PHOTON BEAMLINES FOR SXL

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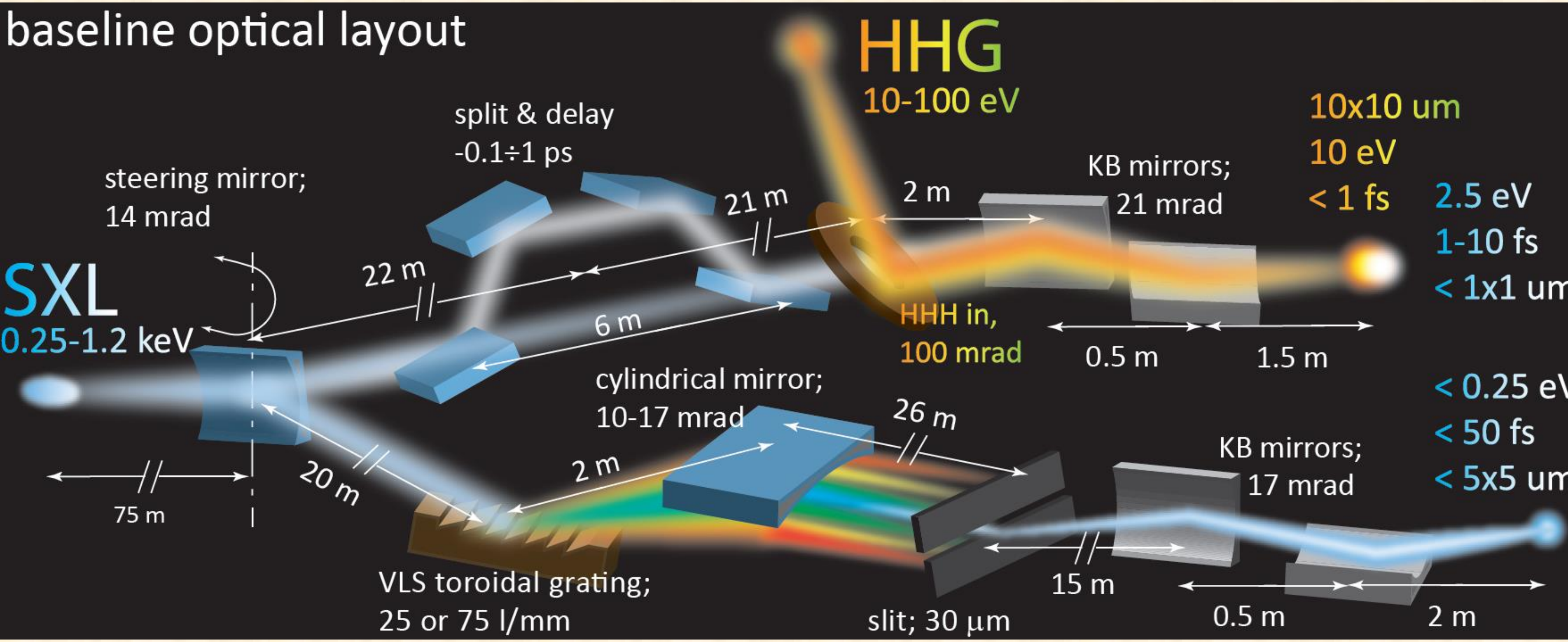
Conceptual SXL layout

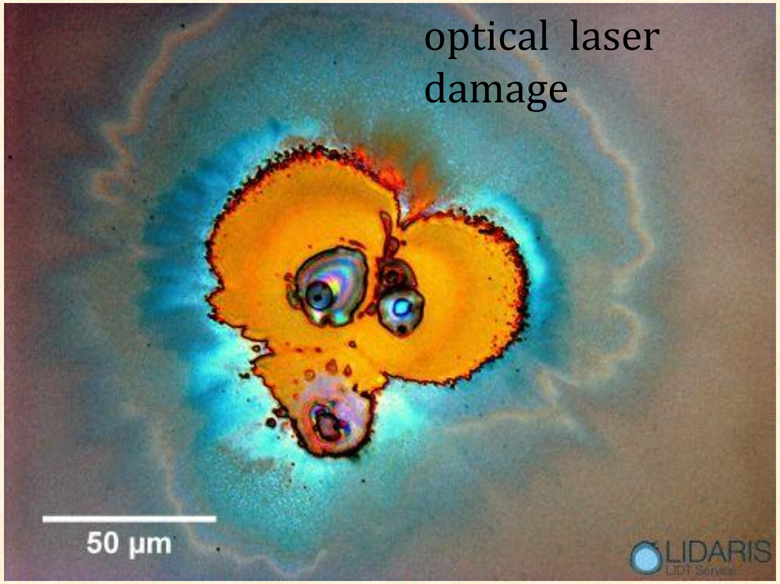


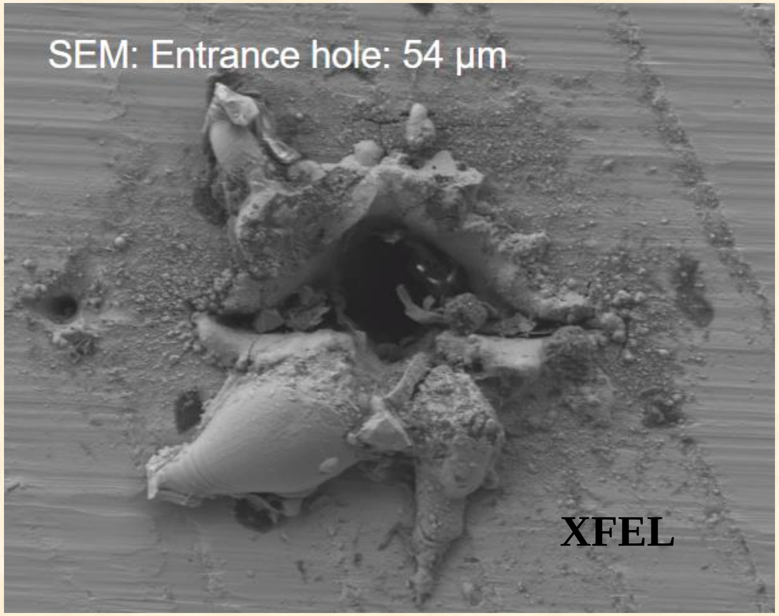
Key parts of the beamline:

- Pink (microscopy) and mono (spectroscopy) branches
- Focusing optics
- Monochromator (only for mono branch)
- Split & delay unit
- External lasers for pump-probe experiments

Optical damage of X-ray optics

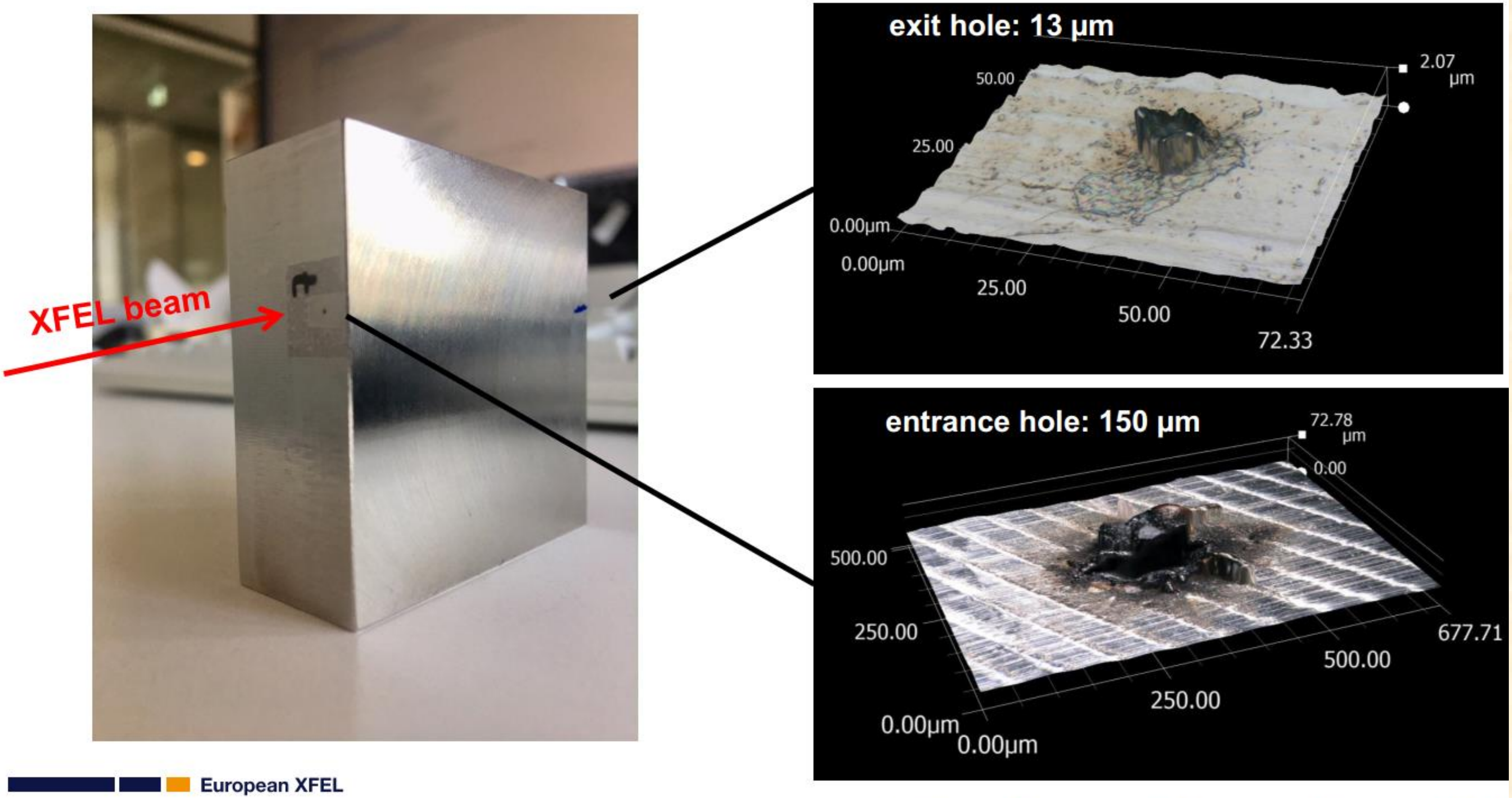
- High-fluence FEL pulses can cause a **single-shot damage** of optical components .
- **Damage dose** ~ energy to raise the material's temperature from room temperature to its melting point.
- The LCLS beam drills steel at a rate of ~ mm/sec if the threshold is exceeded.
- Ablation speed ~ 10 um/shot at 1 mJ.
- The FEL beam must first be magnified via free-space diffraction.
- A wide range of materials such as B4C, Mo, Ru, Rh, W, and Pt on a Si substrate have been studied by the X-ray optics community.





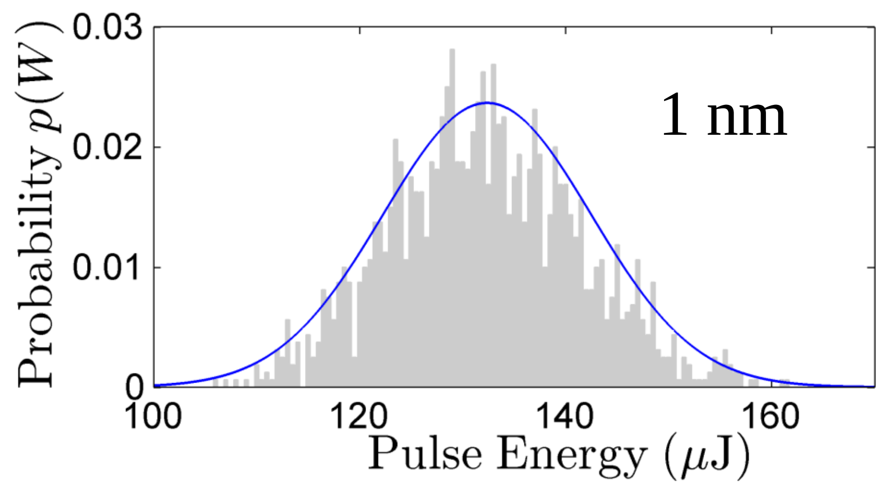
European XFEL: example

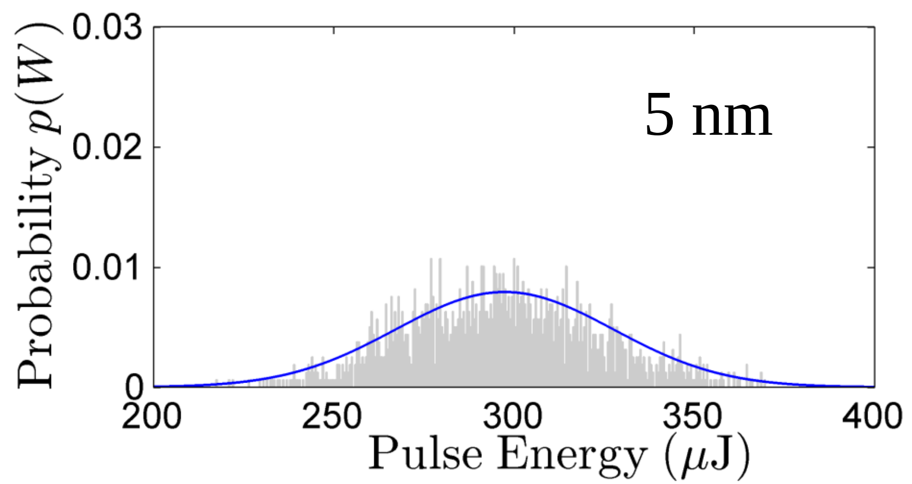
Drilling with XFEL beam through 50 mm of steel in 26 seconds

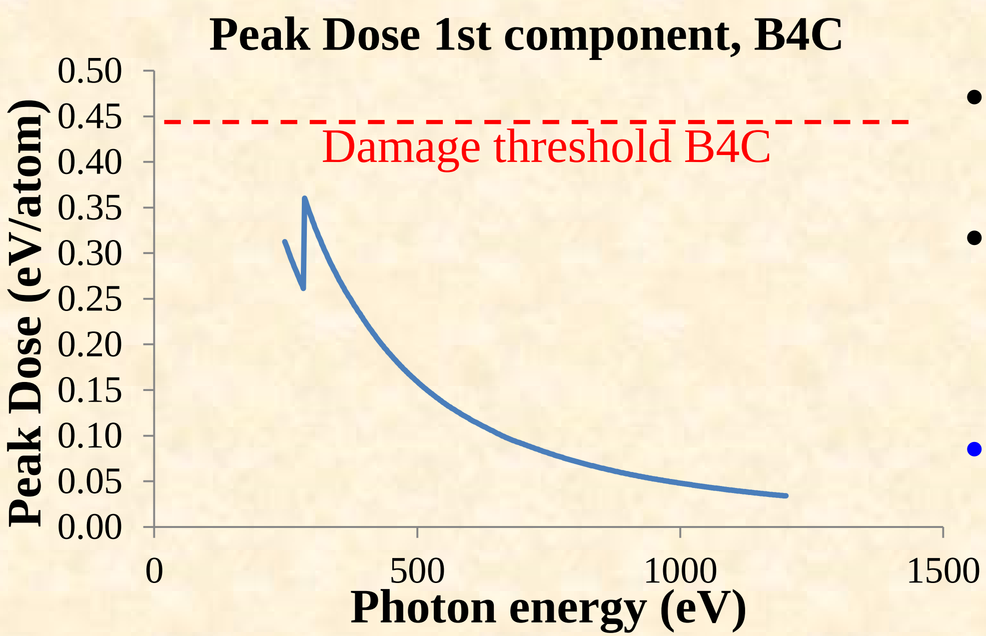


H. Sinn, A. Leuschner, F. Yang et al., European XFEL

Maximum FEL pulse energy

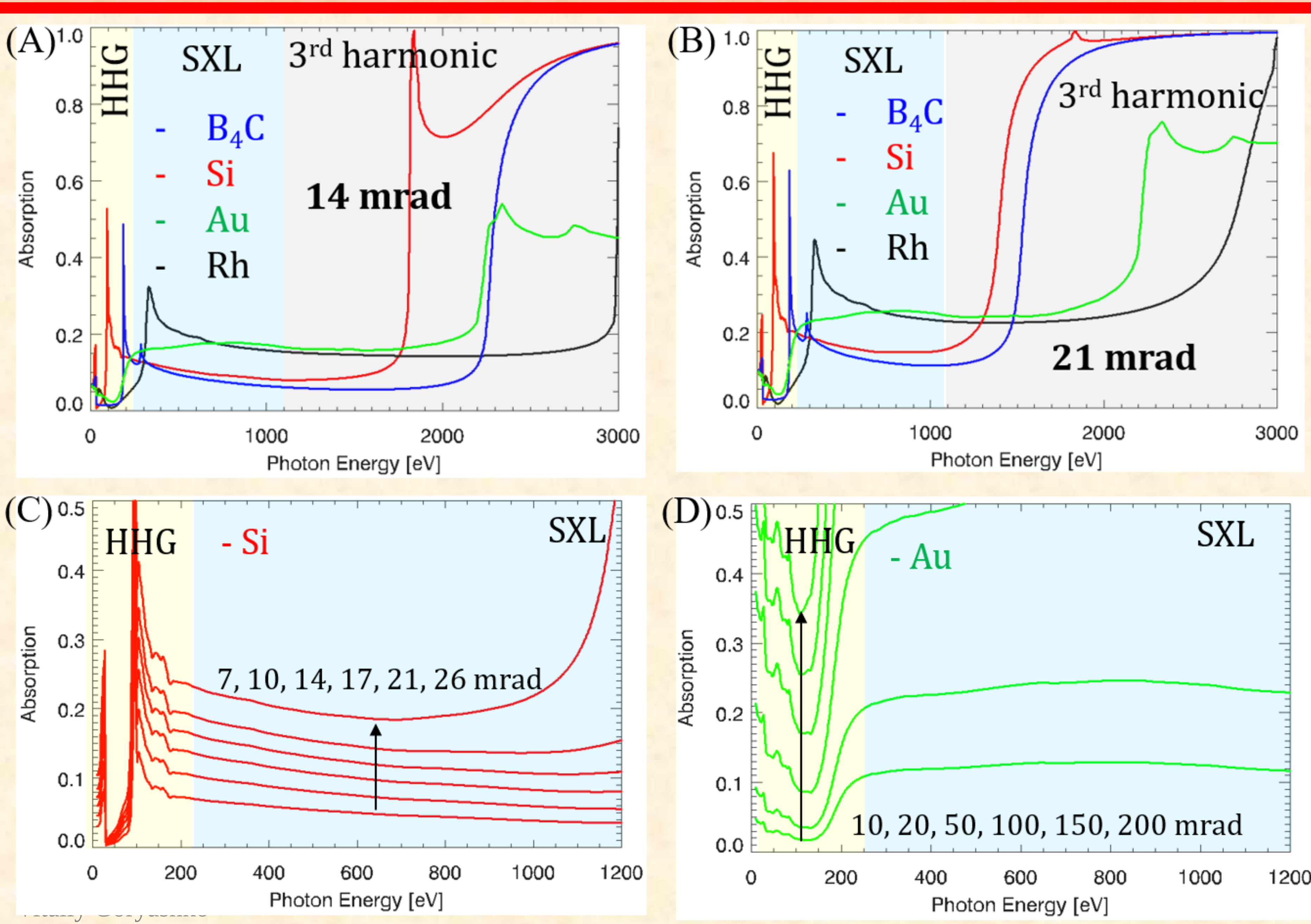




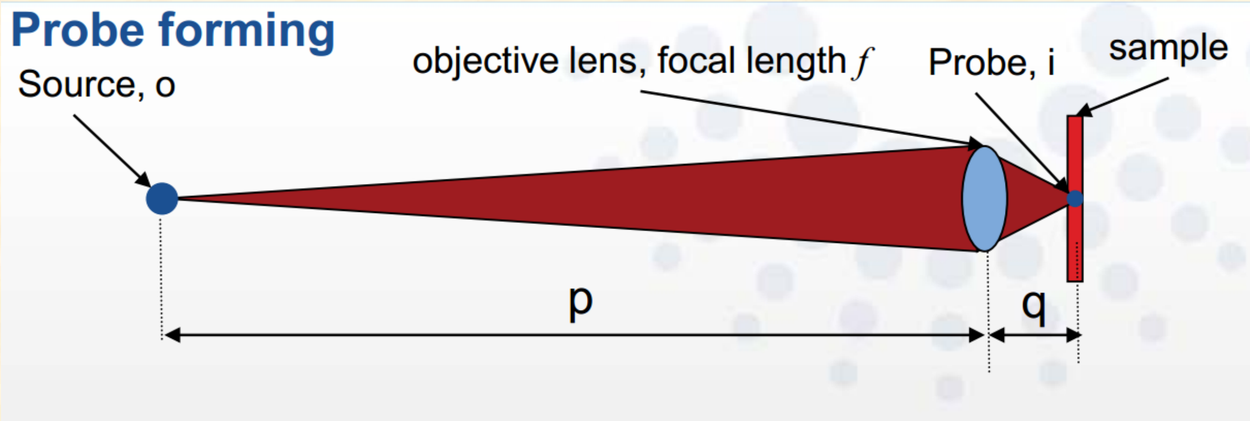


- SASE is a stochastic process with a Gaussian-like energy distribution.
- The uncertainty of S2E simulations is ~ 20%. The margin for optical design is assumed to be 20%.
- For safe optical design, we assume 1.2 mJ at 1 nm and 4.3 mJ at 5 nm.

Mirror coating for SXL up to 3 keV



Focusing and beam size



Thin lens $\frac{1}{p}+\frac{1}{q}=\frac{1}{f}$

Magnification, $M=\frac{i}{o}=\frac{q}{p}$

For fixed p, $M\uparrow \Rightarrow f\downarrow$

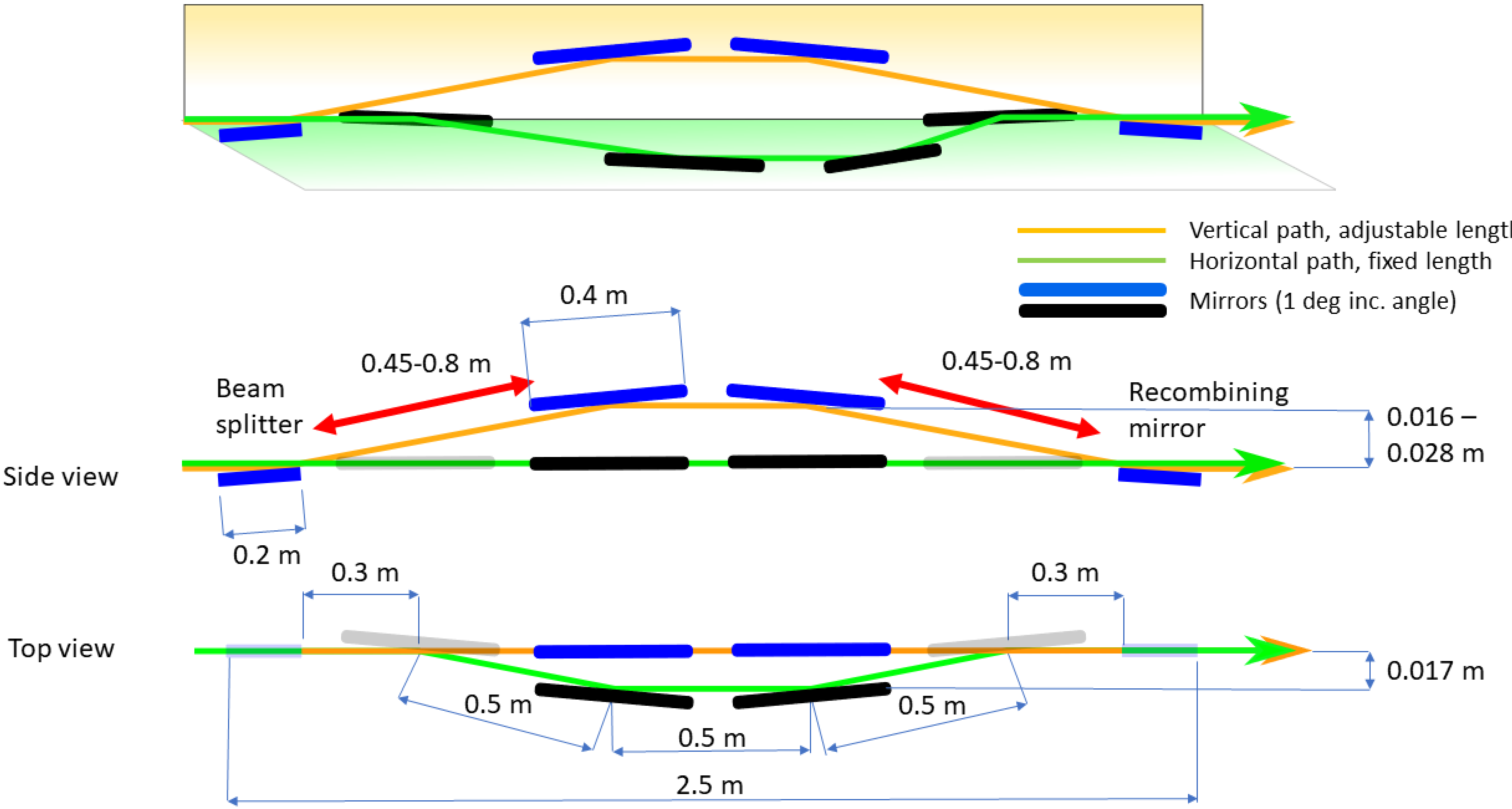
R. Barret, ESRF

- FEL beam size $\sigma_0 \sim$ 20-50 um
- desired beam size at the sample $\sigma_0' \sim$ 0.5 um
- required demagnification ~ 100
- if the exit arm ($\approx f$) equals 1 m, then the **entrance arm 100 m**
- for a real beam of light, the lens equation must account for diffraction

$$\frac{1}{p+z_0^2/(p-f)}+\frac{1}{q}=\frac{1}{f} \qquad \sigma_0' = \frac{\sigma_0\ f}{\sqrt{(p-f)^2+z_0^2}}$$

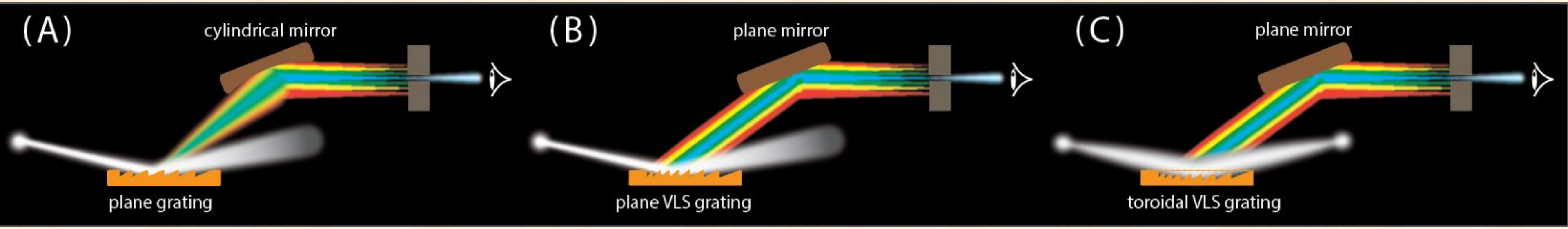
z_0 - Rayleigh length

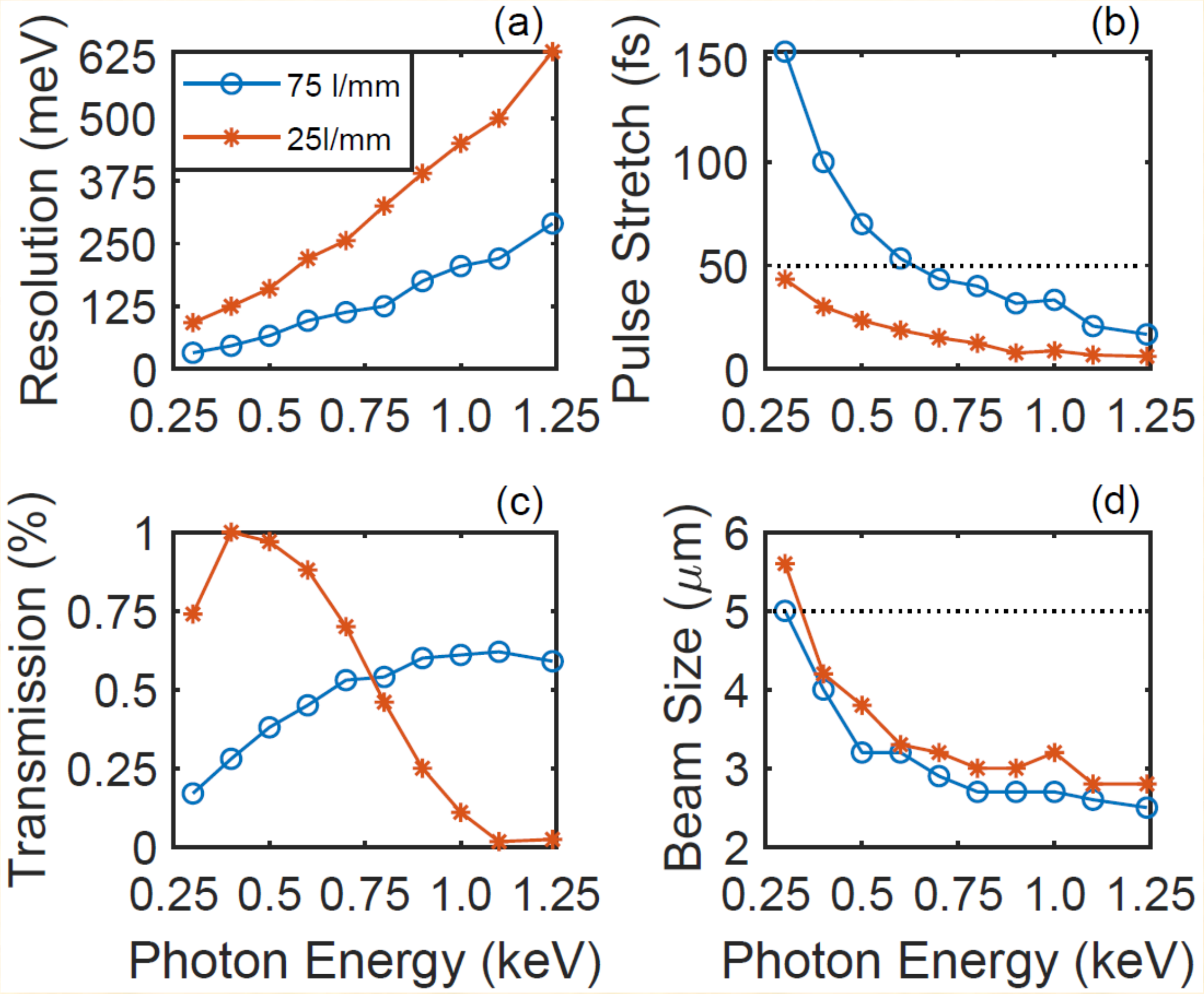
Split & delay



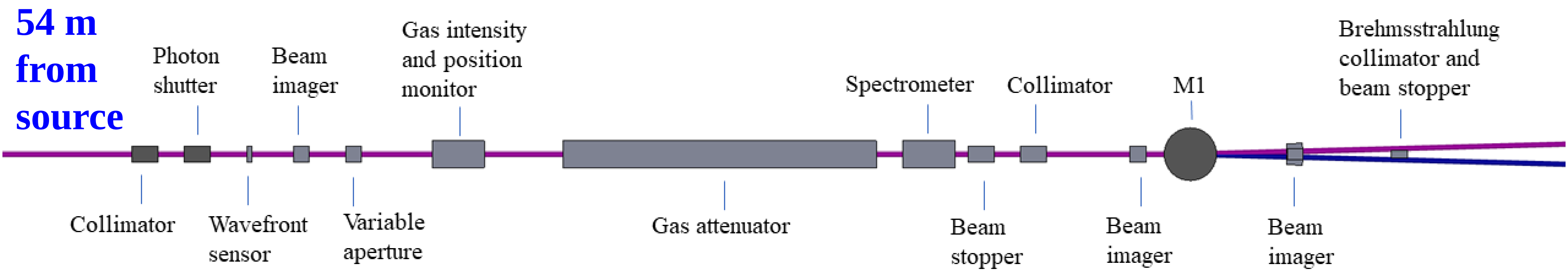
Vertical path, adjustable length
Horizontal path, fixed length
Mirrors (1 deg inc. angle)
0.4 m
0.45-0.8 m
0.45-0.8 m
Beam
splitter
Recombining
mirror
0.016 –
0.028 m
Side view
0.2 m
0.3 m
0.3 m
Top view
0.017 m
0.5 m
0.5 m
0.5 m
2.5 m

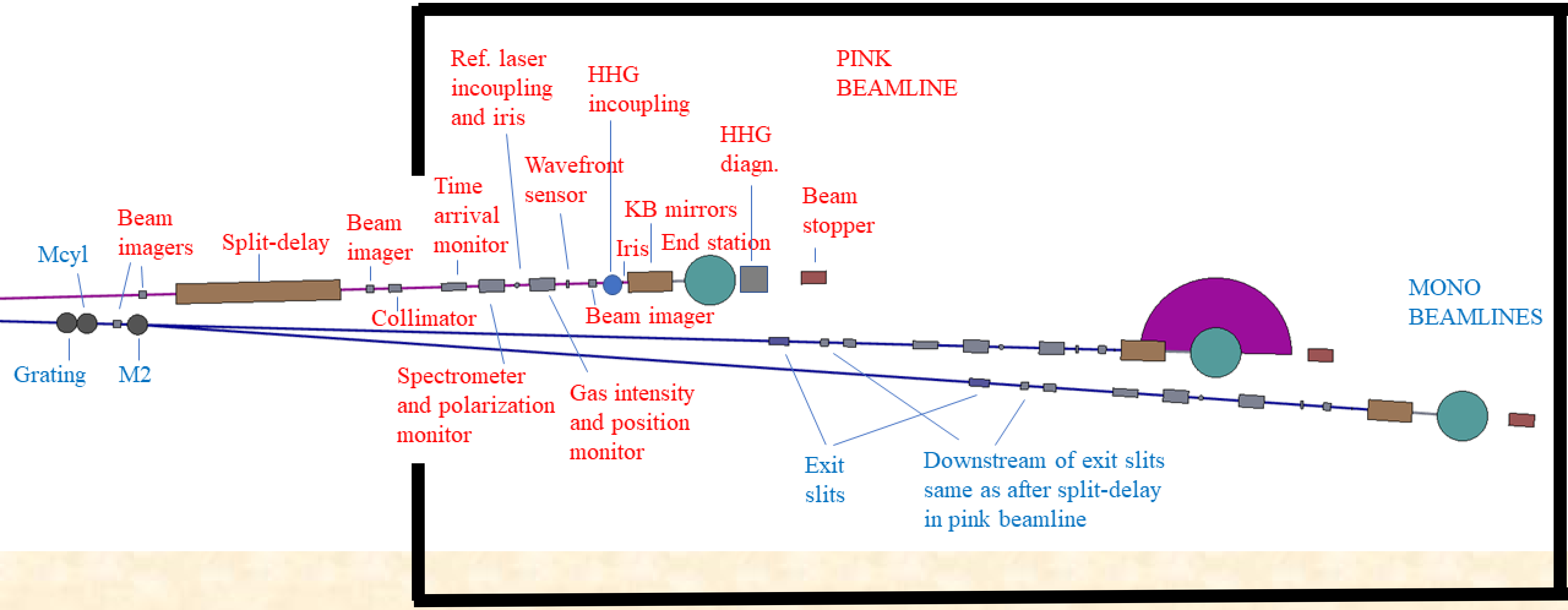
Grating type and mount





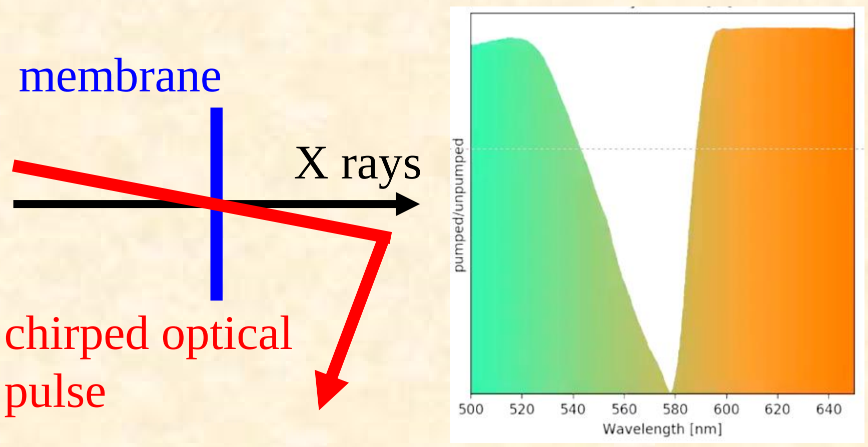
Overview of instruments and detectors





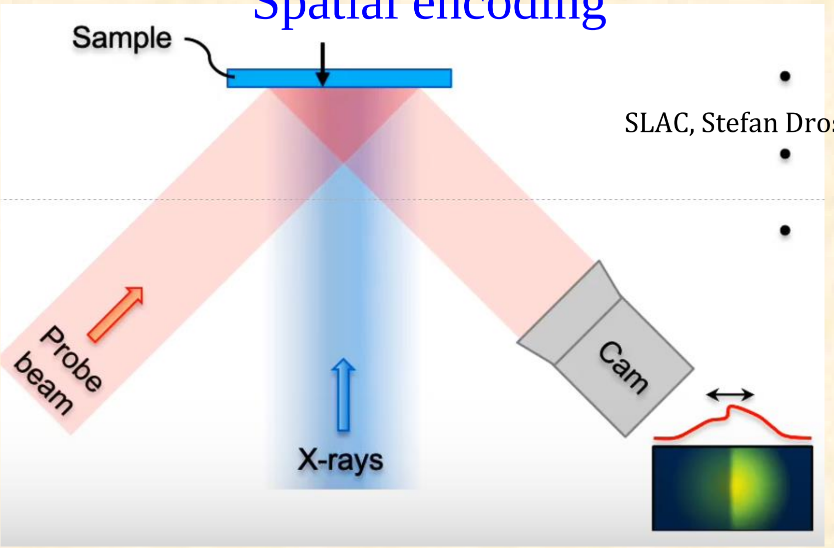
Temporal X-ray pulse characterization

Spectral encoding



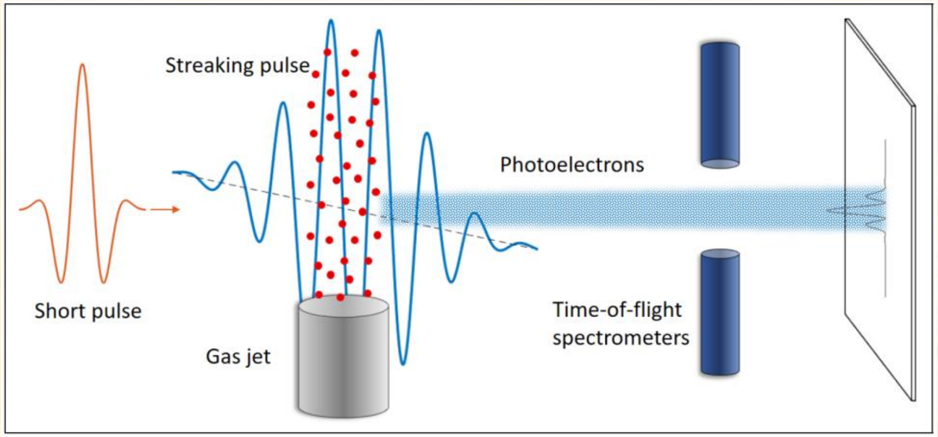
PSI

Spatial encoding



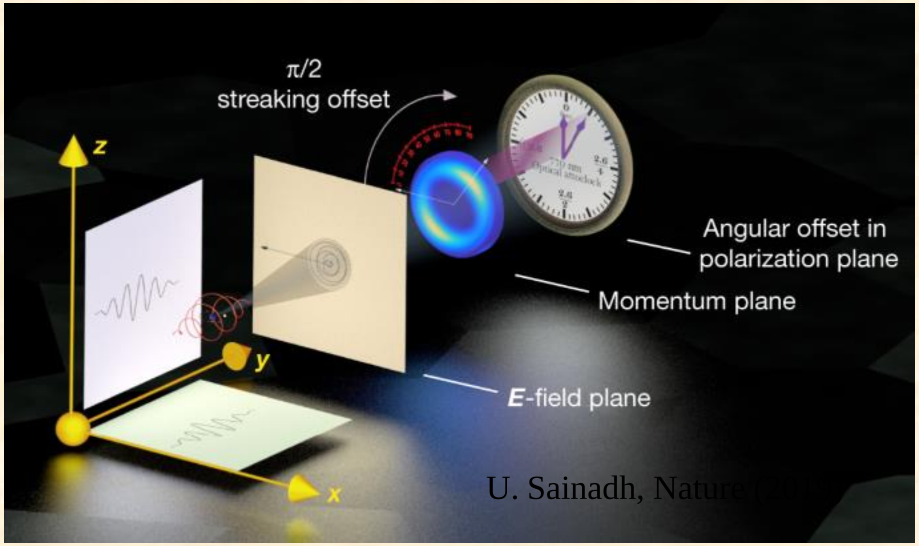
SLAC, Stefan Droste

Linear THz streaking



UU, G. Shamuilov

Angular IR streaking



U. Sainadh, Nature

Comparison of methods

Method	Arrival time, accuracy (fs)	Pulse duration, resolution (fs)	Measurement interval (ps)	Double FEL pulses, accuracy (fs)
Spatial encoding	1.5	no	2	no
Spectral encoding	4.5	no	3	no
Spectrogram	< 1	no	~4	no
THz streaking	~10	~10 fs	0.5	25
mid-IR streaking	~1	0.25 (0.1 for double pulses)	0.34	1
VMI streaking*	N/A	~ 0.1	?	?

- Mid-IR angular streaking is a very complicated technique
- But only mid-IR angular streaking measurement capabilities comply with all the XLS science requirements
- In the baseline design, we could start with THz streaking that is simpler.

* works well only for pulse energies > 100 uJ in SXR. Not tested for HXR