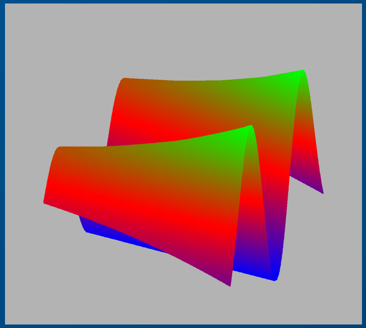

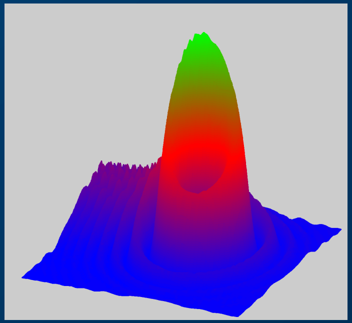

# SYNCHROTRON INFRARED VS SYNCHROTRON X-RAYS


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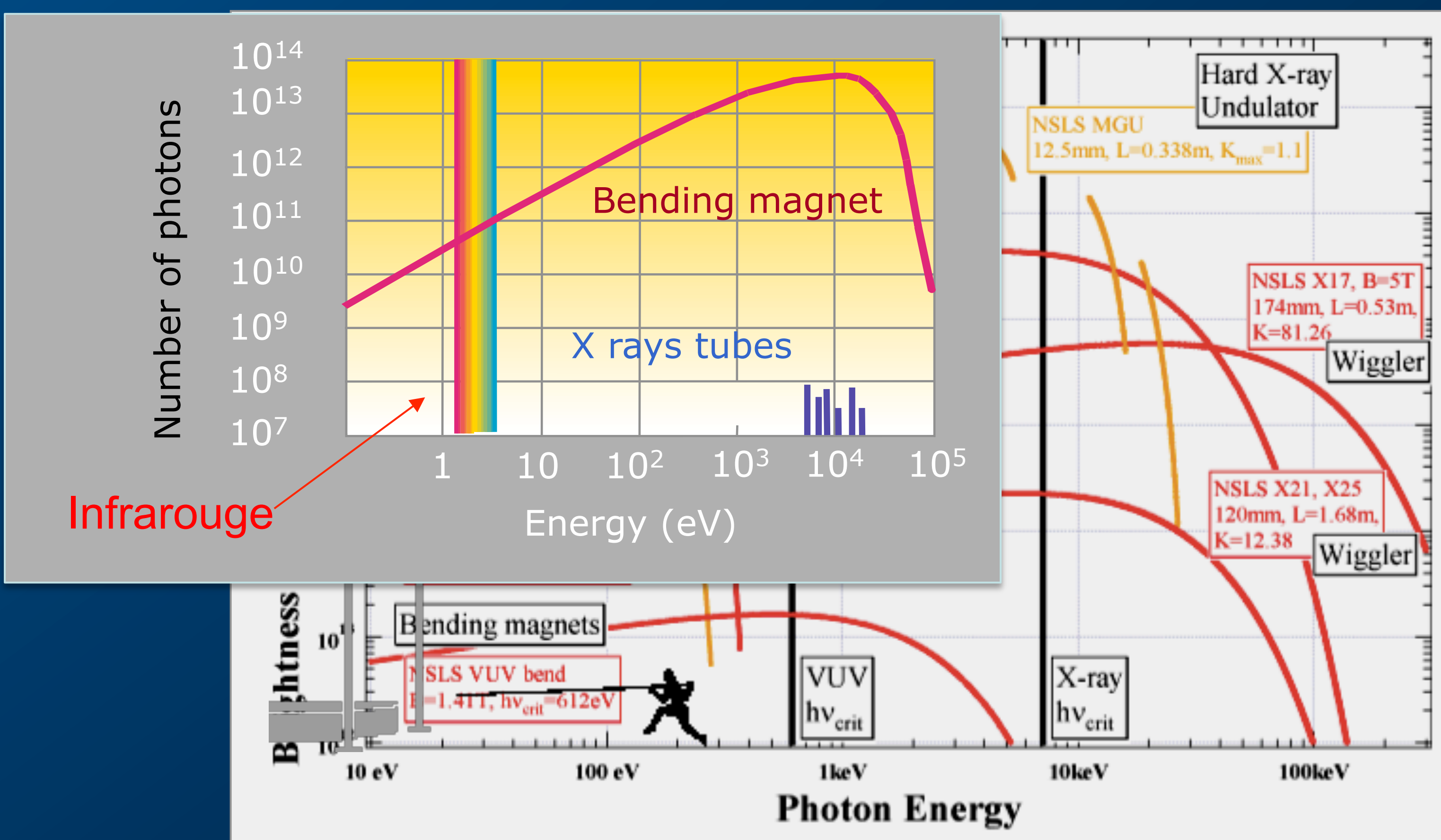
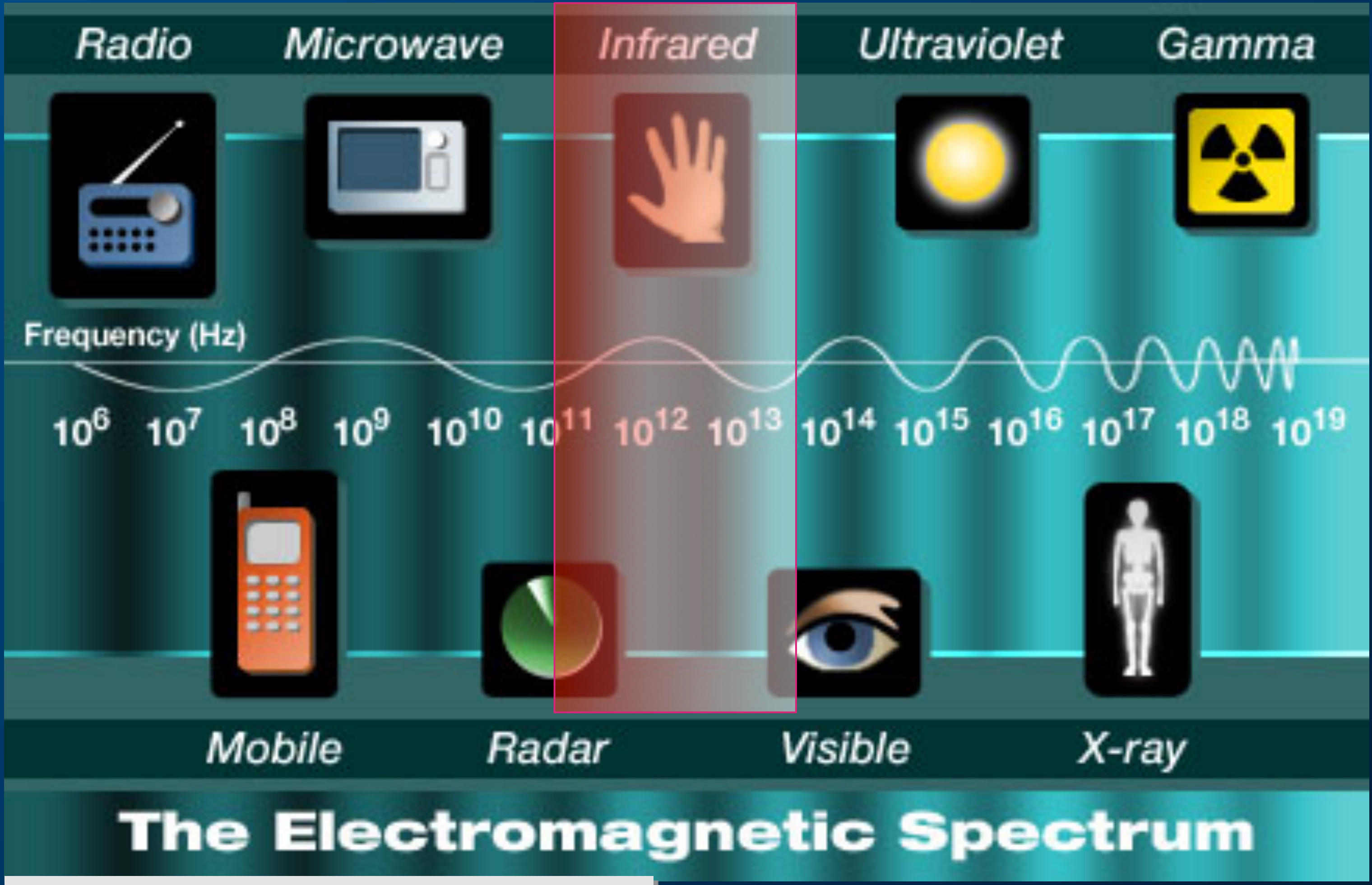
# Infrared versus X-rays:
# Similarities ,differences and specificities

# The Infrared region is not often mentionned in the flux/brightness performances of synchrotron facilities




**NSLS-2**

# INFRARED VERSUS X-RAYS

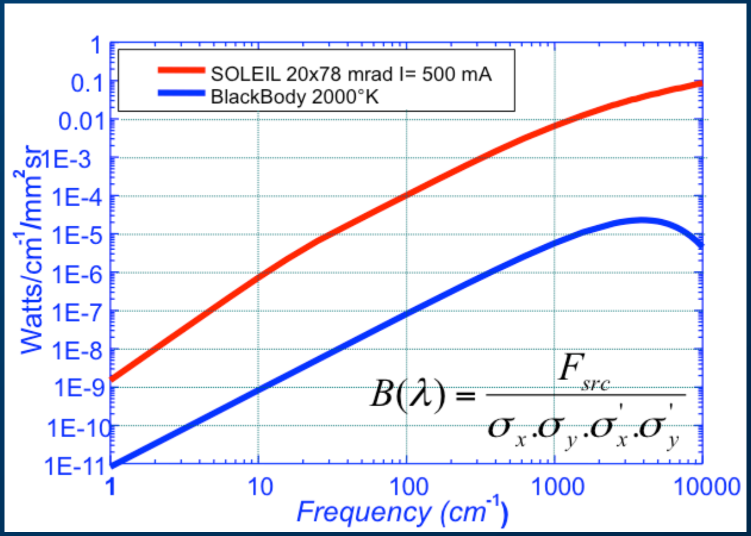



E (keV) = 12.3985/λ (Å)

# Similar properties

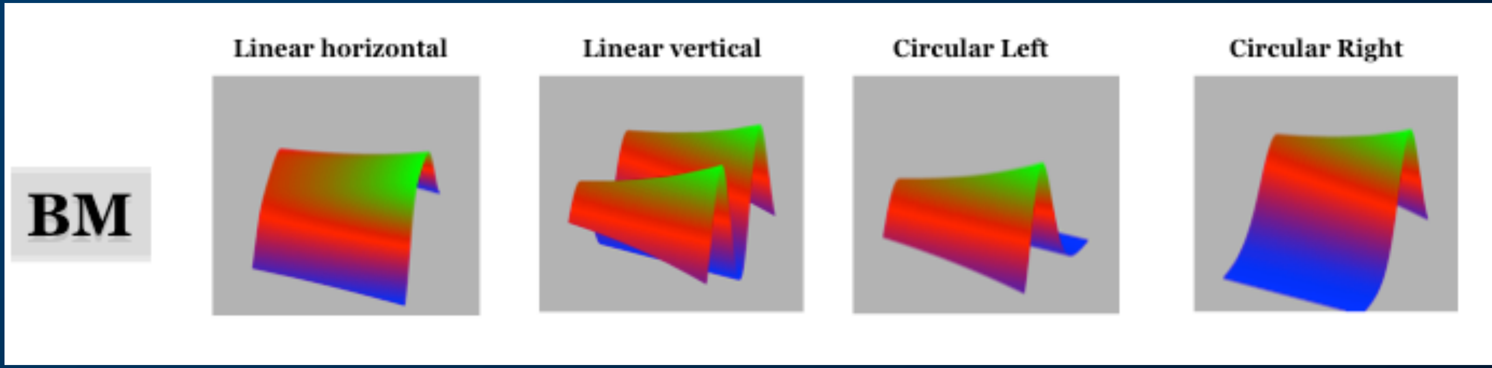
✓ Brightness :

*two to three orders of magnitude*




✓ Polarisation :

*Well defined*



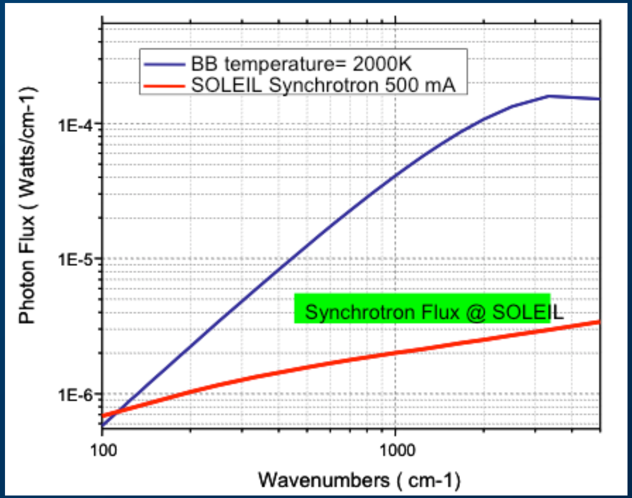
# INFRARED VERSUS X-RAYS

Brightness ( spectral radiance): a simple picture

# Differences

✓ Flux :

Not a high flux of photons



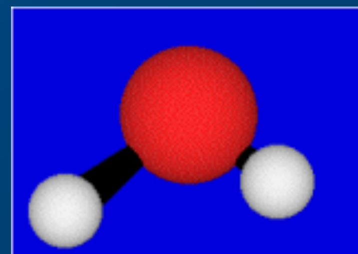

but…one can study live cells, alike X-rays!

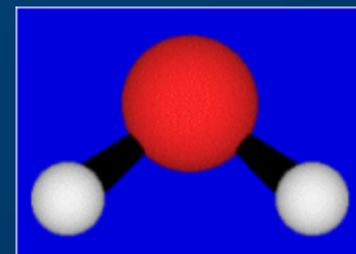
✓ Wavelength and spatial resolution:

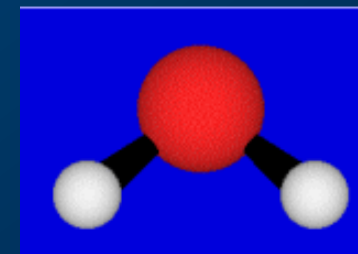
Infrared are microns-range wavelength. Resolution is not atomic but rather in the micron scale

Infrared is probing vibrational motions of functional groups in molecules

# VIBRATIONAL ( MOLECULAR) MOTIONS





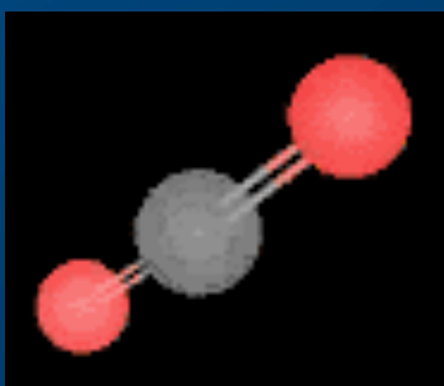


3756 cm-1

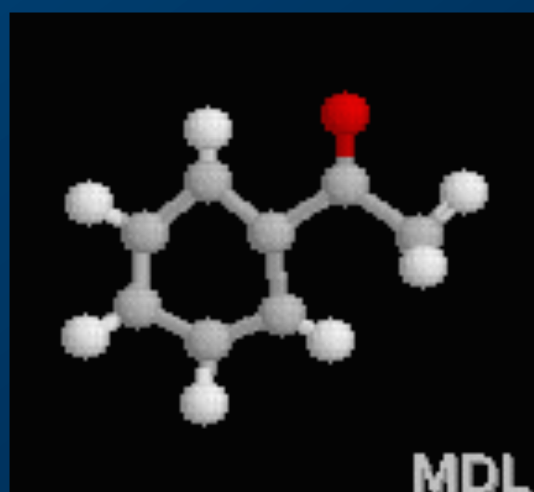
3652 cm-1

1595 cm-1

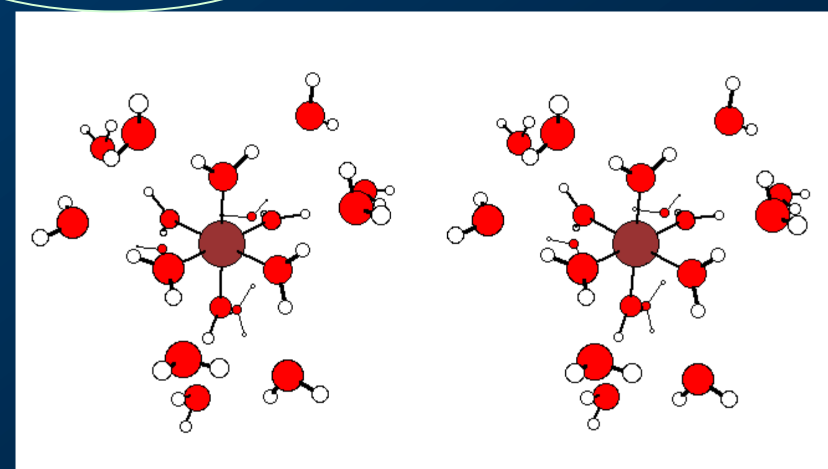
**~2.8 μm**



**~6 μm**

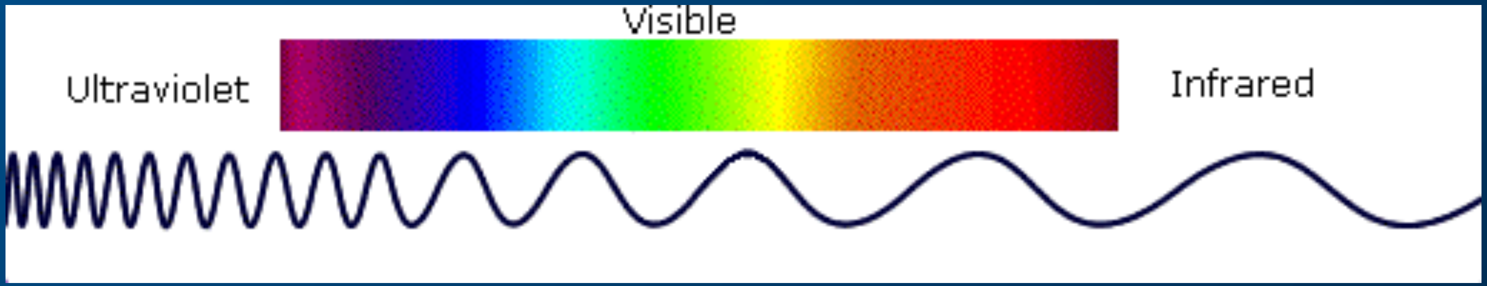



**~10 μm**



**~30 μm**

# THREE MAIN DOMAINS

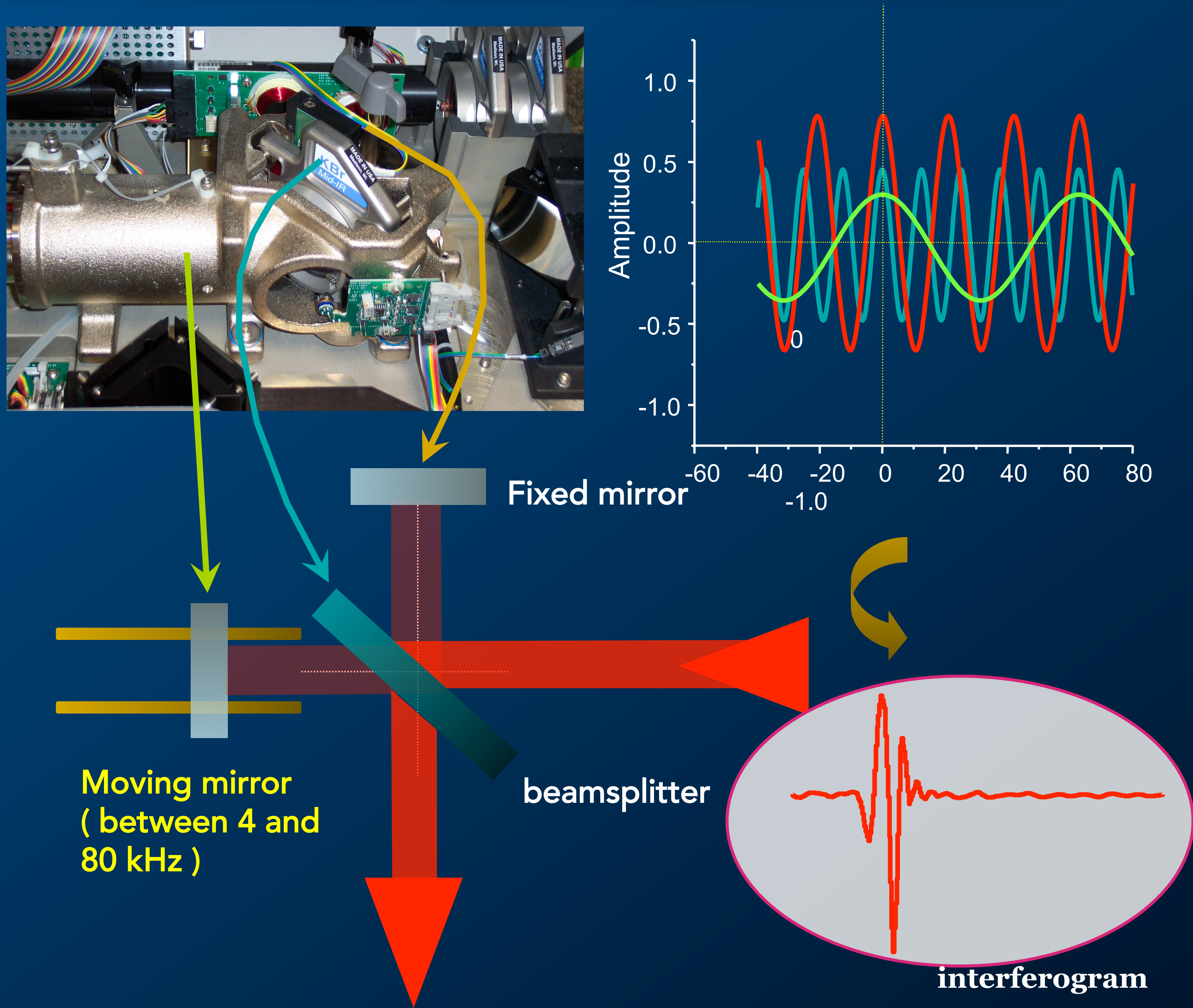



Wavelengths are in the micron range

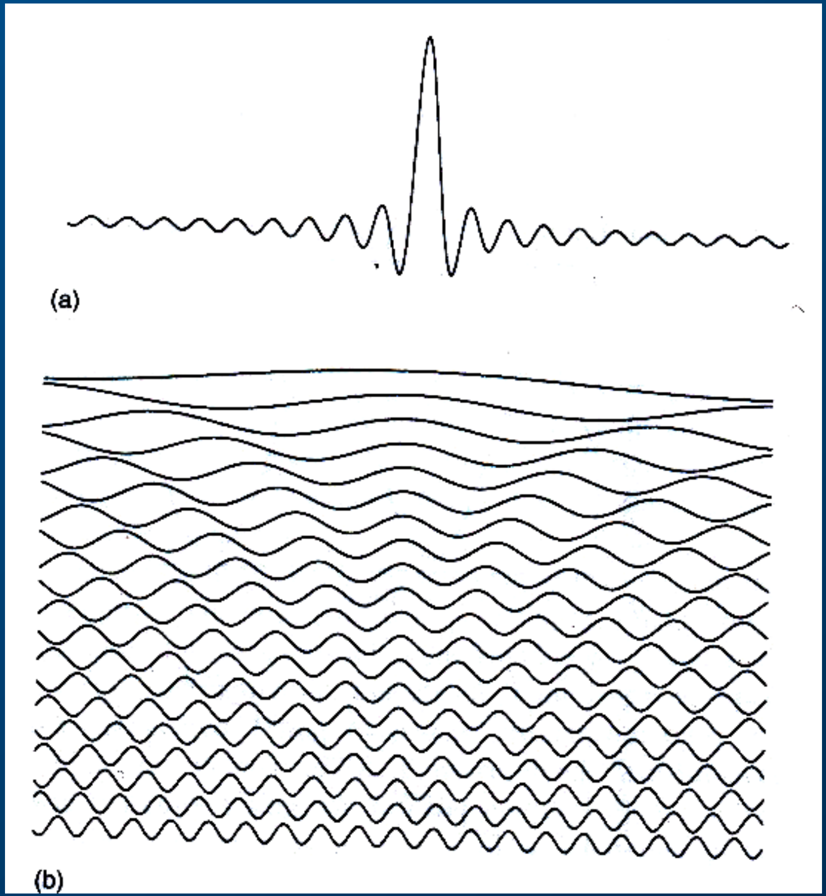
✓ Energy range: 1 to ~500 µm
( 10000 to 20 cm-1 or 1.23 to 0.0025 eV)

✓ ~1 to ~2.5 µm ( 10000-4000 $cm^{-1}$) Near IR
✓ ~2.5 à 20 µm ( 4000-500 $cm^{-1}$) Mid- IR
✓ ~20 à ~2500 µm ( 500-50 $cm^{-1}$) Far IR

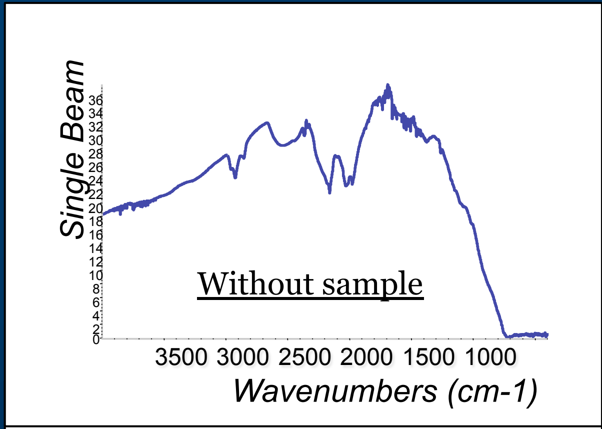
# FOURIER TRANSFORM INFRARED SPECTROSCOPY

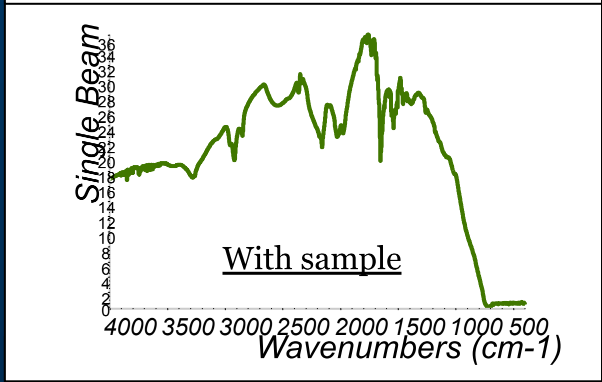


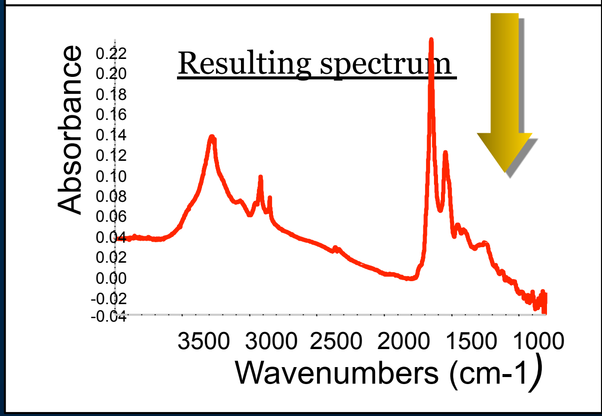
# FOURIER TRANSFORM INFRARED SPECTROSCOPY




**Fast Fourier Transform FFT**




HIGH TEMPORAL STABILITY REQUIRED

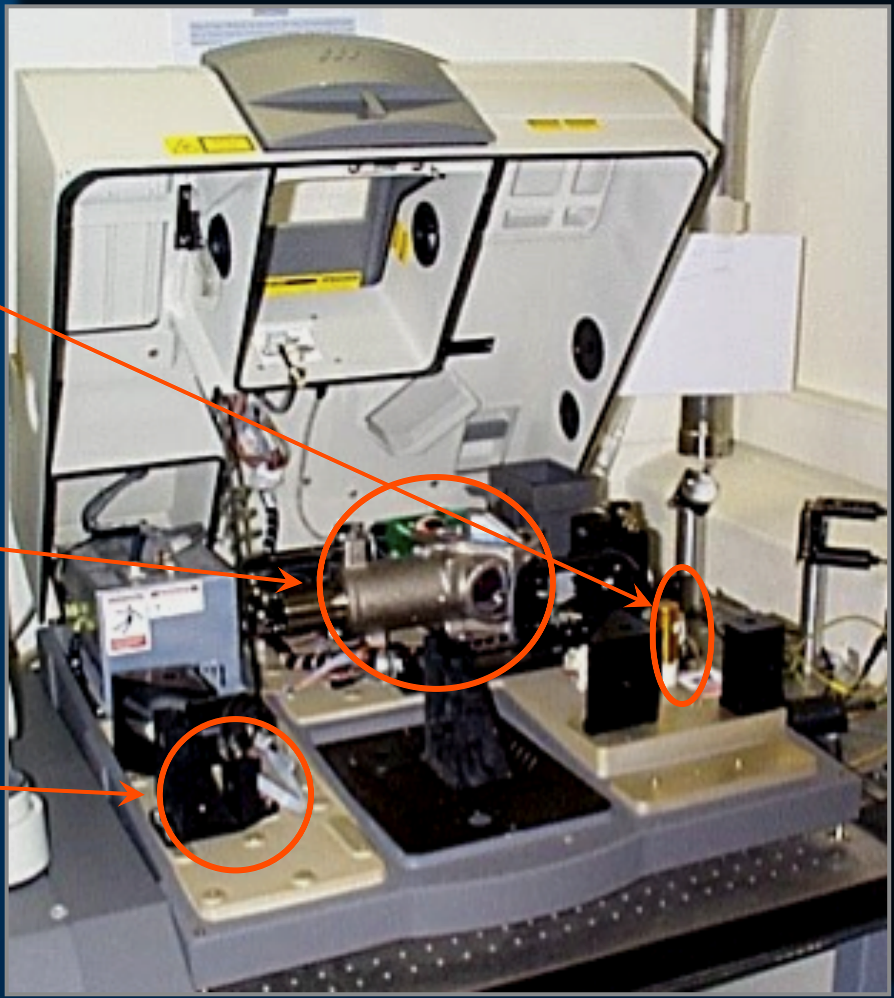
# INFRARED SPECTROMETER

Three main components inside a spectrometer

1- A thermal source(SiC) heated to 1500-1800 K

2- Michelson-type interferometer ( in this case)

3- Infrared detector



# WHAT DO WE DO WITH IR?

## ADVANTAGES

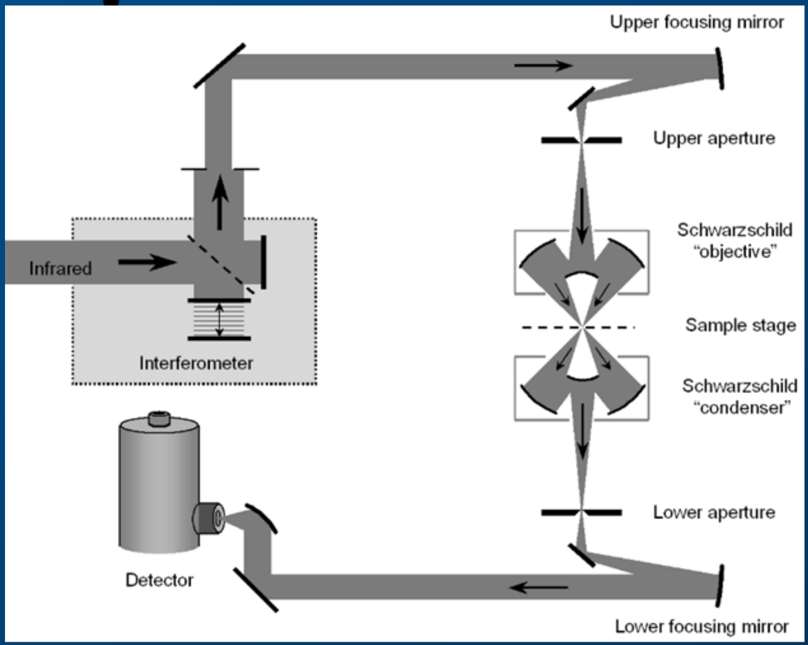
- SIMPLE
- CHEAP
- NON-DESTRUCTIVE
- COUPLING WITH OTHER TECHNIQUES
- QUICK
- SENSITIVE
- FLEXIBLE: SOLIDS, LIQUIDS, POWDERS, THIN FILMS, GAZ …

## APPLICATIONS

- ASTROPHYSICS
- BIOLOGY
- PLANT BIOLOGY
- CHEMISTRY
- GEOLOGY
- HERITAGE SCIENCE
- PHARMACEUTICS
- PHYSICS
- POLYMERS
- SURFACE SCIENCES
- ENVIRONMENTAL SCIENCE

# COUPLING WITH A MICROSCOPE

•



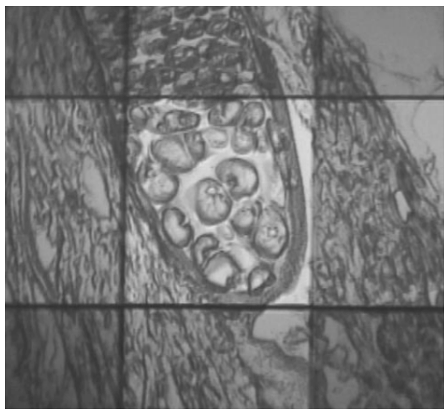


- SMALL SAMPLE ANALYSIS (<500 µm, even < 5 µm with synchrotron)
- ANALYSIS OF INCLUSIONS IN A MATRIX
- DISTRIBUTION OF COMPONENTS : CHEMICAL MAPS

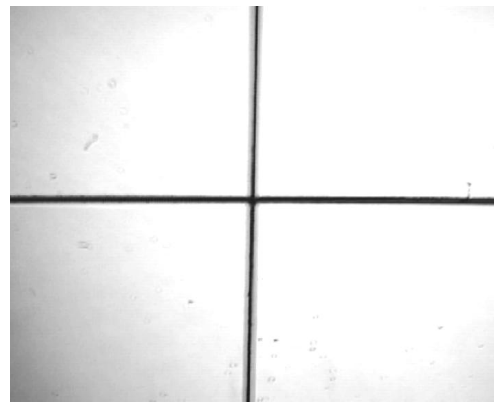
# APERTURING AND SPATIAL RESOLUTION

- Set by aperture

**KNIFE EDGE APERTURE**



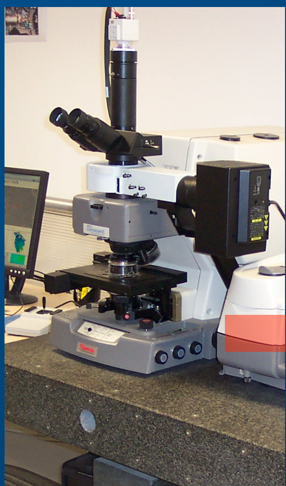
**open**

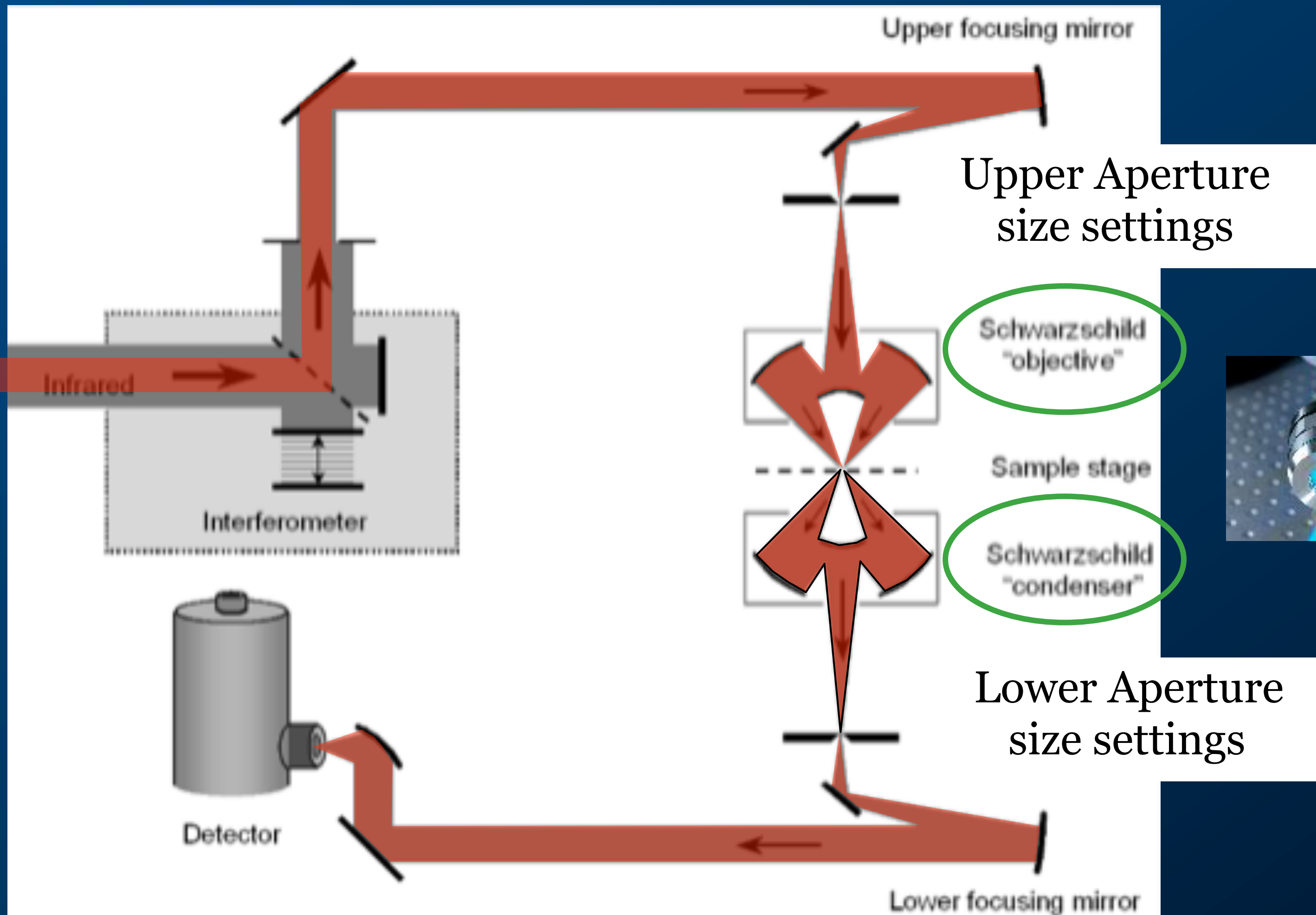


**close**

- Dual aperturing improves resolution…

# SRS-IR microscope works in confocal geometry






Typical N.A. 0.6

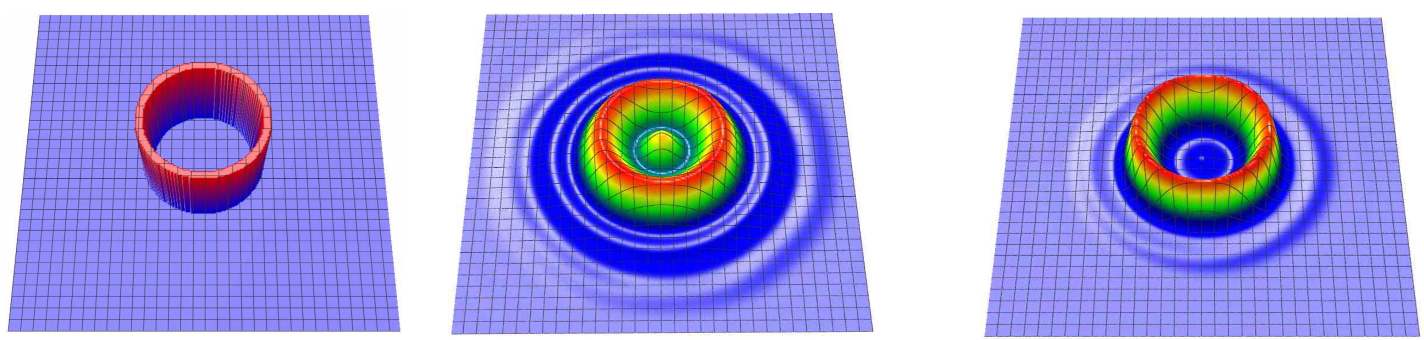
Lateral resolution ~λ/2

# ABOUT SPATIAL RESOLUTION

- MINIMUM DISTANCE BETWEEN TWO INDEPENDENTLY MEASURED OBJECTS THAT CAN BE DISTINGUISHED BY THE SPECTRA
- CLASSICAL SOURCE:
  - LIMITED BY SOURCE BRIGHTNESS: 20-500 µm
- SYNCHROTRON SOURCE:
  - DIFFRACTION LIMITED: 2-12 µm

**FOR $\lambda$ = 6 µm**

*SIMULATION FOR AN ANNULAR DISK*



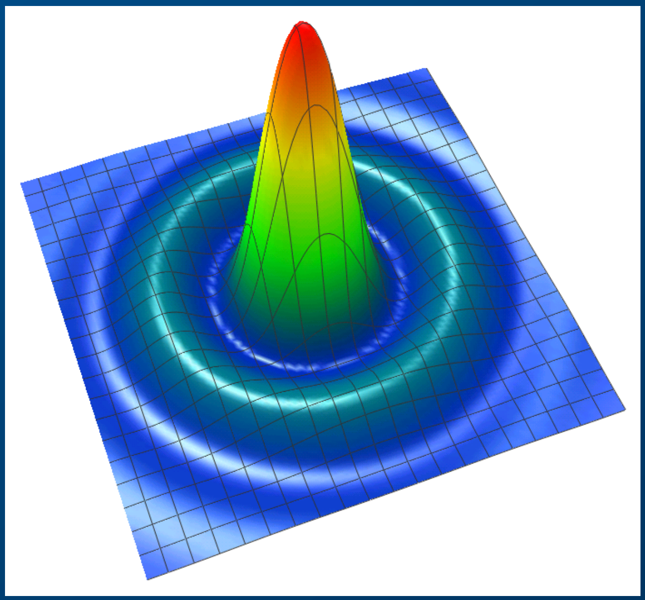
REAL OBJECT
ø int. 13 µm
Ø ext. 17 µm

SINGLE APERTURE

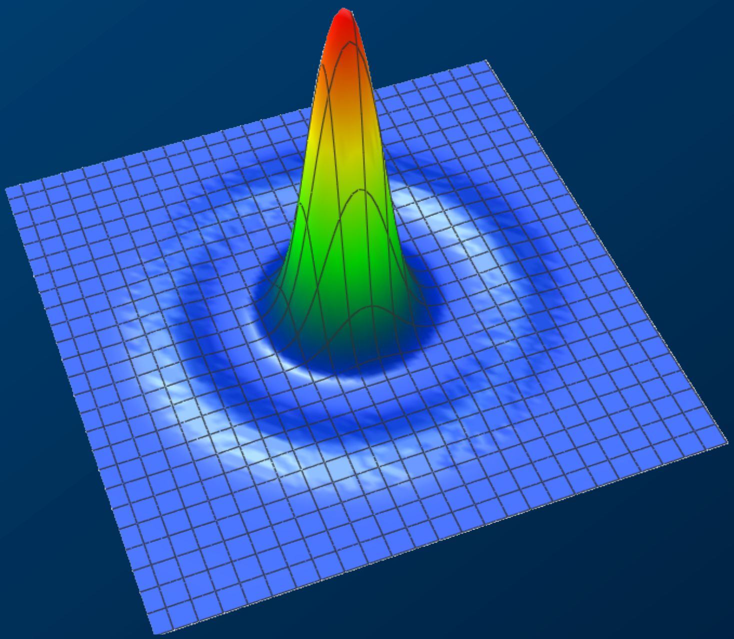
DOUBLE APERTURE

# SPATIAL RESOLUTION: CONFOCAL/NONCONFOCAL

PSF



(PSF)$^2$

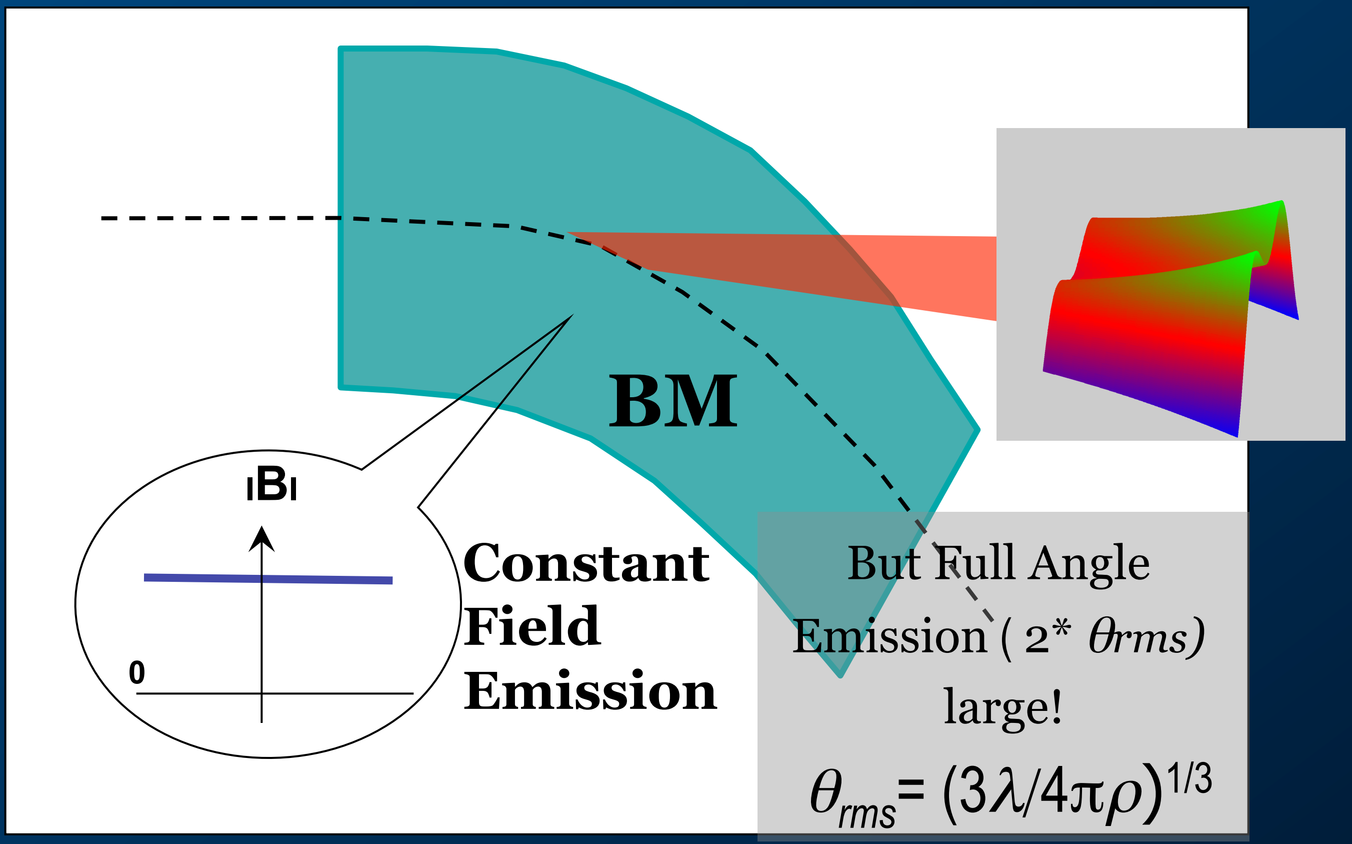


For IR, spatial resolution = $\lambda/2$

Confocal results in narrower central peaks, and also reduces effect of 1st order diffraction ring.

# COLLECTING IR FROM A STORAGE RING
( tomorrow’s introduction)

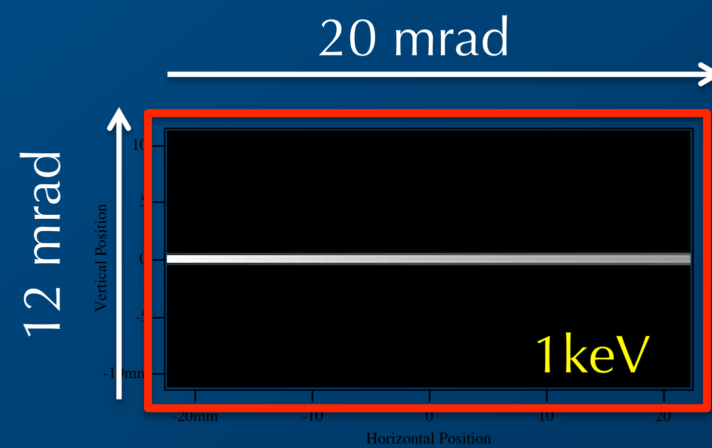
# The most conventional is a Bending Magnet emission

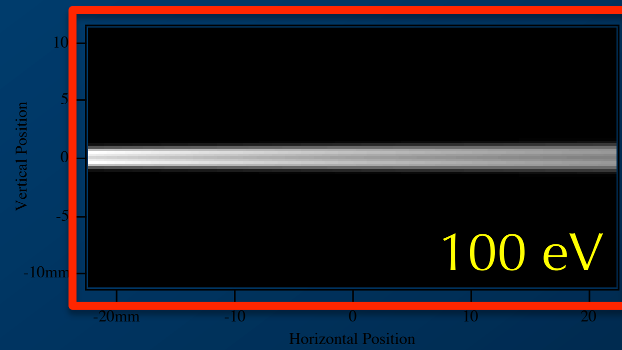


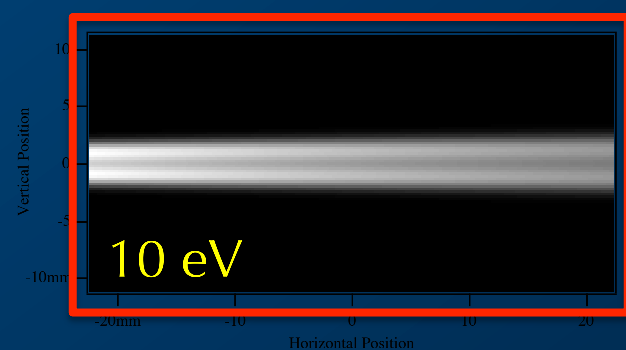

**SRW:** **Chubar O, Elleaume P. Accurate And Efficient Computation Of Synchrotron Radiation In The Near Field Region. 1998; EPAC98 Conference p. 1177-9.**

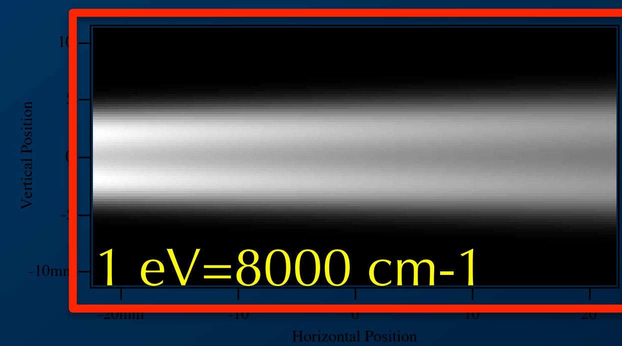
# Larger emission angles

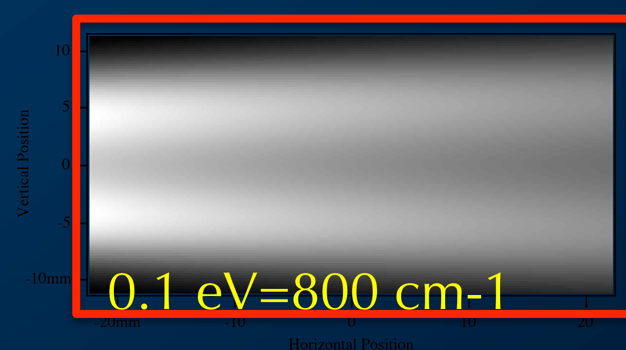
E=3 GeV
1.4 T



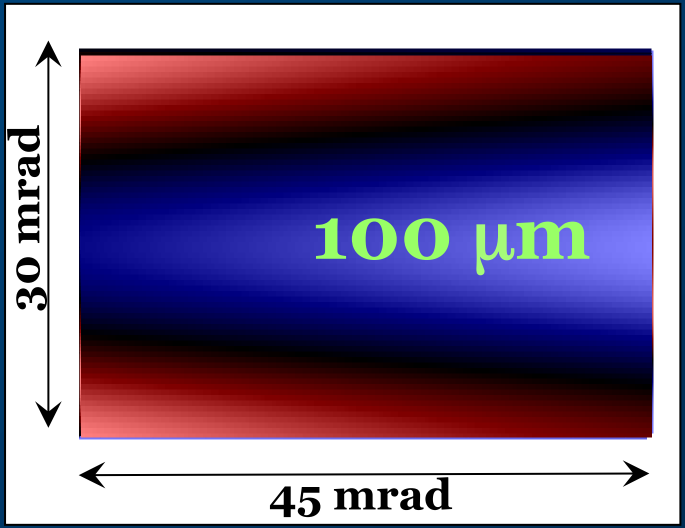

Full Angle Emission
( 2* *θrms*)

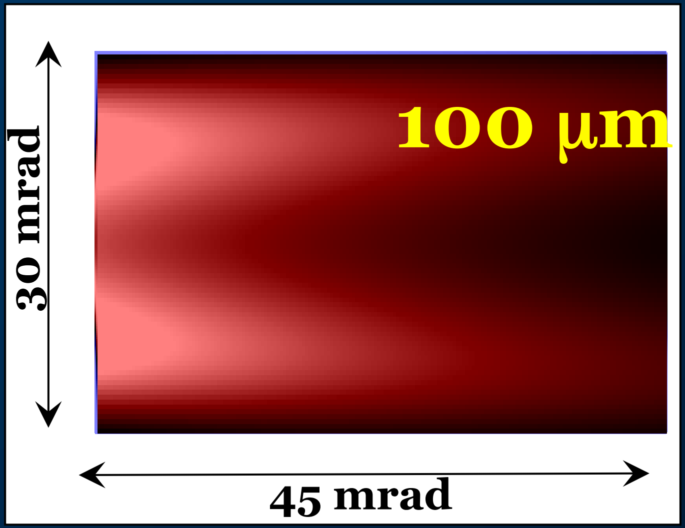
$\theta_{rms} = (3\lambda/4\pi\rho)^{1/3}$

# VERTICAL OPENING ANGLE DEPENDS ON ELECTRON ENERGY

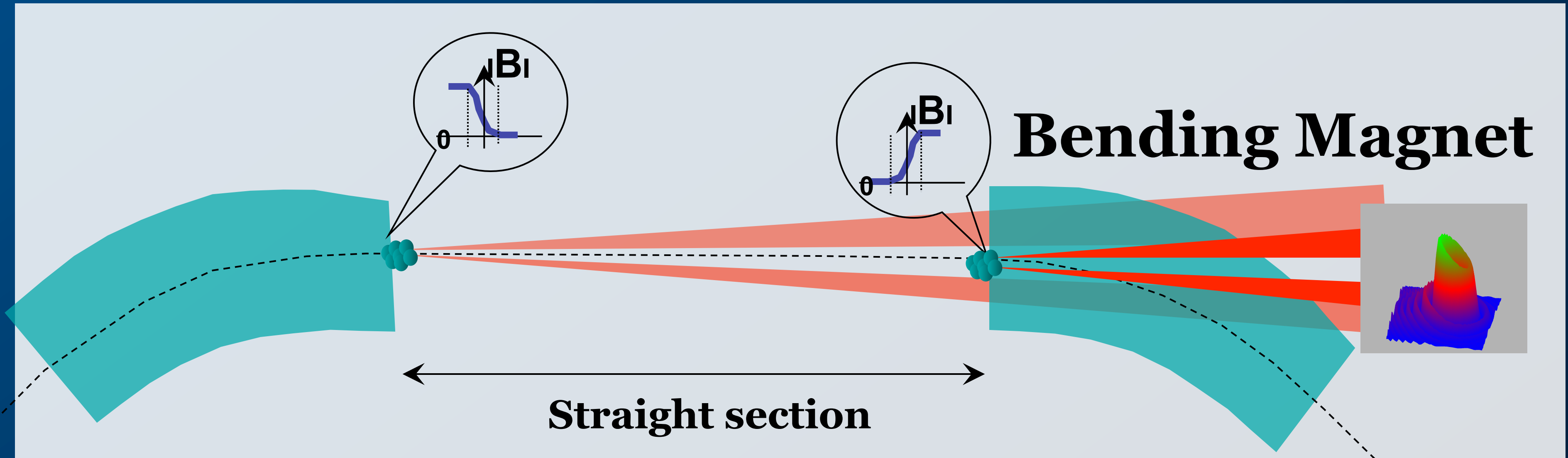
***INDUS***
**0.45 GeV**
**45 mrad H X 30 mrad V**
**BM**

***DIAMOND***
**3.0 GeV**
**45 mrad H X 30 mrad V**
**BM**



# Edge radiation is the second source of IR emission

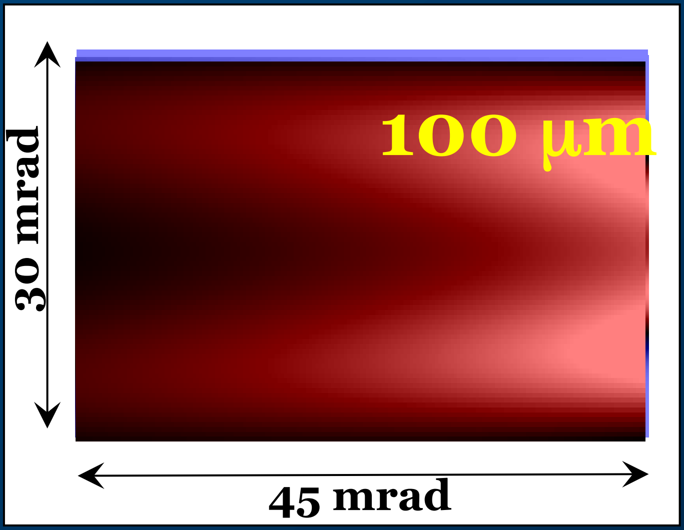


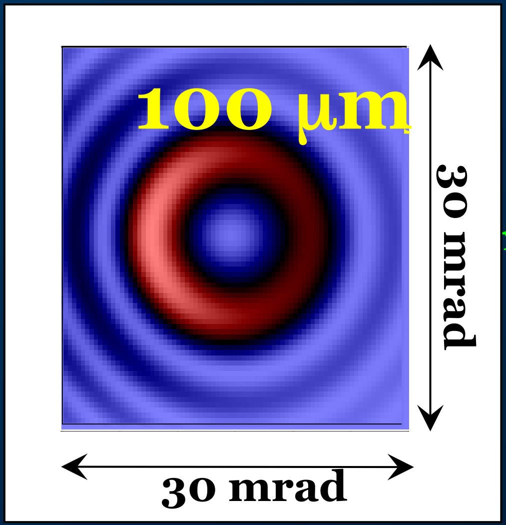

- Edge radiation emitted at transitions entering/exiting dipole magnets (two-edge interference, cancellation on-axis).
- Intrinsically bright.
- Radial polarization .

# EDGE RADIATION EMISSION IN A NARROWER CONE

***SOLEIL***
**2.75 GeV**
**45 mrad H X 30 mrad V**
**BM**

***SOLEIL***
**2.75 GeV**
**30 mrad H X 30 mrad V**
**BM**



# ER and BM EMISSION HAVE DIFFERENT POLARISATION PROPERTIES