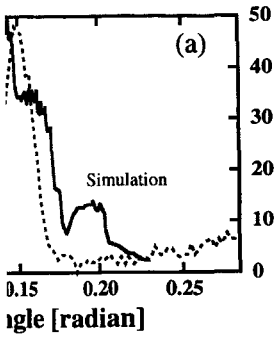

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Generation of highly ionized cadmium plasma columns for a discharge-pumped Nickel-like Cd laser

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Abstract. We report the observation of strong line emission from Ni-like Cd ions in a capillary discharge plasma. Spectroscopically pure Cd vapor was produced in a room temperature environment utilizing a capacitive discharge. The metal vapor was injected into a capillary channel where it was subsequently excited with fast current pulses of up to 200 kA. These results open the possibility of observing laser amplification in the $3d^9 4d$-$3d^9 4p$ line of Ni-like Cd at 13.2 nm and in laser lines of other Nickel-like ions in a discharge-created plasma.

Large amplification in capillary discharge-pumped ultrashort wavelength lasers has been achieved in several elements at wavelengths ranging from 46.9 nm to 60.8 nm [1-3]. In particular, a tabletop Ne-like Ar laser operating at 46.9 nm has produced the highest average power reported to date from a soft x-ray laser, 3.5 mW [4]. This laser has been successfully utilized in numerous applications [5]. There is significant interest in extending the operation of these practical discharge-pumped collisional soft x-ray lasers to shorter wavelengths. This will require, in most cases, the use of lasing materials that are solid at room temperature. We have previously demonstrated that it is possible to generate large amplification in capillary discharge sulfur plasmas generated by ablation of solid sulfur [2]. However, the extension of this scheme to significantly shorter wavelengths requires the excitation of plasmas produced from elements heavier than argon and much larger discharge powers. For this purpose, we have developed a high power capillary discharge designed to generate the hotter and denser [6]. This pulsed power generator, that consists of three pulse-compression stages, produces pulses of up to 200 kA with a 10-90% risetime of typically 12-14 ns. In this paper we discuss progress in the generation of highly ionized cadmium plasma columns for amplification in Ni-like Cd. In this scheme Cd vapor is generated by a secondary pulsed discharge and is injected into the capillary channel where is excited by a fast current pulse. XUV spectra of capillary discharge Cd plasma columns excited by 170-200 kA current pulses show dominant emission from Cu-like and Ni-like ion lines. Emission from $3d^9 4d$-$3d^9 4p$ Ni-like Cd lines has been observed. These results suggest a high power capillary discharge might be capable of exciting a Ni-like Cd laser operating in the $3d^9 4d\ ^1S_0$-$3d^9 4p\ ^1P_1$ transition at 13.2 nm.

The plasma columns were generated exciting a capillary channel filled with Cd vapor with the fast current pulse produced by a pulse power generator consisting of a three-stage pulse compression stages. The pulse generator has been described in a previous publication and consists of a Max generator, a water dielectric capacitor and a Blumlein transmission line [6]. The Marx generator is used to pulse charge the

water capacitor in about 1 μs. In turn, the water capacitor is discharged through an spark-gap filled with SF_6 to charge a radial water Blumlein transmission line in about 0.1 μs. Seven simultaneously triggered spark gaps located in the outer diameter of the Blumlein are used to rapidly discharge the transmission line and produce current pulses with amplitude of up to 200 kA and a risetime of less than 15 ns through the capillary load. The capillary channel is located at the axis of the radial Blumlein. Cd vapor is injected into the capillary throughout the hollow anode electrode of the capillary discharge. All the data reported herein was obtained using polyacetal capillaries with diameters ranging from 4 to 5.7 mm and 2 cm in length. The Cd vapor is produces by a metal vapor gun that was designed to produce metal vapor in a room temperature environment by rapidly heating a cadmium electrode by discharging a capacitor. Figure 1 shows a spectra of the visible/ultraviolet light emitted by the Cd vapor jet produced by this auxiliary discharge. All the strong features in the spectra were identified to correspond to either first or second order of neutral Cd transitions. No significant impurity lines were observed, an indication that the Cd vapor jet produced by this discharge is of a high purity.

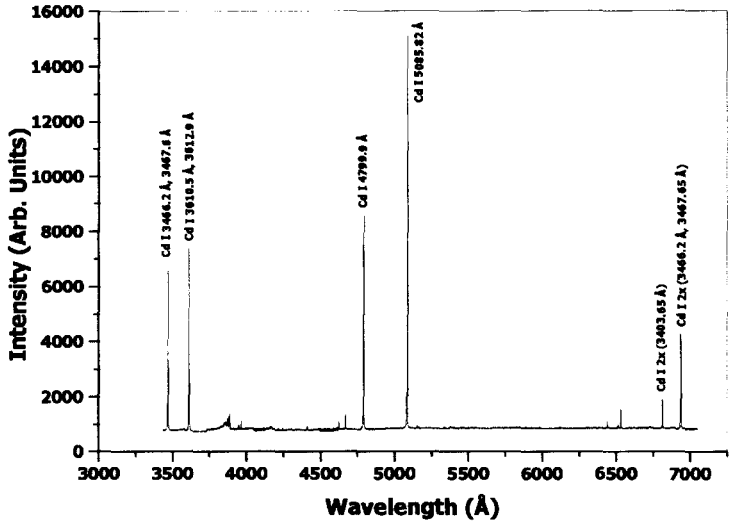

Figure 1. Visible spectra of the emission from vapor produced at room temperature by a capacitively driven discharge containing a Cd electrode. All the lines observed in the 340-700 nm region correspond to Cd I, an indication of the high degree of purity of the metal vapor produced.

End-on spectra of the capillary discharge plasma were obtained using a 2.2 meter grazing incidence spectrograph provided with a with either a 600 or 2400 lines per millimeter gold coated grating. Time resolution of about 5 ns was obtained by gating a multichannelplate intensified detector. Figure 2 shows an spectra of the Cd capillary discharge plasma for the 23-26 nm region. The spectra corresponds to a discharge in a 5.7 mm diameter polyacethal capillary excited by a current pulse of 196 kA peak amplitude. Many of the dominant lines are identified to correspond to the Ni-like and Cu-like ionization states of Cd [7]. All the Ni-like Cd lines in this spectral region are $3d^94p$-$3d^94s$ transitions. Figure 3 is a spectra covering the 17.2-18.4nm region. In this spectra strong line emission is observed from $3d^94d$-$3d^94p$ lines of Ni-like Cd at 18.02 and 18.03 nm. This results shows that a fast capillary is capable of

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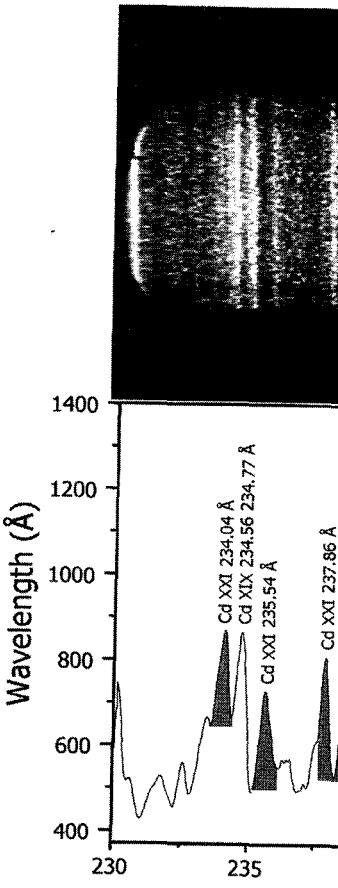

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exciting the 4d levels of Ni-like Cd, suggesting this type of a high power capillary discharge might be capable of generating amplification in the 4d-4p line of Ni-like Cd at 13.2 nm.

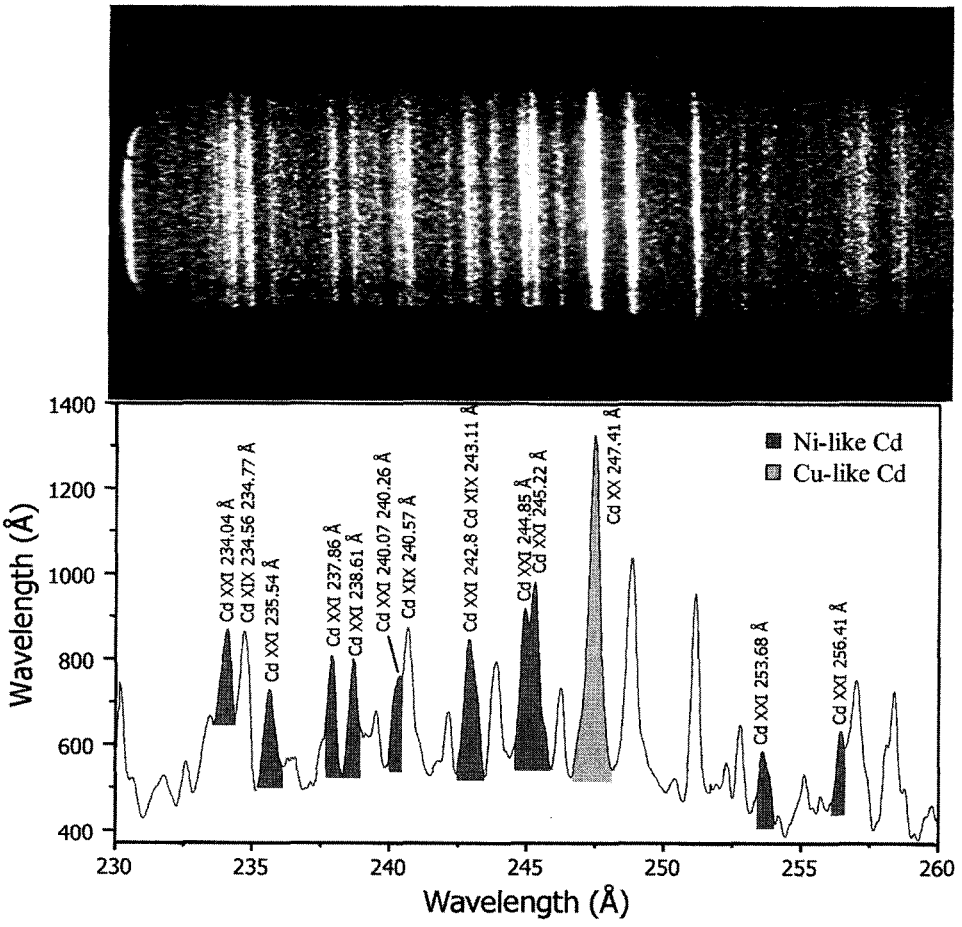

Figure 2. On axis time resolved spectra of a Cadmium capillary discharge. The peak current was 196 kA. The spectra was obtained 31 ns after the beginning of the current pulse.

In summary, we have demonstrated that a fast capillary discharge is capable of exciting line emission from Ni-like Cd ions. Spectroscopically pure Cd vapor was produced by a secondary discharge and injected into a capillary channel where was excited by fast current pulses of up to 200 kA. Soft x-ray spectroscopy of the capillary discharge plasma identified line emission from numerous Ni-like Cd ion lines, including 4d-4p lines. This is the first time to our knowledge that line emission from twenty times-ionized ions is observed in a capillary discharge plasma. This results open the possibility of observing laser amplification in the J= 0-1 4d-4p line of Ni-like Cd at 13.2 nm, and in laser lines of other Nickel-like ions in a capillary discharge plasma column.

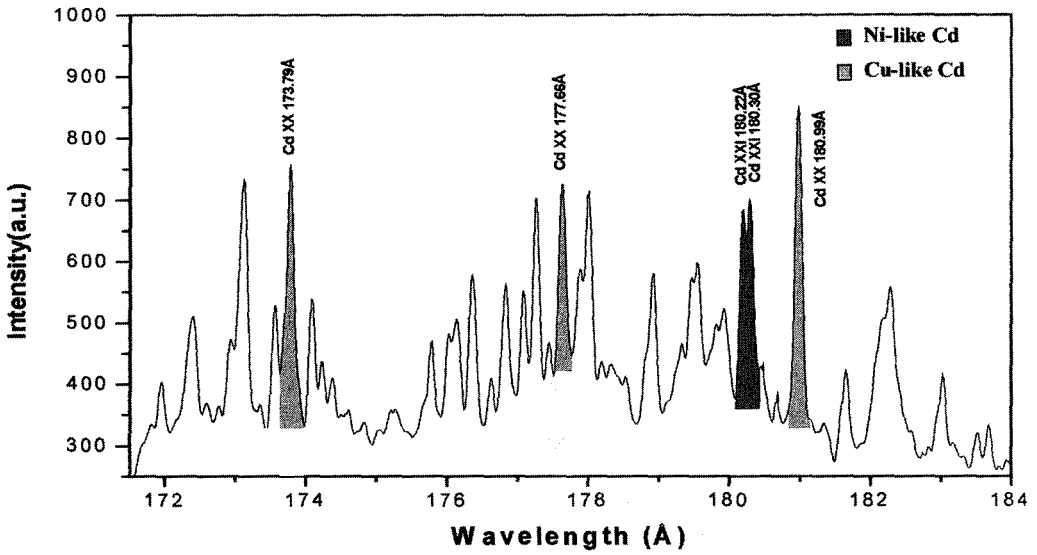

Figure 3. Time resolved spectra of Cd capillary discharge in the 17.2-18.4 nm region. Line emission from the 4d- 4p lines of Ni-like Cd at 18.02 and 18.03 nm is observed. The capillary diameter was 5 mm

This work was supported by DARPA and by the National Science Foundation. We also gratefully acknowledge support from the W.M. Keck Foundation.

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J. Phys. IV France **11** (2001)

A study of electrical di

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[2] Institute of Theoretical and Exp Russia

Abstract. A fast electrical disc and realized. Steady state discha of the IONMIX code results. S various experimental conditions evaluated macroscopic parameter

1. RECOMBINATION PUMP

We carry on a research of x-ray l electrical capillary discharge [1,2,3 polyethylene $(CH_2)_n$ or polyacetal (C discharged through it. The wall mat electrical current passing through it a radiation.

To achieve a gain coefficient G > energy level should be $N_u > 2.2 \times 1$ [4]. To prevent the collisional mix density should not exceed the value density should be approximately equal

The primary laser pumping proce fully stripped carbon ions and electr temperature be high enough to get hig the other hand, the efficient three-bo $T_e^{low} < 30 \div 40$ eV. Thus, an ideal pu plasma electron temperature from T_e computer model of carbon plasma clai

2. EXPERIMENT

Polyacetal 2.5 cm long capillaries wit energy is stored in a bank of 2 - 6 ca two circular flat plates providing a lov is 40 kV, so that up to 12 J could be st to 300 J.cm^{-3} of the delivered energy d created between the coaxial electrod discharge decreases very quickly and described as an under-dumped resonan forms measured for 15 and 5 nF capac times are 36 ns and 26 ns and the curre