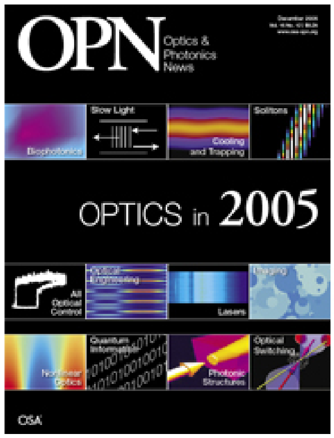
opn
Optics & Photonics News
THE MAGAZINE OF THE OPTICAL SOCIETY OF AMERICA



The December Optics & Photonics News (OPN) is a special issue that highlights the most exciting optics research to have emerged in the preceding 12 months. “Optics in 2005” offers readers a unique opportunity to access—in a single source—summaries of cutting-edge research that have been reported in peer-reviewed journals. (See Introduction.)

December

Features

High Repetition Rate Tabletop Soft X-ray Lasers with Saturated Output at Wavelengths down to 13.2 nm

Yong Wang, Miguel A. Larotonda, Bradley M. Luther, David Alessi, Mark Berrill, Mario C. Marconi, Vyacheslav N. Shlyaptsev and Jorge J. Rocca

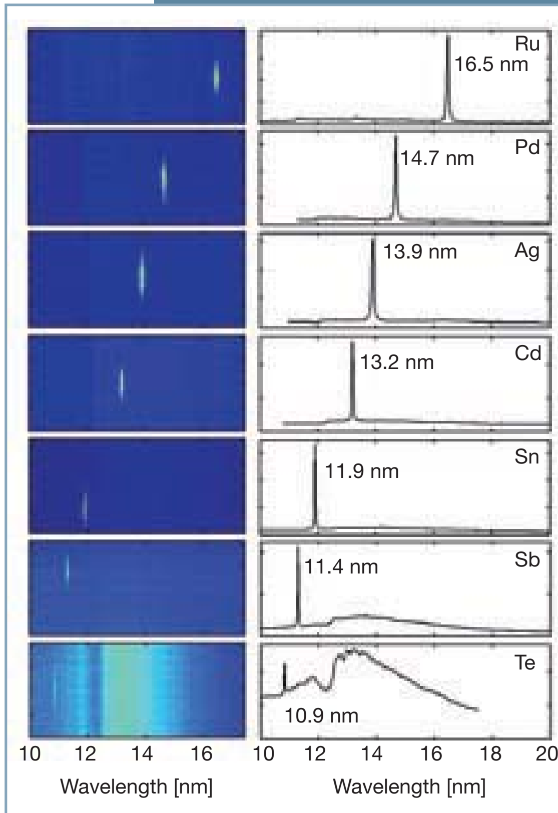
Compact, soft X-ray laser sources capable of producing high average powers could make possible a variety of new studies in science and enable development of unique metrology and processing tools for industry. Lasing in the gain saturation regime, which is necessary for efficient energy extraction, has been demonstrated for wavelengths as short as 5.9 nm in laser-created plasmas, but only at repetition rates of a few shots per hour due to the high laser pump energy required.

Researchers have made significant efforts to develop high repetition rate soft X-ray lasers for applications. Fast discharge excitation of capillary plasmas operating at a repetition rate of 4 to 10 Hz has produced milliwatt laser average powers at 46.9 nm. Different soft X-ray lasing schemes have been investigated to reduce the necessary pump energy and enable high repetition rate laser operation in laser-created plasmas at shorter wavelengths. Recently, scientists have demonstrated that the laser pump energy required to reach gain saturation can be significantly decreased by directing the pump beam at grazing incidence into a pre-created plasma.[1,2]

This geometry takes advantage of the refraction of the pump beam in the plasma to increase the path length of the rays in the gain region, thereby increasing the energy deposition efficiency into a pre-selected plasma region with optimum electron density for amplification. Pumping of the 18.9 nm line of Ni-like Mo with 150 mJ of total pumping energy from a 10 Hz laser has reportedly generated a gain-length product of roughly 14,[1] and subsequently the use of 1 J heating pulses resulted in operation in the gain-saturated regime.[2]

We have shown gain-saturated operation of table-top soft X-ray lasers at 5 Hz repetition rate producing microwatt average powers at wavelengths ranging from 13.2 to 32.6 nm in transitions of Ni-like and Ne-like ions.[3-6] Lasing was also observed for shorter wavelength transitions of Ni-like ions with amplification approaching gain saturation in the 11.9 nm line of Ni-like Sn and progressively reduced gain for wavelengths as low as 10.9 nm in Ni-like Te.[3] The figure shows on-axis spectra of lasers in transitions of the $4d^1S_0 \rightarrow 4p^1P_1$ Ni-like isoelectronic sequence at wavelengths ranging from 16.5 nm for a Ni-like Ru (Z=44) plasma down to 10.9 nm for Ni-like Te (Z=52).

We obtained these results by heating a pre-created plasma with an optical laser pulse of approximately 8-ps duration with an energy of only 1 J impinging at optimized grazing incidence angles between 14 and 23 degrees. For several transitions between 13.2 and 32.6 nm, laser operation at 5 Hz repetition rate produced average powers of 1 to 2 µW. The findings demonstrate the feasibility of producing high average power laser beams in the 100 eV spectral region for applications using a table-top source.



Single shot on-axis spectra of 4 mm line focus plasmas showing lasing in the $4d^1S_0 \rightarrow 4p^1P_1$ transition of the Ni-like ions at wavelengths ranging from 16.5 to 10.9 nm.

This work was supported by the National Science Foundation's Engineering Research Center for Extreme Ultraviolet Science and Technology under NSF Award EEC-0310717.

[Yong Wang, Miguel A. Larotonda, Bradley M. Luther, David Alessi, Mark Berrill, Mario C. Marconi and Jorge J. Rocca are with the National Science Foundation's Engineering Research Center for Extreme Ultraviolet Science and Technology, Colorado State University, Fort Collins, Colo. Vyacheslav N. Shlyaptsev is with the Department of Applied Science, University of California Davis-Livermore, Livermore, Calif.]

References

1. R. Keenan et al. Phys. Rev. Lett. **94**, 103901 (2005).
2. B.M. Luther et al. Opt. Lett. **30**, 165-7 (2005).
3. Y. Wang et al. Phys. Rev. A **72** (in press).
4. D. Alessi et al. Opt. Express **13**, 2093-8 (2005).
5. B.M. Luther et al., IEEE J. Quantum Electron. (in press).
6. J.J. Rocca et al. Opt. Lett. **30**, 2581-3 (2005).