

AppNote4: Unique Characteristics of the KMLabs Wyvern 1000– XUUS Coherent EUV Source

The KMLabs Wyvern 1000 - XUUS laser source and EUV beamline represents the only commercial fully integrated coherent EUV light source.

- **The KMLabs Wyvern uses patented (#6,804,287) cryogenically cooled laser-amplifier technology. This technology virtually eliminates detrimental thermal lensing in the laser amplifier. Unique laser characteristics unmatched in the commercial marketplace include:**
 - Single amplification stage.
 - Higher average power: >12 W average power specification. The closest competitor on the market: Coherent Legend Elite HE+[™] max 8 W at fixed 5 kHz.
 - Higher pulse repetition-rate: depending on the specific optimization of the laser, it can run at repetition-rates from 1-50 kHz, with >10W average power from 5-10 kHz (this is the commercial spec without reconfiguring the amplifier).
 - The capability to continuously vary the pulse repetition rate over a significant range (~2-3x) with minimal readjustment only in the pulse compressor, and while maintaining nearly constant average power. This makes it possible to make use of the full power output at any given required pulse energy (within the operating range of the laser).

- **The KMLabs XUUS light source is unique:**
 - The integrated Wyvern and XUUS source are supplied and warrantied by the same manufacturer, and tested as a system before delivery.
 - KMLabs characterizes the XUUS using a reliable EUV flux measurement process:
 1. Current measurement using a NIST-calibrated Al₂O₃ vacuum diode with very low IR-VIS light sensitivity;
 2. Procedure employing multiple thin-film metal filters systematically inserted and removed. This allows complete elimination of background light and robust cross- calibration of filter throughput.
 3. The EUV flux and spectrum and beam profile are cross-checked using an EUV CCD camera;



- Typical Performance at ~45 eV:
 - HHG in argon gas to the energy range 35-45 eV
 - Driving laser: ~0.5 mJ @ 1 kHz
 - Driving laser pulse duration ~35 fs
 - Source flux: 10^{11} photons/sec for single harmonic at 45 eV
- Typical Performance at ~72 eV:
 - HHG in Helium gas
 - Driving laser: ~2 mJ @ 1 kHz
 - Driving laser pulse duration ~35 fs
 - Source flux: 10^8 photons/sec for single harmonic at 72.4 eV
- Typical Performance at ~92 eV:
 - HHG in Helium gas
 - Driving laser: ~2.5 mJ @ 1 kHz
 - Driving laser pulse duration ~35 fs
 - Source flux: 10^7 photons/sec for single harmonic at 92 eV
- **The XUUS system employs a patented (#6,151,155) hollow waveguide for the high-harmonic upconversion process. This technique offer unique advantages:**
 1. Gas usage is minimized—gas escapes to vacuum only from the ends of the waveguide through which the laser beam itself passes. Compared with other geometries, gas usage is 1-4 orders of magnitude lower.
 2. The waveguide produces a constant pressure region with sharp pressure gradient that allows coherent signal buildup and then for the EUV light to escape the interaction region into vacuum with minimal re-absorption;
 3. Optimal phase matching produces fully spatially coherent EUV light without compromising conversion efficiency
 4. The waveguide serves as a spatial filter of the laser beam so that it filters out high order laser mode and laser beam pointing fluctuations, yielding a stable and near-Gaussian coherent EUV beam.
 - KMLabs' proprietary cartridge-based waveguide holder allows users to change the cartridge in <5 min. User can also readily optimize EUV flux using the same XUUS setup in different photon energy ranges, using different gasses.
 - The repetition rate and pulse energy of the Wyvern can readily be adjusted to optimally drive the high-harmonic process: i.e. high pulse energy low rep-rate for short EUV wavelength and low pulse energy high rep-rate for long EUV wavelength.
 - The XUUS system employs 4 axis active stabilization of the laser beam pointing into the waveguide to maintain EUV flux to <5% RMS for 8 hours and beam pointing stability to <10 μ rad.



- **KMLabs' XUUS-compatible EUV beamline modules offer flexibility to work with EUV light and spectrum**
 - Modularized beamline design allows user to build up an EUV beamline tailored to their application at lowest cost and highest flexibility.
 - A complete set of well-engineered beamline modules that capable of:
 - focusing,
 - single harmonic selection,
 - beam pointing steering,
 - high power IR light rejection,
 - in-line flux measurement,
 - spectral measurement
 - beam shape measurement of the EUV beam.

