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Effects of external axial magnetic field on soft X-ray radiation from capillary discharge hydrogen-like nitrogen plasma

高速キャピラリ放電水素様窒素プラズマの軟 X 線放出に対する外部軸方向磁場の影響

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It is considered that lasing of a H-like N Balmer α soft X-ray laser (SXRL) at wavelength of 13.4 nm might be possible by utilizing an expansion phase of Z-pinch discharge plasma. To realize the SXRL we studied the soft-x-ray amplification in discharge- plasma produced in an externally applied axial magnetic field. The purpose of this technique is to make the concave electron density distribution at the time of lasing and amplify the radiation by guiding effect.

1. Introduction

Using a fast capillary Z-pinch discharge to generate a hot-dense plasma column efficiently, Ne-like Ar soft X-ray laser (SXRL) at a wavelength of 46.9 nm was first demonstrated by Rocca et al. in 1994 [1]. It was pointed out later that the suppression of the growth of magnetohydrodynamic (MHD) instability by use of pre-discharge is essential for reproducible lasing of Ne-like Ar SXRL [2]. The capillary discharge scheme has the advantages of relatively high efficiency, large gain volume, and long gain duration. To meet the demand for the realization of a shorter wavelength SXRL pumped by capillary discharge, we have begun to investigate the possibility of lasing the H-like N Balmer α recombination SXRL at a wavelength of 13.4 nm.

To effectively amplify the recombination laser in Z-pinch plasma, the optical waveguide effects by concave electron density distribution at the time of lasing and rapid cooling for recombination are required. Considering an electron density distribution in usual Z-pinch plasma at and after the maximum pinch, a convex electron density distribution, which refracts the ray of light off the axis, will be formed. Thus the refraction prevents the effective amplification of the laser and limits the maximum gain-length product. For this reason, the axial magnetic field, which can generate a concave electron density distribution and cool plasma rapidly in explosion phase by higher internal magnetic pressure, was applied.

2. Experimental Setup

To realize the H-like N Balmer α recombination SXRL, much larger power and shorter pulse width of discharge current than those for Ne-like Ar SXRL are required. Therefore a pulsed power system composed of an LC inversion generator, a pulse transformer, and a water capacitor as shown in Fig. 1, which can supply current with peak amplitude of higher than 50 kA and a pulse width of about 50 ns (FWHM), was made.

As shown in Fig. 2, the measurement of radiation from the nitrogen plasma was carried out using a X-ray diode (XRD). The XRD was located 28 cm from the end of the capillary.

The axial magnetic field was generated by using 4-cm of diameter and 15-cm long coil, positioned concentrically with the capillary channel. The coil, which was excited by a pulsed power supply, produced magnetic fields up to 100 mT.

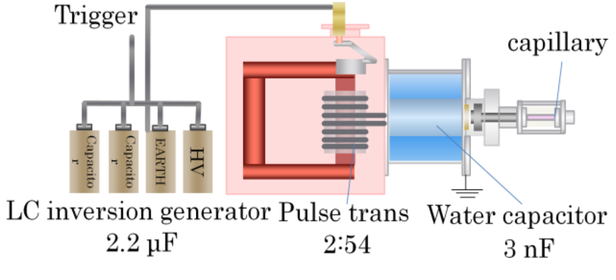

Fig. 1 Pulsed power supply system for SXRL

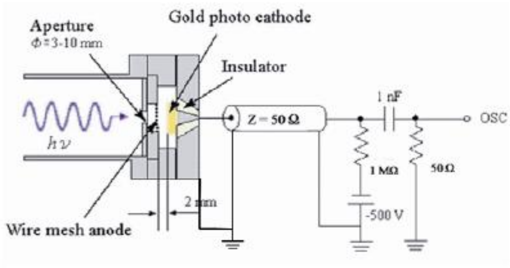

Fig. 2 X-Ray Diode

3. Experimental Result and Discussion

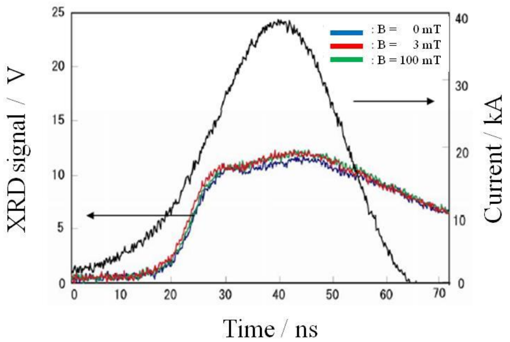

Fig. 3 XRD signal with and without axial magnetic field

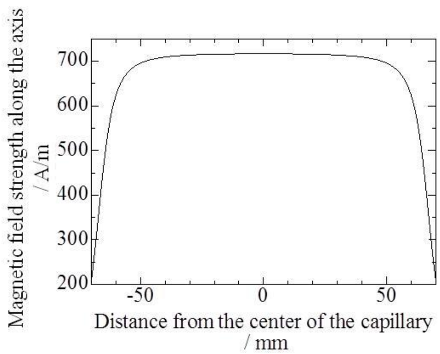

Fig. 4 Magnetic field distribution along the capillary

Figure 3 shows the XRD signal applying magnetic field up to 100 mT. The XRD signal was slightly increased. But, there were no significant effect such as the peak time of XRD signal. The reason for this was considered that the compression by Z-pinch was not presented by axial magnetic field up to 100 mT, and the optical waveguide was formed. However, as shown in Fig. 4, the uniformity of the magnetic field along the capillary was not good. The end of the capillary is located at 70 mm and -70 mm in Fig. 4, so the concave electron distribution could not be generated wholly along the capillary axis.

4. Conclusion

To realize the SXRL, we studied the soft-x-ray amplification in a capillary discharge in an externally applied axial magnetic field. By applying magnetic field of less than 100 mT, the XRD signal is slightly increased. But, there were no significant effect such as the peak time of XRD signal. This result suggests that the optical waveguide caused by convex electron density distribution without affecting the compression by Z-pinch was generated by applying magnetic field under 100 mT. However the uniformity of the magnetic field was not good. Thus it is considered that the concave electron distribution could not be generated wholly along the capillary axis. Then, we plan to measure the spectra when the uniform magnetic field along the capillary is applied. In addition, to cool plasma more rapidly by utilizing the strong radiation from heavier ions, gases such as xenon are planned to be added to nitrogen.

References

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