Intensity Enhancing of 46.9nm Soft X-ray laser pumped by capillary discharge at Harbin Institute of Technology

Huaiyu Cui, Muhammad Usman Khan, Dongdi Zhao, Bo An, Yongpeng Zhao

National Key Laboratory of Science and Technology on Tunable Laser, Harbin Institute of Technology
email of main speaker: cuihuaiyu_hit@163.com

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 expected to be increased. In this report, we present two methods to enhance the laser intensity and adjust the characteristics of the laser spot.

Generally the ceramic capillary used by other groups in the world is with the inner diameter of ~3mm. When we try to increase the main current from 26kA to 40kA in the lab, the laser intensity decreases due to the severe ablation of 3.2-mm-diameter capillary wall. In order to decrease the ablation of capillary wall, the 4.8-mm-diameter capillary is firstly used in our experiment. Figure 1 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. This experimental result proves that increasing the inner diameter of capillary to 4.8mm is helpful to reduce the affect of wall ablation on the laser intensity, which raises the transfer efficiency of the 46.9nm laser under a higher main current.

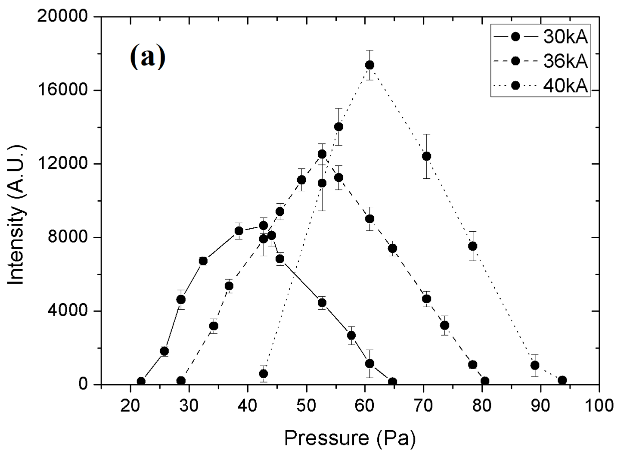


Fig. 1 The laser intensity versus initial pressures.

Figure 2 shows the spatial distribution of the 46.9nm laser spots caught by a Ce:YAG scintillator at optimum pressure under different main current. The annular-shaped spots show good agreement with the theoretical simulation result of the electron densities.

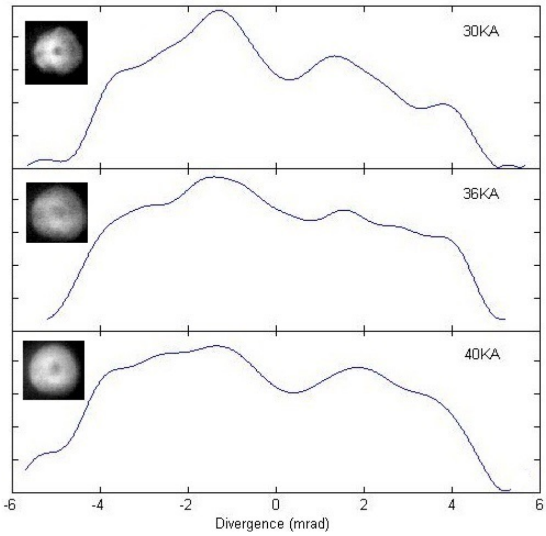


Fig. 2. The laser spots produced at optimum pressure

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 is firstly used to replace the pure Ar by our group[2]. The 46.9 nm laser pulse amplitude is measured by X-ray diode (XRD) with different pressures of He mixed into 20Pa of Ar as shown in Figure 3. The results show that laser intensity can be increased by adding appropriate amount of He. To study the mechanism of the He-effect in the generation of the laser, the relationship between the electron density of the plasma in the capillary and the spatial distribution of the laser spot is analyzed.

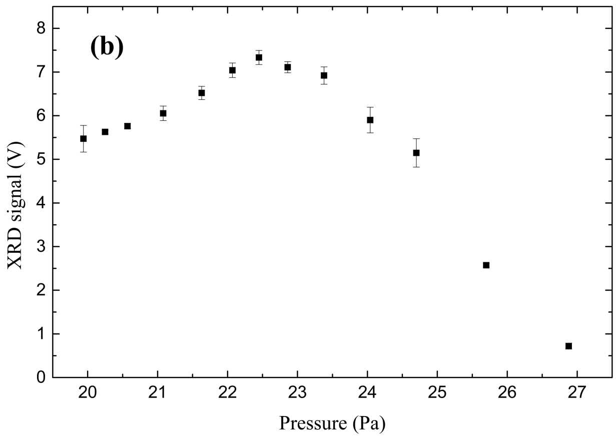
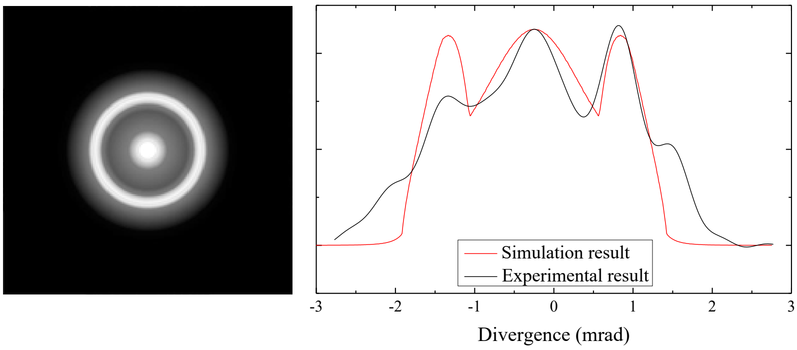


Fig. 3 Laser pulse amplitudes corresponding to the different pressures of He mixed into 20Pa of Ar.

According to the results in Figure 3, 2.5Pa of He mixture into Ar makes the maximum laser pulse amplitude. Figure 4 shows the simulated laser spot and the radial intensity distribution of the experimental result. Compared with the typical donut-shaped spot of the capillary discharge laser, it has a solid spot in the center. By estimating the electron density distribution in the plasma column with this dose of He, the laser spot was simulated. The theoretical results also show that the pressure of He has a non-ignorable effect on the spatial distribution of the 46.9nm laser spot.



(a) (b)

Fig. 4 The simulation laser spot of of Ar-He mixture containing 2.5 Pa of He in 20 Pa of Ar (a) and the radial intensity distribution of the experimental result and the simulation result (b).

To sum up, two methods for enhancing the 46.9nm laser intensity are reported which would help to expand the application of the laser. More optimizations of the 46.9nm laser could be attempted in the future, such as beam shaping, phase transformation and so on.

[1] Muhammad Usman Khan, Yongpeng Zhao, Hui Tong et al., *Opt. Express*, **2019**, *27*, 16738.
[2] Yongpeng Zhao, Dongdi Zhao, Qi Yu et al., *J. Opt. Soc. Am. B*, **2020**,*37*, 2271.