

Summary

HHG demo



Advanced Radiation Sources - PHSY761

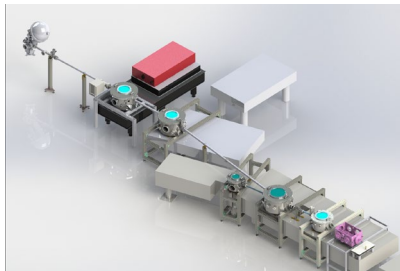
Lecture 07

2 November

2023

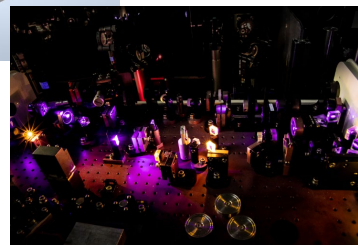
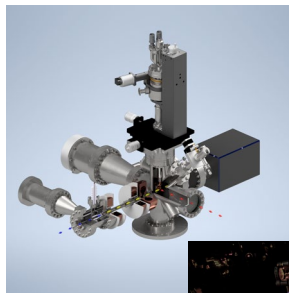
THE FACILITY OVERVIEW

3 laboratories, dedicated to ultrafast spectroscopy with primary and secondary femtosecond sources:



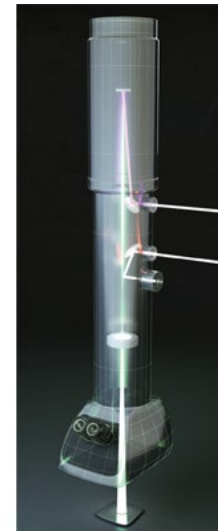
Harmonium

- trARPES
- XUV spectroscopy/scattering



LOUVRE

- UED
- fs optical spectroscopy



LUMES

- uTEM
- trEELS

Photoemission from crystalline solids

Electronic band structure:

$$E(\mathbf{k})$$

Central quantity in condensed matter physics

- Electronic properties
- Optical response
- Many body interactions

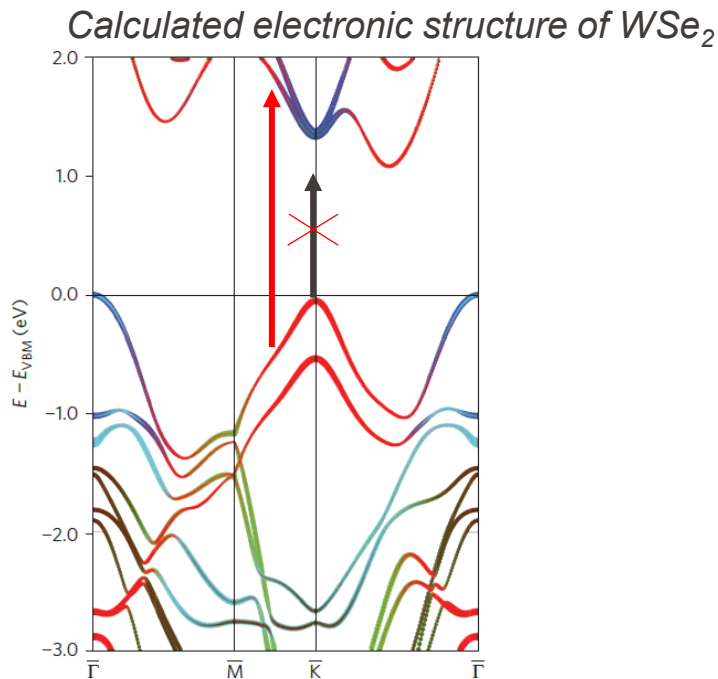
CAN BE MEASURED WITH ARPES:

Momentum conservation:

$$k_{\parallel} = \frac{1}{\hbar} \sqrt{2m E_{kin}} \sin \vartheta$$

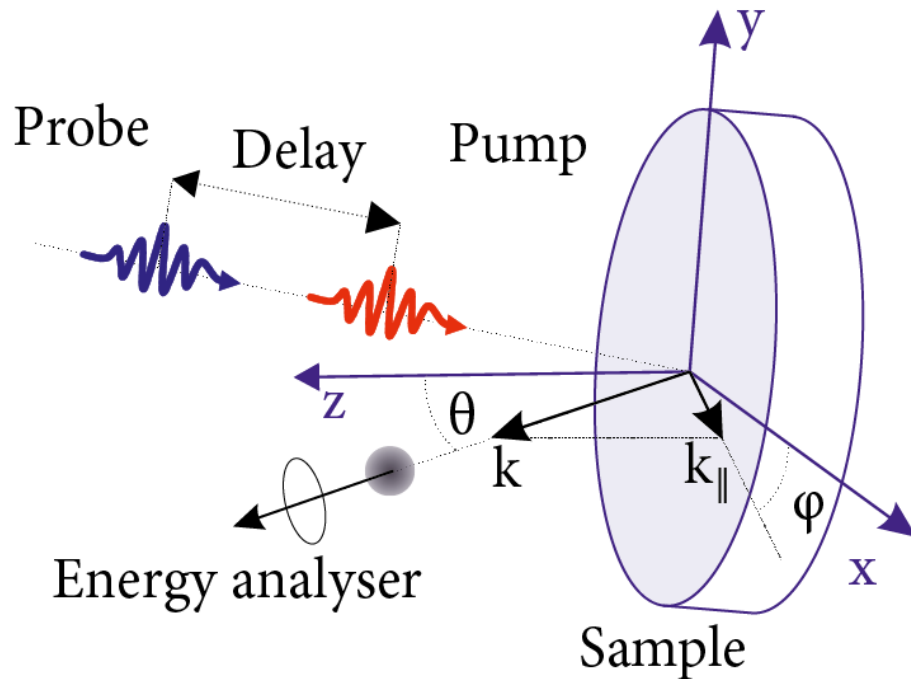
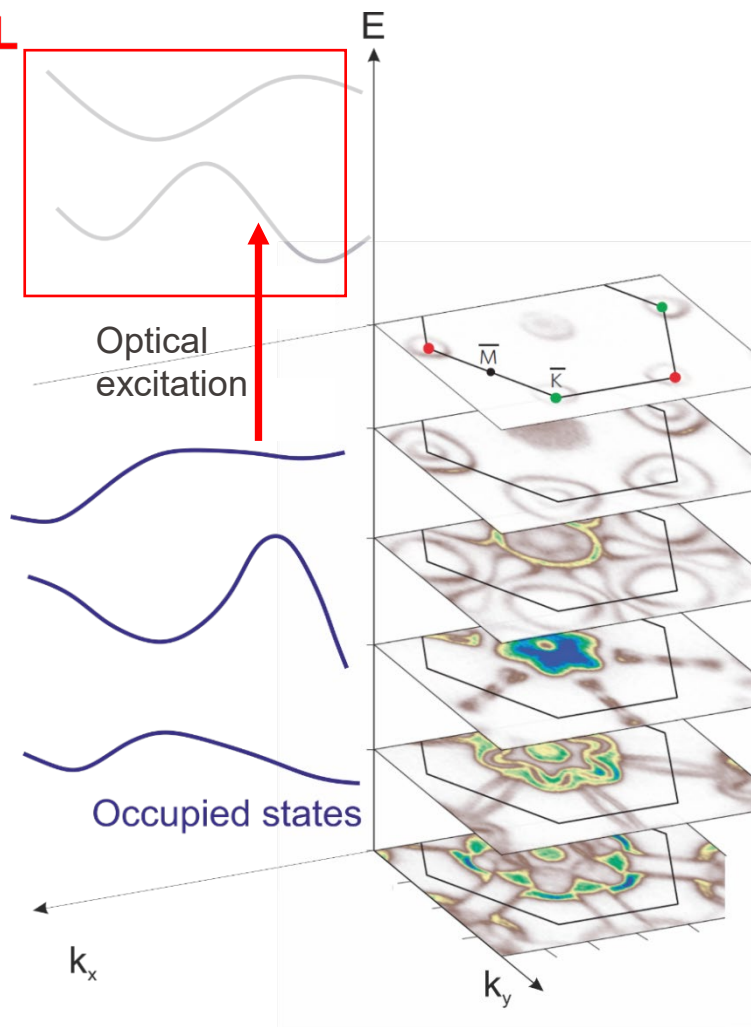
Energy conservation:

$$E_B = \hbar\omega - E_{KIN} - \phi$$



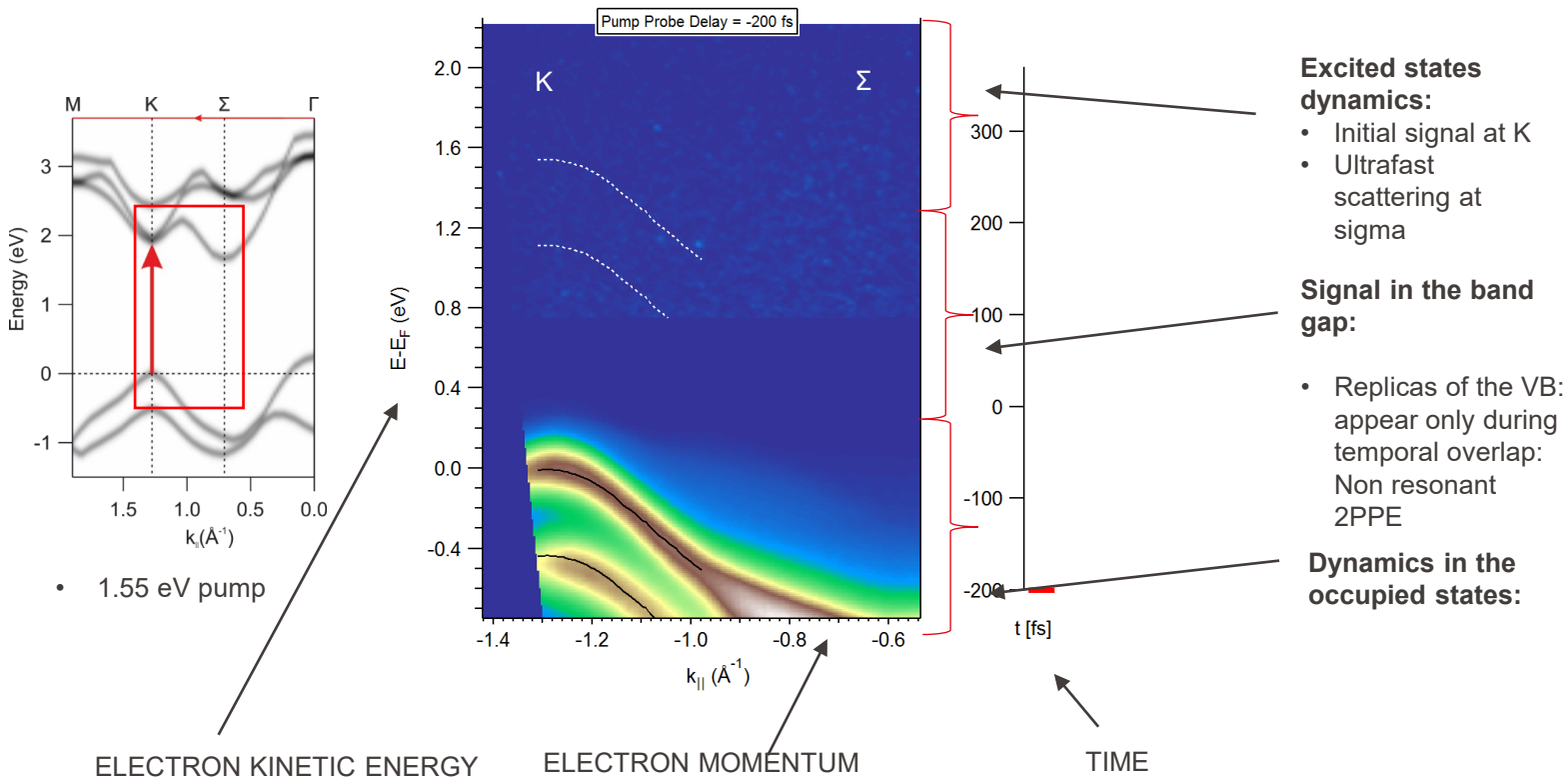
Riley et al. Nat. Phys. 10, 2014

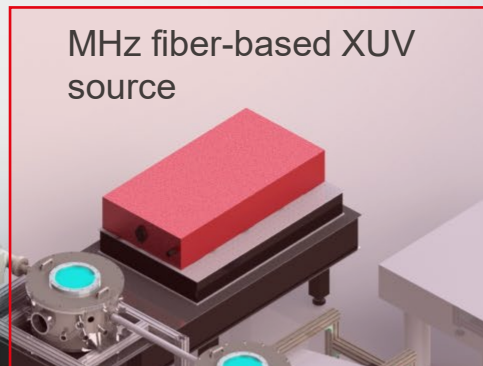
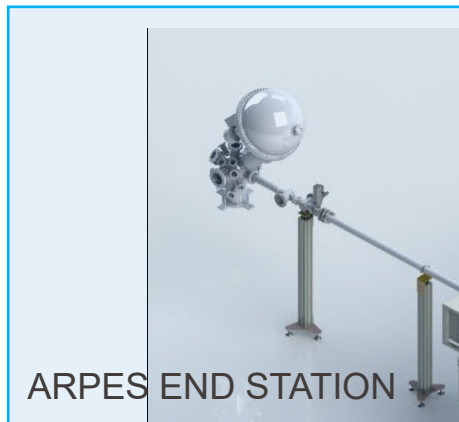
Time-resolved ARPES



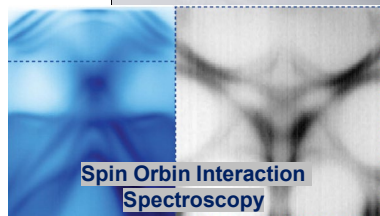
Electronic dynamics in matter

Example: Tr-ARPES on WSe₂

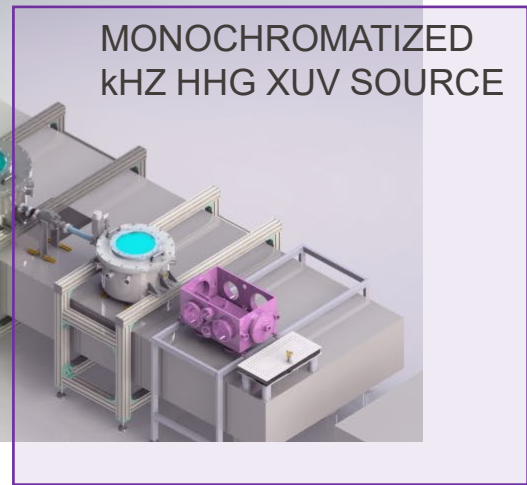




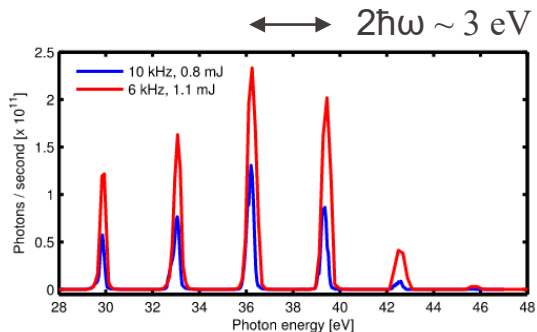
Prof F. Carbone



Prof H. Dil

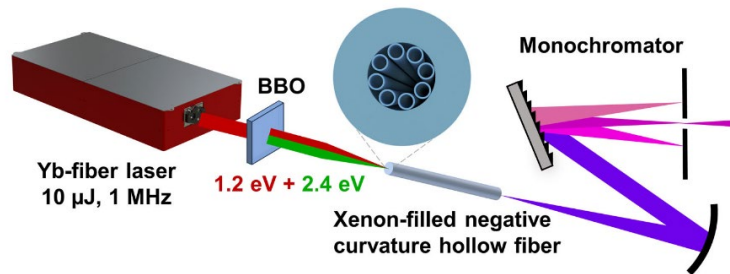


MONOCHROMATIZED kHz HHG XUV SOURCE



- High-harmonic generation
- Time-preserving monochromator: <100 fs, ~ 150 meV
- Energy tunability: Ar 15-50 eV (ARPES)
Ne 60-110 eV (PES)
- Pump probe ARPES with FH, SH, TH excitation
- Synchronized tunable laser source (few ps resolution, 0.2 – 10 μm)

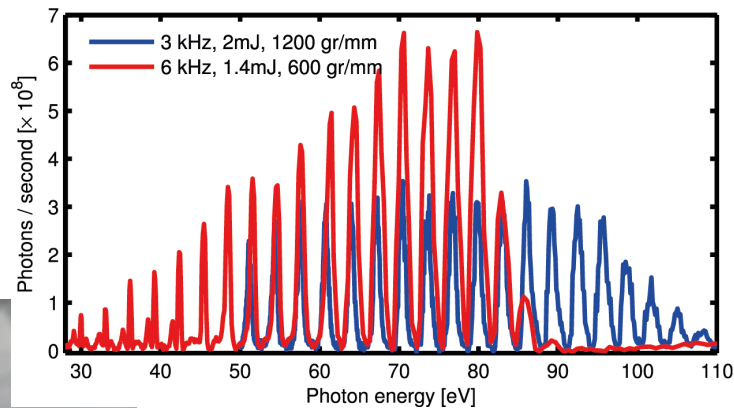
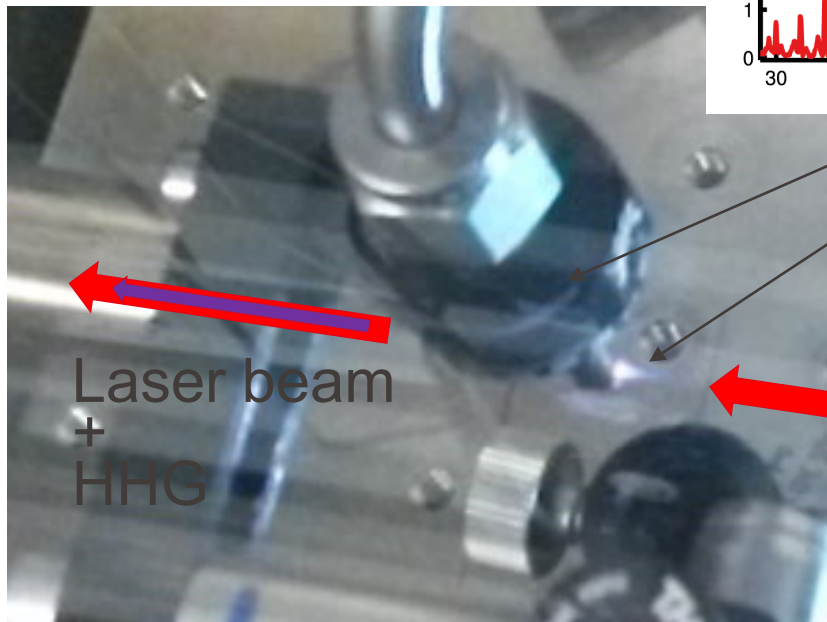
MHz FIBER-BASED XUV SOURCE



- Cascaded harmonic generation in HCF
- Monochromator: 500 fs, < 30 meV
- Energy tunability: Xe 7th (8.4 eV), 8th (9.6 eV), 9th harmonic (10.8 eV)
- Pump probe ARPES with FH, SH



HHG Chamber



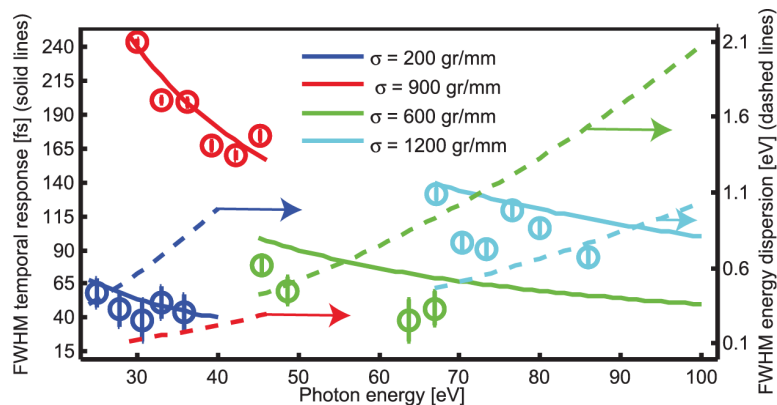
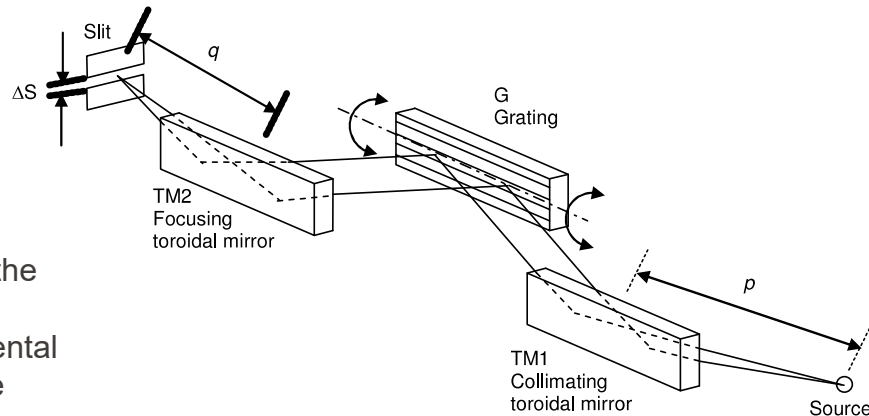
Gas target

Laser beam

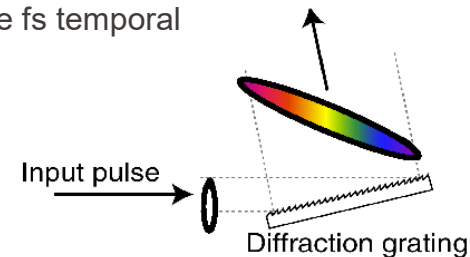


Time-preserving monochromator

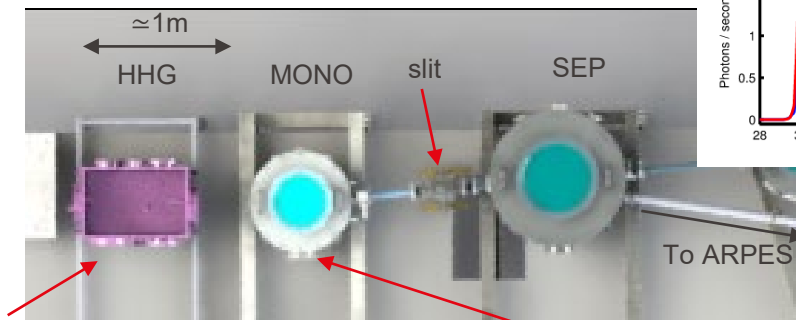
- A single harmonic can be selected from the comb for spectroscopy
- Time-bandwidth product in PES: experimental energy resolution and time resolution are inversely proportional



- Special design is necessary to preserve the fs temporal resolution



- tuneable time-bandwidth:
<100 meV – <50 fs



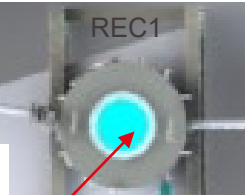
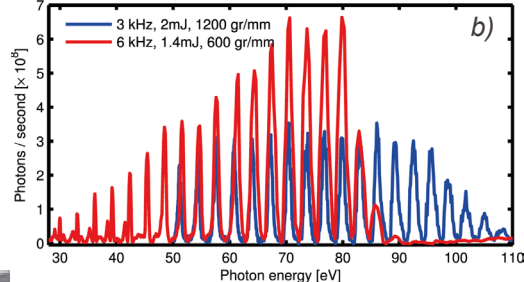
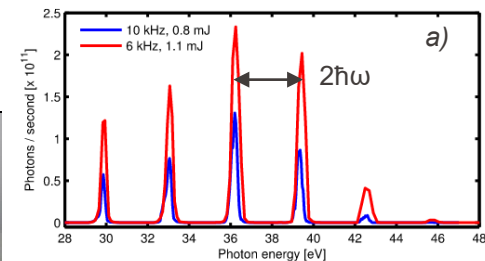
HHG : High harmonic generation

- Highly non-linear effect in a noble gas, spectral comb with only odd harmonics separated by $2\hbar\omega$
- Argon **15-50 eV** : $>10^{11}$ ph/s in SEP, two C coated grazing incidence mirrors before ARPES*
- Neon 70 eV-110 eV : 10^{-2} less flux, can be used for shallow core levels (4d) - not for ARPES

*The flux on the sample is limited due to space charging!
Must be reduced in practice by a factor ≈ 10

Harmonic selection

- Monochromator designed to minimize pulse temporal broadening
- Act as an Harmonic “selector”
- 15-110 eV
- The resolution is NOT limited by resolving power but by harmonic linewidth and space charge trade-off
- Resolution=0.15 eV is reasonable in the (15-50 eV) range, with time res. <100 fs (Note: the Fourier limit is 1824 meV fs)



Example HHG in
a)Ar, b) Ne

Refocusing

- Harmonics retain a laser-like beam properties.
- Refocused on ARPES chamber with a $\approx 100 \mu\text{m}$ spot diameter (toroidal mirror).
- Second beam line with $20 \mu\text{m}$ spot (ellipsoidal on hexapod)