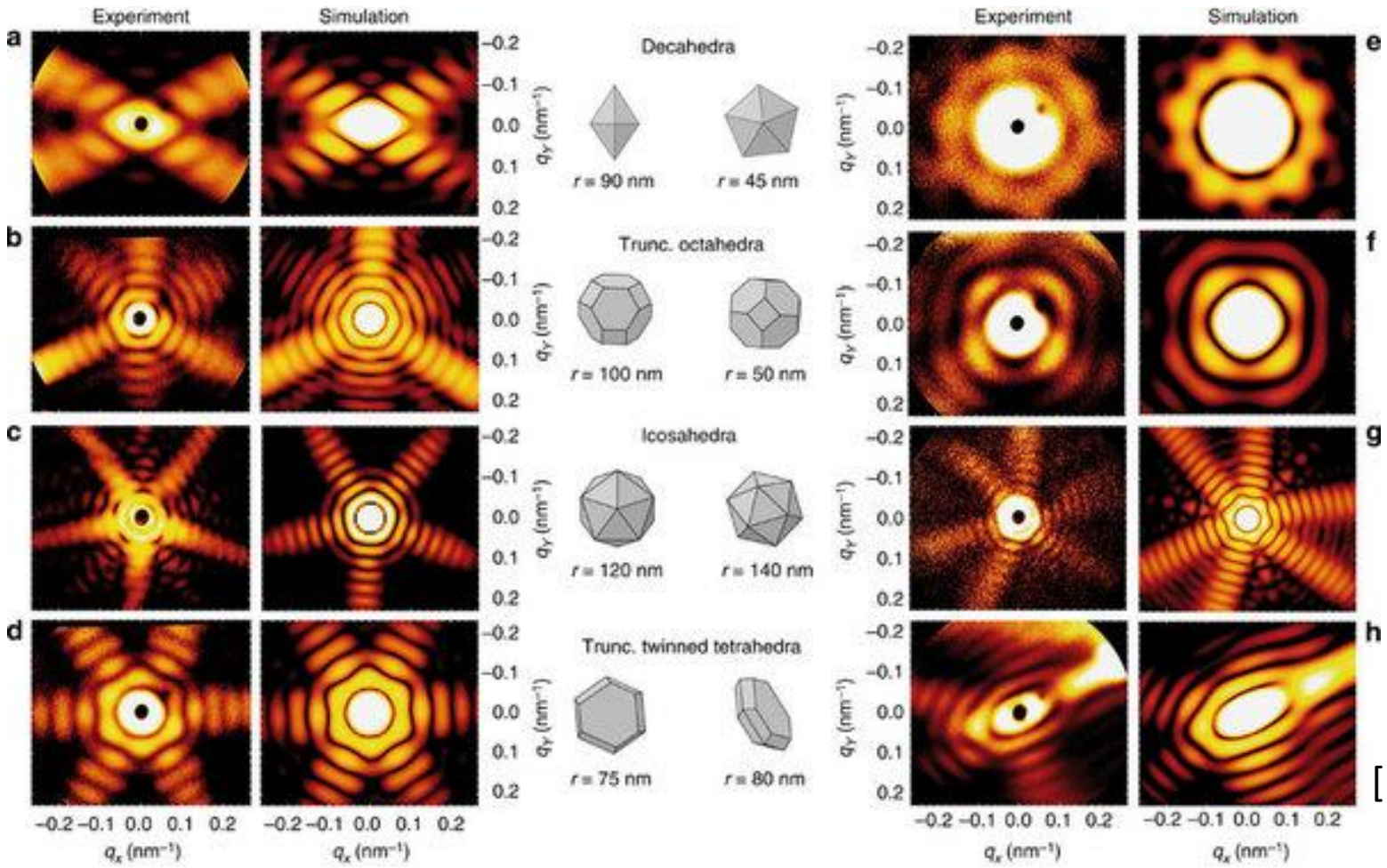






X-ray diffraction

Why are X-rays so important?



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X-ray scattering

[1] I. Barke *et al.*, The 3-D architecture of individual free silver nanoparticles captured by X-ray scattering, *Nature Communications* **6** (2015)

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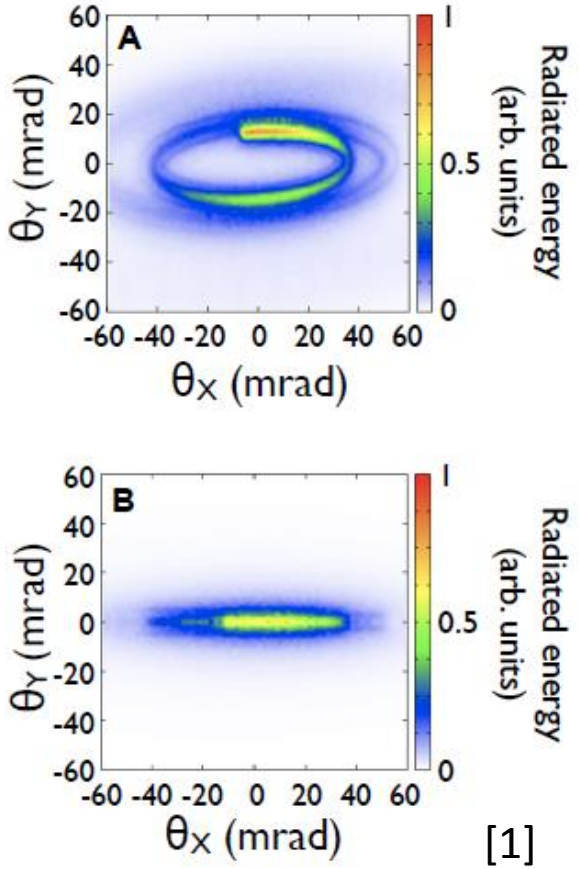

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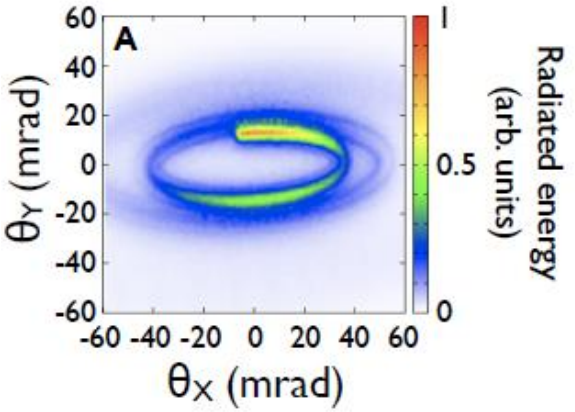

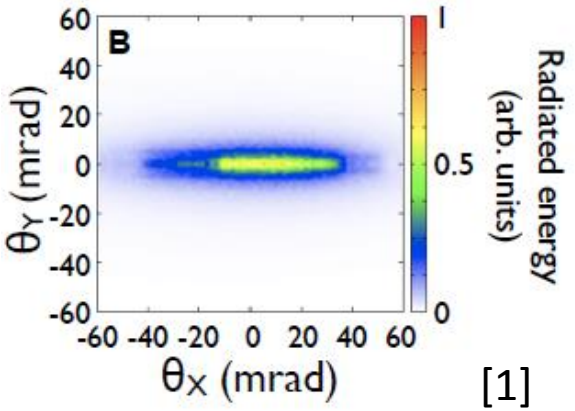

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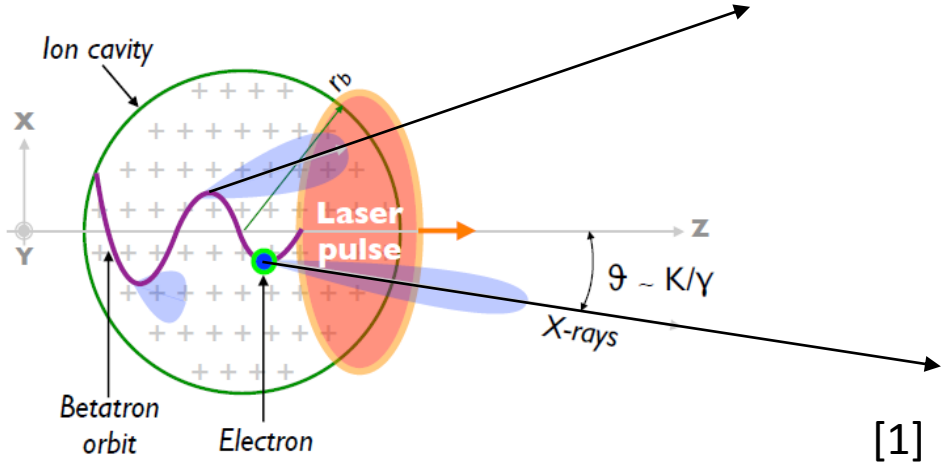

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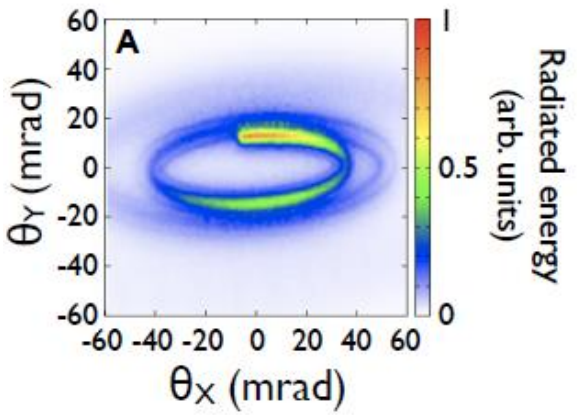

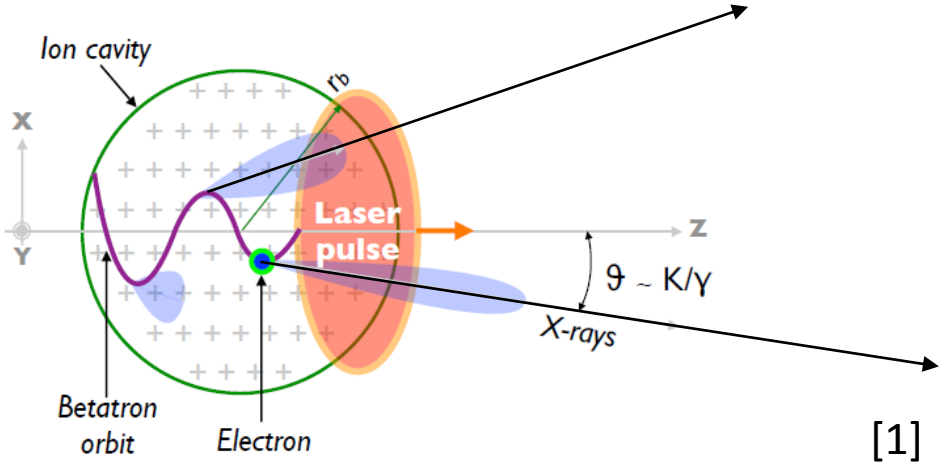

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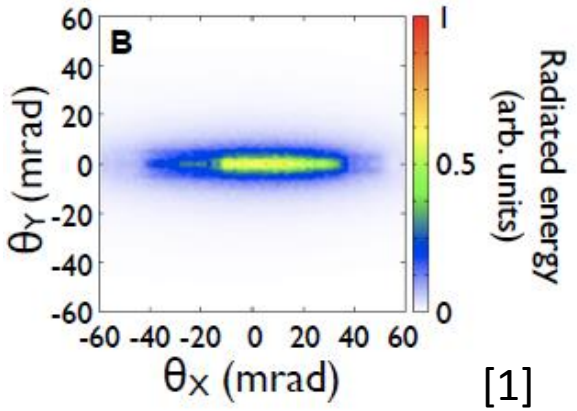

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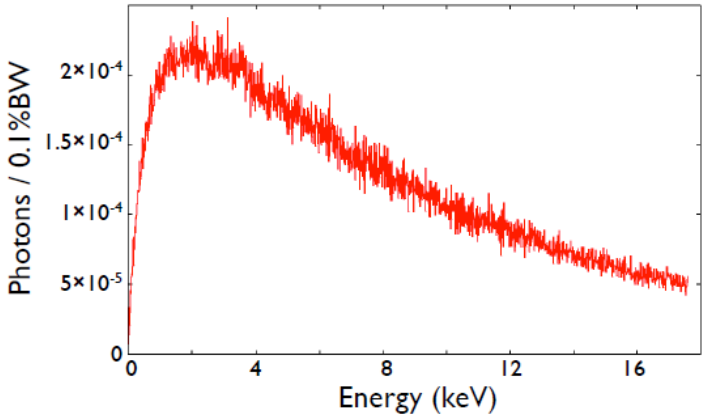

[1]

$$\hbar\omega_c = \frac{3}{2} K \gamma^2 \frac{hc}{\lambda_u} = 5.24 \cdot 10^{-21} \gamma^2 n_e \, [cm^{-3}] \, r_\beta \, [um] \quad [eV]$$

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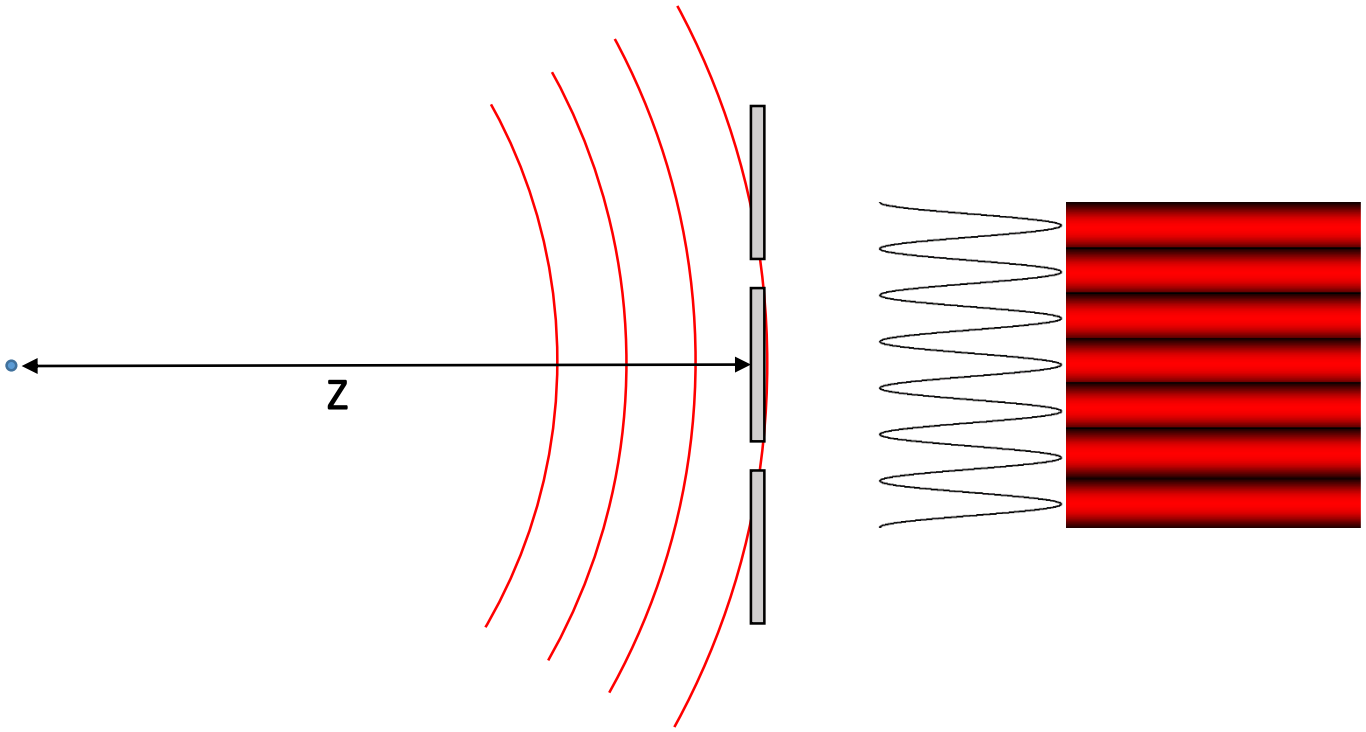
Introduction on coherence



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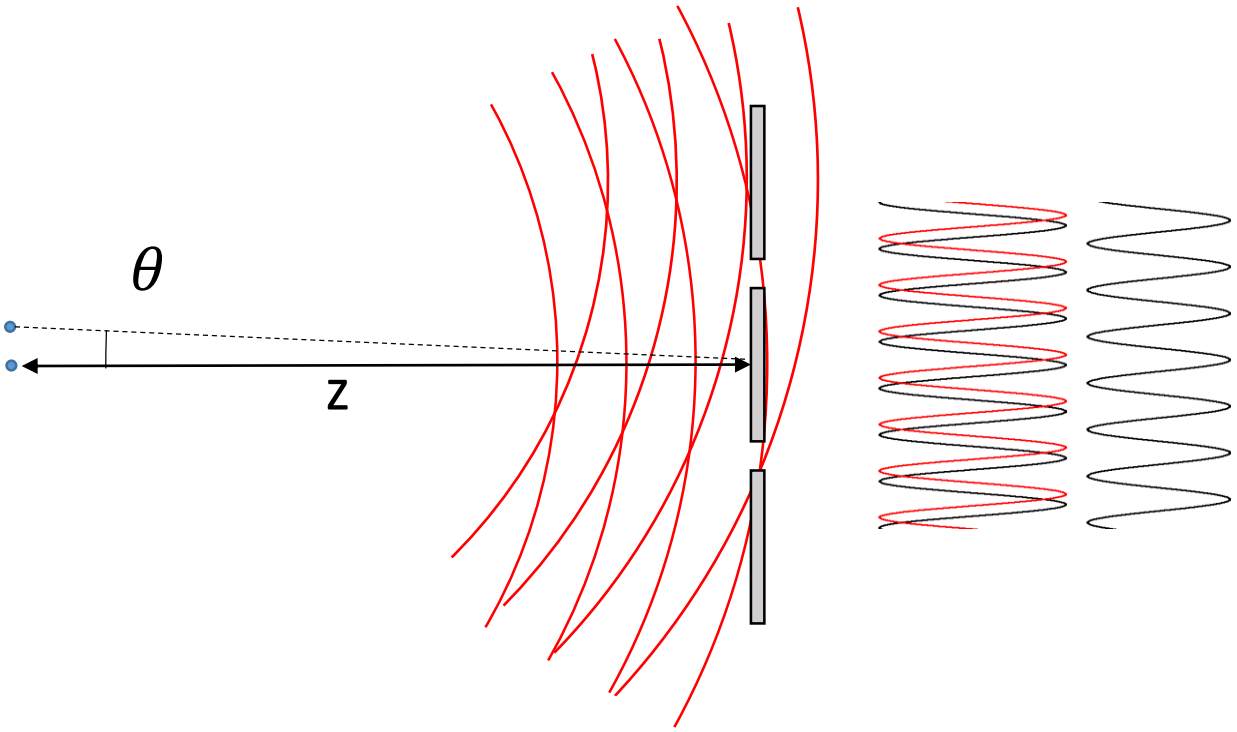

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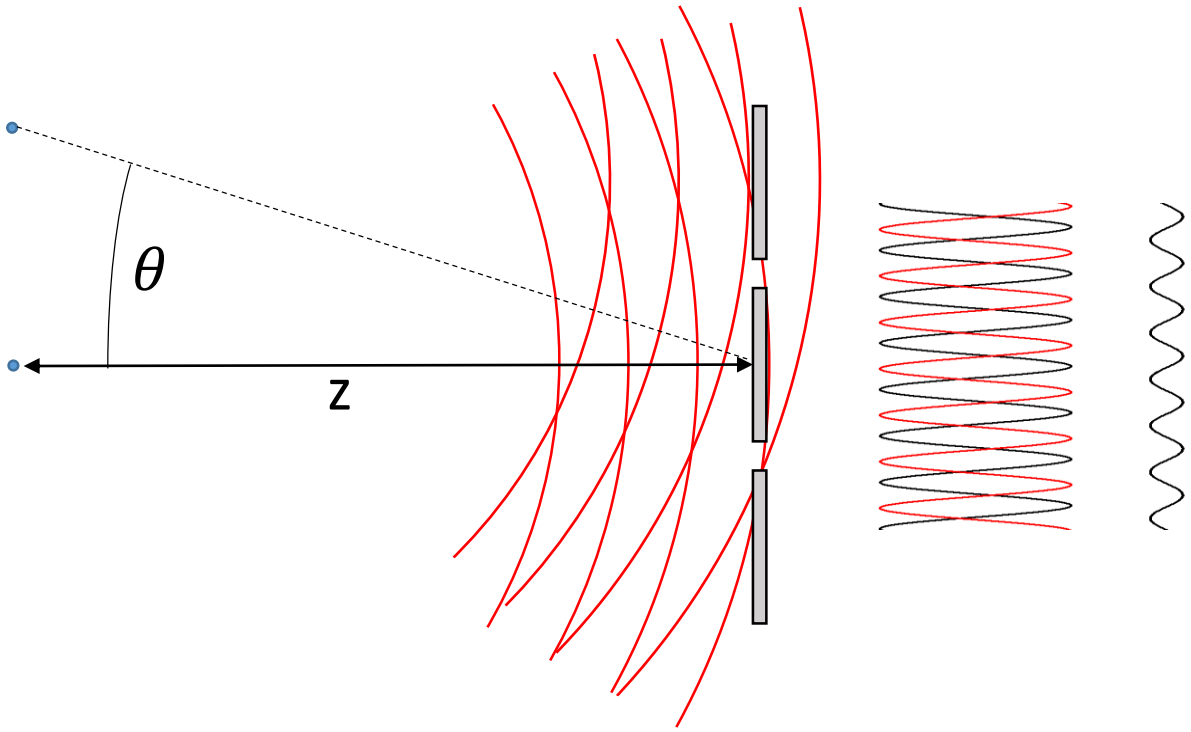

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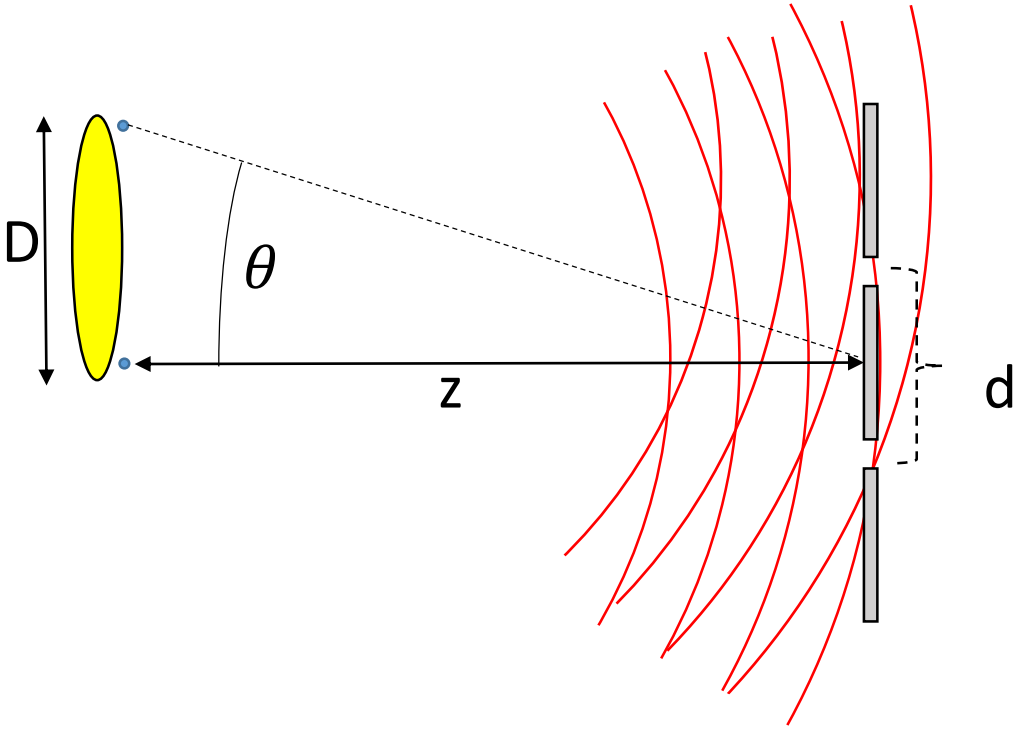

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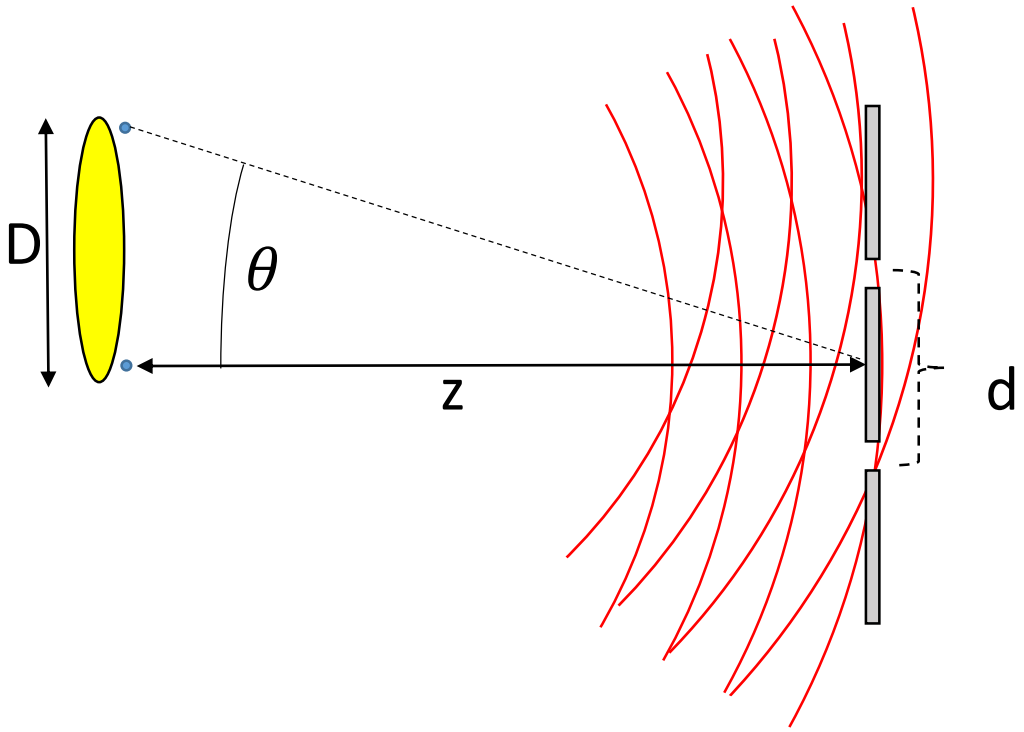
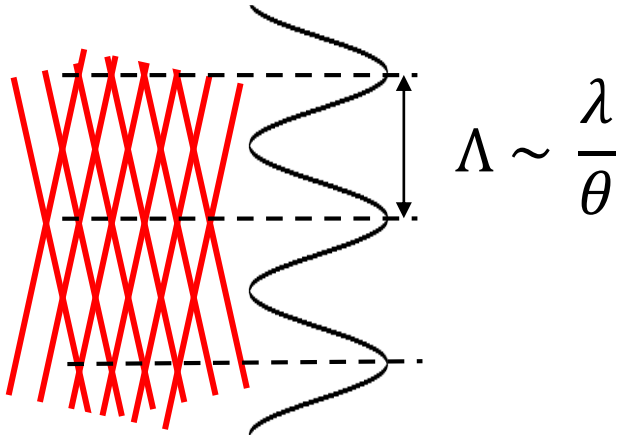




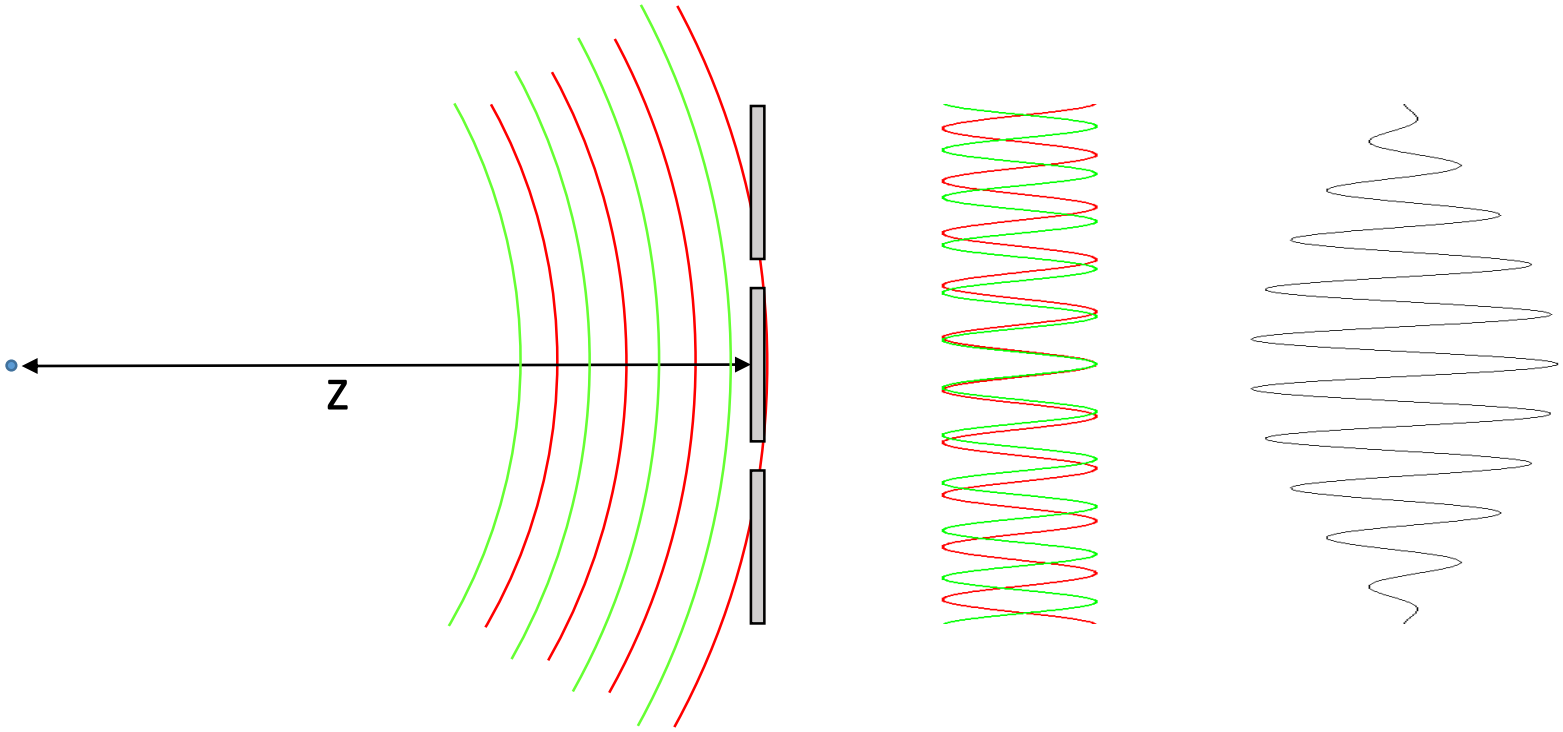
$$\Lambda \sim \frac{\lambda}{\theta}$$

$$d < (\ll) \Lambda \sim \frac{\lambda}{\theta}$$

$$d_{coh} \sim \frac{\lambda z}{D}$$

Van Cittert – Zernike theorem

Introduction on coherence



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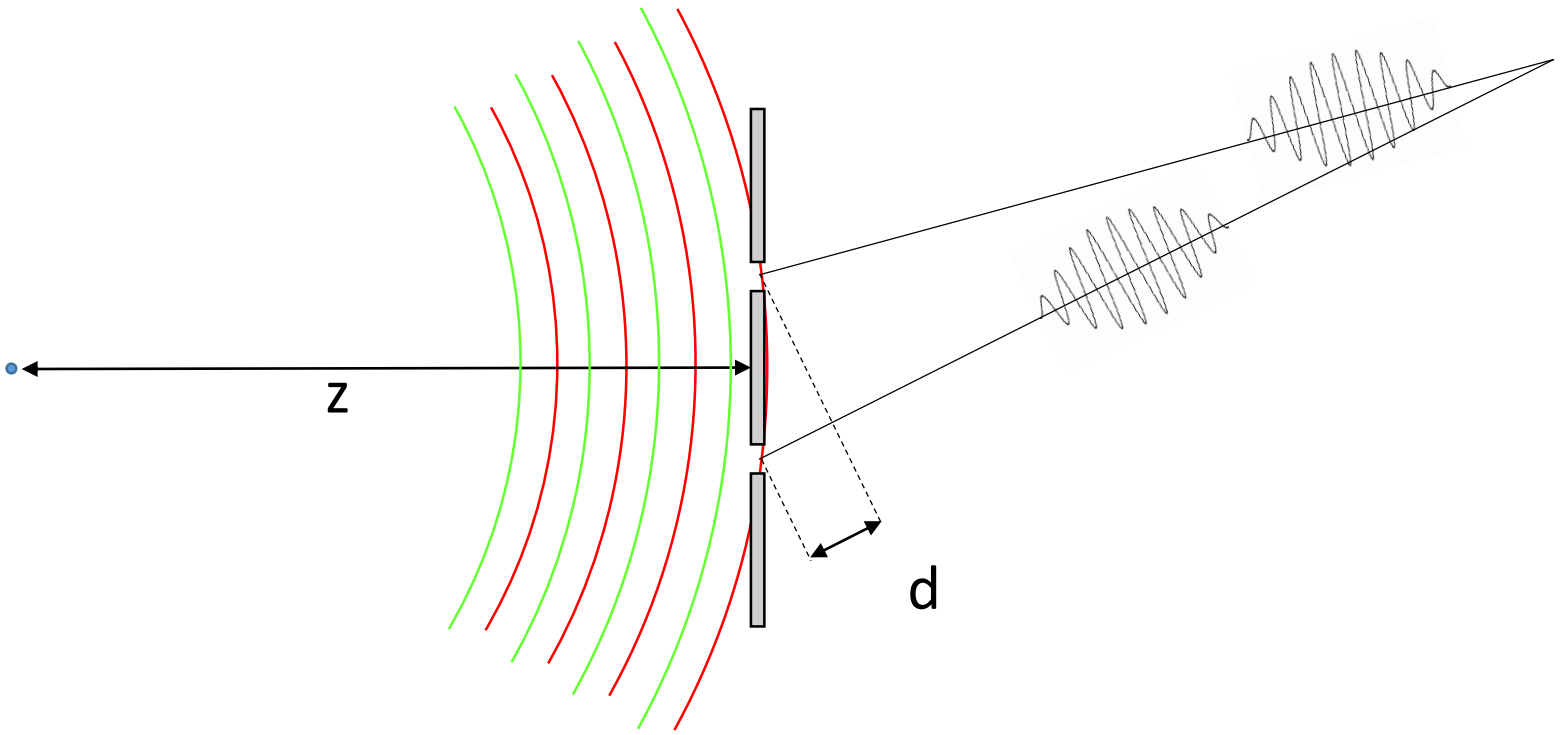
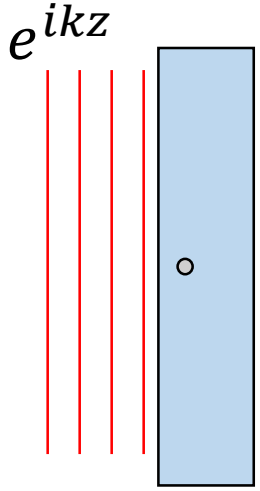


$$d \ < (\ll)\ l_{wavepacket}$$

$$l_{coh} \sim \frac{\lambda^2}{\Delta\lambda}$$

Coherence with colloidal particles: speckle fields



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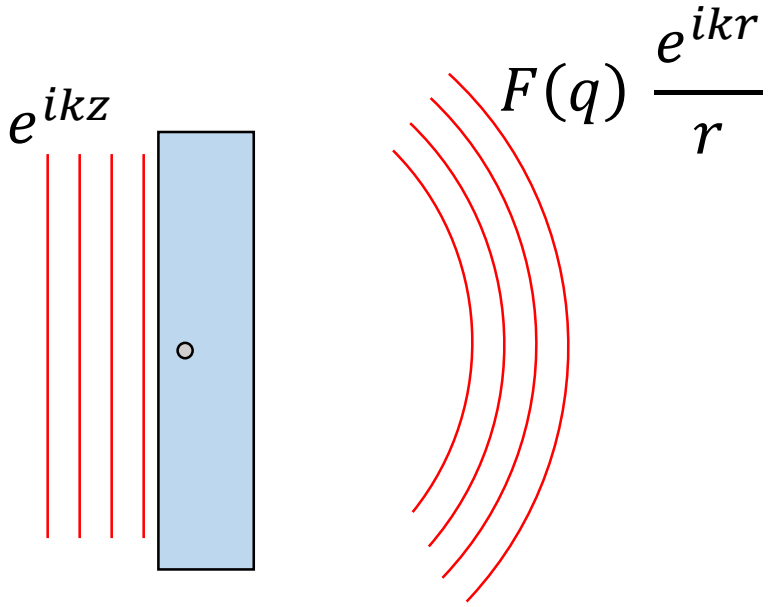
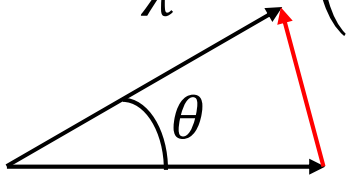


$$|q| = \frac{4\pi}{\lambda} \sin\left(\frac{\vartheta}{2}\right)$$



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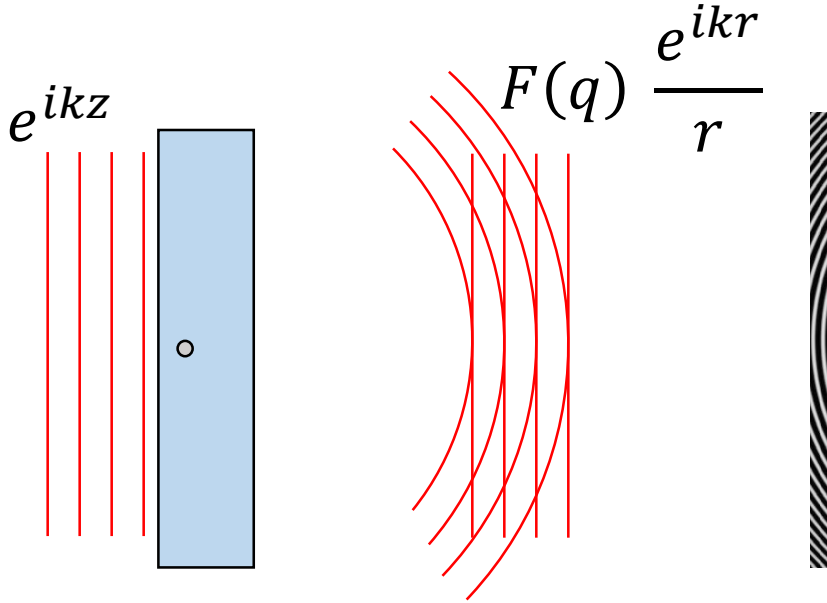

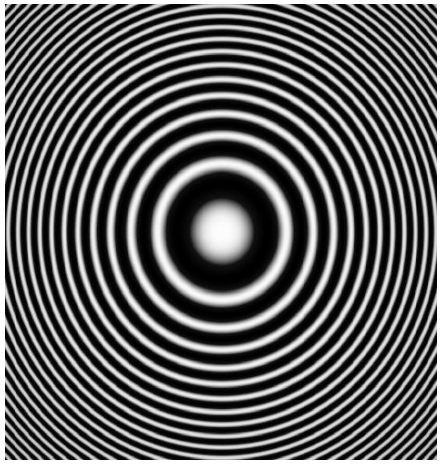

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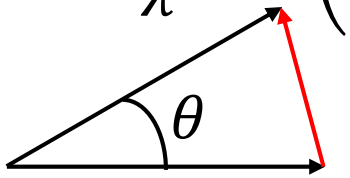

Heterodyne

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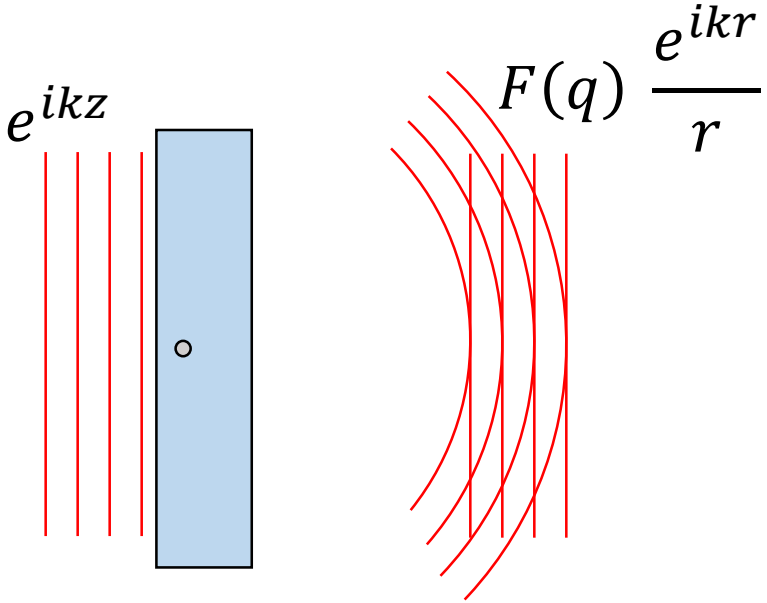

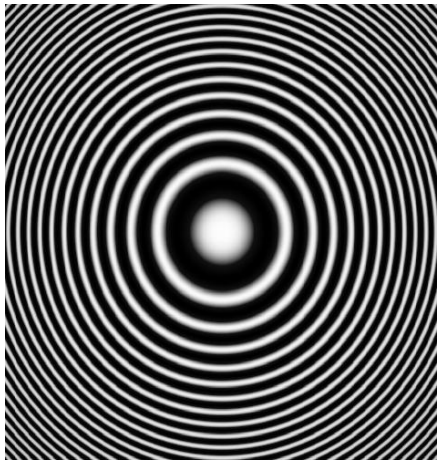

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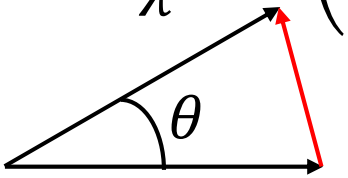
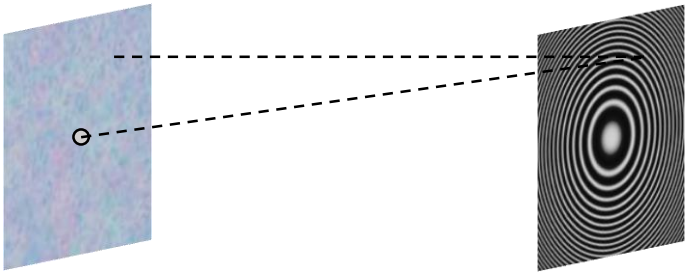


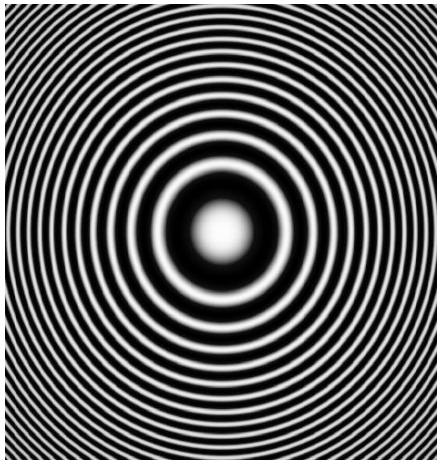


Heterodyne

Coherence with colloidal particles: speckle fields

e^{ikz}

$F(q)\ \dfrac{e^{ikr}}{r}$



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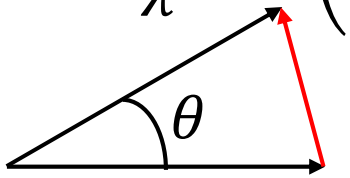

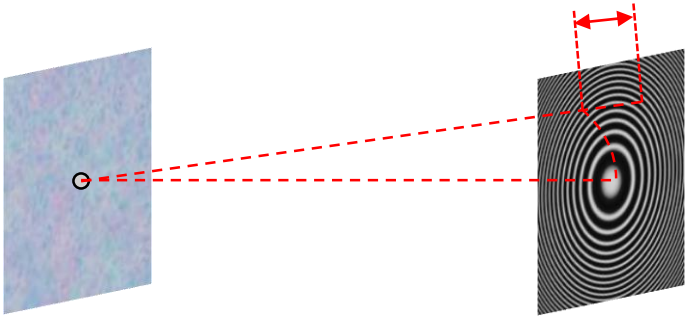

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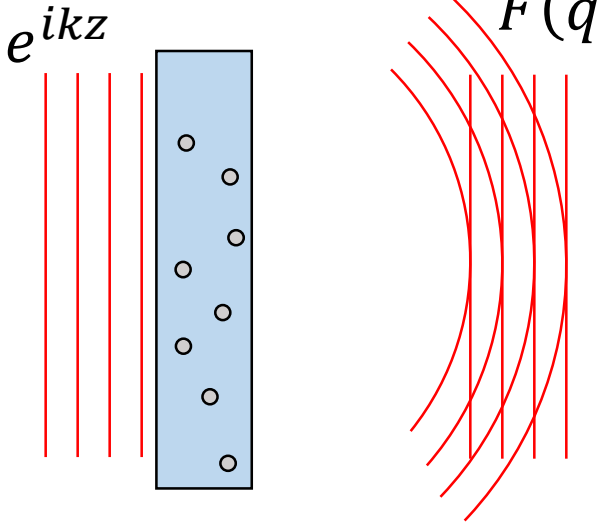
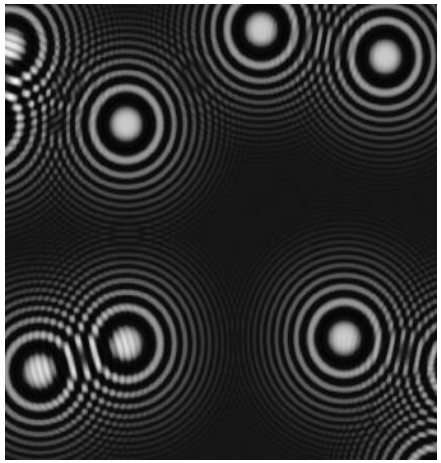
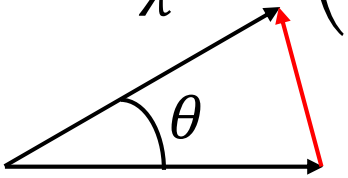
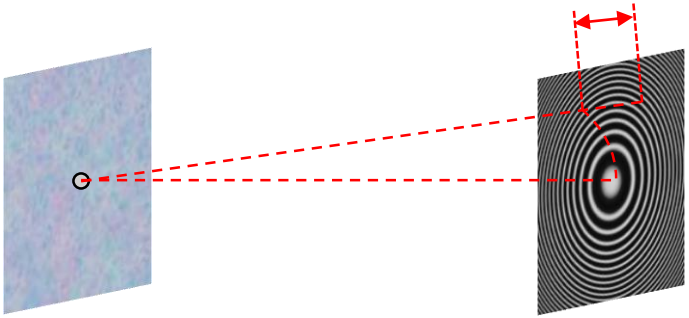




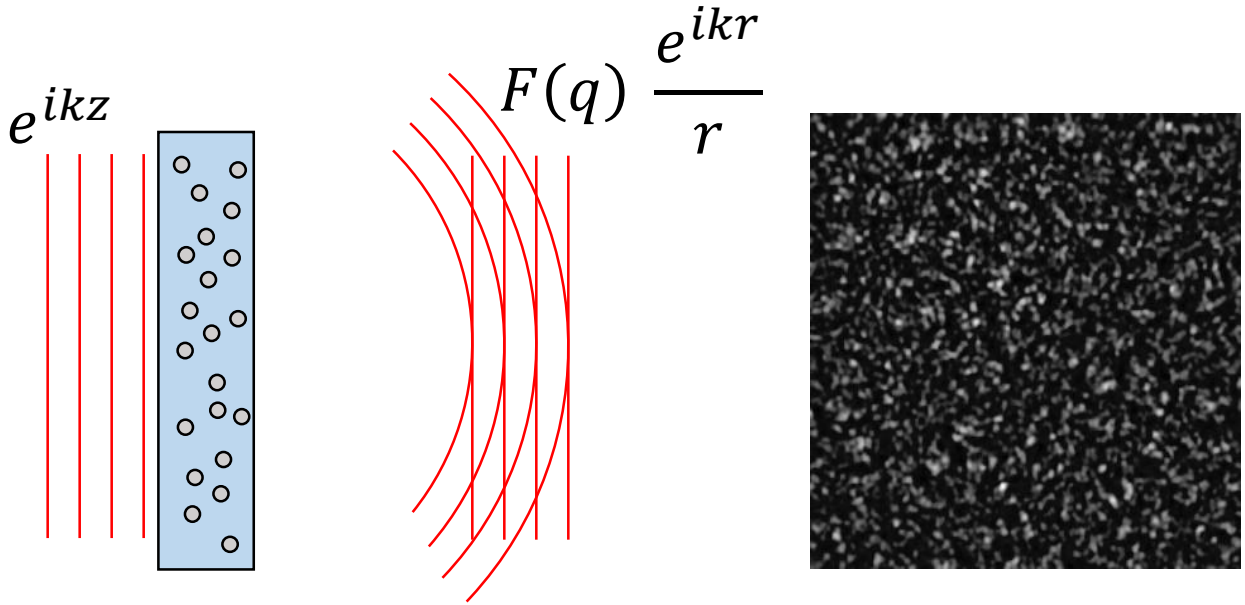
$$|q| = \frac{4\pi}{\lambda} \sin\left(\frac{\vartheta}{2}\right)$$

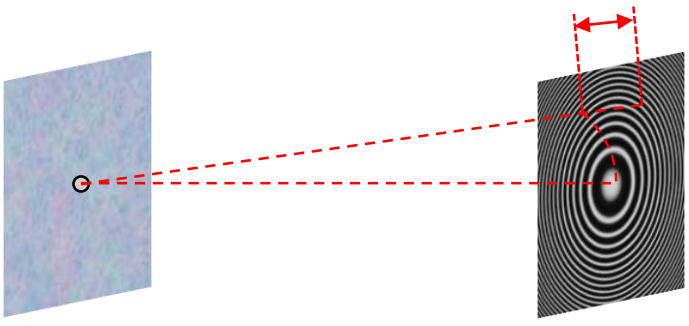




Heterodyne

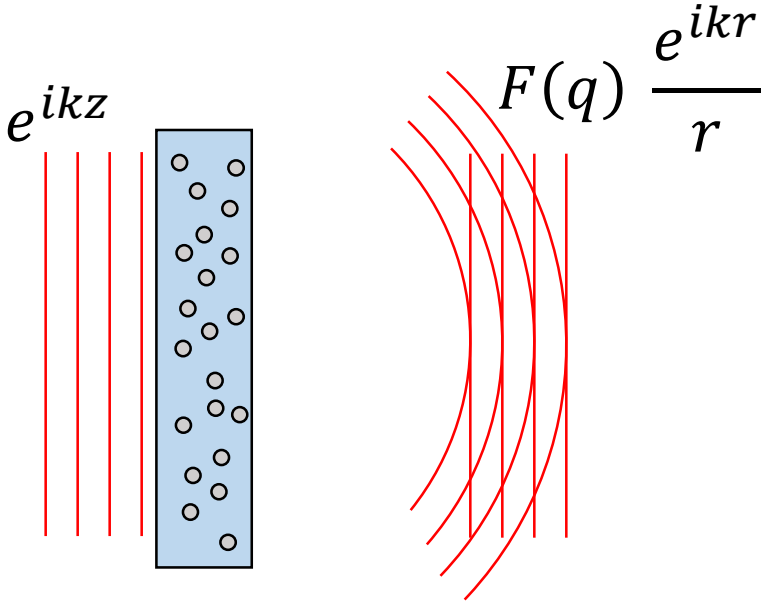
Coherence with colloidal particles: speckle fields

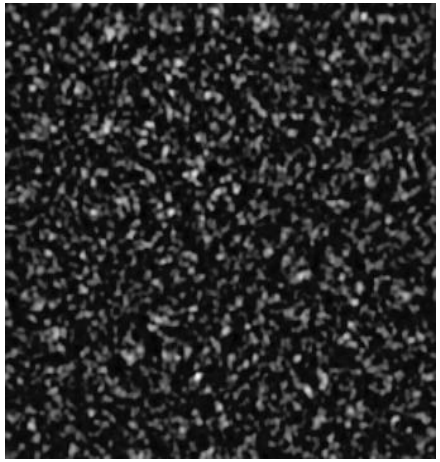


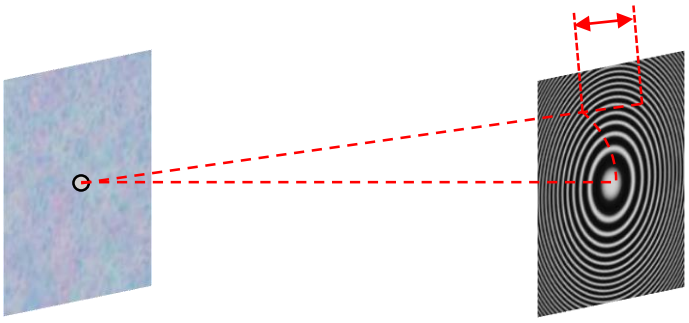


Heterodyne **Speckles**

Coherence with colloidal particles: speckle fields

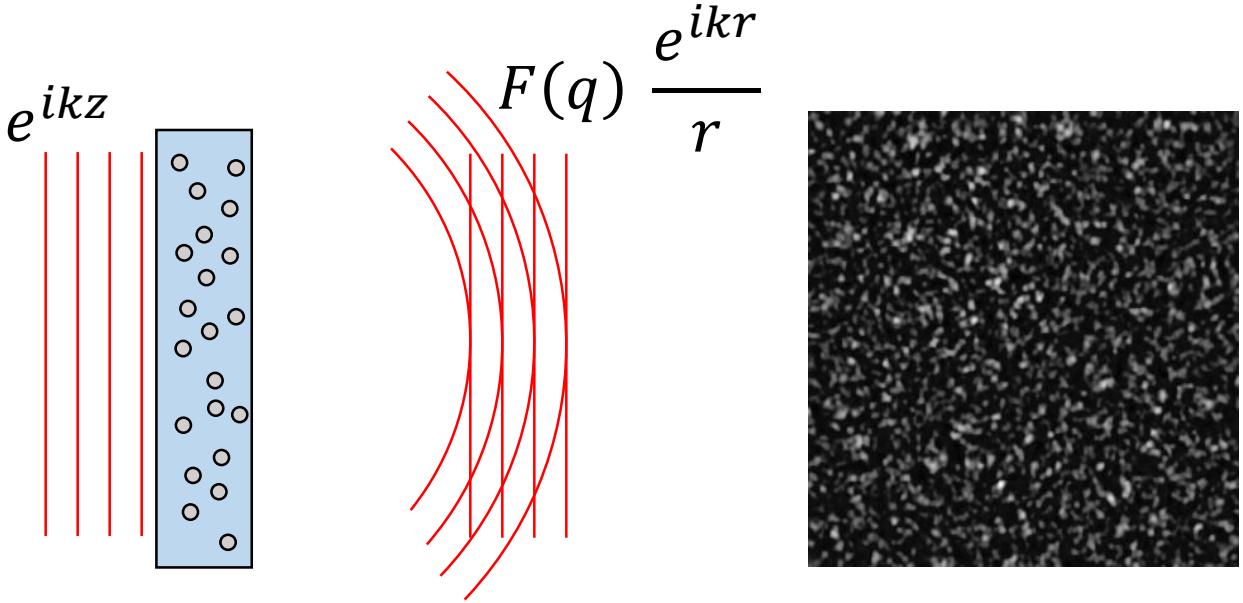




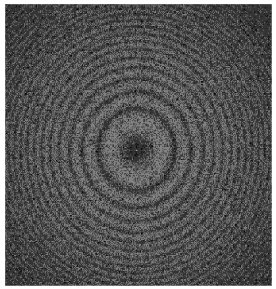


Heterodyne **Speckles**

Coherence with colloidal particles: speckle fields

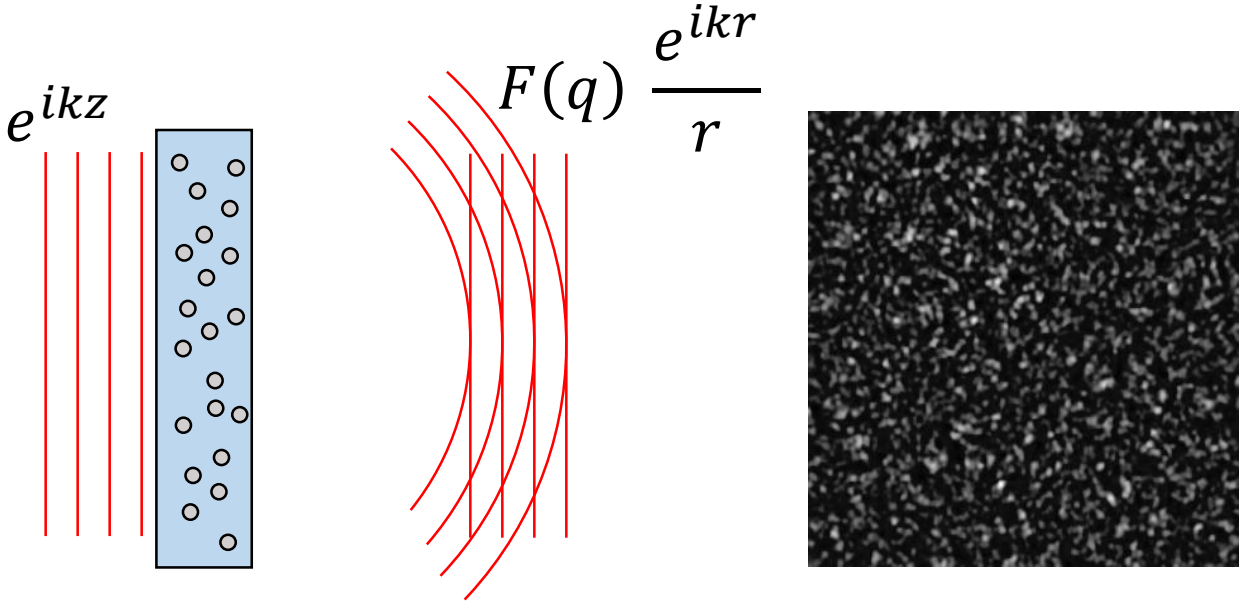


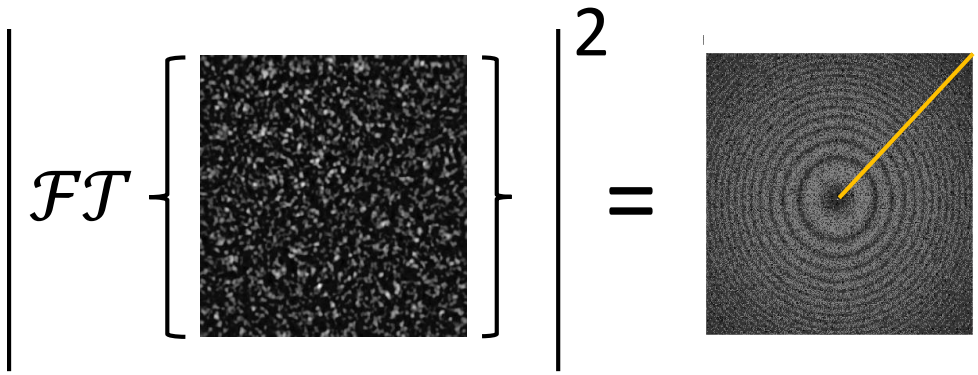
$$\left| \mathcal{FT}\left\{ \quad \right\} \right|^2 =$$

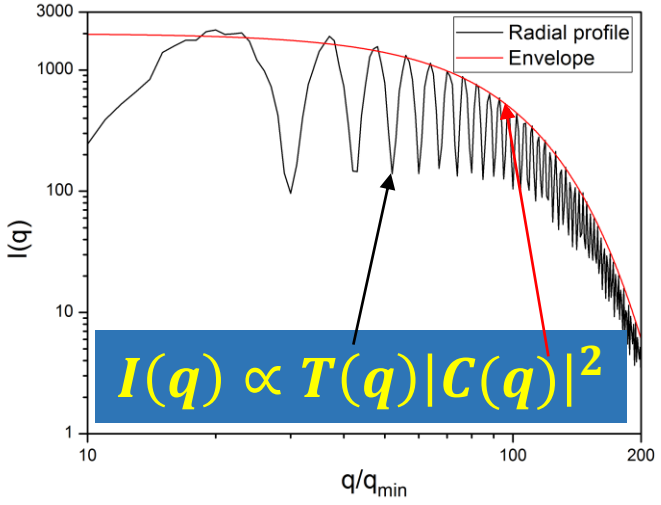


Heterodyne **Speckles**

Coherence with colloidal particles: speckle fields



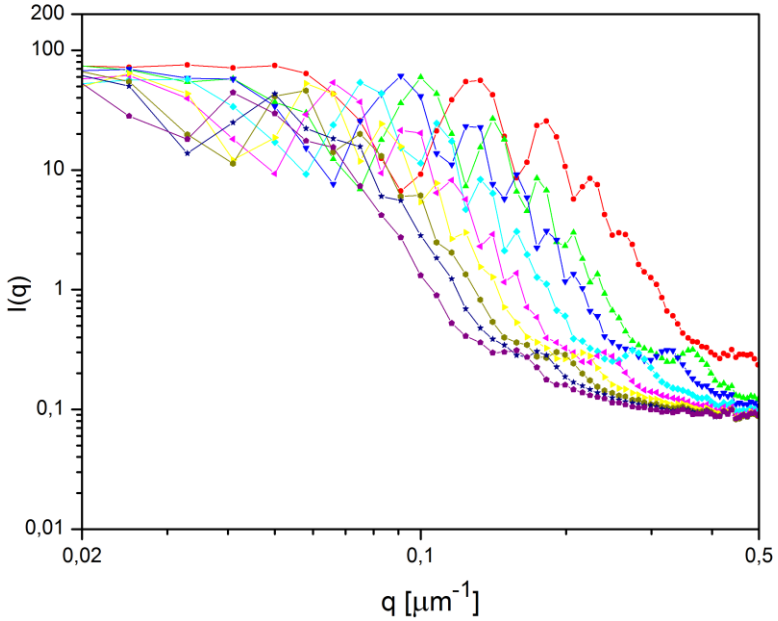


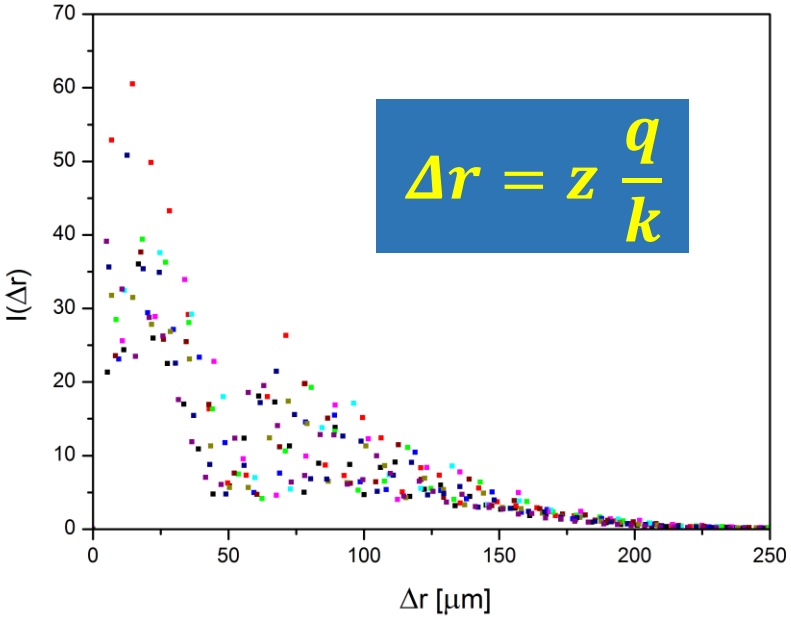


Heterodyne

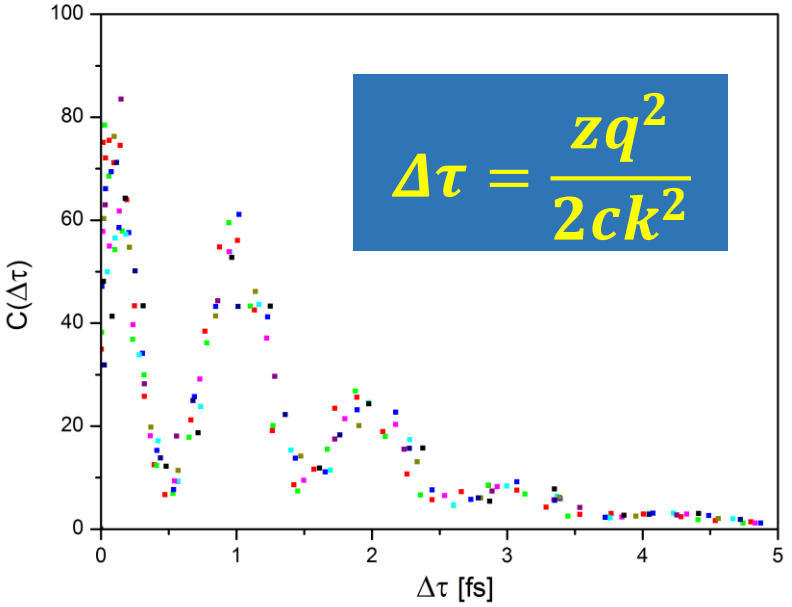
Speckles

Coherence with colloidal particles: speckle fields





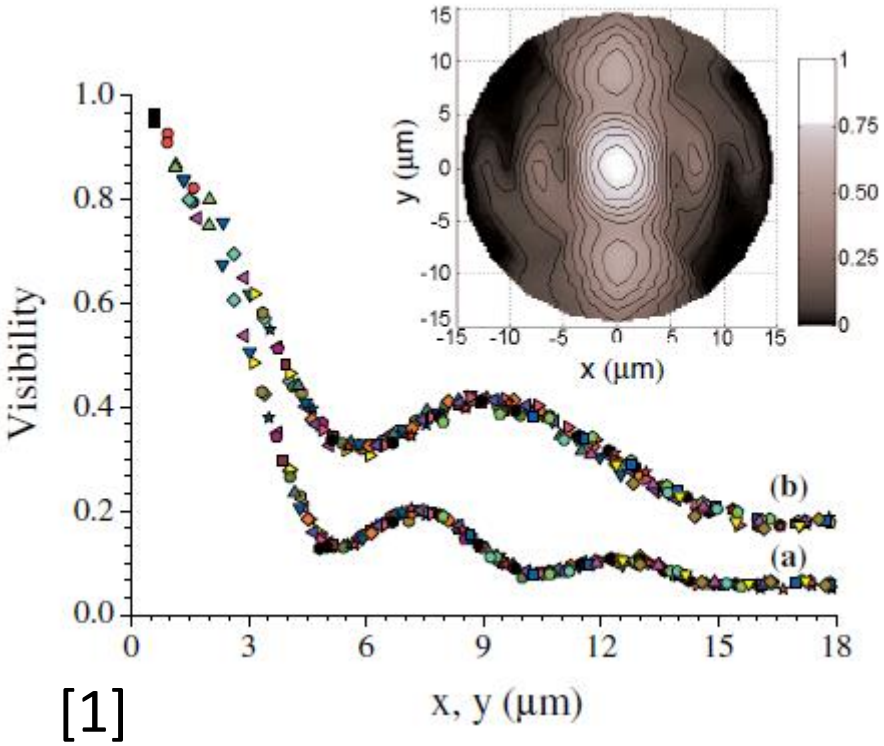
$$\Delta r = z\,\frac{q}{k}$$



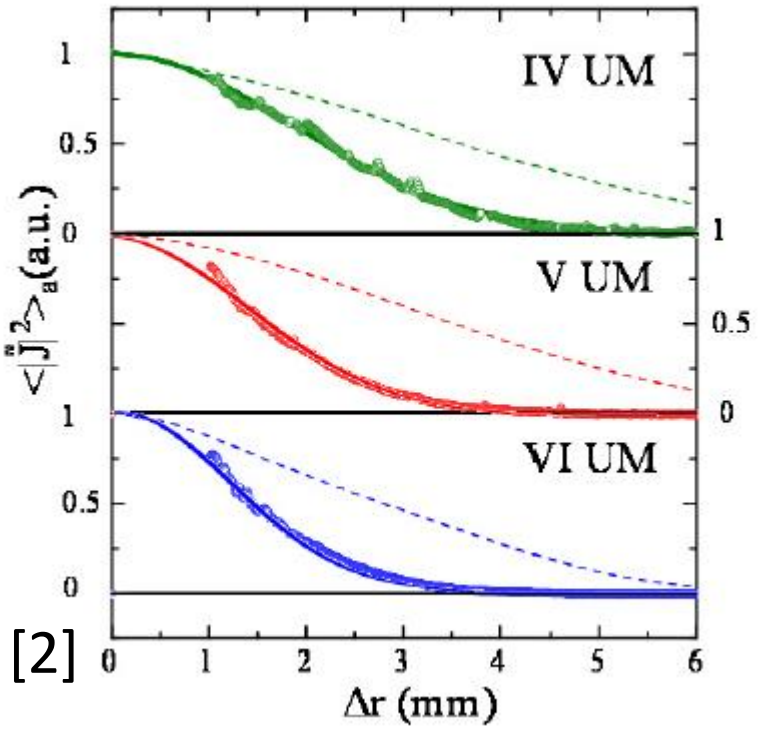
$$\Delta\tau = \frac{zq^2}{2ck^2}$$

Heterodyne Near Field Speckles

X-ray spatial coherence measurements



[1]

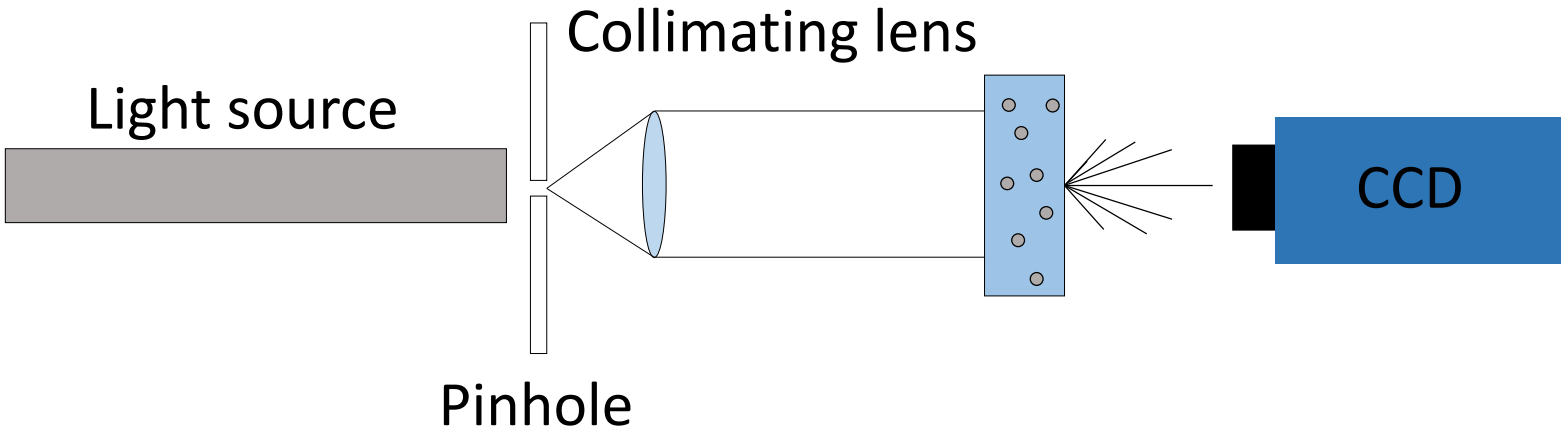


[2]

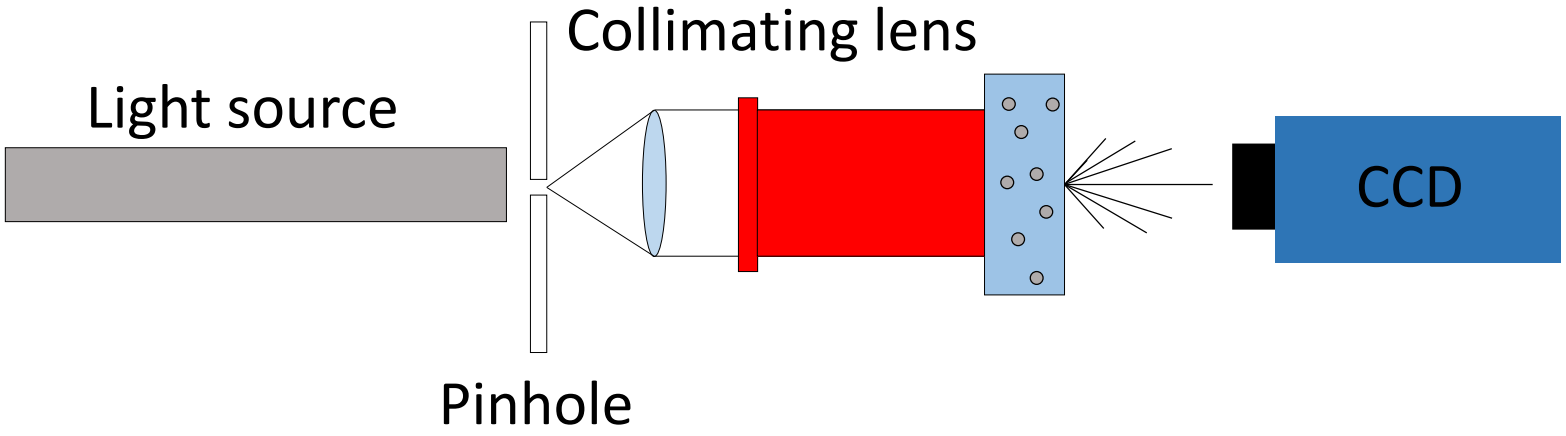
[1] M. D. Alaimo *et al.*, Probing the transverse coherence of an undulator X-ray beam using brownian particles, *Phys. Rev. Lett.* **103,** 194805(2009)

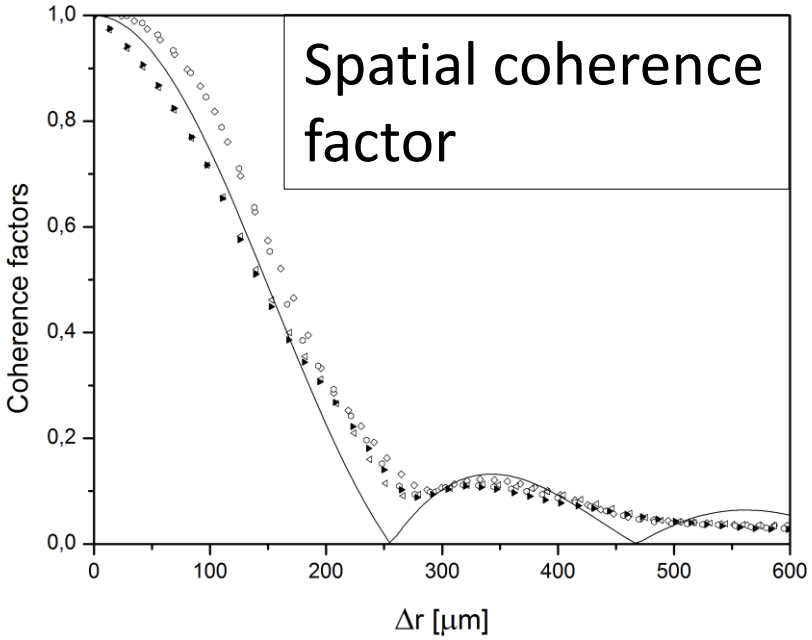
[2] M. D. Alaimo *et al.*, Mapping the transverse coherence of the self-amplified spontaneous emission of a free electron laser with the heterodyne speckle method, *Opt. Express.* **22** (24) (2014)

HNFS with polychromatic light

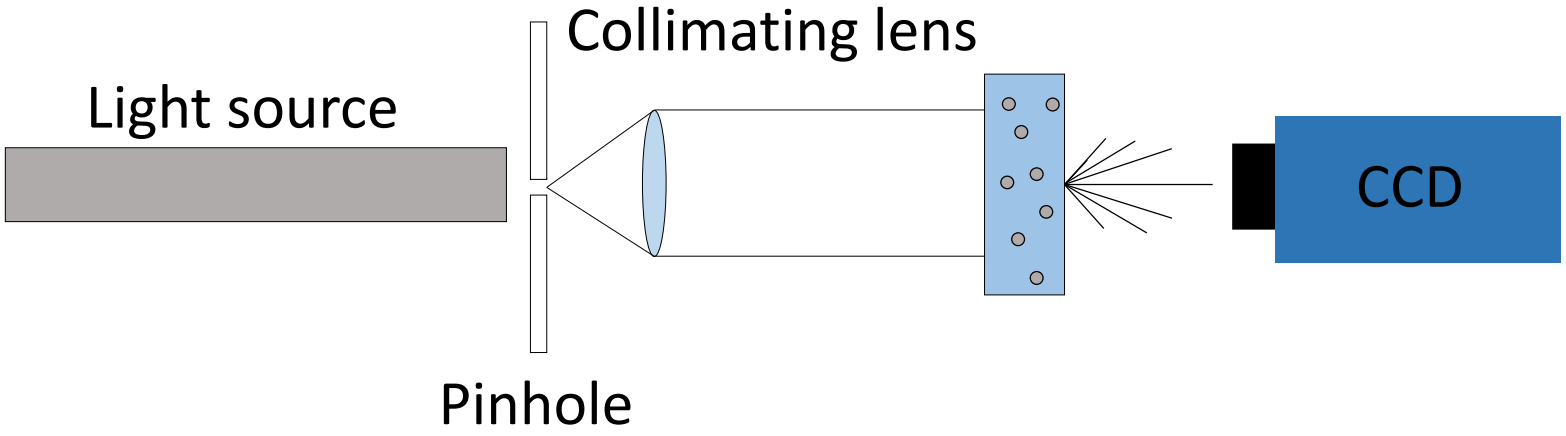


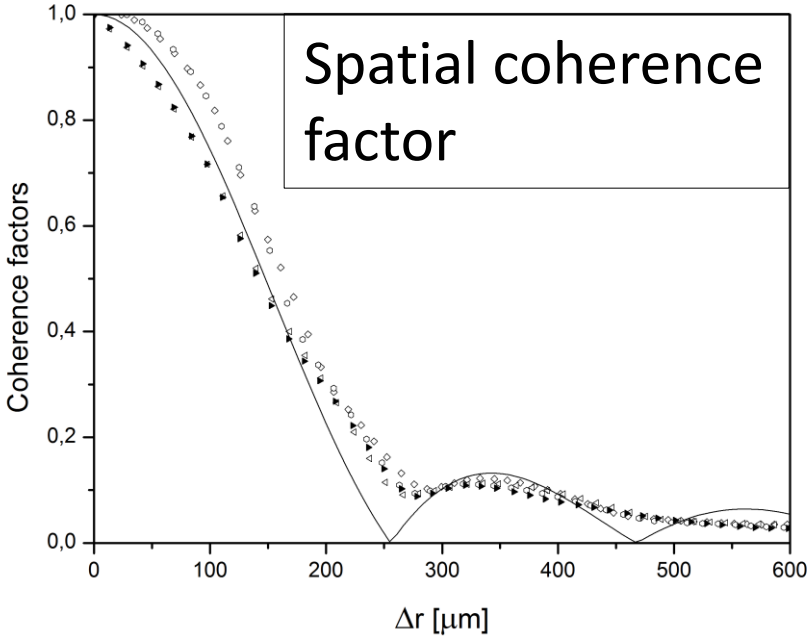
HNFS with polychromatic light

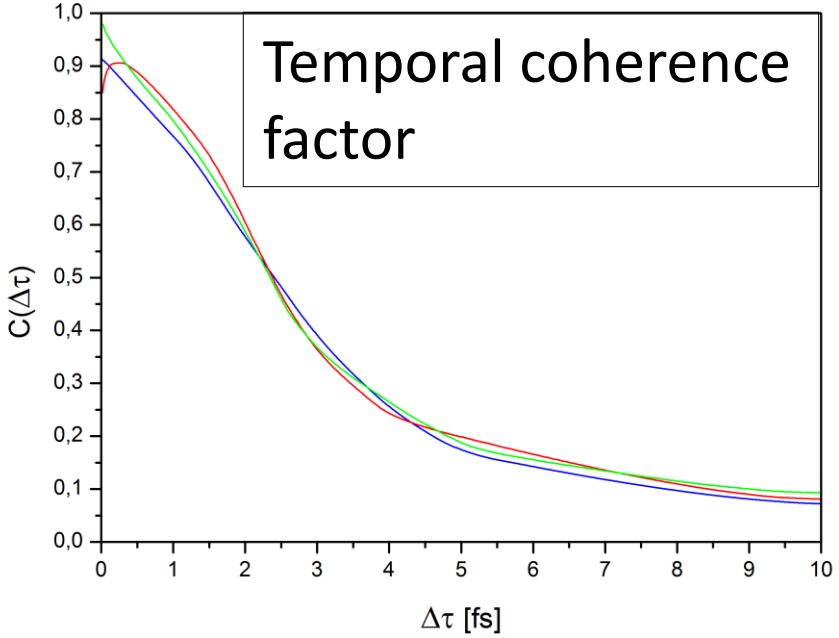




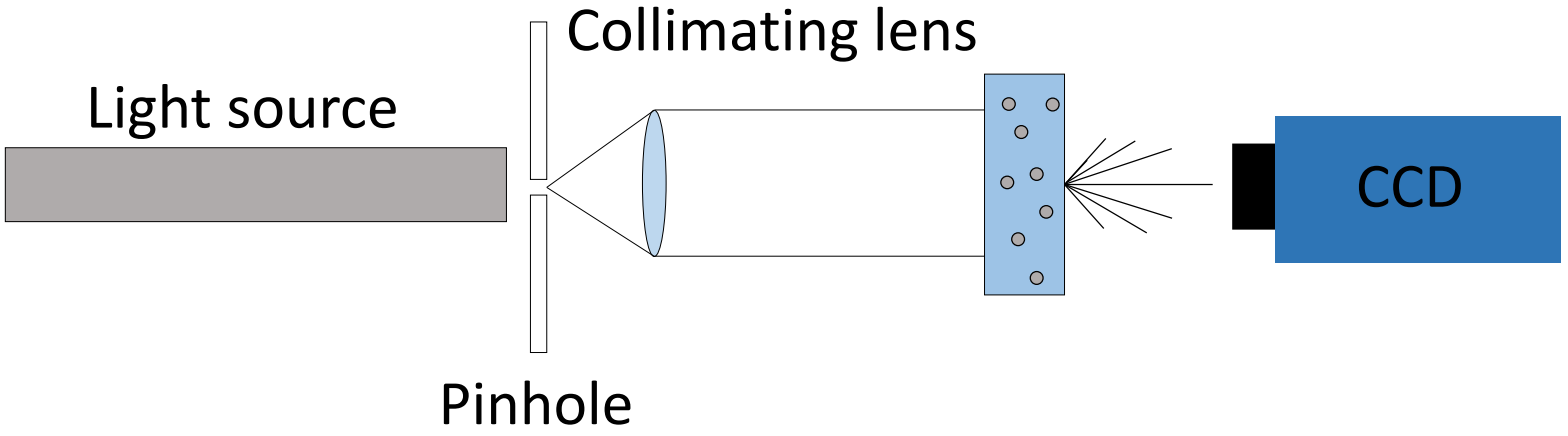
HNFS with polychromatic light

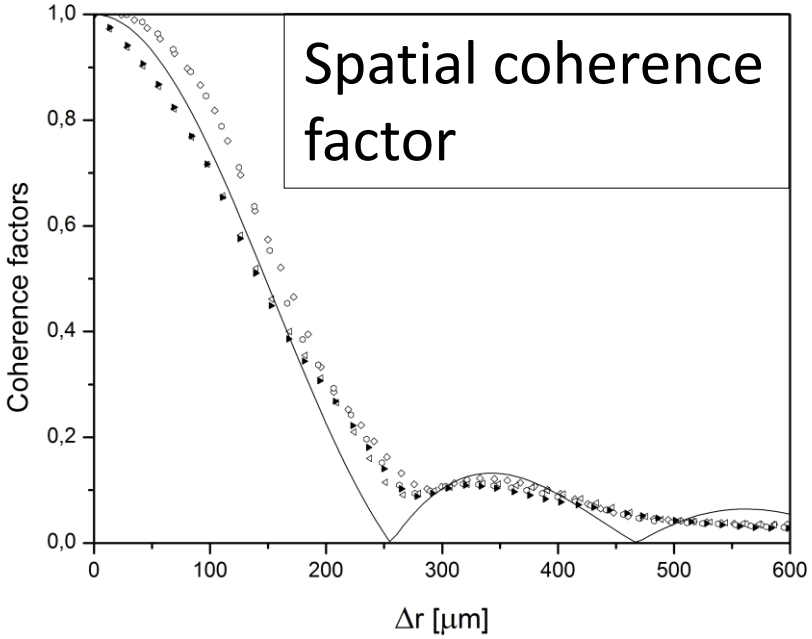


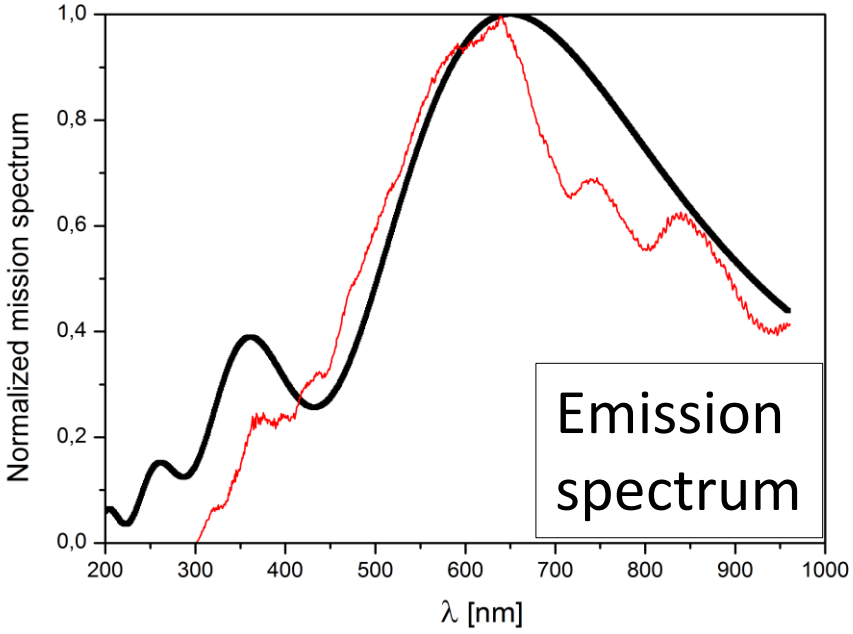




HNFS with polychromatic light







HNFS with polychromatic light

THANK YOU !!!