Laser pulses for Traveling-Wave Electron Acceleration and Thomson Scattering

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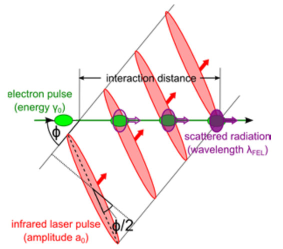
Traveling-Wave Thomson-Scattering (TWTS)

provide incoherent, high-yield sources at hard X-rays

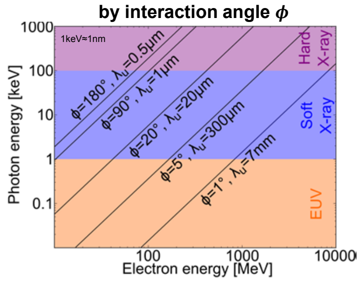


Side-scattering and pulse front-tilt of $\phi/2$ ensure continuous spatial overlap of laser and electrons

- Incident angles up to 120° desired for large photon energies.
- **Requires substantial group-delay- and spatial-dispersion pre-compensation in TWTS pulse synthesis.**
- Relatively compact optical setups with cylindrical focusing only.
- More laser power is better, but there is no initial threshold.

A. Debus *et al.*, Appl. Phys. B, 100(1), 61-76 (2010)

Broad tuneability of FEL wavelength by interaction angle ϕ



TWTS applications

Yield-enhanced TS	10^7-10^{12} photons/pulse incoherent source

Requires high-laser power and good electron beam quality.

Time-bandwidth filtered TWTS	Incoherent, **ultrashort** <10^7 photons / pulse **sub-laser bandwidth**

Useful also for high-emittance or high-divergence electron beams.

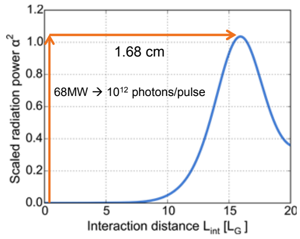
TWTS based optical free-electron lasers

utilize optical undulators with 1000s of periods

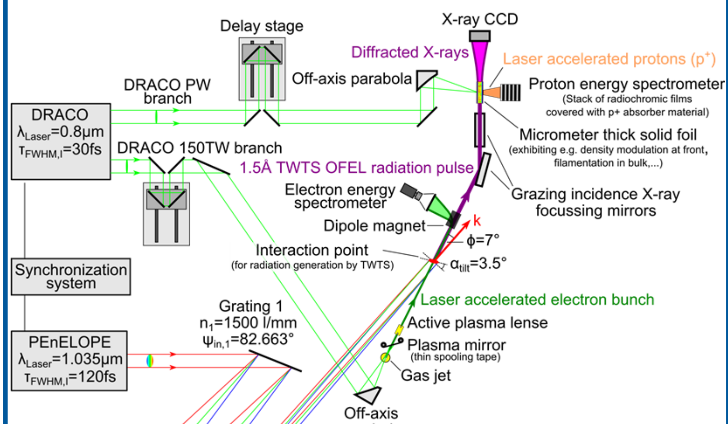
EUV and VUV TWTS-OFELs are realizable with today available technology.

TWTS OFEL	EUV	VUV
Electron energy [MeV]	22	15.0
Scattered wavelength [nm]	13.5	100
Interaction angle [deg]	12.1	10.1
Interaction distance L_{int} [mm]	16.8	5.66
Input laser width [mm]	175	175
f_{eff} [m]	35.9	32.4
Laser power [TW]	1016	997
Transv. intensity profile stability	3.6%	2.5%
Peak power [MW]	68	104
Number of VUV photons/pulse	$1.0\cdot10^{12}$	$2.3\cdot10^{13}$

Self-consistent TWTS OFEL simulation (1.5D)



TWTS-OFEL promising for a future compact XFEL at Angstrom wavelengths



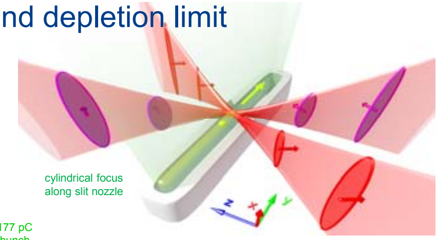
- Small incident angles at 5° - 15°
- Setups often larger than TWTS and require additional focusing optics
- Requires ~1 PW laser system
- Requires high-electron quality: 350MeV, ε_n=0.2 mm mrad @ 0.15nm

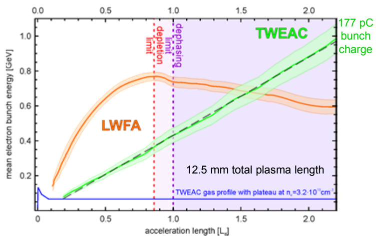
Steiniger, K. *et al.* „Optical free-electron lasers with Traveling-Wave Thomson-Scattering." *J. Phys. B: At. Mol. Opt. Phys.* **47** (2014): 234011

Traveling-Wave Electron acceleration (TWEAC)

eliminates the dephasing and depletion limit

- Two pulse-front tilted lasers enforce vacuum speed of light propagation of the laser overlap in plasma.
- Oblique laser beam geometry continuously feeds a „fresh" portion of the laser beams into an unperturbed plasma.





- Small incident angles (2° - 15°) desired for energy efficiency, but larger angles possible.
- Tight cylindrical foci simplify optical setups and make them more compact.

Readily accessible in compact setups with current lasers

5° incidence angle, 10cm acceleration length
peak a_0=0.5, 2 x 1.5 J, 800nm, 25fs, $w_{0,x}$=1.2μm

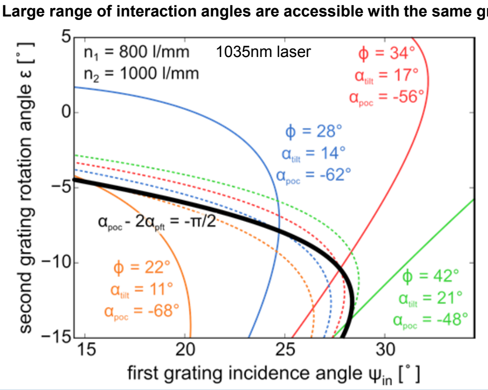
A. Debus *et al.*, *„Breaking the dephasing and depletion limits of laser-wakefield acceleration"*, (paper submitted)

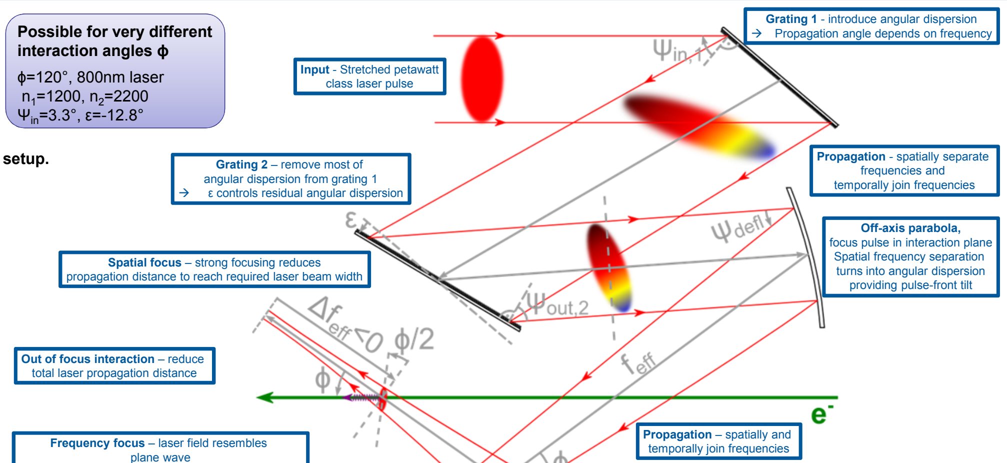
TWTS pulse synthesis

Two-grating setups provide tunability for varying pulse-front tilts

Possible for very different interaction angles ϕ
ϕ=120°, 800nm laser
n_1=1200, n_2=2200
Ψ_{in}=3.3°, ε=-12.8°

Large range of interaction angles are accessible with the same grating setup.





K. Steiniger *et al.*, *„Building an Optical Free-Electron Laser in the Traveling-Wave Thomson-Scattering Geometry"*, (to be published)

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