High intensity attosecond electron and photon beams

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Attosecond e- beams for colliders & photon sources

Attosecond e-beams for short bunch colliders

- Small intense e+/e- bunches required for high luminosity colliders
- Large field of opposite bunch results in strong acceleration producing synchrotron radiation (“beamstrahlung”)
- Beamstrahlung effects can be “switched off” if the bunch length is made small enough (attosecond-level) in a short bunch collider

Parameter	Unit	NPQED Collider	LCLS	Proposed attosecond e- source (PAX)
Beam Energy	GeV	125	10	1-20
Bunch Charge	nC	0.14 - 1.4	0.01-0.1	0.01 - ~0.5
Peak Current	kA	1700	1-5	~1000
Energy Spread	%	0.1	0.01	1
Bunch Length (rms)	μm	0.01 - 0.1	1-100	0.005
Bunch Size (rms)	μm	0.01	10	1-10

Attosecond e- beams allow the study of MA-compression relevant for short-bunch colliders while enabling intermediate applications

• V. Yakimenko et al. Prospect of Studying Nonperturbative QED with Beam-Beam Collisions, PRL. 122, 190404 (2019).
• G. White and V. Yakimenko, Ultra-Short-Z Linear Collider Parameters, Workshop on Future Linear Colliders (LCWS2018),
• HEP GARD Accelerator and Beam Physics: Community-driven strategic Roadmap Workshop, LBNL December 2019

Attosecond e-beams for next-generation photon sources

- 50-100as X-ray pulses with μJ pulse energy are desirable for studying electron motion in atoms.
- HHG sources can currently reach 40 as length with limited (pJ-level) energy
- XFELs can reach μJ pulse energy with minimum pulse length limited by emittance ($\Delta t_{min} \propto \epsilon^{5/6}$) currently to ~ 200as
- An attosecond photon source based on as e-beams can enable new capabilities by combining the benefits of HHG sources & XFELs.

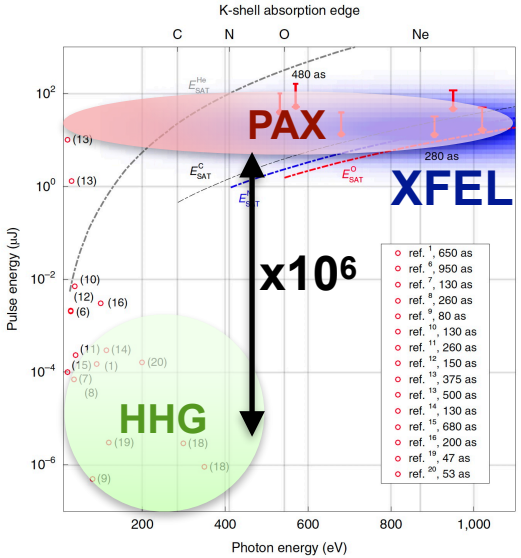


Fig.1 Comparison of state-of-the art attosecond photon sources

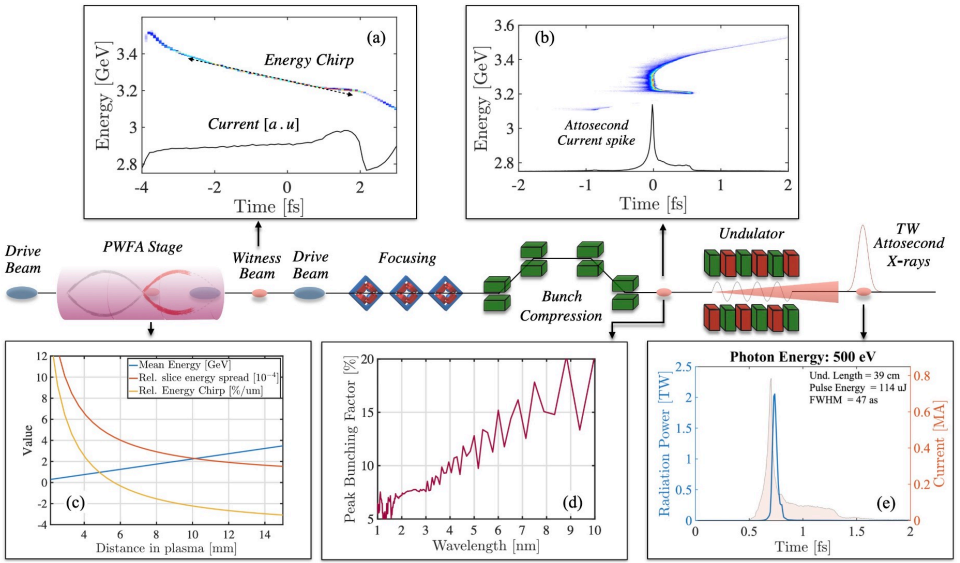
Attosecond e-beams offer path to shorter, higher power photon pulses than state-of-the-art attosecond X-ray sources

• J. Duris *et al. Nat. Photonics* 14, 30–36 (2020)
• Z. Zhang *et al.* New J. Phys. 22 083030 (2020)

An attosecond e- and photon source based on a plasma accelerator

- Large fields existing in plasma accelerators can produce ultra-high brightness beams with strong energy chirps.
- Weak bunch compressors can be used to compress beams to as length while preserving good beam quality.
- These e-beams can generate TW-power X-rays through coherent undulator radiation in an ultra-short (cm-long) undulator.
- ***Not an XFEL starting from noise*** **-** relaxes tolerances on energy spread, emittance and pointing stability.
- HEP facilities e.g. FACET-II can enable initial experimental tests and conceptual demonstration in next 2-5 years.

Schematic of an as photon source based on a high intensity as e- beam



C. Emma et al., in preparation

Attosecond e- and photon beams may be generated by exploiting the unique properties of plasma accelerators

R&D in this direction in line with P(L)WFA roadmap towards near-term applications