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All-optical free electron lasers – realizable with Traveling-wave Thomson scattering

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Optical free-electron lasers (OFEL) based on the Traveling-wave Thomson scattering (TWTS) geometry are realizable using existing petawatt class laser systems and electron beams from either conventional or Laser-wakefield accelerators. Such OFELs operate in the EUV to x-ray range, while at the same time remaining compact.

Such TWTS OFELs optimally exploit the high spectral photon density in high-power laser pulses by spatially stretching the laser pulse and overlapping it with the electrons in a side scattering setup. The introduction of a laser pulse-front tilt provides for interaction lengths appropriate for FEL operation, so that beam electrons witness an undulator field of near-constant strength and wavelength over hundreds to thousands of undulator periods, thus giving enough time for self-amplified spontaneous emission (SASE) to seed the FEL instability and the realization of large laser gains.

Based on results from our analytical 1.5D-theory and numerical investigations, we discuss scaling laws and show using example scenarios that TWTS OFELs can be realized with existing RF sources such as ELBE at HZDR as well as LWFA electrons. We detail the necessary equipment for a TWTS OFEL experiment and discuss how current experimental limitations affect the design.

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