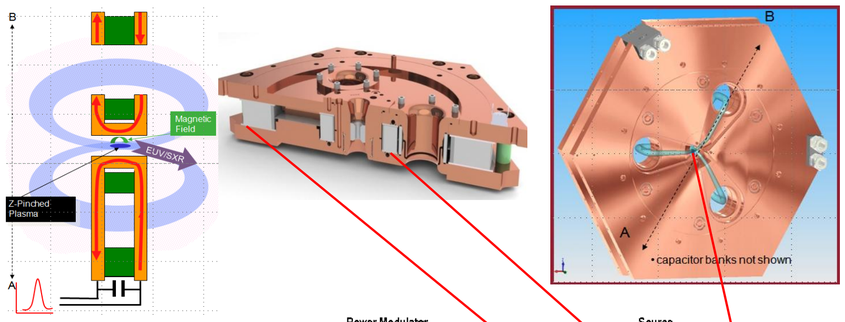
Light Source Development at Energetiq

Stephen F. Horne, Donald K Smith, Matthew M Besen, Paul A Blackborow, Deborah S Gustafson, Matthew J. Partlow, Huiling Zhu

Energetiq Technology, Inc.

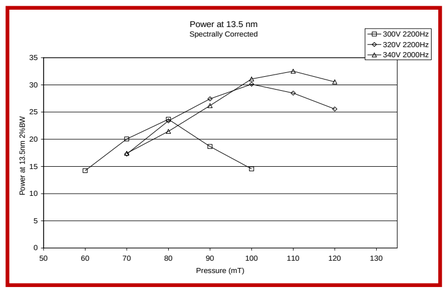
Energetiq Technology Inc. produces a variety of light sources. This poster will review the physics of these products (and some proposed devices), with an emphasis on applications.
The technology to be described includes the basic EQ-10 at 13 nm wavelength, and related devices including higher power, high pulse rate, and proposed high brightness concepts, and the 2.88 nm source for water window microscopy derived from the EQ-10. In addition, we will present a summary of the physics and applications of the family of products based on Energetiq's Laser Driven Light Source technology.

Electrode-less Z-Pinch™

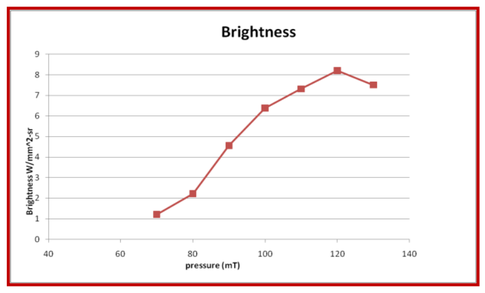


Inductively driven, electrode-less Z-pinch – integrated magnetic switch.

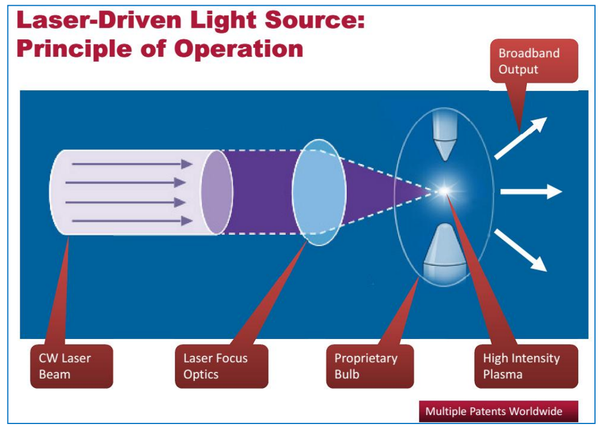
20 W of 13.5nm ±1% Power in 2π
~8 W/mm2-sr brightness
>95% uptime; 24/7 operation



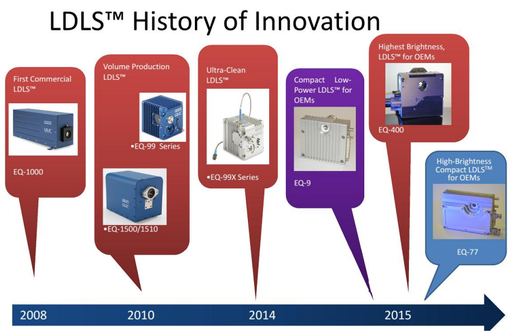
Industry standard source for EUV infrastructure R&D, Inspection, Resist development, Outgassing, Mirror testing, &etc…

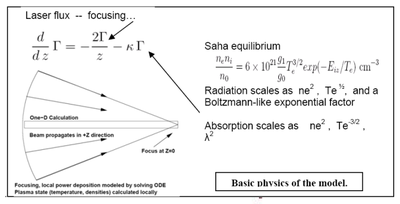


Vis/UV Light Sources - LDLS™



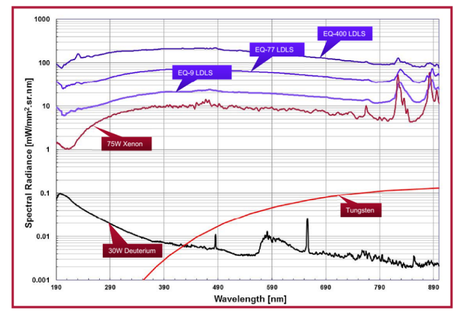
Spectral brightness scales with laser power (unlike arc lamp, where plasma increases in size, limiting brightness).





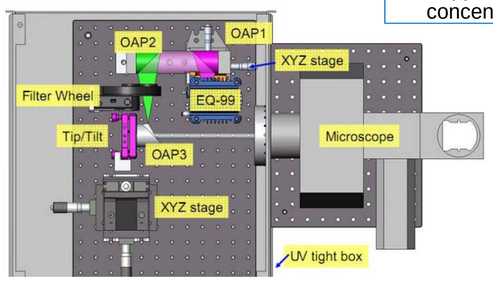
Applications

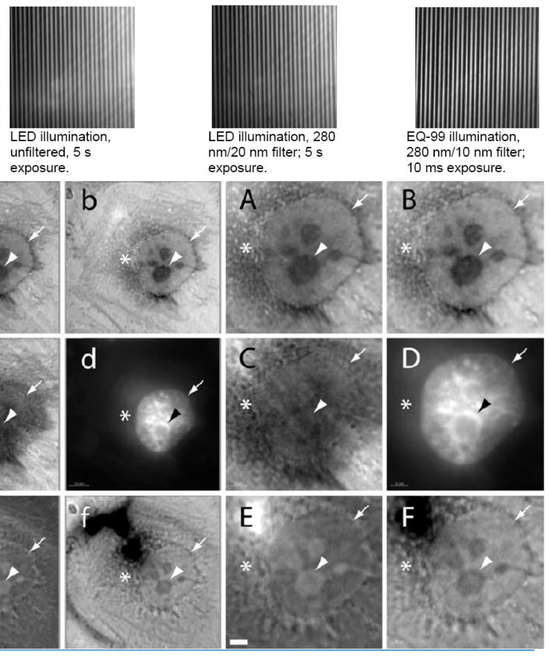
Analytical Spectroscopy
HPLC, AA, UV-Vis
Materials Characterization
Environmental Analysis
Hyperspectral Imaging
Gas Phase Measurements
Advanced Microscopes
Endoscopes…



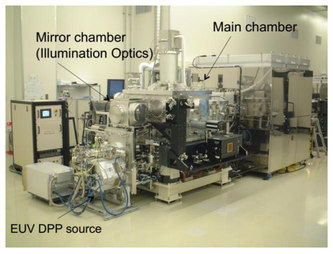
Application – UV Microscopy

250x improvement in exposure times compared to UV LED. Allows direct mapping of protein concentrations.[11]



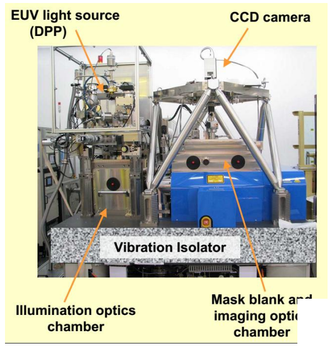


Applications and Installations ~ 25 worldwide

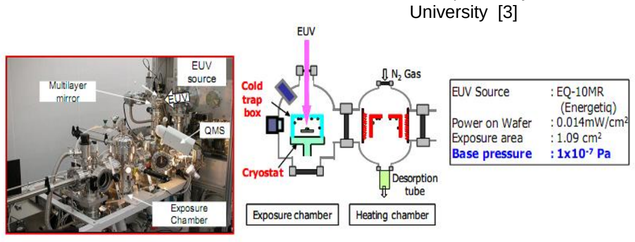


Lasertec/EIDEC mask inspection tool [1]

Flood Exposure system installed at Osaka University [3]

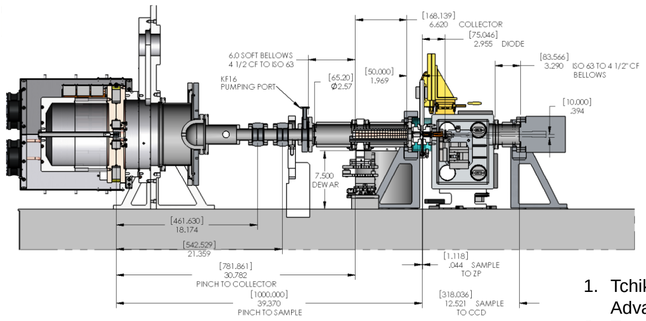


Actinic mask inspection SELETE [2]



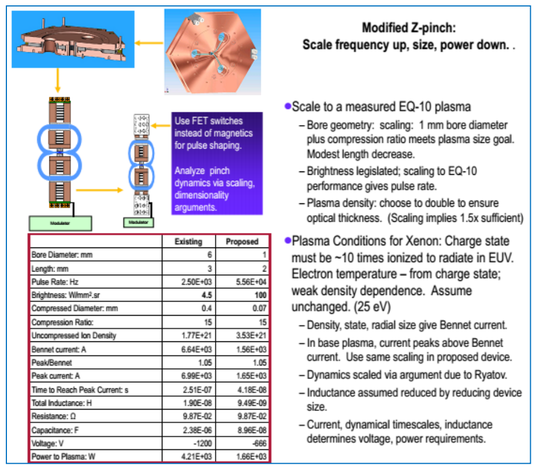
EUV Technology Outgassing Tool Installed at IMEC [4]

LithoTech Outgassing Tool installed at Selete [5]

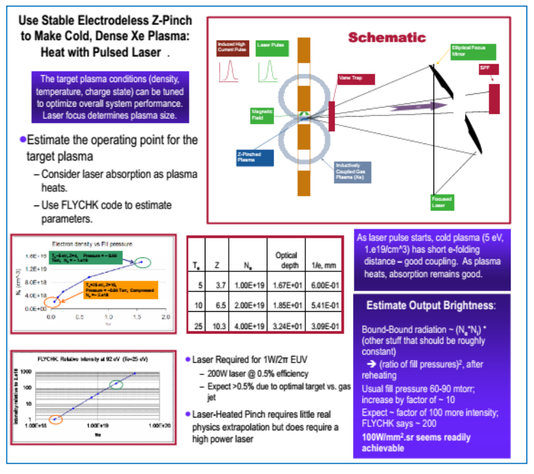


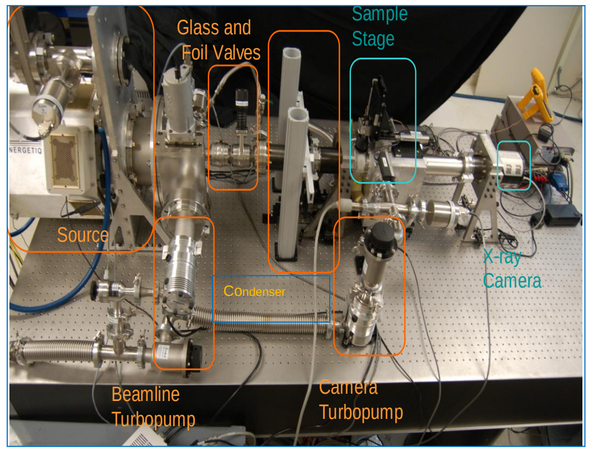
Water Window microscope (2.88 nm) at Energetiq[9]

Advanced Concepts[8]



	Existing	Proposed
Bore Diameter: mm	6	1
Length: mm	3	2
Pulse Rate: Hz	2.50E+03	5.56E+04
Brightness: W/mm².sr	4.5	100
Compressed Diameter: mm	0.4	0.07
Compression Ratio:	15	15
Uncompressed Ion Density	1.77E+21	3.53E+21
Bennet current: A	6.64E+03	1.56E+03
Peak/Bennet	1.05	1.05
Peak current: A	6.99E+03	1.65E+03
Time to Reach Peak Current: s	2.51E-07	4.18E-08
Total Inductance: H	1.90E-08	9.49E-09
Resistance: Ω	9.87E-02	9.87E-02
Capacitance: F	2.38E-06	8.96E-08
Voltage: V	-1200	-666
Power to Plasma: W	4.21E+03	1.66E+03





References

1. Tchikoulaeva, Anna, et al. "EUV actinic blank inspection: from prototype to production." SPIE Advanced Lithography. International Society for Optics and Photonics, 2013.
2. Terasawa, Tsuneo, et al. "Development of actinic mask blank inspection technology at Selete." 2008 EUVL Symposium, http://www. sematech. org/meetings/archives/litho/8285/pres/ME-02-Terasawa. pdf. 2008.
3. Sekiguchi, A., et al. "Study on photochemical analysis system (VLES) for EUV lithography." Advanced Lithography. International Society for Optics and Photonics, 2007.
4. Pollentier, I., et al. "Characterization of EUV optics contamination due to photoresist related outgassing." SPIE Advanced Lithography. International Society for Optics and Photonics, 2010.
5. Santillan, Julius Joseph, Shinji Kobayashi, and Toshiro Itani. "EUV resist outgassing analysis in Selete." SPIE Advanced Lithography. International Society for Optics and Photonics, 2008.
6. Horne, S. F., J. Silterra, and W. Holber. "A compact soft X-ray microscope using an electrode-less Z-pinch source." Journal of Physics: Conference Series. Vol. 186. No. 1. IOP Publishing, 2009.
7. Horne, Stephen, et al. "A novel high-brightness broadband light-source technology from the VUV to the IR." SPIE Defense, Security, and Sensing. International Society for Optics and Photonics, 2010.
8. Horne, Stephen F., et al. "High brightness electrodeless Z-Pinch EUV source for mask inspection tools." SPIE Advanced Lithography. International Society for Optics and Photonics, 2012.
9. Horne, S. F., J. Silterra, and W. Holber. "A compact soft X-ray microscope using an electrode-less Z-pinch source." Journal of Physics: Conference Series. Vol. 186. No. 1. IOP Publishing, 2009.
10. US Patent #7,435,982
11. Cheung, Man C., et al. "Intracellular protein and nucleic acid measured in eight cell types using deep-ultraviolet mass mapping." Cytometry Part A 83.6 (2013): 540-551.