

## GAIN MEASUREMENTS AT 5 NM IN NICKEL LIKE YTTERBIUM

B.J. MacGowan\*, J.L. Bourgade+, P. Combis+, C.J. Keane#,  
 M. Louis-Jacquet+, D.L. Matthews#, D. Naccache+, G. Stone#,  
 G. Thiell+, and D.A. Whelan#

\*Center for X-ray Optics  
 Lawrence Berkeley Laboratory  
 1 Cyclotron Road  
 University of California Berkeley  
 Berkeley, CA 94720, USA

LBL--25005  
 DE88 014662

+ Centre Etudes Limeil-Valenton  
 B.P. 27  
 Villeneuve St-Georges, 94190, France

# Lawrence Livermore National Laboratory  
 University of California  
 P.O. Box 808  
 Livermore, CA 94550, USA

## DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Abstract

Soft x-ray gain has been demonstrated at 5.03 nm within a laser produced plasma of Ni-like ytterbium. Experiments will also be described with higher Z Ni-like ions which can produce even shorter wavelength x-ray laser transitions.

REPRODUCTION OF THIS DOCUMENT IS UNLIMITED

*D.H.J.*

**MASTER**

GAIN MEASUREMENTS AT 5 NM IN NICKEL LIKE YTTERBIUM

B.J. MacGowan<sup>\*</sup>, J.L. Bourgade<sup>+</sup>, P. Combis<sup>+</sup>, C.J. Keane<sup>#</sup>,  
M. Louis-Jacquet<sup>+</sup>, D.L. Matthews<sup>#</sup>, D. Naccache<sup>+</sup>, G. Stone<sup>#</sup>,  
G. Thiell<sup>+</sup>, and D.A. Whelan<sup>#</sup>

\*Center for X-ray Optics  
Lawrence Berkeley Laboratory  
1 Cyclotron Road  
University of California Berkeley  
Berkeley, Ca 94720, USA

+ Centre Etudes Limeil-Valenton  
B.P. 27  
Villeneuve St-Georges, 94190, France

# Lawrence Livermore National Laboratory  
University of California  
P.O. Box 808  
Livermore, Ca 94550, USA

Since 1984 soft x-ray amplification has been demonstrated in laser produced plasmas containing ions in the neon like isoelectronic sequence.<sup>1</sup> Inversion and hence gain was obtained on  $3p - 3s$

transitions near 20 nm. Subsequently gain has been demonstrated on the analogous 4d - 4p transitions for ions in the nickel like ionization state.<sup>2</sup> The initial work showed gain of order unity at 7.1 and 6.6 nm in  $\text{Eu}^{35+}$  which are  $J = 0 - 1$ , 4d - 4p transitions sharing the same  $J = 0$  upper state. The upper state is pumped almost exclusively by plasma electron collisions exciting bound electrons directly from the  $3d^{10}$  nickel like ground state. The scheme is of interest because a transition analogous to the 6.6 nm  $J = 0 - 1$  transition in  $\text{Eu}^{35+}$  (at 4.32 nm in  $\text{W}^{46+}$ ) is a possible candidate to produce x-ray amplification within the "water window" between the K absorption edges of oxygen (2.332 nm) and carbon (4.376 nm). The analogous transitions in  $\text{Yb}^{42+}$  are at 5.026 and 5.609 nm and the 5.026 nm line has been observed to have a small signal gain coefficient of  $1.2 \text{ cm}^{-1}$  over 2 gainlengths in experiments carried out using  $0.53 \text{ }\mu\text{m}$  ( $2\omega$ ) irradiation at the Nova laser, at Lawrence Livermore National Laboratory.<sup>3</sup>

The technique used is to irradiate thin foils of Yb ( $100 \text{ }\mu\text{gcm}^{-2}$  areal density) with two 1 nanosecond pulsed beams of line focused light superposed on the foil. Typical irradiances are  $1 - 2 \times 10^{14} \text{ Wcm}^{-2}$ . The resultant explosion of the foil produces a linear plasma of transverse dimension of order  $200 \text{ }\mu\text{m}$  and length up to 2 cm. Space resolved spectra in the 5 nm region have shown that the conditions for gain are localized in a region of transverse dimension  $100 \text{ }\mu\text{m}$ .

Further work has been carried out at the Phebus laser at Centre Etudes Limeil-Valenton, France. The time history of the amplified 5.026 nm line has been observed and indicates an emission time of order 200 picoseconds, compared with the nanosecond timescale emissions of other unamplified lines from the plasma. The results of experiments attempting to optimise the gain at 5.026 nm will be described. These experiments have varied the laser irradiance and pulse duration, the target mass and laser wavelength ( $0.53$  and  $0.35 \text{ }\mu\text{m}$ ) in order to alter the plasma density and temperature time history. The variation resulted in large differences in plasma conditions as diagnosed by comparing time resolved 4f - 3d emission from the Ni-like ions and neighboring ionization states. Measurements of the gain for these different plasma

conditions and different ions will be described.

### Acknowledgment

This work was sponsored in part by the U.S. Department of Energy, Lawrence Livermore National Laboratory under contract No. W-7405-ENG, and by the Air Force Office of Scientific Research under contract F49620-87-K-0001, through the U.S. Department of Energy, Lawrence Berkeley Laboratory, under contract DE-AC03-76SF00098. We also gratefully acknowledge the support of the Centre d'Etudes de Limeil, Limeil - Valenton, France.

### References

1. D.L. Matthews et al., Phys. Rev. Lett. 54, 110 (1985).
2. B.J. MacGowan et al., Phys. Rev. Lett. 59, 2157 (1987).
3. B.J. MacGowan et al., submitted to J. Opt. Soc. Am. B.