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## **Using the X-FEL to drive gain in K-shell and L-shell systems using photo-ionization and photo-excitation of inner-shell transitions**

*Joseph Nilsen*

*Lawrence Livermore National Laboratory, Livermore, CA 94551  
nilsen1@llnl.gov*

Many photo-pumped X-ray laser schemes have been proposed over the last four decades. Demonstrating these schemes has proven to be elusive because of the difficulty of finding a strong resonant pump line or X-ray source. The X-ray free electron laser (X-FEL) now provides a tunable X-ray laser source that can be used to replace the pump line or X-ray source in previously proposed laser schemes and allow researchers to study the physics and feasibility of photo-pumped laser schemes. Many of these photo-pumped schemes are driven by photo-excitation from a resonant line source but others are driven by photo-ionization from a strong non-resonant X-ray source.

Four years ago an inner-shell X-ray laser was demonstrated at 849 eV (1.46 nm) in singly ionized neon gas using the X-FEL at 960 eV to photo-ionize the 1s electron in neutral neon followed by lasing on the 2p – 1s transition in singly-ionized neon. This work was done at the SLAC Linac Coherent Light Source (LCLS) by a multi-laboratory team led by Nina Rohringer and published in the January 26, 2012 issue of Nature. It took decades to demonstrate this scheme because it required a very strong X-ray source that could photo-ionize the 1s (K shell) electrons in neon on a time scale comparable to the intrinsic auger lifetime in the neon, which is typically 2 fsec.

In this work we model the neon inner shell X-ray laser under similar conditions to those used in the XFEL experiments at LCLS and show how we can improve the efficiency of the neon laser and reduce the drive requirements by tuning the XFEL to the 1s-3p transition in neutral neon in order to create gain on the 2p-1s line in neutral neon. We also show how the XFEL could be used photo-ionize L-shell electrons to drive gain on n=3-2 transitions in singly-ionized Ar and Cu plasmas. These bright, coherent, and monochromatic X-ray lasers may prove very useful for doing high-resolution spectroscopy and for studying non-linear process in the X-ray regime.

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