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Soft X-ray and EUV lasers pumped by capillary discharge at Harbin Institute of Technology

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The plasma produced by capillary discharge can be used as laser medium. With the exciting schemes of capillary discharge, many groups have realized 46.9nm soft X-ray laser which has many advantages such as small-scale, high-efficiency and low-cost. The laser has been utilized in numerous fields of science and technology. In order to expand the applications, the 46.9nm laser intensity was increased[1-2] and the new wavelength EUV lasers at 69.8nm and 72.6nm were realized[3-4] in the plasma produced by capillary discharge at Harbin Institute of Technology.

The ceramic capillary of ~3mm inner diameter is generally use by other groups in the world. When we try to increase the 46.9nm laser intensity by increasing the main current from 26kA to 40kA, the experimental results show that the severe ablation of 3.2-mm-diameter capillary wall results in the decrease of 46.9nm laser intensity. In order to decrease the ablation of capillary wall, the 4.8-mm-diameter capillary was firstly used in our experiment. Figure 1 (a) depicts the intensity of 46.9nm laser at different initial pressures when capillary inner diameter is 4.8mm and the main current amplitude is 30, 36 and 40kA respectively[1]. When the amplitude of main current is increased from 30 to 36 and 40kA, the intensity of the laser produced at the optimum pressure increases up to 1.5 and 2 times respectively.

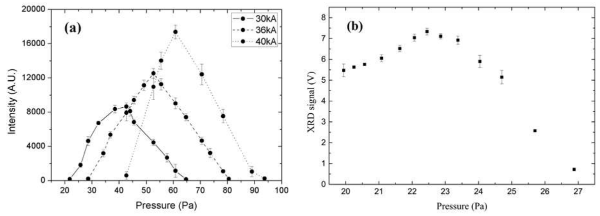

Fig. 1 (a):The laser intensity versus initial pressures. (b): Laser pulse amplitudes corresponding to the different pressures of He mixed into 20Pa of Ar.

Besides of the increase of main current and inner diameter of capillary, the other method of enhancing the 46.9nm laser intensity is the addition of He into Ar as initial gas in the capillary which was firstly used to replace the pure Ar by our group[2]. The 46.9 nm laser pulse amplitudes were measured by X-ray diode (XRD) with different pressures of He mixed into 20Pa of Ar as shown in Fig. 1(b). The results show that laser intensity can be increased by adding appropriate amount of He.

It is significant to realize new wavelength laser with capillary discharge scheme. By decreasing the main current and the initial pressure of Ar, the 69.8 nm and 72.6nm lasers of Ne-like Ar were firstly demonstrated by our group[3]. The 46.9 nm, 69.8 nm and 72.6 nm lasers were firstly realized in one discharge pulse as shown in Fig. 2. Then the gain saturation and double pass amplification of 69.8nm laser were obtained as shown in Fig. 3. Figure 3 shows that the intensity of the 69.8 nm laser increases exponentially for plasma length up to 35 cm corresponds to a gain coefficient of 0.4 cm^{-1}, where it begins to saturate. The gain length product corresponding to 45-cm-long plasma column is about 18[4]. A double-pass amplification of 69.8 nm laser was firstly realized with a SiC mirror without coating[4]. With the half cavity, the effective plasma column length and the effective gain length product can reach 84 cm and 33.7, respectively. The amplitude of laser pulse for double-pass amplification is 9 times larger than that for single-pass amplification.

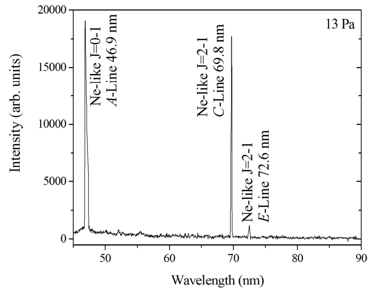

Fig.2 Time-integrated axial emission spectra obtained for initial Ar pressure of 13 Pa.

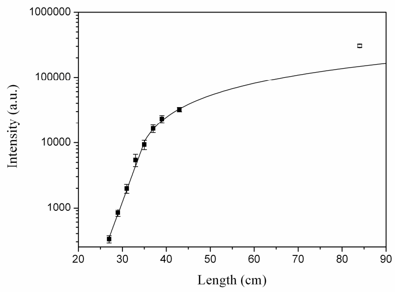

Fig.3 Integrated 69.8 nm laser intensity versus plasma length. The single-pass and double-pass data are indicated by full and open square, respectively.

References

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