

Phase contrast (I)

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EPFL Phase contrast (I) program

- Q and A from MOOC week 7 lectures and exercises
- Demos: “seeing” the PCTF at the microscope using the fast Fourier transform of amorphous carbon
 - effect of defocus, astigmatism, objective aperture

EPFL Fast Fourier transform of a-C film

Phase contrast transfer function (PCTF)

Weak phase object $\rightarrow$ only changes phase of scattered wave

PCTF: $T(\vec{u}) = A(\vec{u}) E(\vec{u}) 2 \sin \chi(\vec{u})$

With C_s : $\chi(\vec{u}) = \pi \Delta f u^2 + \frac{1}{2} \pi C_s \lambda^3 u^4$

$\vec{u}$: reciprocal space vector

$u = |\vec{u}|$: spatial frequency

$A(\vec{u})$: (objective) aperture - cut higher u

$E(\vec{u})$: envelope - describes coherence of optical system : spatial coherence (source size)

Δf : defocus of objective lens
 $\hookrightarrow$ Focus lens

Standard microscope: C_s fixed

$T(\vec{u})$ continued...

Temporal coherence - energy spread of source

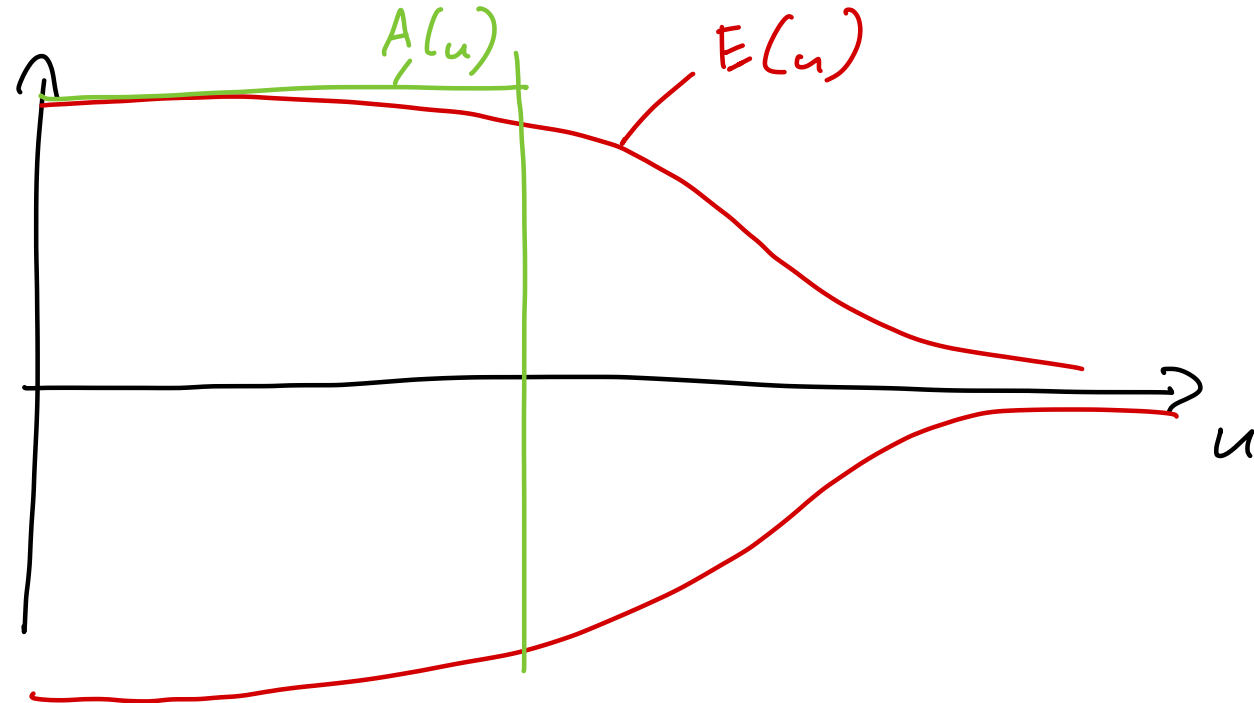
ΔE : LaB6 - $\Delta E \sim 1.2-1.5 \text{ eV}$

energy Schottky FEG $\Delta E \sim 0.6-0.8 \text{ eV}$

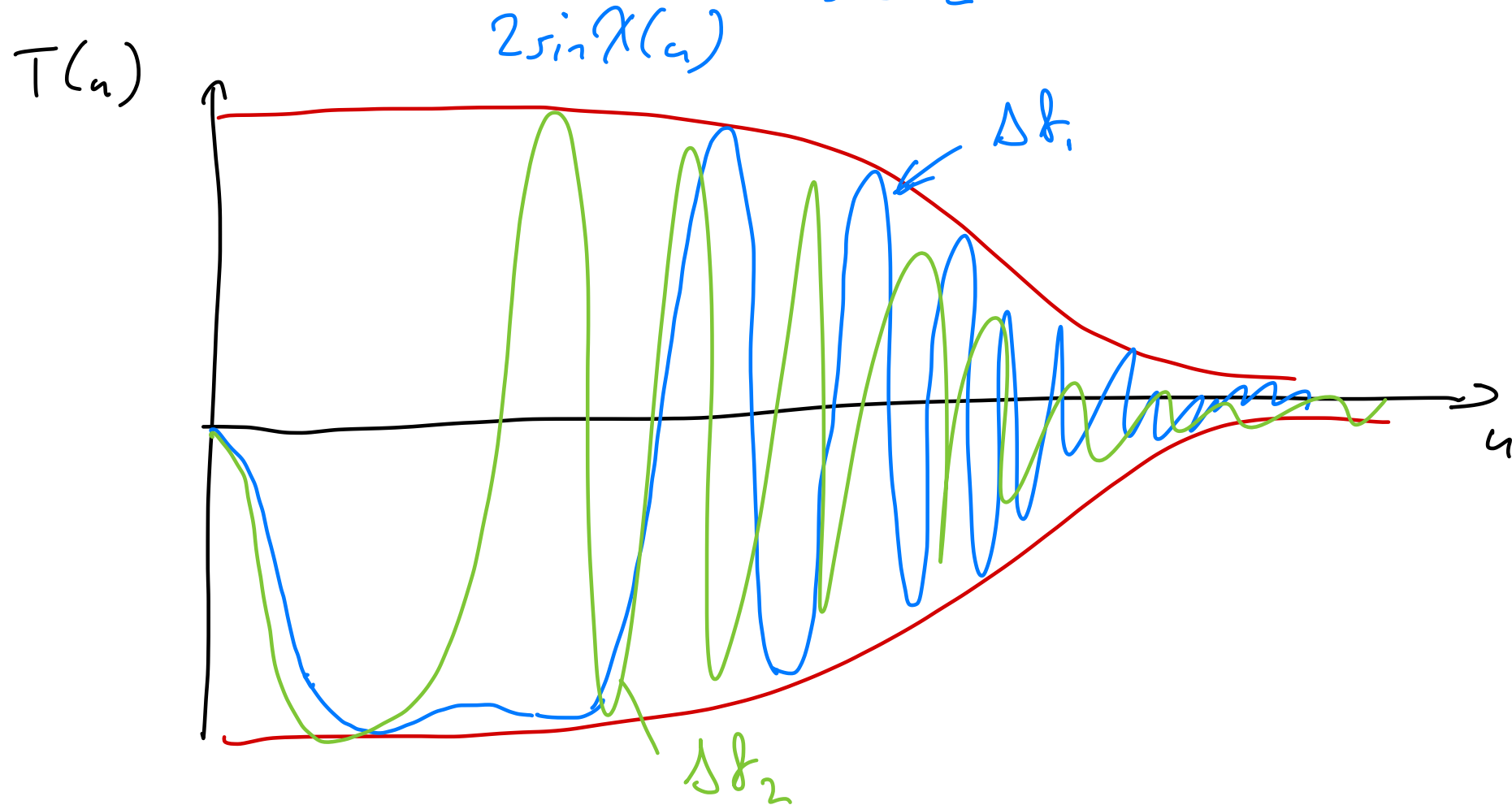
Cold FEG $\Delta E \sim 0.3-0.4 \text{ eV}$

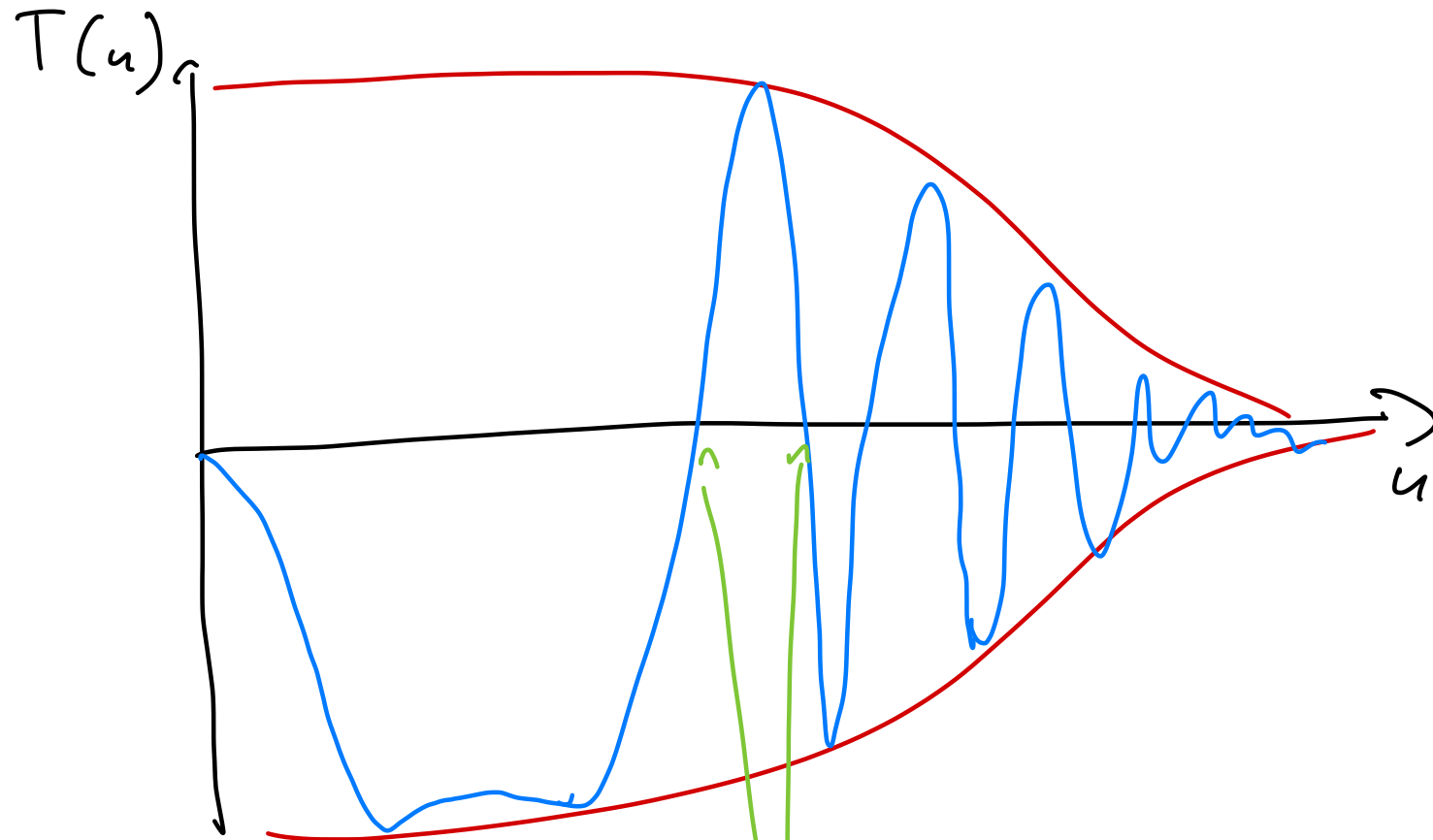
C_c
chromatic
aberration
term

PC TF



Fixed C_s : Talbot / Dirichlet $C_s = 1.2 \mu m$
 JEOL 2200F5 $C_s \approx 2 \mu m$

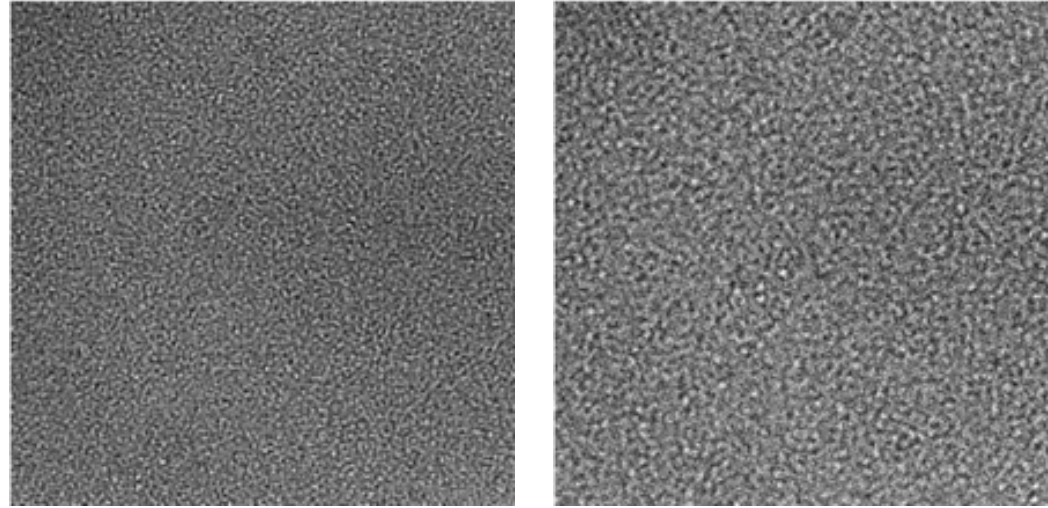




At cross over : no information

EPFL Fast Fourier transform of a-C film

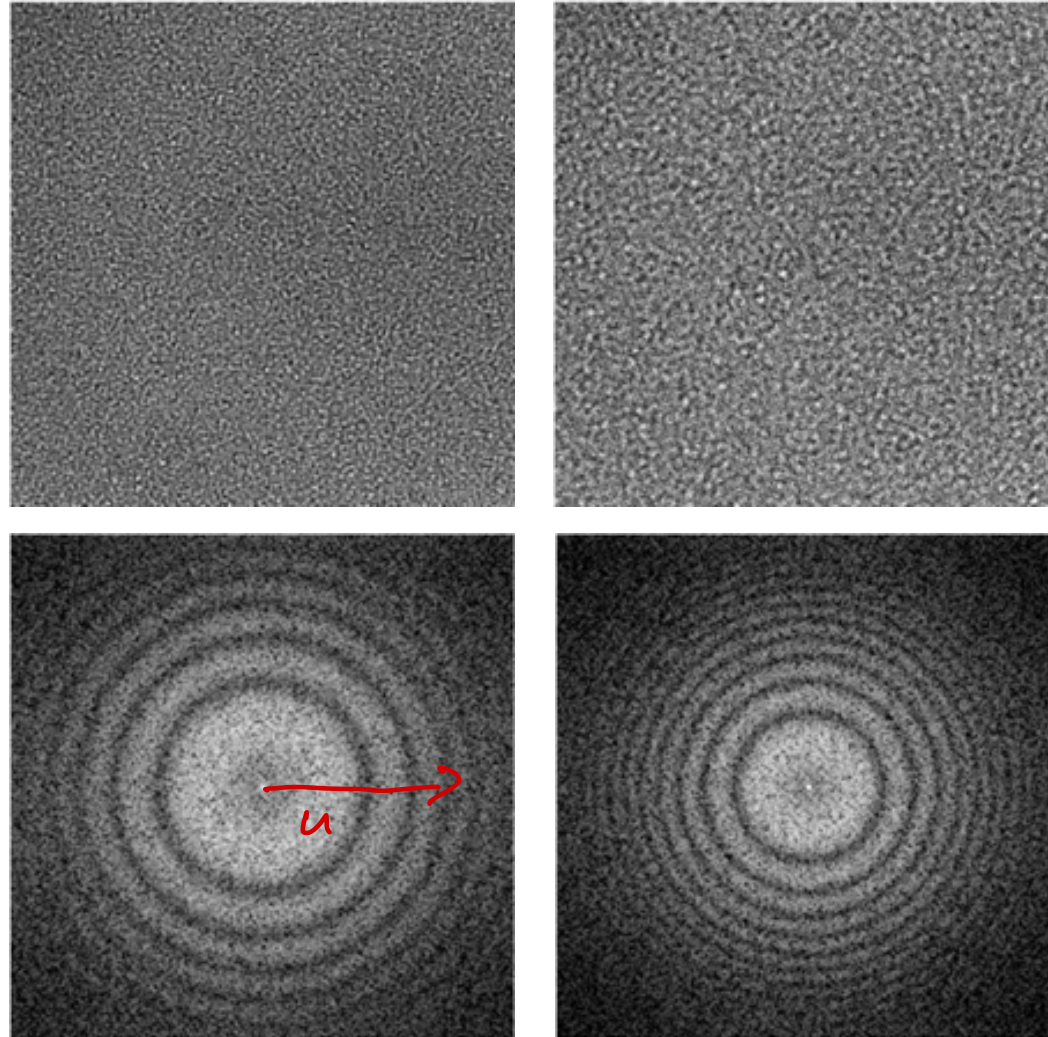
Sample:
amorphous
carbon film
↑
Contains all
spatial frequencies



Goal:
evaluate PCTE
@ μ scope ??

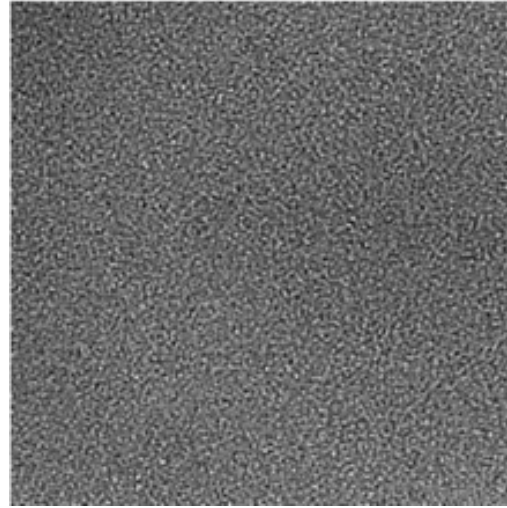
Apply fast Fourier transform
to image →

EPFL Fast Fourier transform of a-C film

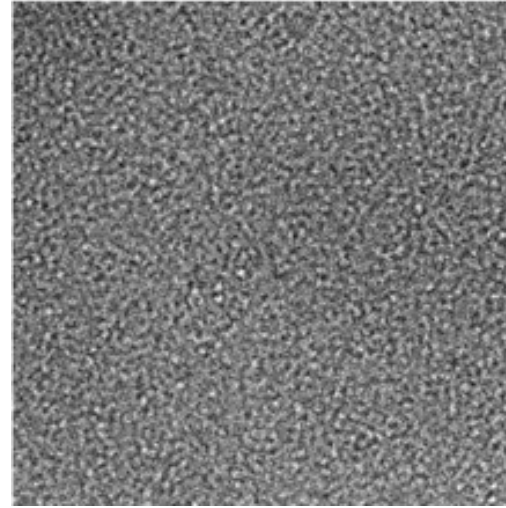


EPFL Fast Fourier transform of a-C film

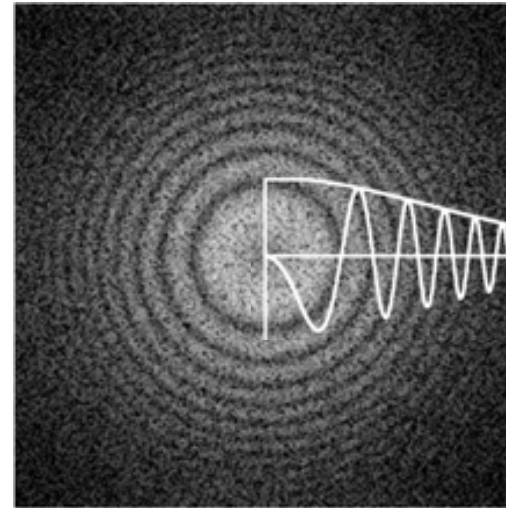
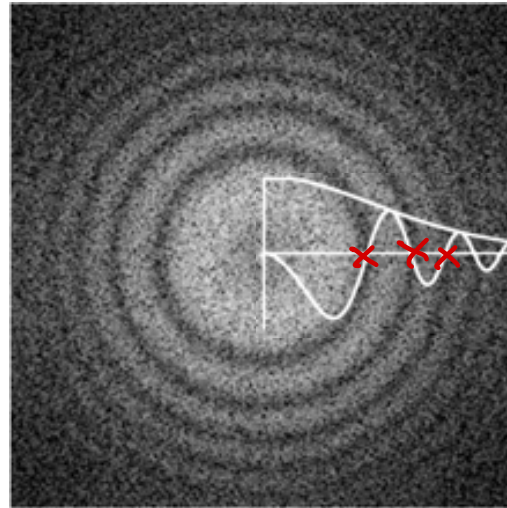
Δf_1 -
 $\Delta f = 500 \text{ nm}$



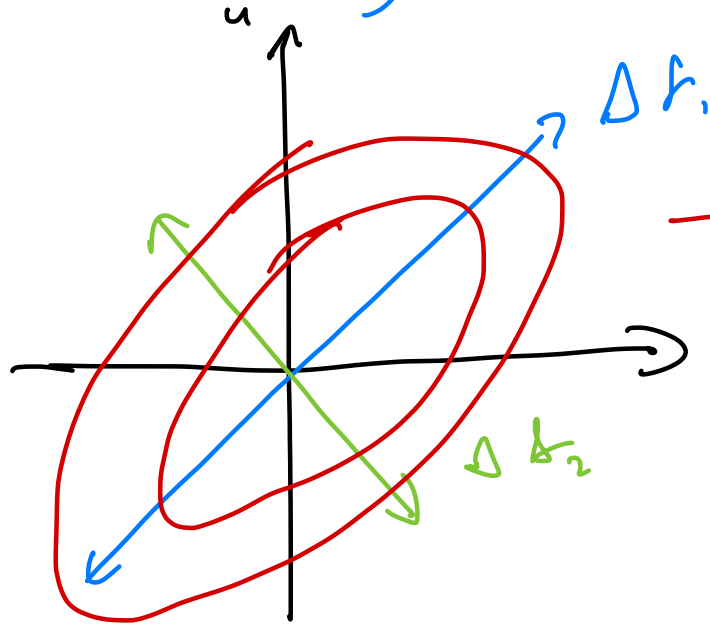
- Δf_2
 $\Delta f = 1 \mu\text{m}$



At cross-over
of RCTF:
spatial freq is
not transmitted
 $\Rightarrow$ Black ring
in FFT of
a-C ("Thone ring")



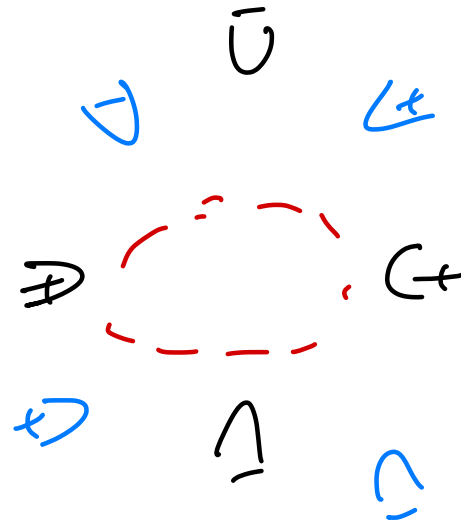
Stigmatism of objective lens?



→ Elliptical Thue rings

Use FFT & a-c to correct astigmatism

Stigmator : quadrupole lens



Control "ellipticity"
of beam

2 sets @ 45° angle