UNIVERSITY OF OXFORD

Solid Density Plasmas Created and Diagnosed with X-ray Lasers

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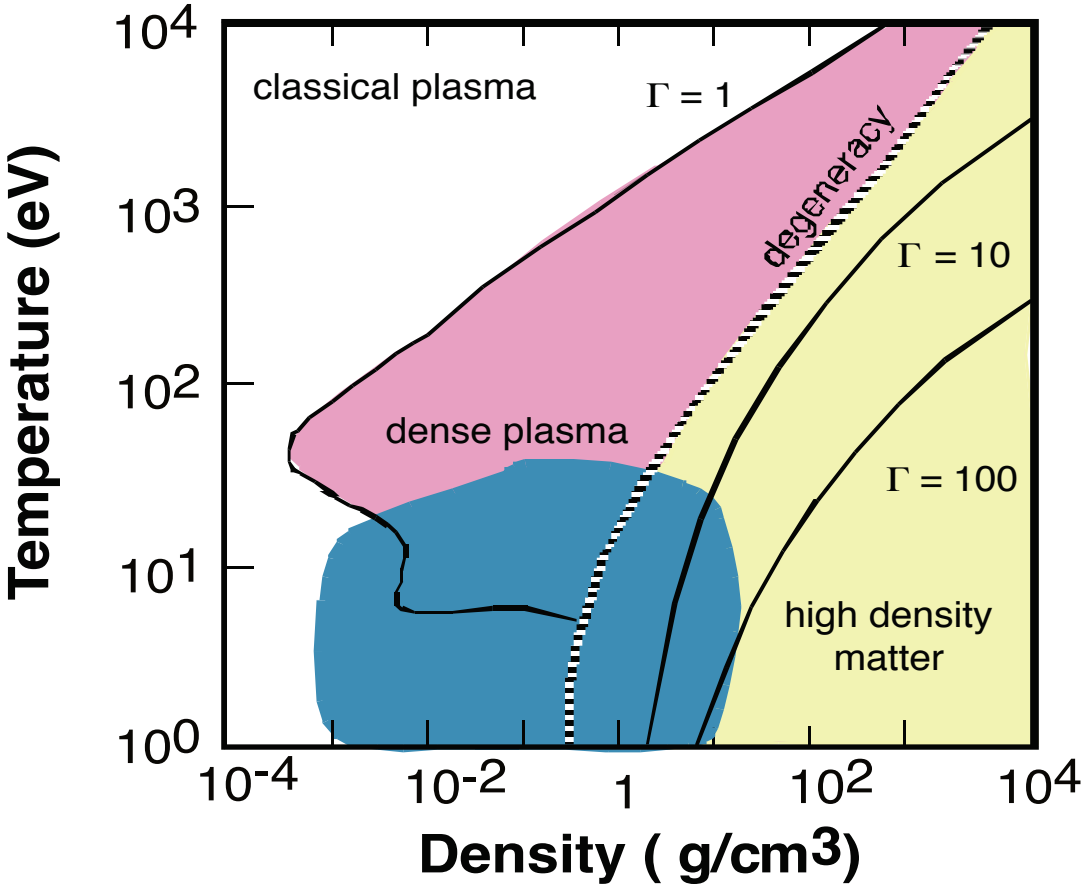
Dense Plasmas are Hard to Model

- **Not described as normal condensed matter, i.e., T ~ 0**
- **Not described by weakly coupled plasma theory**

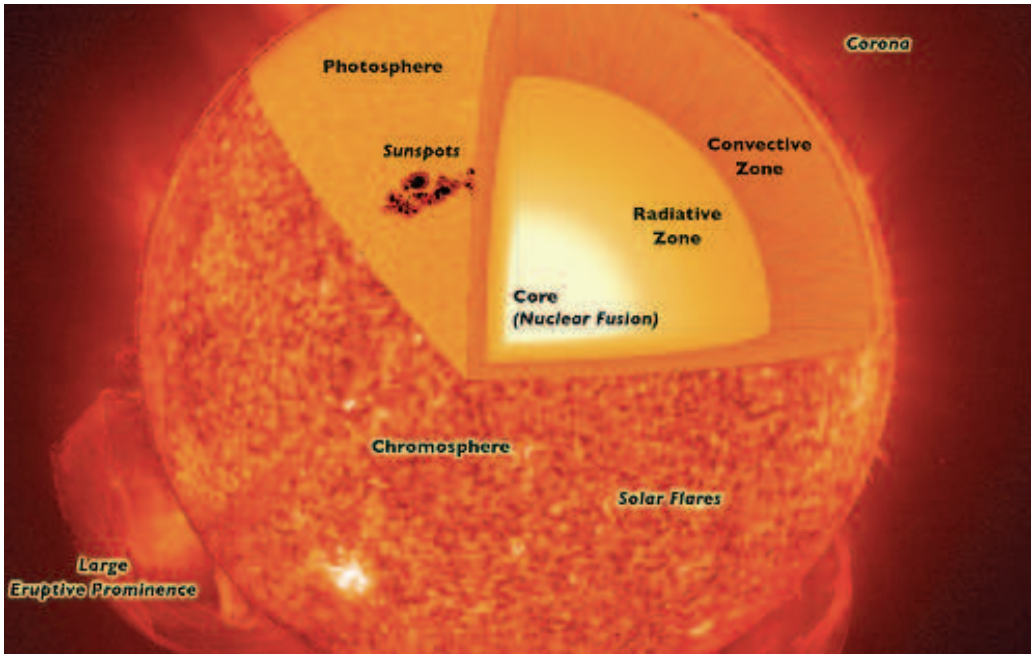


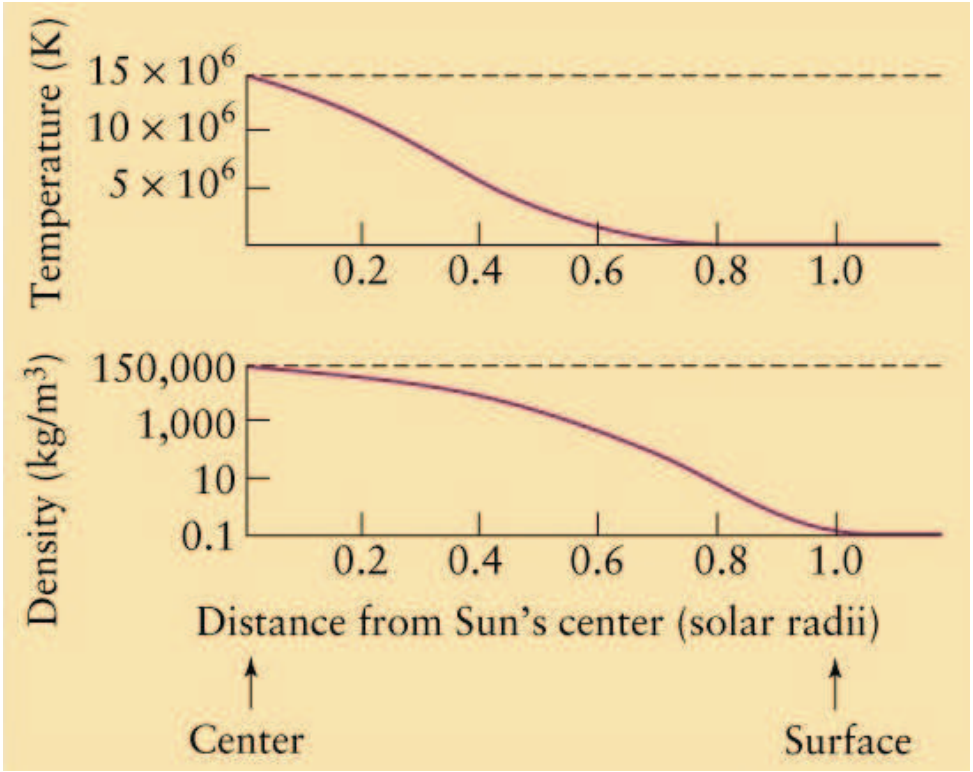
- Γ is the strong coupling parameter, the ratio of the interaction energy between the particles, V_{ii}, to the kinetic energy, $k_B T$

$$\Gamma = \frac{V_{ii}}{k_B T} = \frac{Z^2 e^2}{4\pi\varepsilon_0 r_o k_B T}$$

- where $r_o \propto \frac{1}{\rho^{1/3}}$

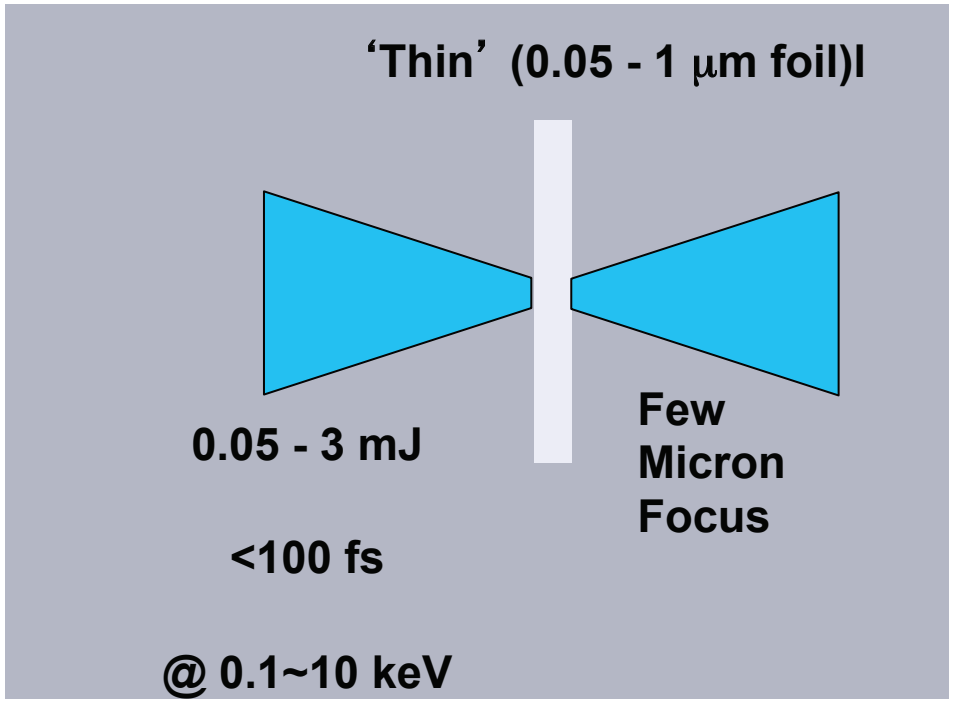
Oxford Physics Solid Density: Half way within the Sun





Creating Solid Density Plasmas

X-rays can penetrate relatively long distances, whilst depositing energy, hence generating a uniform plasma.



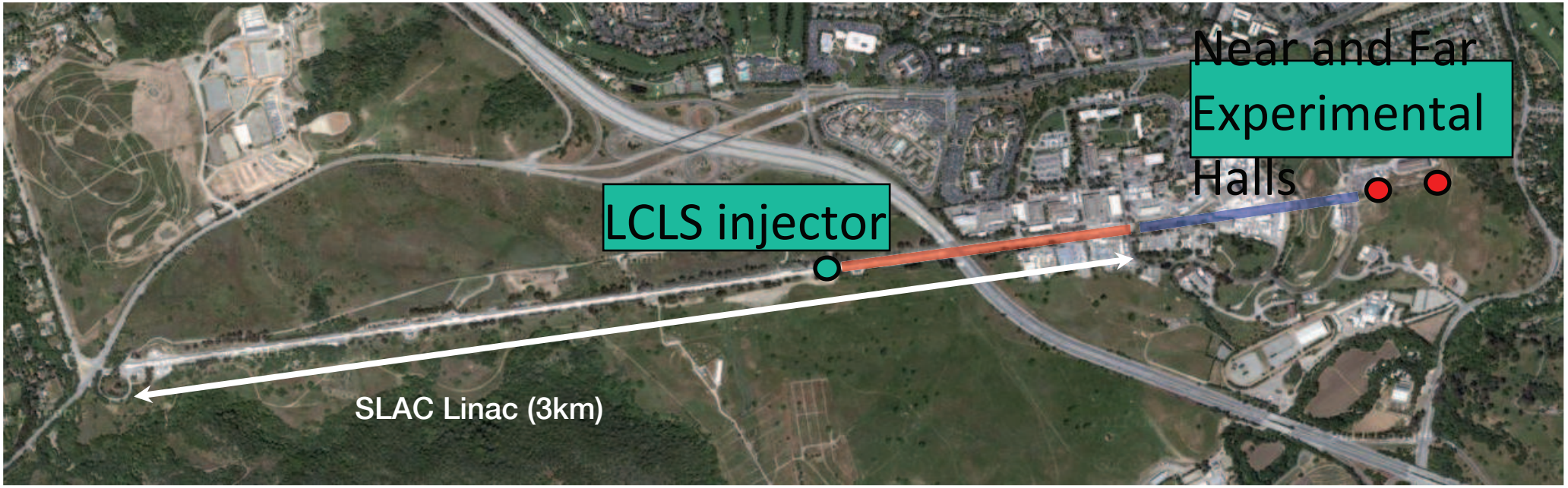
- Want to produce at least several eV plasma.

Speed of sound x target thickness >> compared with electron ion coupling time.

Absorption depth >> thickness (uniform energy deposition).

Require uniform lateral energy profile.

Linac Coherent Light Source (LCLS)



Photon energies: 500 eV – 10 keV (fundamental), 0.3 % bandwidth

Pulse lengths: <10 fs – 300 fs

120 Hz, 1-2 mJ per pulse

4th generation light sources: Free-Electron Lasers

Peak brightness 10^9 higher than 3rd generation synchrotrons

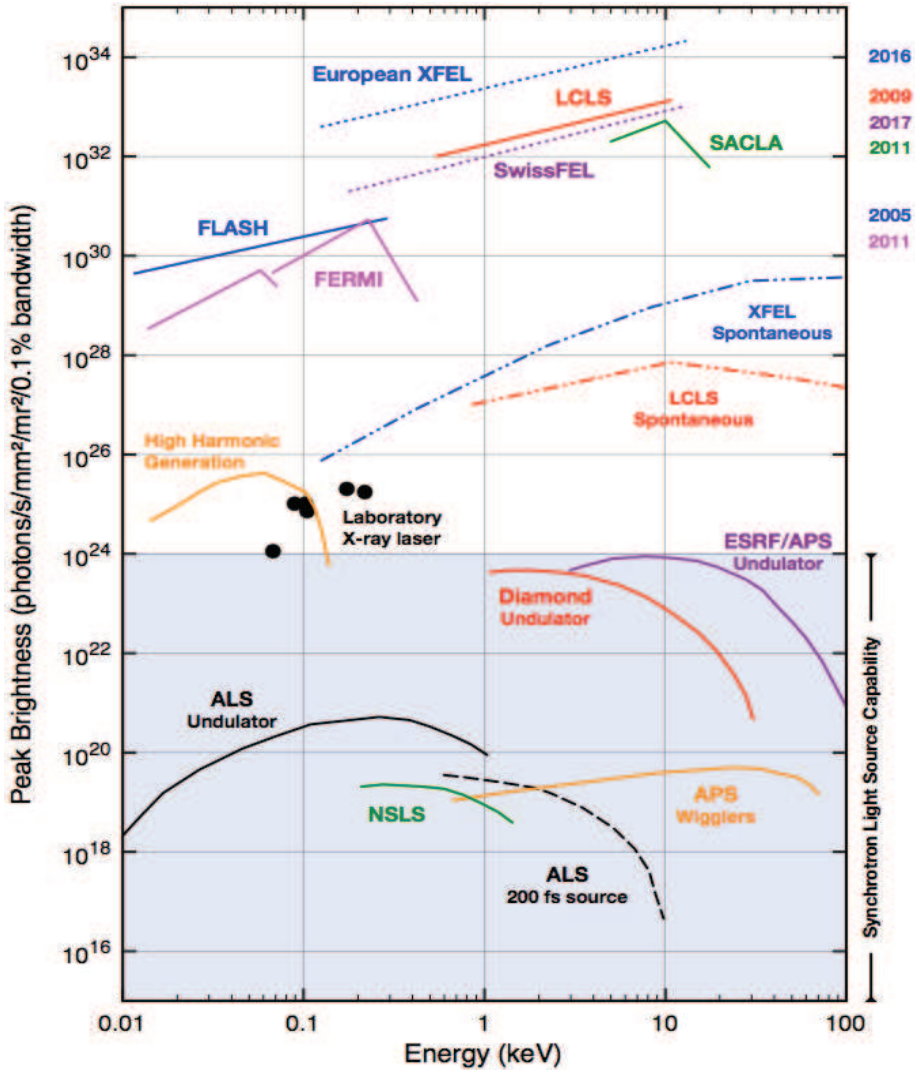
short pulse duration (sub 100 fs);

lots of photons per bunch ($\geq 10^{12}$);

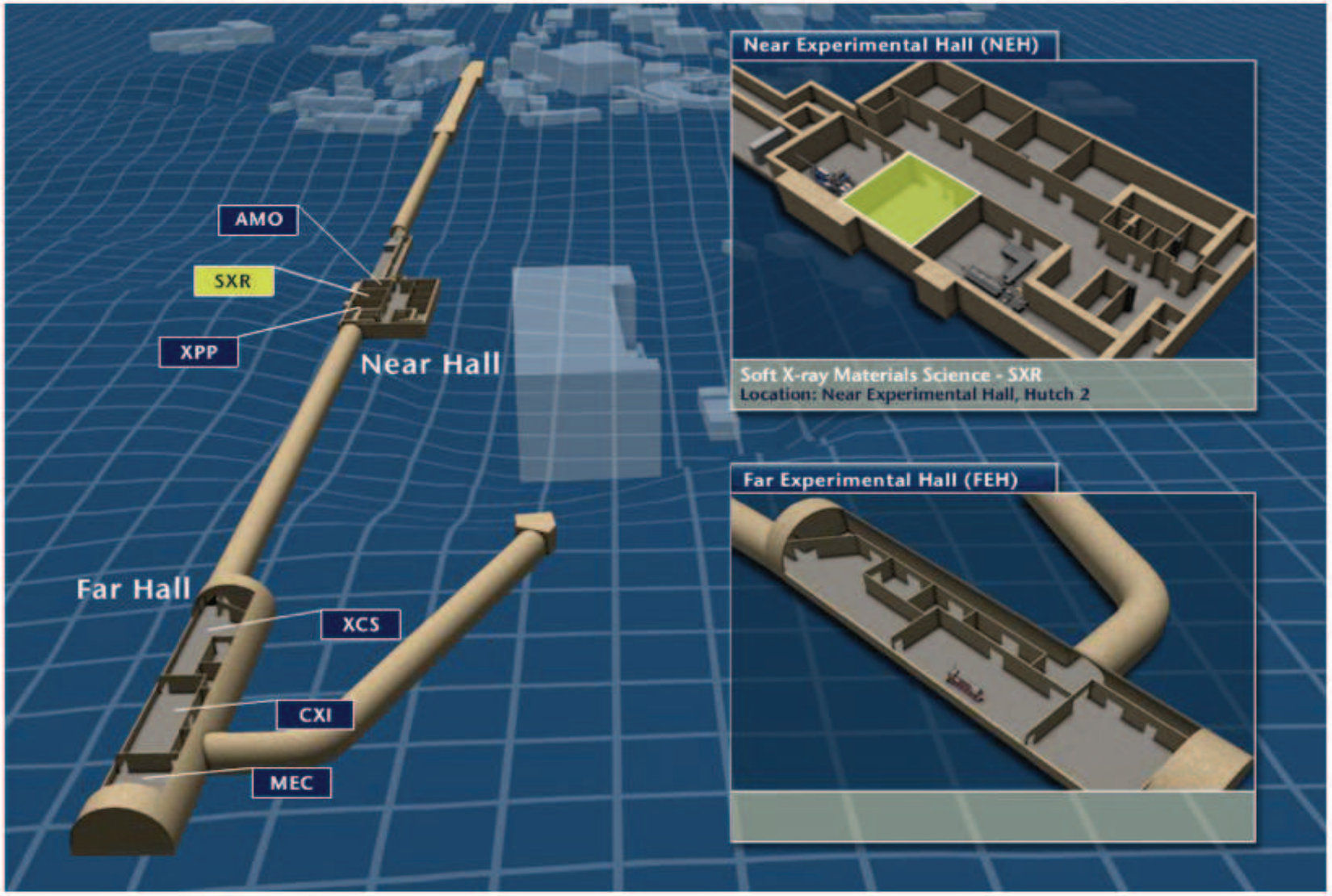
tunable wavelength

Hard X-ray FELs:

- **LCLS at SLAC, USA : 0.12-2.5 nm, 2009**
- **SACLA at SPring-8, Japan : 0.1 - 3.6nm, 2011**
- **European X-FEL at DESY, Germany: 0.1 - 6nm, 2015+**
- **Swiss-FEL at PSI : 0.1 - 7nm, 2016**



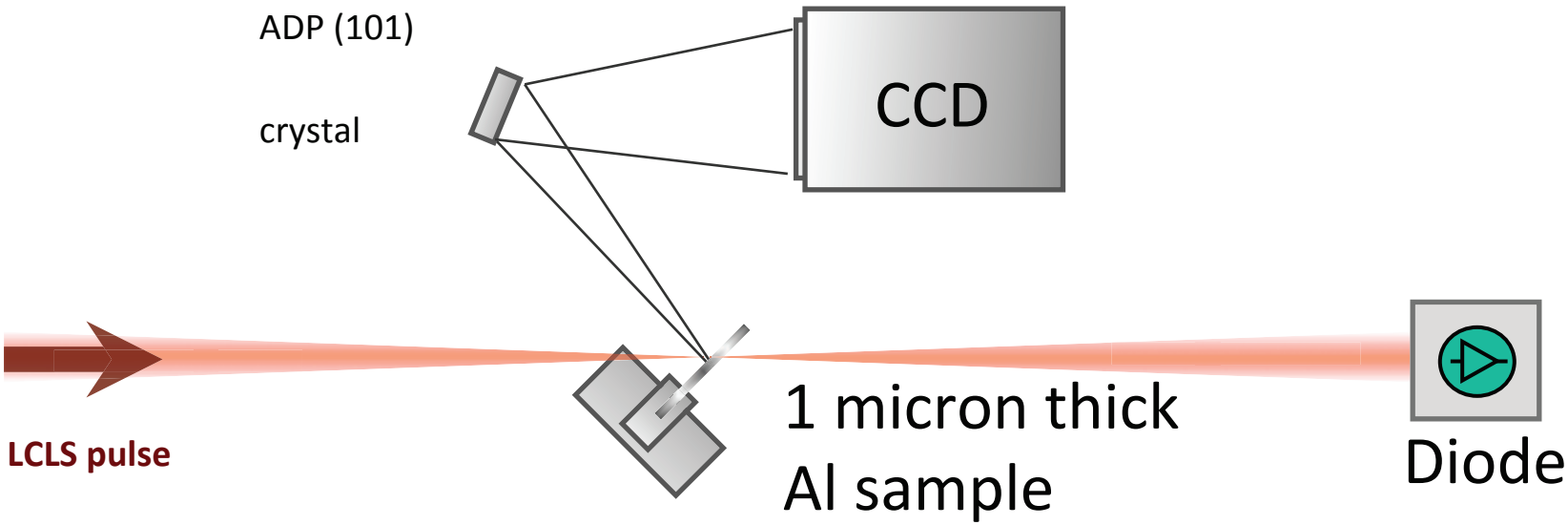
SXR Endstation



LCLS:SXR experimental setup

X-ray spectrometer: Al K-alpha emission

1460–1680 eV



Photon energy: 1560–1830 eVPulse length < 80 fs Pulse Energy ~1.5 mJBandwidth ~ 0.4%

Peak Intensity ~10^{17} W cm^{-2}