Elements of comparison between some XUV-fs sources

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What are the relevant characteristics to compare?

Linear regime of interaction

$\text{Signal} \propto E^2 x S^* \tau^* f^* t^* n^* l$

Medium density

Thickness

target

Integration time

Electric field E

Repetition rate

Surface

Time duration

Physics

Intensity $I = \varepsilon_0 c E^2/2$

Power

Energy

<Power>

Photon Flux <Nphotons/s>=<P>/hν

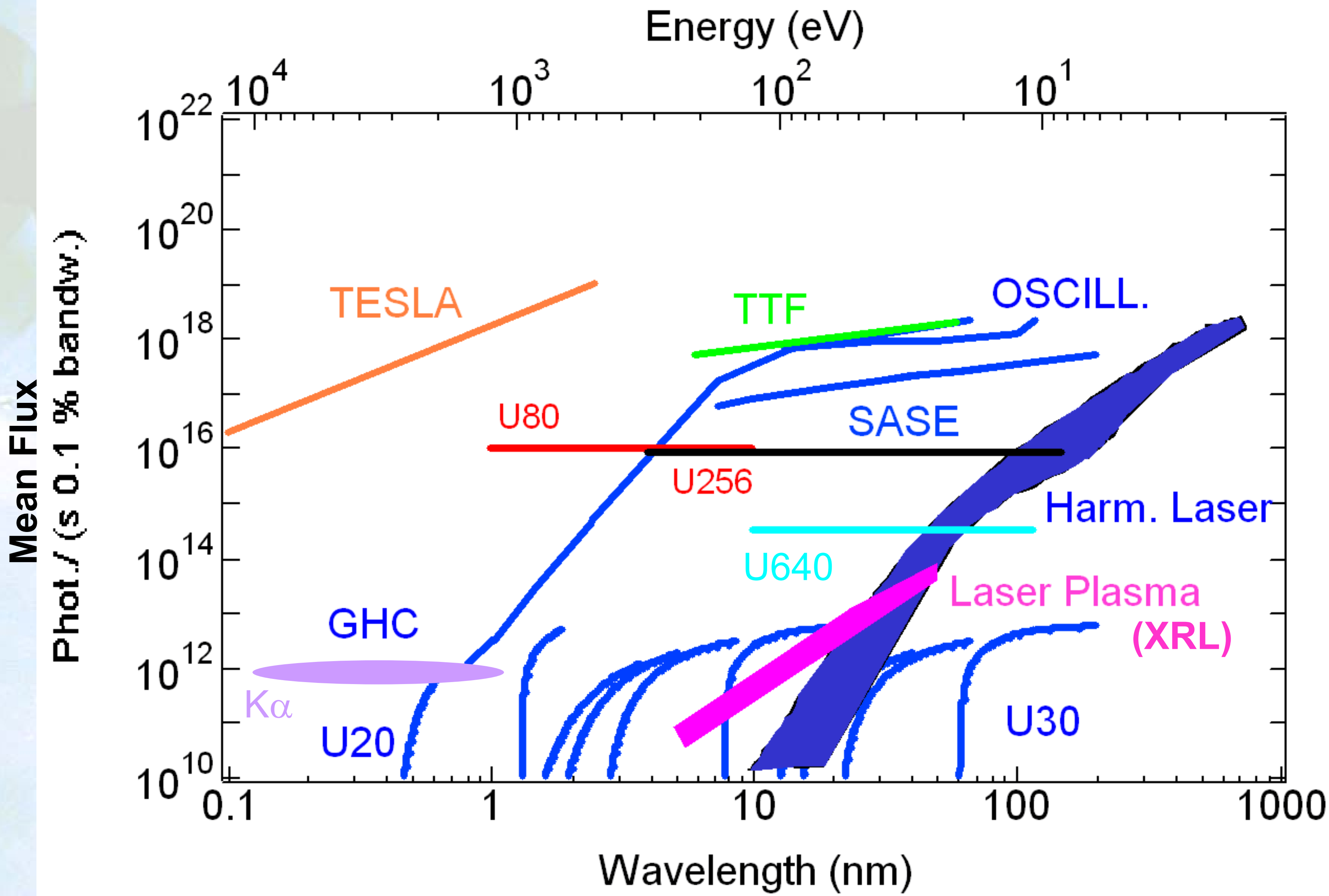
Wide band sources: selection of a spectral range by a monochromator: $\Delta\lambda/\lambda = 10^{-4}$

<Nphotons/s/0.1%BW>

!

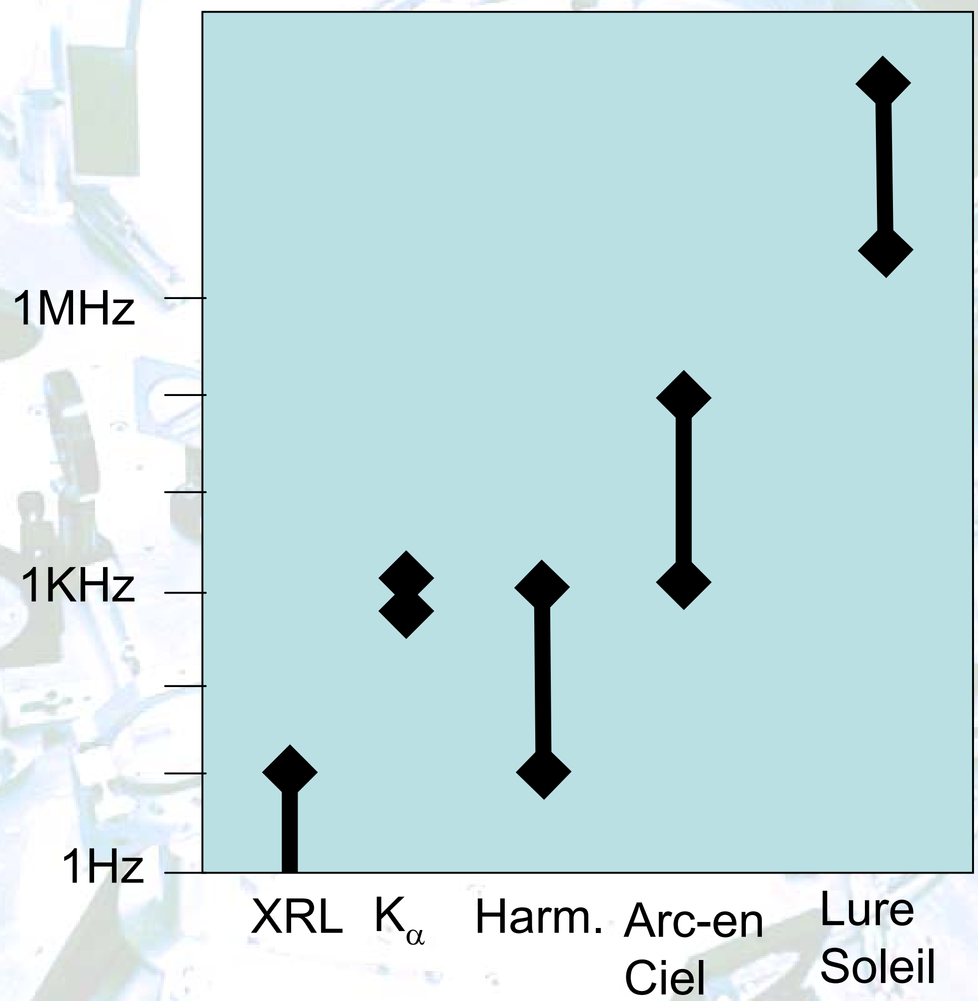
For 100fs pulses $\Delta\lambda/\lambda = 3\text{x}10^{-5} \text{x} \lambda(\text{nm})$ ($3\text{x}10^{-3}$ for $\lambda = 100\text{nm}$)

Large flux required because: Low cross section-low medium density-
Thin medium-low reflectivity-Optically thick
-moderate integration time-


Energy (eV)
10^4
10^3
10^2
10^1
10^{22}
10^{20}
10^{18}
10^{16}
10^{14}
10^{12}
10^{10}
Mean Flux
Phot./(s 0.1 % bandw.)
TESLA
TTF
OSCILL.
U80
SASE
U256
Harm. Laser
U640
Laser Plasma
(XRL)
GHC
Kα
U20
U30
0.1
1
10
100
1000
Wavelength (nm)

Experiments using coincidence techniques

⇒ Repetition rate



Non-Linear regime of interaction

$$\text{Signal} \propto (E^2)^n x S^* \tau^* f^* t^* n^* l$$

- Electric field E
- Surface
- Time duration Physics
- Repetition rate
- Integration time
- Medium density } target
- Thickness } target

Intensity $I = \varepsilon_0 c E^2/2$

Oscillating energy of a free electron $\propto I\lambda^2$

Not source intensity but rather on-target intensity!

$\Rightarrow$ Peak Brightness

Nphotons/s/mm^2/mrad^2/0.1%BW

For coherent beams: close relation between S(mm^2) and θ^2(mrad^2)

Example: For gaussian beam with a M2 defect

$$I = \frac{I_0}{1+\left(z/z_R\right)^2} e^{-2 \, r^2 / r_0^2\left(1+\left(z/z_R\right)^2\right)}$$

Beam waist increased by M2/diffraction limit:

$$r_0 = M2 \times \frac{f\lambda}{\pi r}$$

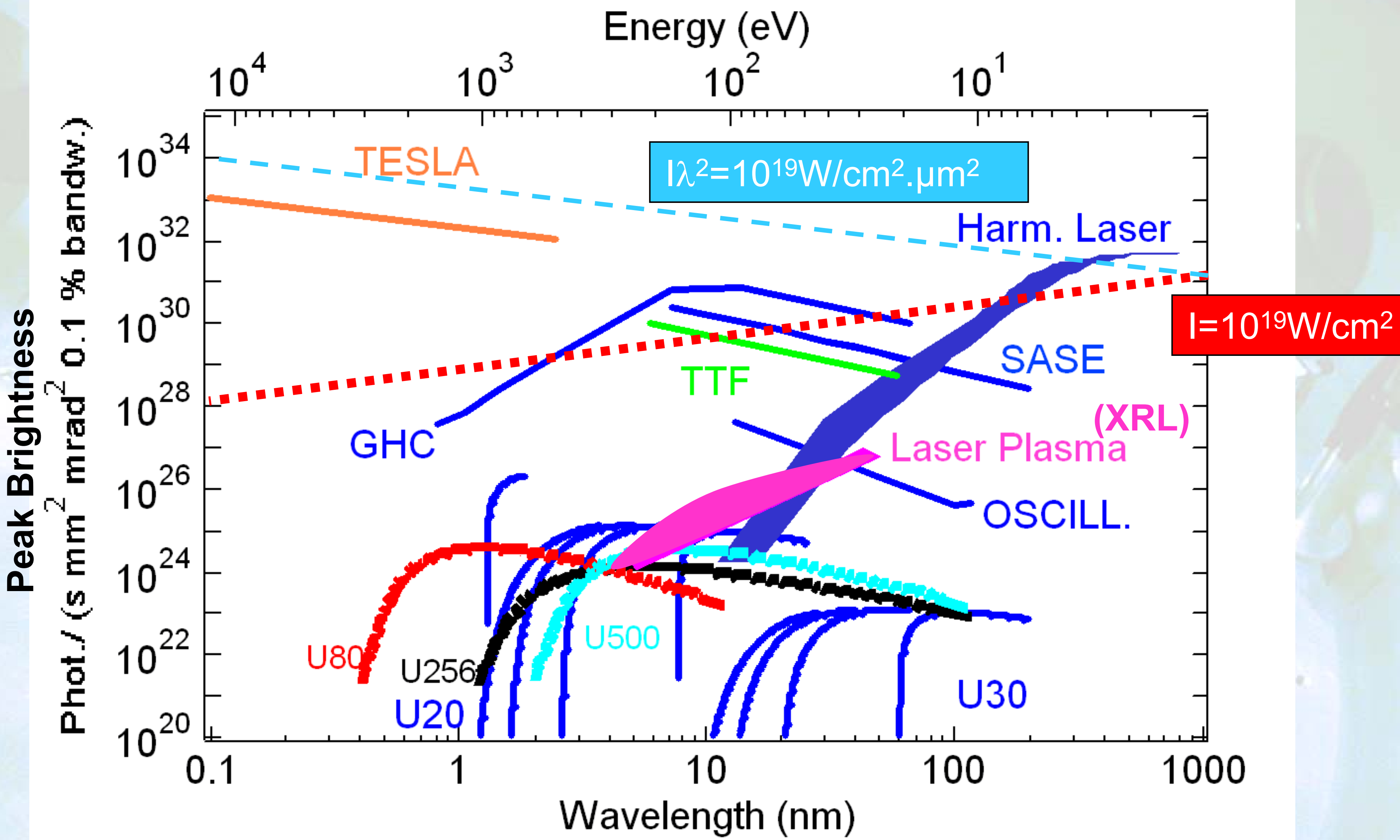
$$B = \frac{\text{Nphotons/s/0.1\%BW}}{(\mathbf{M2})^2\lambda^2}$$

Brightness includes a measure of the spatial coherence
⇒ good indicator of the maximum intensity reachable

« realistic focusing optic »($S_{min}=10\lambda^2$ for a perfect wavefront)

$$I_{max} \approx \frac{10^{-9} \mathrm{x} \mathbf{B}}{\lambda(\mathrm{nm})}$$

Small focal spot allows to reach high intensity and to probe small objects !


Energy (eV)
10^4
10^3
10^2
10^1
Peak Brightness
Phot./ (s mm^2 mrad^2 0.1 % bandw.)
10^34
10^32
10^30
10^28
10^26
10^24
10^22
10^20
TESLA
Iλ²=10¹⁹W/cm².µm²
Harm. Laser
I=10¹⁹W/cm²
SASE
TTF
GHC
(XRL)
Laser Plasma
OSCILL.
U500
U80
U256
U20
U30
0.1
1
10
100
1000
Wavelength (nm)

Summary

Arc-en-Ciel should be able to provide coherent light from VUV up to the keV

Photon Flux close to 10^{18}/s/0.1%BW from 100nm to 10nm

Rep. rate up to 100 kHz

Brightness up to 10^{31} Ph/s/mm^2/mrad^2 at 10 nm

Intensity in the VUV comparable to the one achievable with the state of the art conventional laser