

Compact Storage Ring FEL: a kW-scale EUV lithography source

Rod Loewen

Lyncean Technologies, Inc.

Present-day FELs have evolved from the successful development of accelerator and undulator technology at the core of fourth generation X-ray light sources pioneered at national laboratories. These sources rely on some form of electron accelerator linac to generate high peak currents, combined with low emittance and small energy spread beams, to achieve high single-pass FEL gain. High gain is a necessary condition at wavelengths where optics are inefficient, including EUV. The challenge with an FEL linac source for EUV lithography is how to adapt its high *peak power* capability to high *average power* capability. High average power requires high repetition rates, or high beam power, consequently demanding some form of energy recovery to be efficient. And by requiring a linac FEL to run to saturation to improve the efficiency of extracted radiation power, the total length of the FEL device must be very long, on the scale of 100m or more. This path leads to the ‘factory’ approach of a large scale FEL that feeds many EUV scanners at once.

Is there a way to construct a more compact FEL? Yes, using an electron storage ring, or more accurately, a damping ring. A damping ring has a few advantages — a high average beam power and repetition rate (~100MHz), a low equilibrium emittance, and a high ‘cooling’ rate from synchrotron radiation. It also has disadvantages — the electron bunches have a modest peak current, there is limited room to insert an undulator system, and most importantly, the stored electron beam is ‘heated’ by the FEL process, increasing the equilibrium electron beam energy spread which directly limits the FEL extracted power. We present a design that overcomes the challenges of a storage ring EUV FEL by using a multi-pass EUV amplifier architecture in which high single-pass undulator gain can be maintained with a large energy spread beam using appropriate optics. The equilibrium energy spread during steady-state FEL operation is a balance between the FEL heating and synchrotron radiation cooling. The solution is consistent with the generation of kW-scale coherent EUV average power and is scalable. This approach also avoids FEL saturation while reducing the undulator system itself to ~20m in one straight of a racetrack storage ring that fits within a 10m x 40m footprint, a size more consistent with an EUV source installed in the sub-fab and matched to one or two scanners.

Rod Loewen, CTO of Lyncean Technologies, Inc., is a technologist developing electron accelerators, laser systems, and feedback controls related to accelerator-based light sources spanning EUV to X-rays to Gamma rays. Rod has a Ph.D. in Physics from Stanford University and previously worked at the SLAC National Laboratory for a decade before co-founding Lyncean Technologies to develop inverse Compton storage ring sources, and more recently, coherent EUV source design for lithography.